From Screen to Green:

Nature as an Upstream Determinant of Psychological Well-being for Young People in a High-Tech Era

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THESIS ABSTRACT

Background

Mental health problems are the leading cause of reduced quality of life among young people globally, and prevalence is increasing. From a public health perspective, it is important to prevent mental illness and promote mental well-being in young people, given this is a developmental period which can determine an individuals' mental health trajectory across the lifespan. Identifying and addressing risk and protective factors for youth mental health is central in achieving this. While a plethora of determinants of youth mental health exist, two trends which characterise contemporary youth as markedly different from previous generations have been postulated to partially explain observed increases in mental illness among young people. These two trends are: (1) significant increases in the time young people spend engaged with screen-based technologies (increased "screen time"), and (2) significant decreases in young people's contact with nature (decreased "green time"). Screen time and green time have been identified as relevant and important activities by young people themselves, as well as parents, educators, and health professionals.

Aims

1. To critically review the existing literature looking at the relationships between screen time, green time, and psychological outcomes (including mental health, cognitive functioning, and academic achievement) in children and adolescents
2. To explore potential risk and protective factors for the mental health of young Australians (including screen time and green time) in the context of the COVID-19 pandemic
3. To explore mechanisms and pathways underpinning associations between screen time and psychological well-being in young people, paying attention to neurological, cognitive, and social developments experienced in adolescence

4. To investigate the acute psychological impacts of screen time for adolescents, and to explore the restorative (or "buffering") potential of nature immersion.

Methods

A public health psychology research approach, capitalising on the strengths afforded by epidemiology and psychology, was employed to address the research aims. Four studies were conducted, using the following methods:

1. A systematic scoping review was conducted to collate and critically review the existing literature looking at the relationships between screen time, green time, and psychological outcomes in children and adolescents
2. An online national cross-sectional study was used to explore potential risk and protective factors relevant to young Australians in the context of the COVID-19 pandemic, drawing on the Complete State Model of Mental Health which considers indicators of mental well-being in addition to symptoms of mental illness
3. A theoretical paper, including a conceptual model, was developed to present an integrated synthesis of literature on the theme of contemporary digital technology use and mental health in the context of adolescent development, with a specific focus on the role of self-regulation
4. A randomised pre-post pilot study was undertaken to investigate the short-term impacts of screen time on psychological outcomes in adolescents, and to explore the restorative potential of nature immersion.

Results

In the systematic scoping review, 186 eligible studies were identified. The majority of included studies were cross-sectional (62%). In general, high levels of screen time were associated with unfavourable psychological outcomes while green time was associated with favourable psychological outcomes. Underlying mechanisms and pathways were poorly articulated in the literature and additional high-quality studies with a longitudinal or experimental component are needed. Evidence suggested that young people from disadvantaged backgrounds may be disproportionately affected by high screen time and low green time, meaning future research should prioritise youth from low socioeconomic backgrounds. This review also highlighted the importance of considering the way in which specific screen-based technologies and green time exposures affect children and adolescents of diverse ages, depending on social and biological factors unique to their developmental stage of life. Few studies considered screen time and green time together and possible reciprocal psychological effects. There was preliminary evidence that green time could "buffer" consequences of high screen time, but more robust evidence is needed to support this premise.

Just over 1,000 young Australians living in metropolitan areas participated in the online cross-sectional study. Using the Complete State Model of Mental Health, participants were cross-classified into four mental health states according to their relative proportion of mental well-being and mental illness symptoms. The best mental health state was "Flourishing", which was characterised by high levels of mental well-being alongside no-to-mild mental illness symptoms. Contrastingly, the worst mental health state was "Floundering", characterised by low levels of mental well-being alongside moderate-to-severe mental illness symptoms. The two intermediary mental health states were "Languishing" (low levels of mental well-being alongside no-to-mild mental illness symptoms) and "Struggling" (high levels of mental well-being alongside moderate-to-severe mental illness symptoms). Important sociodemographic factors such as age, gender, area-level socioeconomic status, and employment status were adjusted for in analyses. According to the results, using screen time to connect with family and friends during COVID-19 lockdowns was associated with

Flourishing mental health, while those who experienced screen fatigue and withdrew from tech-communications were more likely to be Floundering or Struggling, emphasising the important role of technology during the pandemic. Reporting increased contact with nature during lockdowns, living in a green/natural neighbourhood, having access to a private outdoor space, and living within walking distance of a green or bluespace (e.g., lake) were protective of mental health during the pandemic, highlighting the benefits of urban green infrastructure for mental health "in place". The sample used for this study was not a random representative sample, meaning reliable prevalence estimates could not be provided; however, quota sampling was used to recruit a sample which was diverse and well distributed across the spectrum of socioeconomic status.

While a substantial body of literature has demonstrated associations between extensive screen time and poor mental health for adolescents, debates are ongoing and cannot be settled unequivocally with available evidence. Following the precautionary principle, in the theoretical paper it was argued that the pursuit for scientific certainty about the psychological impacts of screen time should not postpone preventive measures to protect adolescent well-being. Rather, specifying plausible mechanisms and possible pathways was considered an important step forward. In line with this, the theoretical paper integrated important segments of the literature relating to both cognition and emotion, and offered a developmental perspective on how contemporary digital technologies could undermine adolescent mental health by impeding several critical neurological, cognitive, and social developments in adolescence, which are associated with self-regulation capabilities. These capabilities enable cognitive control of emotions to protect against internalizing problems seen in depression and anxiety, through reappraisal of threats and reducing rumination. It was argued that a large amount of daily time devoted to digital technologies could displace opportunities for experience-dependent maturation of self-regulation capabilities, and also exploit immature neuroanatomy. Presented in the paper is an in-depth discussion on how the development of these capabilities required for self-regulation may be specifically affected by (1) the addictive properties of digital technologies, (2) media multi-tasking, and (3) pervasive exposure to social and emotional content online. These factors were considered within the broader contexts of contemporary adolescent socialisation and evolutionary neurobiology. A conceptual model was developed to integrate findings and highlight relevant synergies.

Eighty-seven adolescents (52% female, mean age = 15.5 years) were recruited to participate in the randomised pre-post pilot study. In brief, participants completed validated, computer-based measures of mood, sustained attention capacity (Sustained Attention to Response Task), and inhibitory control (Stop-Signal Task) at three time-points: (1) at baseline, (2) after a period of screen time, and (3) after a period of rest. Participants were randomised to either an indoor setting or an outdoor environment (nature immersion in the Botanic Gardens) for the rest period. It was hypothesised that (a) following the period of screen time, adolescents would experience acute decreases in mood, inhibition, and attention abilities, and (b) following the period of screen time, adolescents who participated in nature immersion would experience superior mood, inhibition, and attention restoration when compared to adolescents who rested in the indoor setting. The results did not support the first hypothesis, which meant that the second hypothesis could not be adequately tested. The 30-minute screen time period did not provide the anticipated reduction in mood, inhibition, or attention abilities. Pre-determining a screen time period which may lead to this detectable deficit was a challenge due to the lack of experimental evidence available in the screen time literature. A number of important conceptual and methodological lessons were learned through this study, particularly around potentially useful screen time activities for experimental studies, required sample sizes and statistical power, and meaningful outcome measures which are more applicable in real-world scenarios. These lessons will provide valuable guidance for future research in this field.

General conclusion

Screen time and green time appear to influence psychological well-being in contrasting ways, with high levels of screen time typically associated with unfavourable psychological outcomes and green time associated with favourable psychological outcomes. As such, the combination of high screen time and low green time may present a dual-burden on youth psychological well-being in the 21st century. The existing evidence mostly comes from cross-sectional studies; however, the preponderance of studies with broadly similar findings, across a myriad of settings and heterogeneous exposure measures, suggests that the associations are not chance findings and are possibly causal. The study conducted during the COVID-19 pandemic added some complexity and demonstrated that context matters, with screen time presenting as an important support for young Australians during lockdowns. The study also highlighted the importance of investing in urban green infrastructure to support youth mental health in the immediate pandemic context and for years to come. There remains a need for more (appropriately powered) experimental studies which explore how green time may be used as a public health resource in a high-tech era.

Overall, societies need to shift away from solely relying on clinical responses to youth mental health problems, to public mental health solutions that prevent mental illness, promote mental well-being, and ensure lifelong psychological well-being for whole populations. Screen time and green time are an important part of this response and illustrate where this change is invited.

PUBLICATIONS CONTRIBUTING TO THESIS

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., & Moore, V.M. (2020). Psychological impacts of “screen time” and “green time” for children and adolescents: A systematic scoping review. *PLOS ONE, 15(9)*, e0237725. doi: https://doi.org/10.1371/journal.pone.0237725

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., Kohler, M., & Moore, V.M. (2021). Mental Health of Young Australians during the COVID-19 Pandemic: Exploring the Roles of Employment Precarity, Screen Time, and Contact with Nature. *International Journal of Environmental Research and Public Health*, *18,* 5630. doi: https://doi.org/10.3390/ijerph18115630

PRESENTATIONS ARISING FROM THE THESIS

<u>Peer-Reviewed Oral Presentations</u>

Oswald, T.K., Kohler, M., Rumbold, A.R, Kedzior, S.G.E., & Moore, V.M. (2021). Buffering "screen time" with "green time" in adolescence: A pilot study demonstrating acute psychological effects of screen time and the restorative potential of nature immersion. Abstract accepted for presentation at the *International Conference on Environmental Psychology*. Siracuse, Italy (October 2021).

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., Kohler, M., & Moore, V.M. Mental health of Young Australians During the COVID-19 Pandemic: The Role of Contact with Nature. Presented at the *Nature and Health Virtual Conference.* Washington, USA (October 2021).

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., & Moore, V.M. (2019). Psychological impacts of 'screen' and 'green' time for youth: systematic scoping review. Presented at the *Australian Public Health Conference*. Adelaide, Australia (September 2019).

<u>Invited Public Presentations</u>

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., & Moore, V.M. (2021). From Screen to Green: Nature as an Upstream Determinant of Psychological Well-being for Young People in a High-Tech Era. *Tackling Climate Change and Promoting Youth Mental Health forum by the Inner East Primary Care Partnership.* Victoria, Australia (9th December 2021).

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., Kohler, M., & Moore, V.M. (2021). Mental Health of Young Australians During the COVID-19 Pandemic: Exploring the Role of Employment Precarity. *South Australian 2021 Safety Symposium, Australian Institute of Health & Safety*. Adelaide, Australia (22nd October 2021).

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., & Moore, V.M. (2021). Screen Time vs. Green Time: Nature as an Upstream Determinant of Psychological Well-being for Young People in a High-Tech Era. *Benefits of Nature Engagement for Child Wellbeing and Learning, thematic evening, Healthy Development Adelaide*. Adelaide, Australia (15th June 2021).

Oswald, T.K. Rumbold, A.R., Kedzior, S.G.E., & Moore, V.M. (2021). Psychological impacts of 'screen' and 'green' time for youth: a systematic scoping review. *Public Health in a pandemic year: it is not just about COVID-19, the University of Adelaide School of Public Health Research Symposium*. Adelaide, Australia (15th February 2021).

Oswald, T.K. Rumbold, A.R., Kedzior, S.G.E., & Moore, V.M. (2020). Psychological impacts of 'screen' and 'green' time for children and adolescents. *Robinson Research Institute Research Symposium*. Adelaide, Australia (18th November 2020).

Peer-Reviewed Poster Presentations

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., Kohler, M., & Moore, V.M. (2021). Mental Health of Young Australians During the COVID-19 Pandemic: Exploring the Roles of Employment Precarity, Screen Time, and Contact with Nature. Poster accepted for the *Florey Postgraduate Conference*. Adelaide, Australia.

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., & Moore, V.M. (2019). Psychological impacts of 'screen' and 'green' time for youth: a systematic scoping review. Poster accepted for the *Robinson Research Institute Research Symposium*. Adelaide, Australia.

Oswald, T.K., Rumbold, A.R., Kedzior, S.G.E., & Moore, V.M. (2019). Screen Time vs Green Time. A Systematic Scoping Review of Psychological Outcomes Related to the Use of Screen-Based Technologies, and Exposure to Nature, in Children and Adolescents. Poster accepted for the *Florey Postgraduate Conference*. Adelaide, Australia.

THESIS OUTLINE

An outline of the thesis chapters is provided below.

Chapter	Purpose of chapter
1. Introduction	This chapter provides a background, introduces key concepts, and provides a rationale for the research conducted.
2. Aims and Methodology	This chapter provides an overview of the aims of the thesis and a rationale for the research methodologies used.
3. Paper 1 (Published) Psychological impacts of "screen time" and "green time" for children and adolescents: A systematic scoping review	Paper 1: Published in *PLOS ONE.* This chapter presents the first paper included in the thesis; a systematic scoping review which addresses Aim 1 of the thesis.
4. Paper 2 (Published) Mental Health of Young Australians during the COVID-19 Pandemic: Exploring the Roles of Employment Precarity, Screen Time, and Contact with Nature	Paper 2: Published in the *International Journal of Environmental Research and Public Health.* This chapter presents the second paper included in the thesis; a national study which addresses Aim 2 of the thesis.
5. Paper 3 (Manuscript form) Teens, screens, and a public health perspective: A developmental lens on how extensive use of digital technologies could	Paper 3: In manuscript form. This chapter presents the third paper included in the thesis; a theoretical paper which addresses Aim 3 of the thesis.

	affect self-regulation capabilities and undermine mental health of adolescents	
6.	Paper 4 (Manuscript form) Buffering “screen time” with “green time” in adolescence: A randomised pre-post pilot study exploring the acute psychological effects of screen-based technologies and the restorative potential of nature immersion	Paper 4: In manuscript form. This chapter presents the fourth paper included in the thesis; a randomised pre-post pilot study which addresses Aim 4 of the thesis.
7.	General Discussion and Conclusion	This chapter presents a general discussion of the body of research as a whole. Conclusions, implications, and recommendations are provided.
8.	References	This chapter presents all of the references for the thesis.
9.	Appendices	This chapter provides additional information and attachments relating to the research conducted.

CHAPTER ONE: INTRODUCTION

1.0 Preamble

The purpose of Chapter 1 is to introduce key concepts and provide an overall summary of the literature relevant to the thesis. A systematic review of the literature is presented in Chapter 3, while Chapters 4, 5, and 6 provide additional synthesis of background literature specific to each of the studies presented. This introduction chapter seeks to define and discuss central concepts which underpin, but were beyond the scope of discussion, in the individual studies. Specifically, the concepts of “psychological well-being”, “children and young people”, and “youth” are first defined and discussed. The state of youth psychological well-being is then explored, as well as a discussion describing why this is a public health problem that requires public mental health solutions. Following this, determinants of youth mental health are outlined, and “increased screen time” and “decreased green time” are introduced as potential determinants of psychological well-being for contemporary youth. The potential role of nature as an upstream determinant of psychological well-being in a high-tech era is then proposed.

1.1 Key concepts

1.1.1 Psychological well-being

Psychological well-being is defined as “the combination of feeling good and functioning effectively” (1). In this thesis, *psychological well-being* is used as an overarching term to collectively refer to the distinct but related concepts of mental health, mental illness, mental well-being, and cognitive functioning; all of which are relevant in achieving psychological well-being.

The World Health Organization (WHO) defines *mental health* as “a state of well-being in which the individual realises his or her own abilities, can cope with normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community" (2-4). It is widely accepted that mental health is closely connected with physical health and overall well-being (3). The euphemistic use of the term "mental health", to describe matters related to both mental health and mental illness, has often led to confusion about how to correctly view and conceptualise mental health (3, 5). Contrastingly, *mental illness* collectively refers to diagnosable *mental disorders* and related symptoms (also referred to as *mental health problems*), which significantly affect how a person feels, thinks, and behaves, causing distress and often impairing functioning in social, familial, and professional areas of life (6, 7). Examples of common mental disorders are depression and anxiety, otherwise known as mood, affective, or internalising disorders. Depression is characterised by persistent sadness, helplessness, and a loss of interest in activities which were previously seen as enjoyable, causing significant impairment in daily life (8). Anxiety disorders are characterised by intense and prolonged feelings of distress, fear, and worry, that are strong enough to interfere with one's daily functioning (9).

The WHO emphasises that mental health does not merely equate with the absence of mental illness (5), which is highlighted by the inclusion of "well-being" in their definition. The concept of *mental well-being* has been described as comprising two main elements: hedonic well-being (feeling good) and eudemonic well-being (functioning effectively) (2). It is widely accepted that an individual may have a diagnosed mental disorder but simultaneously enjoy high levels of well-being, and vice versa (3). It is also recognised that individuals with low levels of mental well-being are at an increased risk of experiencing mental illness (10). This highlights the importance of considering the dimensions of both mental illness and mental well-being when discussing mental health, rather than viewing mental health on a single continuum with mental illness and mental well-being sitting at opposite ends of the same spectrum (3).

Cognitive functioning is defined as "the performance of the mental processes of perception, learning, memory, understanding, awareness, reasoning, judgement, intuition, and language" (11). Executive functions are a range of complex cognitive functions, involving the executive attention network in the brain, including abilities such as sustaining and shifting attention, inhibition control, and monitoring and updating information in working memory (12, 13). Cognitive functioning – particularly executive functions – serve a critical role in psychological well-being. Deficits in these functions have shown to increase vulnerability to mental illness, including symptoms of depression and anxiety (this is discussed in-depth in Chapter 5) (14-16).

1.1.2 Children and Young People / Youth

Defining specific periods of human development by age is a complex and constantly evolving process. Traditionally age-bound definitions of life phases have generally been related to biological age, puberty, and sexual development, yet even these definitions are greatly influenced by social, cultural, and environmental factors, meaning it is difficult to establish consensus (17). As shown in Figure 1.1, Sawyer and colleagues (18) illustrate how the degree of overlap between terms used to describe the developmental periods of childhood, adolescence, and adulthood are not distinctly related to age, with varying terminology.

Given the lack of clear consensus, the overarching terms of *"children and young people"* and *"youth"* are used interchangeably to describe individuals aged 0 – 24 years in this thesis (19). This overarching term is further divided into sub-groups where consideration of more specific developmental experiences is required (see Table 1.1).

According to the United Nations, children and young people (aged 0 – 24 years) made up 44% of the world population in 2010; 47% in low-middle-income countries (LMICs) and 30% in high-income countries (HICs) (19, 20). This youth population is projected to drive future global economic prosperity, meaning the health and psychological well-being of this group should be viewed as important for not only individuals, their families, and immediate communities, but also as an asset for the future success of societies as a whole (19).

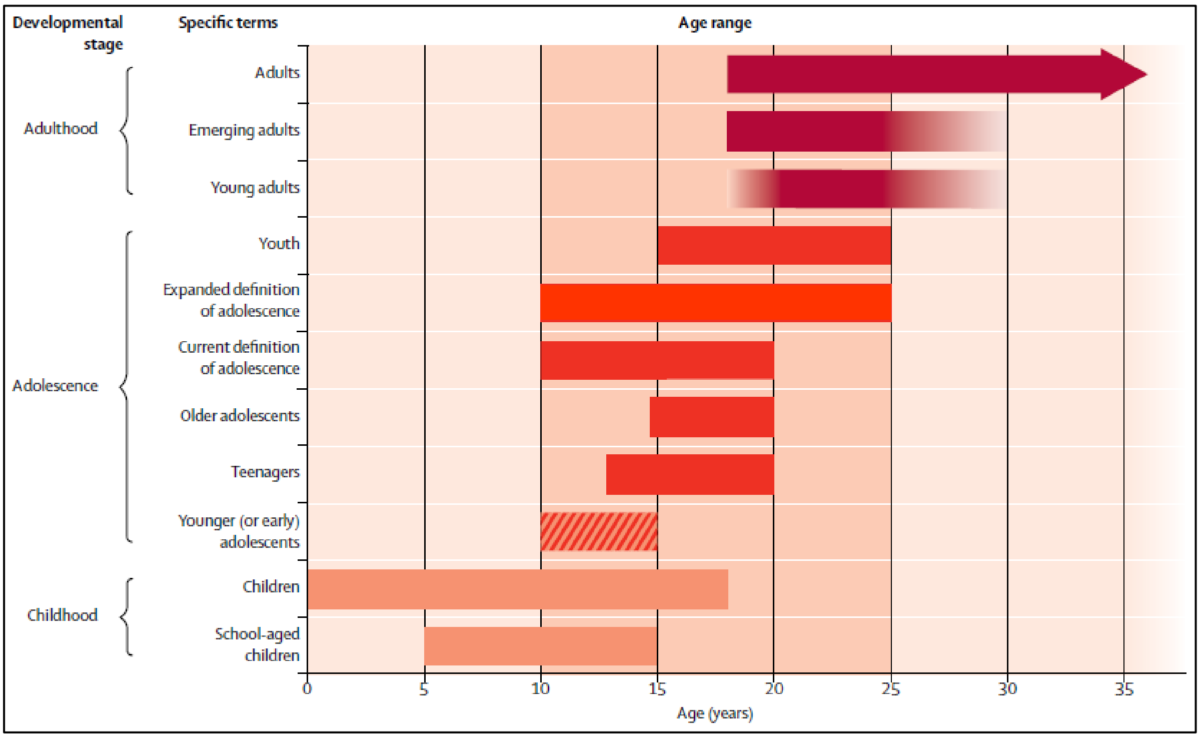

Figure 1.1 Variation in terminology used to define specific age groups, with overlapping developmental periods of childhood, adolescence, and adulthood, as shown by Sawyer et al. (2018)

Table 1.1 Age definitions used in the thesis and relevant developmental experiences (21)

Label	Age range	Select relevant developmental experiences
Children and young people / Youth	0 – 24 years	
Children	0 – 11	
Young children	<5 years	• Language development • Cognitive development • Motor development
Schoolchildren	5 – 11 years	• Primary education • Puberty starting • Increasing importance of peers and relationships outside of the family
Adolescents	12 – 18 years	
Early adolescents	12 – 14 years	• Secondary education • Ongoing/complete pubertal development • Romantic relationships • Intimacy in friendships • Increased risk-taking • Refinement of cognitive capabilities (e.g., higher order thinking/executive functioning) • Experiencing co-occurring emotions • Casual employment
Older adolescents	15 – 18 years	
Young adults	18 – 24 years	
		• Tertiary education or training • Move away from the home • Employment / establishing career path • Financial autonomy • Diverse social circles and supports (parental, partner, own children)

1.2 The state of youth psychological well-being

Drawing together the key concepts outlined in section 1.1, this section explores the current state of youth psychological well-being. The section is comprised of three sub-sections. The first sub-section discusses the onset of mental illness in youth and associated impacts. The second sub-section outlines the epidemiology of youth mental health problems, including prevalence and burden. The third sub-section involves a discussion on whether youth mental health problems are currently increasing.

1.2.1 Onset of mental illness in youth and associated impacts

It is widely accepted that most mental health problems begin in youth, although they are often first detected later in life (9, 10, 17, 22, 23). McGorry and colleagues' 2011 review of the age of onset of mental disorders demonstrated that 75% of incident cases of mental disorders emerged before the age of 25 years (24). According to a more recent (2021) global meta-analysis of 192 epidemiological studies, the onset of mental illness peaks at 14.5 years of age (25).

It is also widely accepted that experiences of mental illness in young people have broad impacts across the lifespan, as they tend to persist beyond childhood and adolescence, into adulthood (9, 10, 22, 23, 26, 27). For example, longitudinal research has shown that depressive symptoms in adolescence are predictive of clinical depression in adulthood (28), and childhood anxiety is predictive of poorer functioning in adulthood (29, 30). In a 15-year prospective longitudinal study by Kim-Cohen and colleagues, among adults who were diagnosed with a mental health disorder using validated diagnostic tools, 74% had received a prior diagnosis before 18 years of age and 50% before 15 years of age, suggesting that most adult mental disorders could be considered extensions (or recurrences) of youth mental disorders (31).

Youth is an important period of life, involving a number of transitions and milestones, often including completion of one's academic career, establishing oneself in the job market, extending support networks outside of the family, and exploring romantic relationships. Patel and colleagues (17) argue that experiences of mental illness during these formative years may reduce the likelihood of these transitions and milestones being completed successfully, or may at least increase the difficulty with which a young person may be able to achieve them. It is this disruption which may create a level of vulnerability and ultimately have an effect on related social and economic outcomes which extend into adulthood (2, 9). Mental disorders are associated with a broad range of health impacts, including suicide, increased risky behaviours, physical illness, and premature mortality (for reasons other than suicide), as well as non-health related outcomes such as poorer education attainment and employment outcomes, crime and violence (32).

1.2.2 The extent of youth mental health problems

Measurement of youth mental disorders is increasingly being included in national surveys of health in many countries, however, determining precise prevalence estimates is currently hampered by variation in use of diagnostic tools and use of select populations (19). Nevertheless, estimates based on a number of global studies provide some insight. For example, in a synthesis of community epidemiological studies, Patel and colleagues reported that one in every four to five 12 to 24-year-olds will suffer from at least one mental disorder in any given year (17). This synthesis was based on population- or school-based studies in non-mental healthcare settings, published since 1995, with a substantial sample size, and using structured diagnostic instruments like the Diagnostic and Statistical Manual of Mental Disorders or the International Classification of Diseases (17). The authors noted that substantial cross-cultural variations were evident, and much less information was available from low-middle-income countries (LMICs).

In a global coverage study of prevalence data for mental disorders in young people, Erskine and colleagues reported that there is sparse high quality and representative data on the prevalence of mental disorders in children and young people, relative to data available for other age groups (33). This is particularly the case in LMICs, where epidemiological evidence is very limited and communicable disease research is often the priority (22, 26, 33). Of 187 countries studied by Erskine et al, 66% had no prevalence data available for depression and anxiety disorders in children and young people. The mean prevalence coverage for all HICs combined was 26.4%, which fell to 4.5% for all LMICs combined. Although global prevalence coverage is increasing for mental disorders in children and young people, future research needs to address these existing information gaps to allow for improvement in mental health policy and service provision planning (26, 33). According to Kieling and colleagues (23), more consistent and precise prevalence estimates could be obtained by using the same methodology or instrument across countries, such as defining cases according to the Diagnostic and Statistical Manual of Mental Disorders or the International Classification of Diseases (23). The challenge in this approach, however, is taking into account differences in resource availability, languages, and cultural conceptualisations of mental health and well-being (33).

While precisely estimating the global prevalence of youth mental health problems has proven difficult to date, determining the burden of disease attributable to youth mental health problems is more straightforward, owing to a number of large seminal global burden of disease studies. Burden of disease can be measured through years lived with disability (YLDs) and years of life lost due to premature mortality (YLLs). Disability adjusted life years (DALYs) are often used as a metric of overall burden, combining both non-fatal (YLDs) and fatal (YLLs) burden of a disease, with one DALY being equivalent to the loss of one year of healthy life as a result of a disease state.

Using data from the WHO's 2004 Global Burden of Disease study, Gore and colleagues found that neuropsychiatric disorders (e.g., depression, panic disorder, substance use, and others), were the main cause of burden for 10 – 24-year-olds in HICs, especially amongst those aged 15 – 24 years old (50 DALYs per 1000 males and 52 DALYs per 1000 females) (22). The burden of disease from these neuropsychiatric disorders was also high in LMICs and was identified as the main cause of disability for 10 – 24-year-olds in all global regions studied, accounting for 45% of all YLDs (22).

Baxter and colleagues' used data from the 2010 Global Burden of Disease study to explore the global burden of disease attributable to anxiety disorders specifically. While other non-communicable diseases had significantly higher mortality rates, this study reported that anxiety disorders incurred greater global disability (9). For example, the global disability of anxiety disorders was more than 15-times higher than that attributed to HIV/AIDS or malaria, and the YLD rates for anxiety disorders were six times higher than all cancers combined. The majority of anxiety-related disability was concentrated within the adolescent and young adult age groups, with greater burden among females. Specifically, anxiety disorders were ranked as the 6th highest cause of YLD for young people aged 5 – 14 years (4th for females and 7th for males), but were less important for in those aged ≥50 years, being ranked 10th or greater for YLD (9).

Data from the 2010 Global Burden of Disease study was also used by Erskine and colleagues to explore the global burden of disease attributable to a wider range of mental disorders (grouped with substance use disorders) in children and young people only (aged 0 – 24 years) (19). Mental and substance use disorders were identified as the leading cause of disability for children and young people in both HICs and LMICs, accounting for a quarter of all YLDs (54.2 million). Globally, mental and substance disorders ranked 6th in terms of DALYs (55.5 million) accounting for almost 6% of total disease burden in the age group. This DALY ranking rose to 5th when mortality burden of suicide was considered. In HICs mental and substance use disorders were the leading cause of DALYs, but they ranked 7th in LMICs due to mortality attributable to communicable diseases.

1.2.3 Are mental health problems increasing among children and young people?

Considerable increases in the diagnosis and treatment of youth mental disorders have been observed in recent decades (26). There are a range of explanations which may account for this trend over time. In particular, increased help-seeking by parents and young people, greater pathologising of feelings and behaviours that may have previously been considered a normal part of growing up, broadening of diagnostic criteria for mental disorders, and improved screening and recognition of mental health problems in primary care and school settings (26). However, even accounting for these factors which could arguably increase detection of mental disorders, there is emerging evidence that indicates there have been increases in underlying prevalence and thus burden of youth mental health problems in recent decades (26, 34).

Collishaw conducted a review to assess whether rates of youth mental health problems have changed over time, from as early as 1973, through to 2012 (26). The review focused on comparisons of representative population samples of children (which the authors defined as 2 – 9 years) and adolescents (10 – 18 years), mostly from studies undertaken in HICs. Studies included in the review from the United Kingdom, Greece, Germany, Sweden, Iceland, the Netherlands, Norway, New Zealand, and China, support the view that adolescent internalising problems (anxiety, depression, and emotional problems) have increased in recent decades. These studies included evidence from both youth- and parent-reports, and the majority suggested that this increase in adolescent internalising problems has been greater for girls than for boys (26). Notably, studies included in the review were prospective, used equivalent validated assessments of mental health, typically reported high response rates (>80%) or addressed the possibility of selective drop-out appropriately, meaning estimates across studies were generally high quality.

Importantly, in terms of absolute effect sizes, these studies indicate non-trivial increases in prevalence of internalising problems among adolescents over time. This was especially noted in a number of studies conducted in the UK between the late 1980s and early 2000s. For example, one Scottish study reported that the number of adolescents meeting case criteria on the General Health Questionnaire, a validated measure of internalising problems, almost doubled for boys and more than doubled for girls within a 20-year time period (1987 – 2006) (35). Similarly, in 2006, 15% of UK adolescents reported experiencing five or more symptoms of anxiety or depression on the General Health Questionnaire, compared with 7% of adolescents two decades prior (36). Parent-reports of high emotional problems in their teens also increased by 70% between 1986 and 1999 in the UK (37).

Bor and colleagues conducted a review of time trends of children and young people's mental health problems, across 12 (primarily) HICs, into the 21st century (34). They found that changes in mental illness burden in children and young people depended on symptom type, gender, and developmental stage. Overall, recent cohorts of young children and schoolchildren did not exhibit worsening of mental illness symptoms over time; however, in line with the work by Collishaw, the majority of studies indicated an increase in internalising problems for adolescent girls. The studies reviewed by Collishaw, Bor and colleagues were diverse in terms of country of origin, sample, and method of mental health assessment. Despite this, most studies pointed to an increase in internalising problems among adolescents. It is this convergence of evidence across diverse study methods and multiple informants which adds weight to the assertion that there has been an increase in mental health problems among youth over time (26, 34).

Trends in youth mental health problems have also been examined in Australia, where the research for this thesis was conducted. Jorm and Kitchener (38) did this most recently, using meta-analytic methods on available national and state datasets between 2001 and 2018. These datasets all used the Kessler-10 Psychological Distress scale, including the National Health Survey, the Victorian Population Health Survey, and the New South Wales Population Health Survey. Jorm and Kitchener found that there were no significant changes in the prevalence of high and very high psychological distress among young Australians (aged 12 – 25 years) from 2003 to 2014 (prevalence between approximately 12 and 17%), but there was a statistically significant increase from 2015 onwards (prevalence between approximately 18 and 26%), even after adjusting for differences in methodology. These findings were consistent with prevalence data from Australian national surveys of child and adolescent mental health carried out from 1998 to 2013 – 2014 (39, 40), which found a significant increase in the prevalence of major depressive disorder in adolescents in later years. The findings were also consistent with data from the *Household, Income and Labour Dynamics in Australia* study, which found a decline in mental health of young adults (aged 18 – 24 years) from 2013 onwards (41). Possible reasons for the secular increases in youth mental health problems are discussed in section 1.4.1.

1.3 Youth mental health problems: A public health problem

With widespread prevalence, increasing incidence, and consequently growing global burden of disease attributable to youth mental illness, this issue may be considered a public health problem deserving urgent attention. Despite this, public health is not strongly engaged in the sphere and youth mental health issues have been largely overlooked in public health agendas in many countries (2, 42). Historically, mental health has been viewed as residing outside of public health, because major public health foci and decisions have generally been informed by mortality statistics, while a lack of emphasis has been placed on morbidity (5). The historic lack of emphasis on disease morbidity has considerably undervalued the significant global impact of youth mental illness (5), and consequently the burden of mental illness has not been reduced in recent decades (5, 43).

A consequence of the epidemiological transition (which saw the pattern of mortality and disease in populations shift from high infant mortality and infectious disease, to greater life expectancy and chronic diseases) is the need to reorient the focus of public health to non-communicable, and typically non-fatal, sources of disease burden that originate in adolescence and persist across the lifespan (9, 19). This is occurring for health conditions such as youth overweight and obesity, for example. The aforementioned global burden of disease studies, which collect more than just suicide statistics as an indicator of mental health, play an important role in drawing attention to youth mental health problems as a public health issue.

1.3.1 The dominant discipline: Clinical Psychology

Currently, the dominant professional discipline which is addressing youth mental health problems is clinical psychology (and psychiatry in more serious cases). Clinical psychology predominantly focuses on understanding and treating an individuals' intrapsychic processes through widely-used evidence-based psychotherapies (44). While undeniably valuable and important for treating mental illness, psychotherapies tend to be highly individualistic, clinical, and costly, placing the onus of mental well-being on the individual, and typically fail to consider other conceptualisations of mental health which look beyond the individual to wider social, political, familial, cultural, and ecological determinants of mental health (44).

The authority of clinical psychology has been demonstrated by considerable investment in person-based care. For example, in 2011 the Australian government spent $10 million (AUD) per week on the *Better Access Scheme,* which was designed to expand the availability of psychological treatment for Australians under universal health insurance (45, 46). Furthermore, the Australian Government also committed to expanding the clinical services of *headspace,* Australia's National Youth Mental Health Foundation, with an additional $51.8 million in funding in 2019 (47). While not arguing that this funding is not necessary, these examples are a *response* to mental illness, and essentially reflect a *large-scale treatment-orientation* to mental health. To give an analogy, this may be considered the equivalent of the government committing to funding bariatric surgeries but not attempting to curb other determinants of obesity, such as fast-food advertising, inappropriate food labelling, and unsafe neighbourhoods which prevent physical exercise. According to Seager (48), "we are still very much in the pre-Victorian age" when it comes to psychological well-being; reactively treating disorders and symptoms, rather than examining and improving the underlying circumstances that give rise to different mental health states.

Despite the considerable investment in clinical mental health services, clinical psychology is unable to tackle the current situation alone. Currently, there is a vast gap between youth mental health needs and service/resource availability (23). Most mental health needs are still unmet for young people in HICs, and provision of care is far less in LMICs (17, 32). These service and resource strains have been further exacerbated by the corona virus disease 2019 (COVID-19) pandemic over the past two years, which has seen increased psychological distress experienced across populations as well as a shift in resourcing to acute and high dependency care (49-51). With these service strains making it difficult to access clinical psychologists or other mental health professionals, currently there is a considerable reliance on medications to manage youth mental health problems, which are prescribed through General Practitioners (52).

Of those who do access clinical mental health services, individual psychotherapies appear to be falling short. Relapse rates following psychotherapy have been reported to be between 40% and 70% for young people with anxiety or depression (11-13). Jorm (45) reported that there was no reduction in the prevalence of mental disorders in Australia between 2006 and 2015, despite significant investment in Australian mental health care for the whole population through the *Better Access Scheme* at the time (43). Scott and colleagues (43) argue that the primary driver behind this lack of reduced prevalence is the absence of mental illness prevention included in the scheme, as well as limitations of psychotherapies. They assert that psychological therapies are effective in reducing symptoms of mental disorders, but increases in remission attributable to these therapies are very modest, meaning relapse is at best delayed. Evidence has consistently shown that early prevention is typically more cost-effective than later remediation in the context of mental health (23, 53).

1.3.2 The need for public mental health solutions

While treating mental illness is imperative, *it is not the optimal solution*. This goes beyond economic arguments around the expenses of clinical person-based treatment and early prevention proving to be more cost-effective. As discussed in section 1.2.1, experiences of mental illness while young can lead to a level of vulnerability and persisting disability for the remainder of an individuals' life. Thus, prevention of mental illness is superior to simply ensuring treatment is accessible once it has developed. It is clear that a shift in focus to prevention of mental illness and promotion of mental well-being is especially important for young people, to prevent burden into adulthood.

Evidence indicates that many mental disorders are preventable through public mental health initiatives or interventions (2), and this prevention of mental illness to avoid persisting impacts is increasingly accepted by experts as a public health priority (2, 42). According to Huppert (1), psychological well-being may be improved via three distinct approaches: (1) *treating* mental disorders when they present, (2) *preventing* mental disorders before they occur, and (3) *enhancing* mental well-being. These three approaches are fundamental to *public mental health,* which additionally requires a *whole population-level approach* to sustainably reduce mental illness and enhance mental well-being (10). Yet, in most nations mental health policy and program efforts remain focussed on treatment.

In 2005, before Australia's *Better Access Scheme* was introduced, the WHO suggested that the dual goals of improving mental health, and reducing the personal, social, and economic costs of mental illness, could only be achieved through a public health approach (3, 54). Almost 10 years later, in 2013, the WHO published the *Mental Health Action Plan (2013 – 2020)*, which was a roadmap for global mental health, highlighting the need for mental health promotion and mental illness prevention alongside treatment of existing mental disorders and associated outcomes (3, 32, 55).

Mental health promotion was conceptualised by the WHO as "the creation of individual, social and environmental conditions that enable optimal psychological and psychophysiological development ... positive mental health, enhancement of quality of life and narrowing the gap in health expectancy between groups. It is an enabling process done by, with and for the people" (3, 56). In addition, mental illness prevention was defined by the WHO as aiming "to reduce the incidence, prevalence, recurrence of mental disorders, time spent with symptoms, or risk factors for a mental illness, preventing or delaying recurrences and decreasing the impact of illness in the affected person, their families and society" (3, 56). In 2016, the United Nations also committed to the treatment and prevention of mental illness, as well as the promotion of mental well-being, through *Goal 3* (*Good Health*) of the *Sustainable Development Agenda* (32, 57).

As with other public health interventions, public mental health interventions can be divided into primary, secondary, and tertiary levels (32). Of particular benefit to children and young people are primary public mental health interventions or initiatives, which involve addressing wider determinants of mental health by promoting protective factors and reducing risk factors (2, 32). When implemented effectively, these universal interventions/initiatives can prevent future mental illness and afford many years of good mental health for young people (5, 58). For example, a systematic review of 11 studies by Garcia-Carrion et al (59) found that universal interventions conducted in schools and communities, which implemented strategies to foster young people's interactions and interpersonal connections with teachers, parents, community members, and other professionals, had positive effects on children and adolescents' mental health. Specifically, these social interventions resulted in decreased internalising symptoms associated with depression and anxiety, as well as increased social skills and well-being.

Despite the known need for, and benefits of public mental health interventions, currently investment in these population-level interventions is limited (particularly outside of school settings), even in HICs (32, 43). The discrepancy in both investment and action between clinical care and public mental health, is currently perpetuating increasing morbidity and mortality attributable to mental illness (60). Successfully addressing youth mental health problems will be contingent on the field's capacity to be permeable to interdisciplinary approaches (61), whereby the work being done by mental health professionals is supported (and hopefully reduced) by wider public mental health approaches across a myriad of settings.

1.4 Determinants of youth mental health

Public mental health calls for health professionals and decision-makers to be cognisant of the determinants influencing the prevalence and incidence of mental illness in children and young people (43). Bronfenbrenner's socio-ecological model of human development is useful for identifying and presenting risk and protective factors relevant to youth psychological well-being, across a number of levels; from the individual level, through to the micro-, meso-, exo-, and macrosystems, each of which are embedded within the chronosystem (time and historic influences) (62). The model is especially helpful for guiding public mental health policy and practice when interactions between and within these systems are considered (63).

Drawing upon the literature (64-66), Figure 1.2 below offers an extensive (but not exhaustive) representation of determinants of youth psychological well-being across Bronfenbrenner's systems/levels. Potential risk factors are coloured in orange, and potential protective factors are coloured in blue. It is the cumulative effect and interplay of these risk and protective factors that can predispose young people to increased vulnerability to mental health problems (5).

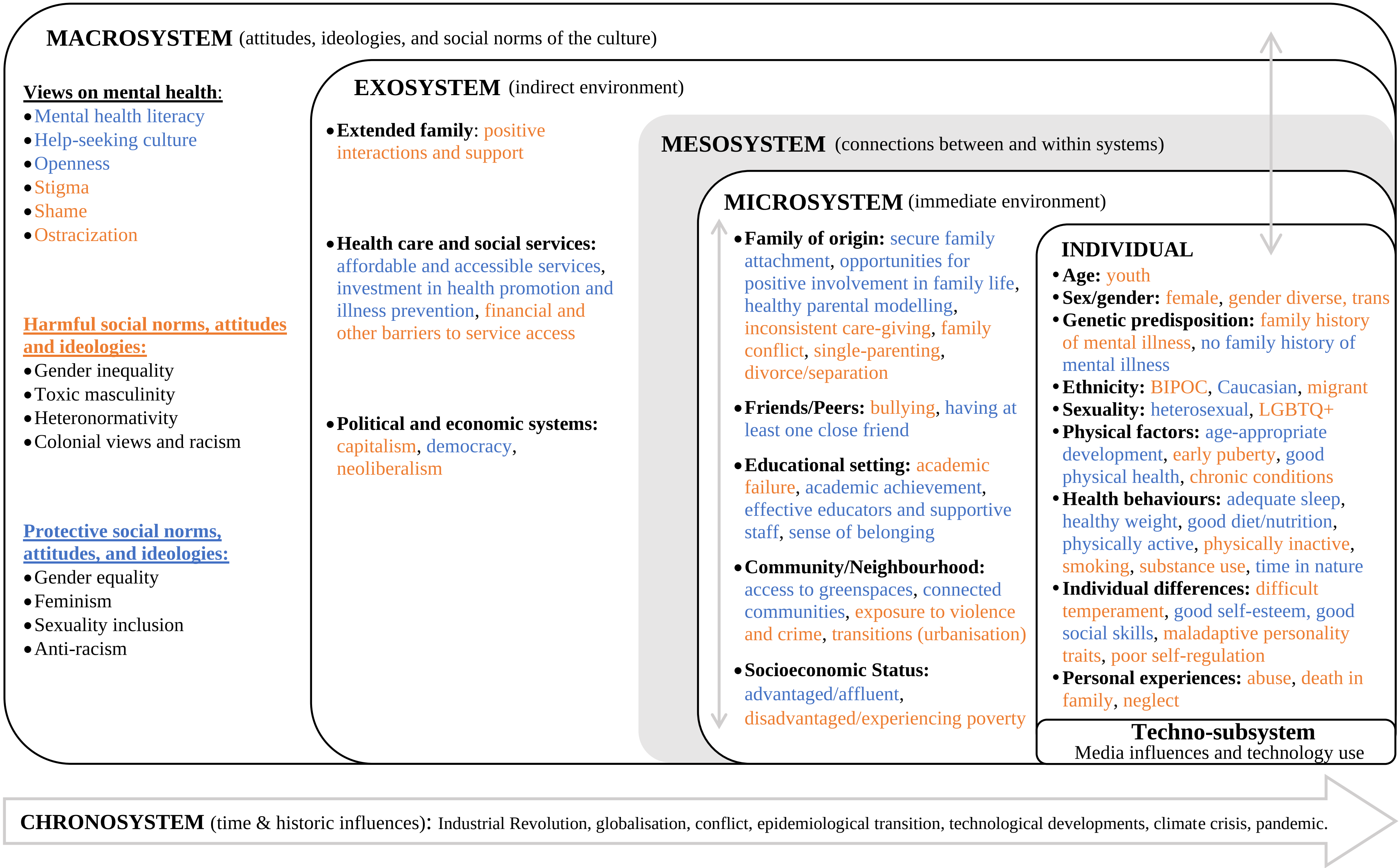

Figure 1.2 Using Bronfenbrenner's socio-ecological model to present select risk and protective factors for youth psychological well-being

1.4.1 Potential explanations for secular increases in youth mental health problems in high income countries

There are a number of possible explanations for secular increases in mental illness among young people in HICs into the 21st century, and Figure 1.2 may be drawn upon when considering this. For example, secular trends in the timing of puberty is one consideration (26). Specifically, there have been marked decreases in age for pubertal maturation across time (67), which may be problematic given early puberty is associated with higher rates of mental illness in children and adolescents (67). Puberty launches a series of hormonal, neural, and social changes that individually and collectively impact adolescent propensity for internalizing disorders, and may essentially be more difficult for younger individuals to manage (68). However, there is currently a lack of direct evidence testing the extent to which this trend has contributed to increased incidence of mental illness in adolescents (26).

In considering another trend, a meta-analysis by Matricciani, Olds and Petkov (69) indicated a substantial decline in sleep duration among schoolchildren and adolescents over the past century. Given the known importance of sleep for psychological well-being, this is also another regular contender postulated to influence secular changes in mental health problems (26).

There have also been notable changes in young people's broader social, cultural, and economic milieu in the 21st century, which may have potential consequences for the mental health of contemporary cohorts (26, 34). These changes have largely been driven by globalisation (9), a multi-faceted concept generally seen to encompass increasing trade liberalisation, internationalisation of markets, and the spread of global networks linked by information communication technologies (70, 71). While globalisation has been accompanied by improvements in some aspects of health, such as increased life expectancy and reduced infant mortality in some countries (72), it has also facilitated changes in social systems (including values, culture, and attitudes) at an unprecedented rate, which impacts children and young people in a range of ways (9).

Globalisation has been occurring for centuries (73), but from the 1980s rapid progression has been facilitated by the political philosophy of neoliberalism which tends to exacerbate economic insecurity and inequality (74), meaning many developed economies have experienced rising affluence and worsening income inequality in the 21st century (34). In the process of maximising profit and capital, globalisation has transformed local economies, which in HICs has often meant the disappearance of manufacturing and other industries along with the job opportunities and stability they offered. New forms of work have increasingly been part-time or casual, especially for young adults (70), and this precarity is generally adverse for mental health (75, 76). As such, contemporary youth often experience considerable pressure in school and tertiary education settings to improve prospects of future employment (17, 26, 34, 77).

Contemporary youth also frequently express concerns about the environment, planetary health issues, and climate change, as evidenced through the dominance of youth in climate activism. In a 2021 survey of over 10,000 adolescents from 10 countries, over 50% reported feeling sad, anxious, angry, powerless, helpless, and guilty about climate change (78). Furthermore, almost half of respondents indicated that their feelings about climate change negatively affected their daily life and functioning (78). Given the relative recency of these global environmental events, it is not clear the extent to which they have or may contribute to secular changes in youth psychological well-being over time, although they are likely to have a plausible impact.

The gendered increase in internalising problems among adolescent girls is likely to reflect the challenges females continue to face in the 21st century (34). For example, societal changes around media and consumer culture (79) and exposure to earlier sexualisation (80-82) have been suggested to negatively impact recent cohorts of girls and young women. Worries about success in school, as well as concerns around weight and physical appearance, may also accumulate and create increasing pressures on adolescent girls (83). Wiklund et al. (84) highlighted that girls tend to report experiencing greater school performance pressure than their male peer counterparts. Across the board, girls are suggested to be more socially and emotionally attentive than boys, which may predispose them to internalising problems when combined with negative cognitive styles (e.g., rumination) (85). However, it is important to note that gender norms also create expectations of girls being attentive and caring, as well as dictating acceptable expression of emotions (86).

While a plethora of temporal factors and upstream determinants of youth mental health clearly exist, two proximal trends which characterise contemporary youth in HICs as markedly different from previous generations, have regularly been postulated to partially explain observed increases in mental illness among adolescents. These two trends are: (1) significant increases in the time young people spend engaged with screen-based technologies (increased "screen time"), and (2) significant decreases in young people's contact with nature (decreased "green time"). Below, screen time and green time are defined and briefly discussed as determinants of youth psychological well-being.

1.4.2 Increased Screen Time

"Screen time" refers to time spent engaging with screen-based technologies, including television (TV), videogames, computers, laptops, iPads, tablets, smartphones, and gaming consoles, which also permit access to a range of platforms and applications through the Internet (e.g., social media). Rapid technological developments in recent decades have resulted in increased sophistication of technologies as well as increased time humans spend immersed in these screen-based activities – particularly children and young people. Although difficult to accurately quantify, the average total screen time for children and young people aged 8 – 18 years in the U.S. has been reported at 7.5 hours per day (87), and 30% of the time they simultaneously use more than one device (88). This greatly exceeds recreational screen time guidelines (both Australian and International) of less than two hours per day (89) and has prompted concerns that usage patterns now typically exceed what can be considered "healthy" (90, 91).

Historically, these screen-based activities were not available to children and young people, but screen time behaviour is now regularly proposed as a contemporary risk factor for poor psychological well-being. This was highlighted by Currie and Morgan (64) in their paper which summarised findings from a major international population study exploring determinants of young people's mental health between 1983 and 2020. The paper applied a bio-ecological framework, similar to that presented in Figure 1.2, and their addition of a "Techno-subsystem" in the individual level of the model, highlights the potential role of media influences, the Internet, social media, phones, and other technologies on the mental health of contemporary cohorts of young people.

A considerable amount of research has demonstrated negative associations between screen time and mental health outcomes, as shown through increased depression and anxiety symptoms and decreased quality of life measures (92-107). Similarly, studies have also highlighted the deleterious effects of screen time on cognitive functioning, demonstrated through poorer performance at school and on cognitive tests (108-113). Explanations pertaining to associations between screen time and poor psychological well-being typically focus on the "displacement hypothesis", which posits that screen time displaces behaviours which are protective of mental health, including experiencing adequate sleep (114, 115), physical activity (116, 117), and in-person social interactions (118). Beyond this, few studies have explored other potential mechanisms underpinning associations between screen time and youth psychological well-being, which is addressed in Chapter 5 of the thesis.

Contrastingly, a number of studies have reported benefits for cognitive functioning and psychological well-being resulting from increased practice of certain cognitive skills in videogames (119), increased academic efforts on computers (120, 121) and, in some cases, improved social connections and interactions via social media (122). Furthermore, a considerable number of studies have failed to identify any link between high screen time and youth psychological outcomes (90, 93, 96, 99, 123-126).

At the beginning of this PhD in 2018, the evidence base regarding the impact of screen time on young people's psychological well-being was largely inconclusive, with inconsistencies in findings and a focus on older forms of technology (e.g., television watching). While the state of the evidence is discussed in-depth in Chapter 3 of the thesis, some older systematic reviews at the commencement of the PhD had rated the available evidence as low-to-moderate in methodological quality, and high in risk of bias (127, 128). These quality ratings were given due to use of self-reported and non-standardised measures, predominance of observational studies, use of non-representative samples, or lack of reporting around response and attrition rates (127, 128). It was argued that there was a need for more high-quality studies to provide clarification about the psychological impacts of screen time for children and young people. In addition, with technologies constantly changing and becoming increasingly sophisticated, what applied to previous cohorts of children and young people may no longer be relevant; as such, there is a constant need to update this work to consider the range of technologies now accessed by children and young people.

1.4.3 Decreased Green Time

"Green time" is broadly defined as time spent in, or exposure to, natural environments, elements, or content. Human divergence from the natural world has occurred in parallel with rapid technological developments in recent centuries. Contemporary environments experienced by most urban/suburban dwellers are characterised by a considerable reduction in exposure to natural environments (129). With increasing proportions of people living in urbanised areas, and increased engagement with screen-based technologies, opportunities for spontaneous and regular engagement with natural environments have decreased significantly (130). This has dramatically altered the way humans relate to natural environments over the course of a single generation, with changes being particularly prominent for young people. Sometimes referred to as the "Indoor Generation", the majority of children and young people in HICs are now experiencing significantly lower levels of green time compared with previous generations (131-133).

This decrease in green time has important implications for children and young people because a growing body of evidence, emerging from a variety of disciplines, points to a positive relationship between natural environments and psychological well-being. For example, a study of young Canadian children found that those with more natural outdoor play spaces in their childcare centres experienced less depressive symptoms (134), while another study of young British children found that having access to a private garden at home was associated with less psychosocial problems (135). These associations persisted even after controlling for potential confounding due to socioeconomic disadvantage (135).

Links between green time and psychological well-being have been explored in school-aged children across a number of countries. For example, increased greenness surrounding home or school environments has been associated with better performance on tests of attention (136) and superior scores on developmental assessments in Spanish schoolchildren (137). Similarly, increased time spent outdoors in natural areas has been linked to lower internalising symptoms (UK) (138), better emotional and difficulties scores (Spain) (137), greater positive affect (U.S.) (139), and increased health-related quality of life, self-esteem, and friendships (Scotland) (140) among schoolchildren. Studies concerning adolescents have found that living in green neighbourhoods was associated with increased well-being (Australia) (141), while wilderness expeditions have been found to contribute to increased self-esteem (UK) (142).

The psychological benefits of green time could be gained through a range of indirect factors which are protective of mental health, including increased physical activity (143) and social connections experienced in greenspaces (143, 144), as well as time spent exposed to natural sunlight helping to improve sleep (145). Theories within evolutionary and environmental psychology propose that engagement with natural environments is *directly* beneficial for human health and well-being. Notably, Kaplan's Attention Restoration Theory postulates that nature has specific restorative effects on cognitive functioning (146) and Ulrich's Stress Reduction Theory contends that nature induces positive affect through reduced stress (these theories are discussed further in Chapter 6) (147).

The state of the evidence pertaining to green time and youth psychological well-being is discussed in-depth in Chapter 3 of the thesis. However, some older systematic reviews at the commencement of the PhD suggested that the studies in this field of inquiry were low-to-moderate in quality (148, 149), with weaknesses in study designs and sampling methods (150). Specifically, the non-random selection of study participants, insufficient presentation of data, and inconsistencies in findings were some reasons for these quality ratings. As such, further rigorous inquiry and high-quality studies were arguably required in this space.

1.5 Nature as an upstream protective factor for youth mental health in a high-tech era?

Screen time and green time appear to influence psychological well-being in contrasting ways; while screen-based technologies are thought to displace protective behaviours and exhaust cognitive functions, natural environments appear to promote a range of protective behaviours and encourage attention restoration and stress reduction. As such, the combination of high screen time and low green time may present a dual-burden on youth psychological well-being in the 21st century (151).

From a public mental health perspective, nature may currently be an under-utilised public health resource, which could possibly function as an upstream determinant in mental illness prevention and mental well-being promotion for young people growing up in a high-tech era. However, research investigating the psychological impacts of screen time and green time often fails to delineate the effects of technology and nature on psychological outcomes, given their typical exclusive existence (129). Specifically, in real-world settings exposure to nature and technology are often inversely related; fewer screen-based technologies are available or utilised in natural environments, and less nature exists in spaces in which technology is used heavily (such as in indoor settings or major cities). This is seldom considered in research (129) and there is a need to delineate these effects to ensure suitable recommendations are made regarding appropriate screen time and green time for optimal youth psychological well-being.

With the current prevalence, increasing incidence, and impact of youth mental illness, there is an urgent need for accessible and cost-effective pro-mental health infrastructure (152). This should consider the social and physical environments of young people, which are upstream determinants of mental health, and seek potential ecological solutions for mental health promotion (153). The psychological benefits of nature for young people in a high-tech era are worth exploring and harnessing; it is this premise which is explored in the thesis.

CHAPTER TWO: AIMS & METHODOLOGY

2.0 Preamble

The purpose of Chapter 2 is to provide a rationale for the overall research approach chosen. I first outline the *Public Health Psychology* research approach which underpins the work contributing to this thesis. Next, I discuss the specific aims, objectives, and (briefly) the chosen methods for each of the studies. Detailed information about the methods of each study can be found in Chapters 3, 4, 5, and 6. Finally, I summarise how each of these studies draws upon a public health psychology research approach.

2.1 A Public Health Psychology research approach

As discussed by Jane Wardle in 2000, the term *public health psychology* was coined to describe an important research approach to address psychological problems of major public health importance (154). Historically, research in the field of psychology has typically been concerned with individual-level explorations and explanations, while sociodemographic factors have often been seen to "muddy the waters" and weaken statistical models, meaning they are not typically given a central role when researching psychological phenomena (154). Contrastingly, research questions in the public health sphere tend to centre around the impact of population-level factors on psychological outcomes, such as socioeconomic status, but with limited attention paid to consideration of individual differences (e.g., personality traits as one example) and underlying mechanisms relevant to psychological processes (154). In this sense, psychology and public health research fields may at times function in two silos; one silo in which attention to the individual fails to identify and address common risk and protective factors within and across populations, and the other which focuses on the wider population without fully attending to realities of individuals' lives (60). For some time now, contemporary researchers in both fields have been focussing on bringing these individual and population approaches together. Public health psychology is a research approach which specifically does this, and allows for exploration and an understanding of the spectrum of possibilities for social and health change, from an individual level, through to the way in which society is organised, with the roles of institutions, policy, and wider environments (60). It is an approach which has the potential to inform the limitations of traditional psychological and public health research approaches by building synergies which can result in improved health and well-being for both individuals and populations as a whole (2).

Wardle specified public health psychology as a research approach which requires the traditional conceptual and empirical strengths of psychology to be supplemented with the methodological strengths of epidemiology. A number of these relevant psychological and epidemiological strengths are outlined below in sections 2.2 and 2.3.

2.2 Psychology strengths

Many contemporary psychological questions derive from age-old philosophical questions about the nature of what it means to be human (21). However, by the end of the 19th century, psychology had emerged as a field which aimed to answer questions about mental processes through scientific investigation, including systematic observation and experimentation (21). The first psychology laboratory was opened in 1879 by Wilhelm Wundt, otherwise known as the "father of psychology". Wundt wished to use scientific methods to discover the "elementary units of human consciousness", which he believed would combine to form more complex ideas around human thoughts, feelings, and behaviours (21). This may be likened to the work of chemists, in which atoms are viewed as the building blocks for everything, combining to form molecules, and so on. While Wundt never intended for experimentation to be the only path to psychological knowledge, proceeding generations of experimental psychologists wished to separate themselves from psychology's philosophical past (21). They strived to establish a discipline of psychology firmly rooted in the scientific method; as such, experimentation became the foundation of much psychological research. This approach was founded in medicine and also occurred concurrently across other disciplines.

Experiments are often conducted in psychological research when researchers wish to confidently assert that there is a causal relationship between an exposure and an outcome (155). True experimental research designs capitalise on two procedures which differentiate them from other methodologies: (a) manipulation of selected variable(s) (while holding everything else constant) and (b) random assignment to a condition or conditions (155). These procedures allow researchers to determine whether the variable being manipulated has an effect on the outcome alone, while random assignment helps to equalise groups within an experiment, reducing the chance that the groups are different from each other before the manipulation is conducted. These are the most important advantages of experimental research designs in psychology; they help to minimise confounding factors (e.g., potential sociodemographic and lifestyle factors) and solve the issue of individual differences which are inevitably observed in psychological science (a problem not faced by other scientists (e.g., physicists)) (155).

Maximising both validity and reliability is also central to psychological research, as they are important determinants of the degree to which findings are likely to be accurate approximations of the truth (156). Validity and reliability are especially important properties for psychometric scales which are used to assess latent psychological phenomena that cannot be directly observed. As shown in Figure 2.1, validity refers to the extent to which a scale measures the underlying construct that it proposes to (i.e., hits the target), while reliability refers to the ability of a scale to reproduce a result consistently if applied across time and space (157, 158). Psychometric scales which have been validated and shown to be reliable through psychometric testing should be drawn upon in public health psychology research.

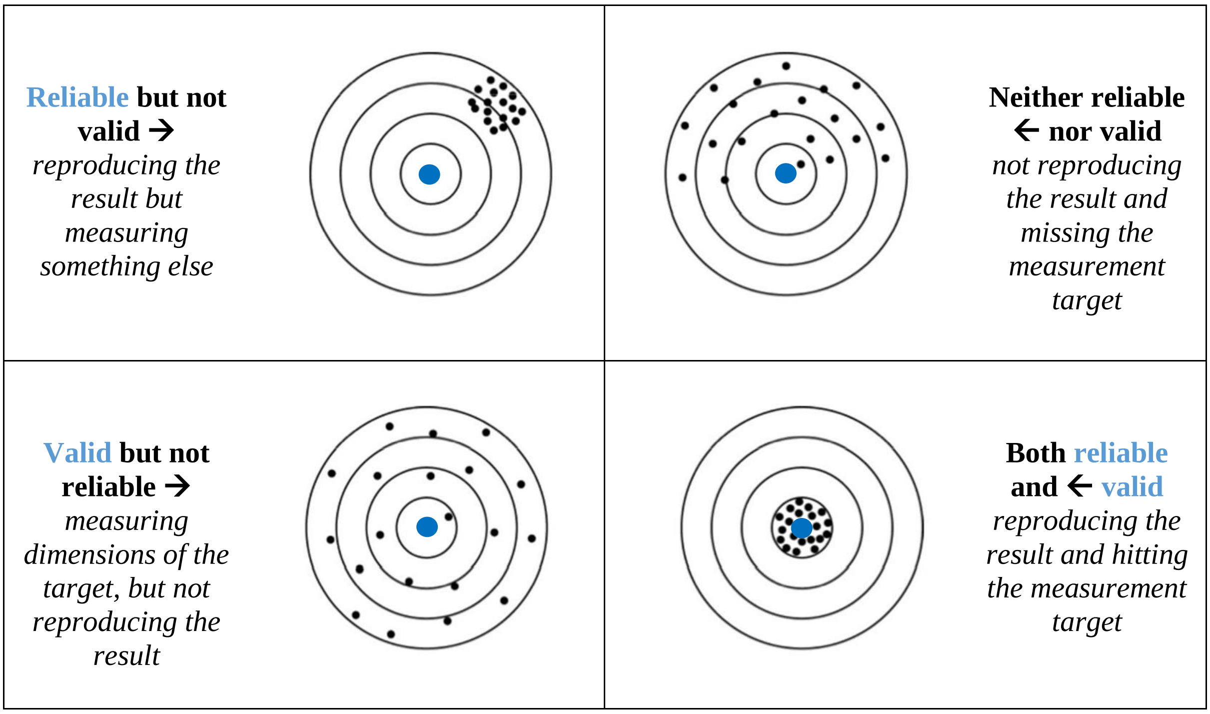

Figure 2.1 Combinations of validity and reliability of psychometric scales (adapted from Souza et al., 2017)

Owing to its broad scope, psychological research can also be divided into a number of sub-disciplines. Different understandings from these sub-disciplines, as outlined in Table 2.1, can be applied to a wide variety of research areas or questions (21). The diverse sub-disciplines offered by psychology are useful in public health psychology research and are especially important in research pertaining to youth. For example, biopsychology, cognitive psychology, developmental psychology, and social psychology all consider the physical, cognitive, and social transformations children, adolescents, and young adults experience across these phases of life, which are highly relevant to their psychological well-being. Considering just one sub-discipline of psychology, such as clinical psychology, would overlook these critical aspects.

Table 2.1 Psychology sub-disciplines relevant to research in youth psychological well-being (as presented by Burton, Westen, and Kowalski, 2012)

Sub-discipline	Description
Biopsychology	Biopsychology investigates the physical basis of psychological phenomena such as thought, emotion, and stress.
Clinical	Clinical psychology focuses on the nature and treatment of psychological processes that lead to emotional distress.
Cognitive	Cognitive psychology examines the nature of thought, memory, sensation perception, and language.
Developmental	Developmental psychology studies the way thought, feeling, and behaviour develop across the lifespan.
Educational	Educational psychology examines psychological processes in learning and applies psychological knowledge in educational settings.
Environmental	Environmental psychology studies the reciprocal relationships between humans and built and natural environments.
Health	Health psychology examines psychological factors involved in health and disease.
Personality	Personality (and individual differences) psychology examines people's enduring ways of responding in different kinds of situations and how individuals differ in the way they tend to think, feel, and behave.
Social	Social psychology examines interactions of individual psychology and group phenomena.

2.3 Epidemiology strengths

A number of methodological strengths in epidemiology research may be used to complement the aforementioned strengths offered by psychology. While experimental designs are particularly useful when looking at relationships between variables, observational study designs are required for assessing prevalence of disease and well-being outcomes. Examples of observational study designs include cohort studies, case-control studies, and cross-sectional studies (159), which are commonly used in public health and some psychology research. However, these study designs necessitate appropriate/rigorous sampling, which is done particularly well in epidemiology research. Psychology has a long history (and current practice) of using convenience samples for research (154), which may involve recruiting undergraduate psychology students to participate in studies, or getting community, workplace, or patient volunteers involved. While this approach can be appropriate in a number of circumstances (such as exploring associations between variables), it can introduce bias if the sample is not representative of the population of interest or if they have different motivation to the desired target group (here associations between variables would not be universal) (154). Population-based sampling is commonplace in epidemiological research, which involves the recruitment of samples that are representative of populations under investigation. A public health psychology research approach encourages researchers to carefully identify appropriate sampling frames for observational research in the nexus of psychology and public health, and to determine which sampling methods are appropriate (such as random and stratified sampling) (154). This also requires the use of appropriate statistical methods, such as multi-level modelling techniques, for analyses where clustering effects may be seen in a sample (154). Where it is not possible to conduct population-based random sampling, it is important that prevalence estimates are not made, and special attention should be paid to the potential representativeness of the sample collected.

Traditionally, scientific, clinical, and psychological research has been concerned with procedures which involve testing a hypothesis and determining whether the observed outcome was unlikely to have occurred merely by chance; otherwise known as relying on statistical significance (154). Public health psychology, along with many other evolving research fields, demands a different approach to statistical analysis, which gives attention to the size of associations between exposure and outcome variables, paying close attention to confidence intervals, and establishing whether associations are independent of other variables. Confidence intervals are particularly important to consider when generalising results, as they provide a likely range of values which would contain the true population parameter with repeated sampling (160).

While psychology is generally more familiar with testing what Cohen (161) defines to be “medium” effect sizes (e.g., $d = 0.5$) in intervention studies, public health research often involves testing small effects in cohort studies (154). Although small effects may only contribute to a small amount of the variance in a health outcome, at a population level these effects can be important because of how widespread an exposure may be. Investigations of small effects can also contribute to enhancing understanding of disease processes. Public health psychology is interested in both small and larger effect sizes, and encourages incorporation of anticipated effect sizes into study design (as in many other areas of population health and clinical medicine) to ensure an adequate sample size is selected with appropriate statistical power to detect the effect (154).

2.4 Additional considerations for a modern public health psychology research approach

In 2020, Perry Halkitis revisited Wardle’s conceptualisation of public health psychology and suggested a number of additional considerations for modern public health psychology (60). Like Wardle, Halkitis emphasised the need for psychology and public health to join research efforts; however, he also emphasised that research in the nexus of public health and psychology needs to be informed by ongoing health disparities across populations, with a focus on the social determinants of these disparities (60). In this sense, Halkitis argued that public health psychology approaches must be rooted in the macro-construct of social justice, to achieve health equity across societies.

Halkitis also discussed the importance of developing strategies which address and seek to ameliorate psychosocial burdens, as well as delineating causal mechanisms which fuel poor psychological well-being. In particular, he emphasised that public health psychology should focus on developing strategies which promote mental health and prevent mental illness, rather than just contributing knowledge to treatments. Achieving this requires conceptualisations of mental health which incorporate indicators of both mental illness and mental well-being. This has been done in more recent waves of psychology research (e.g., positive psychology), through approaches such as the *Complete State Model of Mental Health* (162), which conceptualises mental health more holistically. This approach allows researchers to identify individuals or groups who are Flourishing (high mental well-being and low mental illness) or Floundering (low mental well-being and high mental illness). It also uniquely allows for the identification of those who are not clinically mentally ill, but are still reporting poor mental well-being (known as Languishing), and would benefit from mental health promotion interventions or support.

2.5 Aims of the thesis

This thesis took a public health psychology research approach, capitalising on the diverse strengths afforded by psychology and epidemiology as outlined by Wardle (154), as well as encompassing additional considerations highlighted by Halkitis (60). The overarching purpose of the thesis was to explore the psychological impacts of screen time and green time on young people, as well as to investigate the potential psychological benefits of green time in a high-tech era. To strengthen the work a multi-method approach was taken, meaning a variety of different methods were employed, each of which addressed the same overarching aim while defining questions and operationalising the variables of interest in different ways.

The specific aims and corresponding objectives of the thesis are outlined below in sub-sections 2.5.1 to 2.5.5, along with a brief description of the methods used for each of the four studies. The work was incremental in nature, meaning the aims were informed by the identified research gaps and built on findings from the preceding work. Detailed descriptions of the methods used in each of the four studies can be found in Chapters 3, 4, 5, and 6, respectively.

2.5.1 Aim 1: Systematic scoping review (presented in Chapter 3)

The first aim was to critically review the existing literature looking at the links between screen time and green time with psychological outcomes, including indicators of poor mental health, positive mental health, cognitive functioning, and academic achievement, in young children, schoolchildren, early adolescents, and older adolescents. The specific objectives were as follows:

a) To describe the international literature and evidence regarding the impact of screen time and/or green time on psychological outcomes in children and adolescents;
b) To explore the basis for inference about causal links between screen time, green time, and psychological outcomes for children and adolescents;
c) To explore the extent to which findings hold, or vary, across the spectrum of socioeconomic status;
d) To investigate the extent to which studies have attempted to delineate the reciprocal effects of screen time and green time on psychological outcomes in children and adolescents.

Due to the diversity of study designs, heterogeneous exposure and outcome measurement, and largely observational nature of the existing literature in this field, a scoping review was selected as the preferred method for addressing Aim 1. Unlike systematic reviews, scoping reviews tend to have a less focussed research question, include diverse study designs and methods, and do not focus heavily on the quality of the evidence, which is accepted practice due to the highly variable nature of the literature (163). The current study was referred to as a systematic scoping review because a systematic approach was employed to identify, include, and extract data from studies. The review drew on both the Preferred Reporting Items for Systematic Reviews and Meta Analyses guidelines (PRISMA) (164) and Arksey and O'Malley's widely used framework for systematic scoping reviews (163). Specific details about the systematic scoping review methods, including key definitions, data source used, inclusion/exclusion criteria, study selection, and data extraction and synthesis, are outlined in Chapter 3.

One of the key purposes of a scoping review is to identify gaps in the literature to highlight necessary areas of future inquiry (163). A number of research gaps were highlighted in the systematic scoping review, and are discussed in detail in Chapter 3. However, as shown in Figure 2.2, the ensuing research in this thesis was informed by some of the identified research gaps and built on findings from the preceding work.

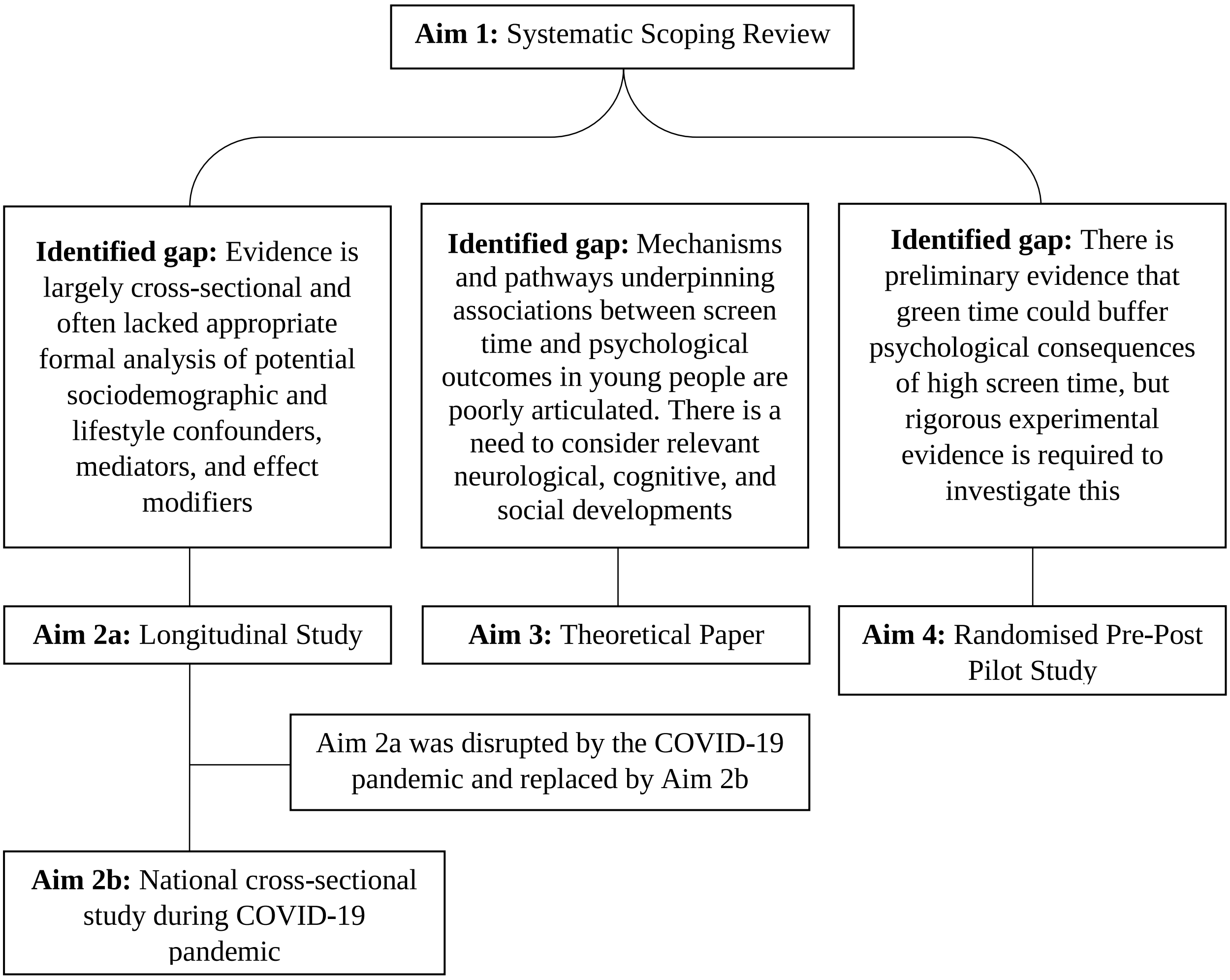

Figure 2.2 Gaps in the literature identified in the systematic scoping review, with proceeding aims and direction of the thesis

2.5.2 Aim 2a: Longitudinal study

The second aim was to examine causal links between screen time, green time, mental health, and academic achievement in South Australian school students (aged 9 – 14 years), using routinely collected data from the South Australian Department for Education. The specific objectives were as follows:

a) To describe screen time and green time behaviours in over 60,000 South Australian school students from 2016 to 2019;

b) To describe the mental health and academic achievement profiles of over 60,000 South Australian school students from 2016 to 2019;
c) To apply advanced statistical techniques which can be used to assess causation through longitudinal data, to explore potential causal links between screen time and green time behaviours, and mental health and academic outcomes, for South Australian school students between 2016 and 2019;
d) To explore differences by sex, age, and socioeconomic status, and to investigate the role of sleep quality, physical activity, and friendship quality on the causal pathway;
e) To explore whether a non-linear “U-shape” relationship exists between screen time and mental health outcomes.

While ethics approval was gained to conduct this study (see Appendix 1), and a working relationship had been established with the South Australian Department for Education, unfortunately it was not possible to carry out this aim during the PhD candidature as a result of the COVID-19 pandemic. Despite numerous attempts, due to competing priorities in the context of the pandemic, the South Australian Department for Education could not provide the longitudinal data necessary to assess the study objectives in a suitable timeframe for this thesis. This included the *Well-being and Engagement Collection* data (165) and *National Assessment Program Literacy and Numeracy* (NAPLAN) data (166). As such, Aim 2b was developed as a replacement (see section 2.5.3 below).

2.5.3 Aim 2b: National cross-sectional study (presented in Chapter 4)

In response to delays in receiving data from the South Australian Department for Education, and given young people’s screen time and green time behaviours inevitably changed during the COVID-19 pandemic (e.g., as a result of lockdowns and shifts to online learning), the research was pivoted to align with the current global context and be relevant to young peoples’ mental health at this point in time. Aim 2b was developed to explore associations between mental health and potential risk and protective factors relevant to young Australians in the context of the COVID-19 pandemic. The specific objectives were as follows:

a) To describe the mental health profile of a national sample of young Australians in the context of the COVID-19 pandemic, using the Complete State Model of Mental Health (162);
b) To investigate associations between screen time, technology experiences, and young Australians' mental health during the COVID-19 pandemic;
c) To investigate associations between purposive and incidental green time, and young Australians' mental health during the COVID-19 pandemic;
d) To consider factors related to employment, financial security, and living arrangements when looking at young Australians' mental health in the context of the COVID-19 pandemic;
e) To consider other relevant psychological constructs, such as level of hope and disruption of core beliefs, when looking at young Australians' mental health in the context of the COVID-19 pandemic.

A national online cross-sectional study was conducted to achieve this aim. Just over 1,000 young adults living in metropolitan areas of Australia, aged between 18 and 24 years, were recruited through *Qualtrics Panels* (a company which manages Internet panel samples) to participate. The sample was limited to young Australians living in metropolitan areas because impacts of the pandemic, as well as risk and protective factors, are likely to differ considerably for young people living in rural areas (167). Timing constraints meant that it was not possible to gain ethical clearance within the early onset of the pandemic to conduct this study with participants under the age of 18 years. Therefore, 18 to 24-year-olds (young adults), at the upper end of the spectrum of "young people", were the focus of this particular study. From a developmental perspective, this age group was particularly important to target in the pandemic context. They are at an important transitional stage of life and face a unique set of challenges related to education, employment, and financial autonomy, alongside diverse and fluctuating social supports (167), all of which were likely to be complicated and exacerbated by pandemic conditions.

Research using online convenience samples, including COVID-related research published to date, has typically attracted mostly female respondents and individuals from high socioeconomic backgrounds (168). To overcome this potential source of bias, and other limitations associated with convenience samples, we worked closely with Qualtrics Panels in an attempt to capture a sample which covered a spectrum of parameters balanced by gender, state/territory, and socioeconomic status. This quota sampling approach meant that the final sample had strengths in terms of size and diversity of participants.

Specific details about the methods for this study can be found in Chapter 4. In brief, participants responded to a number of questions about potential risk and protective factors for mental health in the context of the pandemic; including sociodemographic factors, living arrangements, employment and financial circumstances, and education factors. Participants also answered a series of questions pertaining to their screen time and green time experiences during the pandemic. Based on the Complete State Model of Mental Health, participants completed validated psychometric measures of both mental illness and mental well-being in the survey. They were consequently cross-classified into one of four mental health states based on their relative proportion of mental illness and mental well-being symptoms reported. Multinomial logistic regressions were used to examine associations between potential risk and protective factors, and these four states of mental health. Relative risk ratios (with 95% confidence intervals) were produced, and sociodemographic factors that may confound the relationships were adjusted for where required.

2.5.4 Aim 3: Theoretical paper (presented in Chapter 5)

Aim 3 was to explore mechanisms and pathways underpinning associations between screen time and psychological well-being in young people, paying attention to neurological, cognitive, and social developments experienced in adolescence. The specific objectives were as follows:

a) To bring together important segments of the developmental, clinical, and cognitive psychology, and neuroscience literature, which point to underlying processes and mechanisms in the links between digital technology use and adolescent mental health, while highlighting relevant synergies;
b) To consider how self-regulation may be affected by the addictive properties of digital technologies, media-multitasking, and pervasive exposure to social and emotional content online;
c) To consider the above within the context of contemporary patterns of adolescent socialisation and evolutionary neurobiology;
d) To explore the well-being benefits that digital technologies can afford adolescents and offer suggestions to help develop and strengthen self-regulation, and support mental health, in a high-tech era.

A theoretical paper was developed to address Aim 3. Based on the integration of literature, a new conceptual model was also developed with four principal dimensions. These model dimensions included: (1) self-regulation and mental health, (2) normative adolescent development, (3) contemporary digital technologies, and (4) wider systems factors (e.g., the landscape of adolescent socialisation). The connections between these dimensions and relevant synergies were discussed in-depth in the theoretical paper. Together, the theoretical paper and conceptual model uniquely enhance understanding of the psychological impacts of screen time on adolescents, through a developmental lens.

2.5.5 Aim 4: Randomised Pre-Post Pilot Study (presented in Chapter 6)

Aim 4 was to investigate the acute psychological impacts of screen time on adolescents, and to explore the restorative (or “buffering”) potential of nature immersion. The specific objectives were as follows:

a) To explore the acute psychological impacts of screen time on adolescents’ mood, sustained attention capacity, and inhibitory control;
b) To test whether green time (operationalised as a period of nature immersion) could buffer the psychological consequences of screen time, as shown through superior mood, sustained attention, and inhibitory control restoration;
c) To identify any possible differences by gender and age in the aforementioned explorations;
d) To design a robust study which addressed limitations present in existing intervention studies, including randomisation of participants to conditions, ensuring groups were comparable at baseline on relevant exposure and outcome measures, and minimising procedural bias.

A randomised pre-post pilot study was used to address Aim 4 and the corresponding objectives. Eighty-seven adolescents were recruited from two local schools to participate in the study. Specific details of the study methods are presented in Chapter 6. In brief, participants completed validated, computer-based measures of mood, sustained attention capacity, and inhibitory control at three time-points: (1) at baseline, (2) after a period of screen time, and (3) after a period of rest. Participants were randomised to rest in either an indoor setting (university teaching space) or in an outdoor environment (Adelaide Botanic Gardens). Linear mixed modelling was used to examine the effect of condition (Indoor vs Outdoor) and time (baseline, post-screen time, post-rest period) on mood, sustained attention capacity, and inhibitory control outcomes.

To ensure a rigorous study design, in addition to participant randomisation to conditions, care was taken to ensure participants in the two conditions were comparable at baseline on relevant sociodemographic, lifestyle, and outcome variables. A procedural protocol was also followed at all times (see Appendix 2). Where relevant, the Consolidated Standards of Reporting Trials Statement for Social and Psychological Interventions (CONSORT-SPI Statement) was also used to ensure the study was developed and reported transparently. While the whole CONSORT-SPI statement was not relevant to this small-scale pilot study, relevant items were used to minimise bias and maximise the validity and reliability of the research (169) (see Appendix 3).

2.6 Summary

The overarching purpose of this thesis was to explore the psychological impacts of screen time and green time on young people, as well as to investigate the potential psychological benefits of green time in a high-tech era. The COVID-19 pandemic meant the research had to be adapted, but provided a unique context to address the aims and objectives. As outlined in this chapter, a public health psychology research approach can be used to explore psychological problems of public health importance, by incorporating psychology and epidemiology methods, as well as bearing in mind a number of additional considerations. Four studies were undertaken to address the overarching aim of the thesis, respond to identified research gaps, and build on preceding work. Table 2.2 demonstrates how each study incorporated methodological strengths of the disciplines of psychology and epidemiology to apply a public health psychology research approach.

Table 2.2 Examples of application of the public health psychology research approach to the aims and studies encompassed in this thesis

Psychology Elements	Epidemiology Elements	Additional Considerations
Aim 1: Systematic scoping review		
▪ Engaged various sub-disciplines: cognitive, developmental, educational, and environmental psychology ▪ Inclusion of studies utilising reliable and validated psychometric scales	▪ Consideration of study quality and risk of bias ▪ Discussion of triangulation of evidence	▪ Considered groups that are disproportionately affected by screen time and green time exposures (e.g., youth experiencing disadvantage) ▪ Consideration of wider social determinants of psychological well-being ▪ Explored delineation of screen time and green time on psychological well-being
Aim 2: National cross-sectional study		
▪ Engaged various sub-disciplines: clinical, developmental, environmental, and social psychology ▪ Use of reliable and validated psychometric scales	▪ Careful consideration and discussion of sample frame and diversity ▪ Use of confidence intervals in statistical analysis	▪ Focus on young adults, a group disproportionately affected by pandemic ▪ Consideration of wider social determinants of psychological well-being ▪ Recommendations for mental illness prevention and mental well-being promotion strategies in the pandemic context
Aim 3: Theoretical paper		
▪ Engaged various sub-disciplines: biopsychology, clinical, cognitive, developmental, educational, health, and social psychology	▪ Consideration of study quality and risk of bias (e.g., through scrutiny of sampling)	▪ Consideration of wider social determinants of psychological well-being ▪ Identification of potential mechanisms underpinning associations ▪ Emphasis on mental illness prevention and mental well-being promotion
Aim 4: Randomised pre-post pilot study		
▪ Experimental research design (including variable manipulation and randomisation to conditions) ▪ Use of reliable and validated computer-based psychometric measures	▪ Use of CONSORT-SPI checklist to ensure rigor and reduce bias ▪ Use of confidence intervals and consideration of clusters in statistical analysis	▪ Exploration of strategies to prevent mental illness and promote mental well-being

CHAPTER THREE: PAPER 1 – SYSTEMATIC SCOPING REVIEW (PUBLISHED)

Psychological impacts of "screen time" and "green time" for children and adolescents: A systematic scoping review

(Publication preview presented in Appendix 4)

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Statement of Authorship

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Principal Author

Name of Principal Author (Candidate)	Tassia Kate Oswald		
Contribution to the Paper	Conceptualised research question, conducted data collection (search, screening, and extraction) and analysis, wrote manuscript, acted as corresponding author.		
Overall percentage (%)	70%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	19/01/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the thesis; and
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of Co-Author	Associate Professor Alice Rumbold		
Contribution to the Paper	Supervised development of work including conceptualisation of the study, search strategy, and manuscript editing.		
Signature		Date	07/02/2022

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Contribution to the Paper	Assisted with screening and data collection (extraction), contributed to manuscript editing.		
Signature		Date	19/01/2022

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Contribution to the Paper	Supervised development of work including conceptualisation of the study, helped in data interpretation, and manuscript evaluation and editing.		
Signature		Date	07/02/2022

3.0 Abstract

Technological developments in recent decades have increased young people's engagement with screen-based technologies (screen time), and a reduction in young people's contact with nature (green time) has been observed concurrently. This combination of high screen time and low green time may affect mental health and well-being. The aim of this systematic scoping review was to collate evidence assessing associations between screen time, green time, and psychological outcomes (including mental health, cognitive functioning, and academic achievement) for young children (<5 years), schoolchildren (5 – 11 years), early adolescents (12 – 14 years), and older adolescents (15 – 18 years). Original quantitative studies were identified in four databases (PubMed, PsycInfo, Scopus, Embase), resulting in 186 eligible studies. A third of included studies were undertaken in Europe and almost as many in the United States. The majority of studies were cross-sectional (62%). In general, high levels of screen time appeared to be associated with unfavourable psychological outcomes while green time appeared to be associated with favourable psychological outcomes. The ways screen time and green time were conceptualised and measured were highly heterogeneous, limiting the ability to synthesise the literature. The preponderance of cross-sectional studies with broadly similar findings, despite heterogeneous exposure measures, suggested results were not artefacts. However, additional high-quality longitudinal studies and randomised controlled trials are needed to make a compelling case for causal relationships. Different developmental stages appeared to shape which exposures and outcomes were salient. Young people from low socioeconomic backgrounds may be disproportionately affected by high screen time and low green time. Future research should distinguish between passive and interactive screen activities, and incidental versus purposive exposure to nature. Few studies considered screen time and green time together, and possible reciprocal psychological effects. However, there is preliminary evidence that green time

could buffer consequences of high screen time, therefore nature may be an under-utilised public health resource for youth psychological well-being in a high-tech era.

3.1 Introduction

3.1.1 Background

The prevalence of mental illness among children and adolescents is increasing globally (26, 34, 37). In particular, depression and anxiety are leading causes of reduced quality of life among children and adolescents (9, 17, 19, 22, 23). Experiences of depressive and anxiety symptoms in childhood and adolescence are associated with an elevated risk of poor mental health in adulthood (9, 27, 29, 30, 170), suggesting enduring consequences of compromised mental health while young for well-being and functioning across the lifespan.

Given these lifelong impacts, there is a pressing need to identify and address upstream determinants of mental health, focussing on the prevention of mental illness alongside the promotion of mental well-being. This scoping review focuses on two emerging determinants of interest: time spent engaging with screen-based technologies, referred to as ‘screen time’ (ST), and exposure to or time spent in nature, referred to as ‘green time’ (GT).

With rapid technological developments making access to electronic devices and their presence in our lives pervasive, concern is mounting about the psychological impact of prolonged ST, particularly in children and adolescents (128, 171-175). A decade ago in a U.S. sample of 8-to-18 year olds, the average ‘total screen time’ was reported at 7.5 hours a day (87) and was highest in 11-to-14 year old adolescents (9 hours). This greatly exceeds recreational ST guidelines of 2 hours or less per day (89). With widespread integration of digital technologies in school curricula (176), ST is no longer confined to recreational use, making it an inevitable part of young peoples’ lives.

Moderate ST can be beneficial for young people in a connected world (177) as it may afford them with opportunities to enhance existing relationships, forge new connections, engage in safe identity exploration, aid in academic pursuits, and provide access to information about the world beyond their immediate surroundings (178). However, from a developmental neurobiology perspective, excessive ST may be detrimental to young people as ST stimulates neurobiological systems such as the hypothalamic-pituitary-adrenal (HPA) axis (179) and dopaminergic circuitries (122). Childhood and adolescence are sensitive periods in which these systems develop and change (180-183), making them particularly vulnerable to insult. From a lifestyle and social perspective, it has been argued that excessive ST also displaces important protective behaviours for mental health such as physical activity (116, 117), getting adequate sleep (184), in-person social interactions (118), and academic activities (185).

As ST has increased, regular engagement with natural environments has concurrently decreased among young people. Children in high-income countries are now experiencing significantly lower levels of contact with nature, or GT, than previous generations (186, 187). For example, twelve-year-old children in the U.S. report spending an average of less than 6 hours per week outdoors (131), which is less than the average daily screen time for young people. Similarly, in England fewer than a quarter of children reported regularly visiting their local ‘patch of nature’ and less than one in ten children reported regularly playing in wild places, compared to half of all children in the previous generation (188). Likewise, in a survey of Australian adults, 73% reported playing outdoors more often than indoors when they were children, compared to only 13% of their own children today (189). Young people’s time spent in nature has been strongly influenced by rapid urbanisation which in many nations has reduced access to both urban greenspaces and private gardens (190).

Benefits of natural environments could be gained through increased physical activity (143, 191) and social connections experienced in greenspaces like parks (143, 144). Natural areas also tend to be less crowded, with reduced air and noise pollution, which is beneficial for overall health (143). Furthermore, time spent exposed to natural sunlight helps to regulate circadian rhythms, encouraging healthy sleep-wake cycles and improved sleep (145), which is key for psychological well-being. Several theories within evolutionary and environmental psychology propose that engagement with natural environments is *directly* beneficial for human health and well-being (146, 147). Notably, Kaplan's Attention Restoration Theory postulates that nature has specific restorative effects on cognitive functioning (146, 192) and Ulrich's Stress Reduction Theory contends that nature induces positive affect through reduced stress (147).

Experiences of ST and GT appear to influence psychological well-being in contrasting ways. Screen-based technologies are stimulating and extensive use can potentially displace important protective behaviours, thus they may be detrimental to psychological well-being. Conversely, natural environments may facilitate attention restoration and stress reduction, and support a range of behaviours that promote psychological well-being. As such, it may be argued that the combination of increased ST and decreased GT may be harmful for young people's mental well-being, and increasing GT may serve as an important ameliorator of ST, to promote mental well-being in an inevitably high-tech era. This may be particularly important for children and adolescents from low socioeconomic backgrounds, who typically engage in greater amounts of ST (193-196) and are also less likely to live in green neighbourhoods (197). However, research investigating the psychological impacts of ST or GT typically considers ST and GT in isolation and fails to delineate the reciprocal effects of high technology use and low contact with nature on mental health and cognitive outcomes (129). Such research could give us a greater understanding of 21st century drivers of youth well-being and guide recommendations regarding ST and GT for optimal psychological functioning. We are not aware of any previous review that has attempted to collate evidence about the effects of both of these exposures on child and adolescent psychological outcomes.

This scoping review has four aims:

1. To describe the international literature and evidence regarding the impact of ST and/or GT on psychological outcomes in children and adolescents;
2. To explore the basis for inference about causal links between ST, GT, and psychological outcomes for children and adolescents;
3. To explore the extent to which findings hold, or vary, across the spectrum of socioeconomic status;
4. To investigate the extent to which studies have attempted to delineate the reciprocal effects of ST and GT on psychological outcomes in children and adolescents.

3.1.2 Key definitions

The literature exploring the effects of ST and GT on psychological outcomes in children and adolescents is plagued with inconsistent terminology and calls for clarification and consistency. Therefore, this review will operationalise the following constructs as defined below:

3.1.2.1 Screen time

Screen time (ST) refers to time spent engaging with visual screen-based technologies such as televisions, computers/laptops, videogames, smart phones, tablets/iPads, and handheld electronic or gaming devices. Using the Internet, social media, or communicating via text message are all activities which are included in the definition of ST. Solely auditory activities, such as talking on a phone and listening to music, are not included.

3.1.2.2 Green time

For the purposes of this review, *green time* (GT) is broadly defined as time spent in, or exposure to, natural environments, elements, or content. This can be further specified as (a) *incidental exposure* to green space and/or natural elements, as measured by residential greenness or level of greenness surrounding schools and commuting environments; (b) *accessibility* to green spaces, public parks, open public spaces, private gardens, or green infrastructure; (c) *purposive use* of green spaces, public parks, private gardens, or green infrastructure; (d) *activities* centred around nature such as wilderness expeditions, gardening, horticultural activities, surfing, or outdoor play; and (e) *educational contexts* such as education outside the classroom or forest schools and kindergartens. Both the *quantity* and *quality* of GT may be considered, which includes attending to the size of green spaces or duration of time spent in green spaces, along with the level of naturalness or specific features of the environments under investigation. A definition of this breadth is necessary given the heterogeneity of existing definitions and lack of consistency when considering GT in the literature.

3.1.2.3 Psychological outcomes

For the purpose of this review, *psychological outcomes* is a summary term which encapsulates four constructs, measuring a range of psychological variables, including (a) indicators of poor mental health, (b) indicators of positive mental health, (c) cognitive functioning, and (d) academic achievement (Table 3.1). We have included academic achievement in our scoping review given it can be an indicator of positive psychological functioning (198), integrating aspects of cognitive control such as self-regulation (199), attention (200), executive functions, and working memory (201).

Table 3.1 Psychological outcomes included in the review

Constructs	Variables	
Indicators of Poor Mental Health	Common internalising or externalising disorders or their symptoms, such as:	
	▪ Depression ▪ Anxiety ▪ Stress ▪ Psychological distress ▪ Poor self-regulation	▪ Emotional problems ▪ Psychological difficulties ▪ Psychosomatic symptoms ▪ Negative affect or mood
Indicators of Positive Mental Health	Refers to elements of positive psychology or overall well-being, such as:	
	▪ Happiness ▪ Resilience ▪ Satisfaction with life ▪ Quality of life ▪ Health-related quality of life	▪ Self-esteem ▪ Optimism ▪ Positive affect or mood ▪ Hope ▪ Prosocial behaviour
Cognitive Functioning	Refers to mental processes, such as:	
	▪ Attention ▪ Working memory ▪ Executive function	▪ Visual, spatial, verbal, language, and cognitive development
Academic Achievement	Refers to school measures, such as:	
	▪ Subject grades ▪ Grade point averages (GPA) ▪ Test or examination results	

3.2 Methods

Due to the diverse and largely observational nature of the existing literature in this field, a *scoping* review was selected as the preferred method. Unlike systematic reviews, scoping reviews have a less focussed research question, attempt to describe the available literature broadly, and include diverse study designs and methods (163). Further, scoping reviews do not require an evaluation of the quality of the evidence and do not involve a meta-analysis (163). The current study is referred to as a *systematic scoping review* as a systematic approach has been employed to identify, include, and extract data from studies. This review drew on both the PRISMA Scoping Review Checklist (164) (see Appendix 5) and Arksey and O'Malley's widely used framework for scoping reviews (163).

A three-step search strategy was employed. Step one was key word scoping, which involved an initial limited search of relevant databases, followed by an analysis of text words contained in the title, abstract, and index of terms used to describe key articles. Step two involved constructing and performing a systematic search, using the identified keywords and index terms from step one, across selected databases. Step three involved checking reference lists of included publications and manually searching the literature to identify additional relevant studies which may have been missed in the computerised search.

3.2.1 Data source

The following four databases were searched from inception up until 18 February 2019: PubMed, PsycINFO, Embase, and Scopus. The search strategies are available in Appendix 6.

3.2.2 Study selection

Results from the systematic search were screened for eligibility according to the inclusion and exclusion criteria outlined below.

3.2.3 Inclusion/exclusion criteria

Studies were included if they met the following criteria:

1) Participants were aged ≤ 18 years, with no serious mental, cognitive, or developmental disorder requiring clinical intervention;
2) The exposure being measured was "screen time" and/or "green time" (as previously defined) and was not used as a part of a mental health intervention in a clinical group. Given the breadth of the literature, studies were only included if they measured the duration of exposure to two or more screen-based activities

(e.g., TV and computer use), thus providing a more complete depiction of ST exposure overall for young people. The exception to this was the inclusion of studies measuring only one screen activity if they also measured GT, given the relative rarity of these studies;

3) At least one of the psychological outcomes outlined in Table 3.1 was reported; and
4) Studies were quantitative, involving analysis of original data, and provided a measure of association between the exposure and outcome of interest.

The search was confined to peer-reviewed English publications, with no publication date limit. Studies only concerned with attention deficit hyperactivity disorder (ADHD), non-common mental health disorders (e.g., schizophrenia, bipolar, or personality disorders) or suicide were excluded. Studies focussing on Internet addiction or other compulsive and problematic technology use were also excluded. Qualitative studies and review papers were excluded.

3.2.4 Data extraction and synthesis

Scoping reviews aim to present an overview of all evidence reviewed. As such, according to Arksey and O'Malley (163), decisions about how to present such a large body of literature need to be made judiciously. Consistent with the intention of the scoping review process, which compels researchers to prioritise certain aspects of the literature as key issues and themes surface (163), a progressively focussed approach was taken in presenting the results.

Data was independently extracted and cross-checked from the included studies by two authors (T.K.O and S.G.E.K) using a form designed and tested by the study authors. In line with Aim 1, descriptive characteristics for all included studies were first charted. We examined the number of publications by research topic and year, the distribution of study samples geographically, the study settings, sample sizes, and the study designs utilised in the included studies. Next, key words were extracted from all included studies to create word clouds illustrating how ST and GT are conceptualised and measured in the literature. Larger text in the word clouds illustrates words used more frequently. Psychological outcomes investigated in the included studies were categorised as either indicators of poor mental health, indicators of positive mental health, cognitive functioning, or academic achievement, as outlined in Table 3.1.

The key summary statistic (e.g., mean or median and measure of dispersion) for participant age was extracted from each study so it could be assigned to one of four age categories: (a) young children (aged <5 years), (b) schoolchildren (aged 5 – 11 years), (c) early adolescents (aged 12 – 14 years), and (d) older adolescents (aged 15 – 18 years). Cohorts with large age ranges and no details that identified a dominant age group were allocated to a mixed age groups category. The study results were reported by age group to explore potentially different impacts of ST and GT on children and adolescents of specific ages.

To provide an overview of the existing evidence, while respecting the heterogeneity of constructs and measurements, associations between ST, GT, and psychological outcomes reported in the included studies were presented in tables as either unfavourable associations, favourable associations, or not statistically significant. Unfavourable associations were bolded in tables and were representative of increases in the exposure leading to increased poor mental health or decreased positive mental health, cognitive functioning, or academic achievement. Favourable associations were bolded and underscored in tables and were representative of increases in the exposure leading to decreased poor mental health or increased positive mental health, cognitive functioning, or academic achievement. Studies reporting no statistically significant association between exposure and outcome were not bolded in tables. If results were non-linear they were presented narratively in the body of text. Conventional statistical significance was applied, classifying associations with a p-value ≥0.05 as not significant. Study reference numbers and study designs are indicated in the tables (e.g., *114CS* = reference number 114 which was a cross-sectional study).

In addressing Aim 2, which involved exploring the basis for inference about causal links, certain elements of study designs were considered and are discussed. While a formal risk of bias assessment was not performed (not required in scoping reviews (163)), a preliminary assessment of each study's ability to permit examination of causal linkages, based on two key design features, was conducted. These features included (1) the consideration of baseline psychological profiles in longitudinal studies and (2) the use of comparable groups in experimental or intervention studies. This aided in identifying studies which could address Aim 2. Furthermore, additional variables featured in reported analyses were also extracted from the included studies and discussed. This included, but was not limited to, confounding or mediating demographic and lifestyle variables such as age, sex, physical activity, sleep, and in-person social interactions. Given our focus on socioeconomic status (SES) in Aim 3, indicators of SES were also extracted from each study where available. Studies in which differential associations by SES were investigated and reported were described in text.

In line with Aim 4, a sub-set of studies, which measured both ST and GT were examined to explore the extent to which the psychological effects of ST and GT had been delineated in the existing literature. These studies were relatively rare so each was described briefly in the text as well.

3.3 Results

The literature search identified 8,369 studies; 8,179 studies were removed because they were either duplicates (n = 2,544) or did not meet the inclusion criteria based on information in the title (n = 4,709) or abstract (n = 926). The full text of 190 studies was assessed for eligibility, of which 114 met the inclusion criteria. Screening the reference lists of the included 114 studies resulted in the identification of a further 60 eligible studies. These studies were not captured in the original search because they did not use key words or index terms related to either (a) psychological outcomes (e.g., study primarily focussed on obesity or body mass index (BMI), physical activity, or sleep), (b) childhood or adolescence (e.g., samples included individuals of all ages), or (c) ST (e.g., where ST was simply a secondary variable in a larger study, or was classified as ‘sedentary behaviour’, which may be different from ST). Twelve additional studies were sourced through manually searching the literature. Consequently, a total of 186 studies were included in the review (see Figure 3.1).

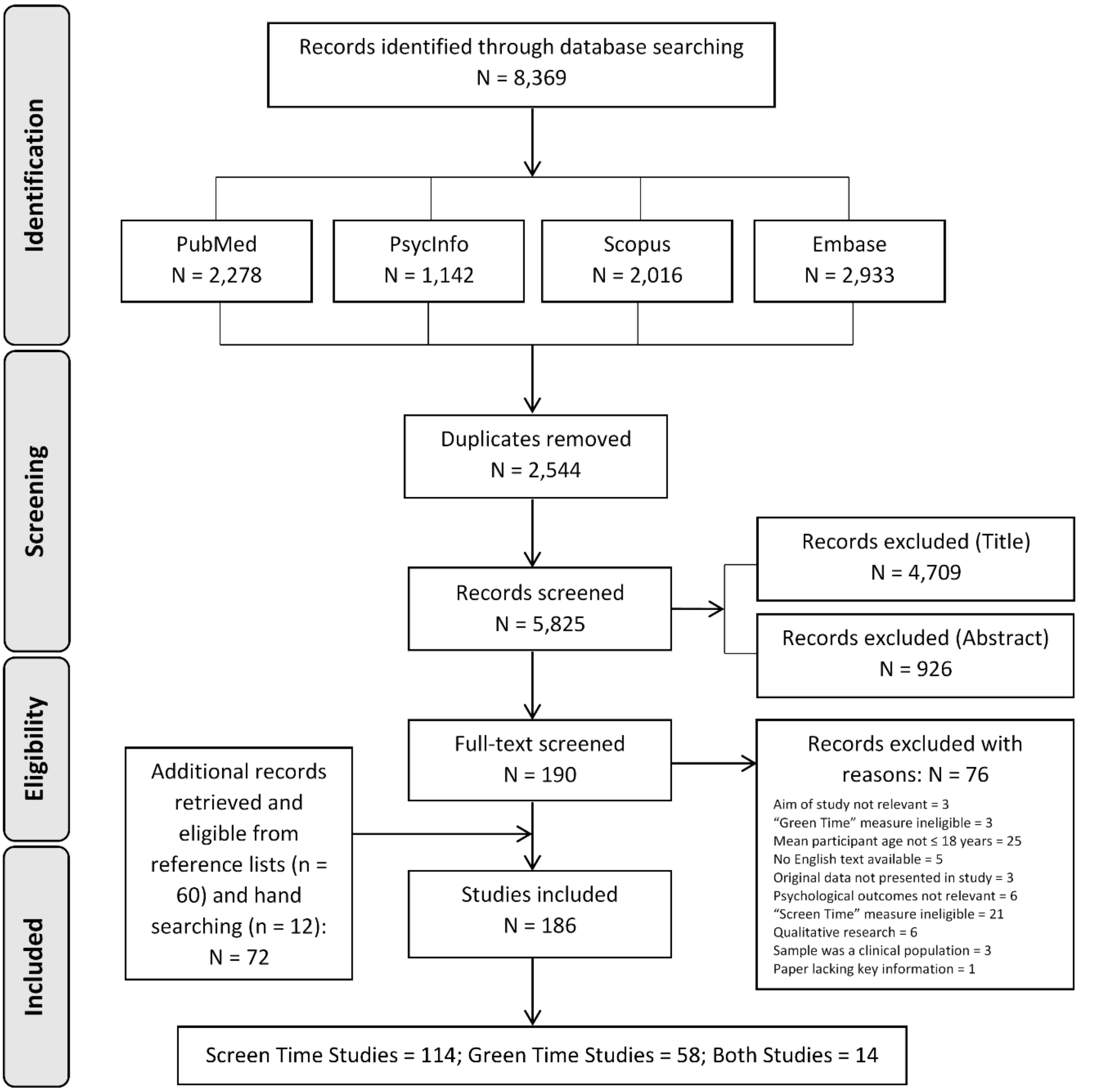

Figure 3.1 Study search and selection

3.3.1 Description of ST and GT literature

The studies included in the systematic scoping review are displayed in aggregate in Table 3.2, as counts and percentages, under several descriptive categories. Descriptive characteristics of individual studies can be found in Appendix 7.

Table 3.2 Collective characteristics of included studies

	Screen Time (n = 114) n (%)	Green Time (n = 58) n (%)	Both (n = 14) n (%)	All Studies (N = 186) N (%)
Sample location[a]				
Asia	8 (7)	1 (2)	0 (0)	9 (5)
Australia & New Zealand	14 (12)	9 (15.5)	2 (14)	25 (13)
Canada	12 (10.5)	4 (7)	1 (7)	17 (9)
Europe	37 (32.5)	20 (34.5)	4 (29)	61 (33)
Middle East	3 (3)	0 (0)	0 (0)	3 (2)
South America	3 (3)	0 (0)	0 (0)	3 (2)
United Kingdom	24 (21)	9 (15.5)	4 (29)	37 (20)
United States	40 (35)	15 (26)	3 (21)	58 (31)
Study setting				
International	3 (3)	0 (0)	0 (0)	3 (2)
National	31 (27)	6 (10)	3 (21)	40 (21)
State	6 (5)	1 (2)	0 (0)	7 (4)
Region or city	51 (45)	17 (29)	5 (36)	73 (39)
Other (school/community/services)	23 (20)	34 (59)	6 (43)	63 (34)
Sample size[b]				
Minimum	40	11	76	11
Median	1,596	214	959	969
Maximum	388,275	230,929	20,122	388,275
Study design[c]				
Cross-sectional	84 (74)	22 (38)	8 (57)	116 (62)
Cross-sectional (with comparison)	0 (0)	2 (3.5)	0 (0)	2 (1)
Longitudinal	26 (23)	7 (12)	5 (36)	36 (19)
Longitudinal (with comparison)	0 (0)	2 (3.5)	0 (0)	2 (1)
Pre-post design	0 (0)	8 (14)	1 (7)	1 (<1)
Pre-post design (with comparison)	0 (0)	2 (3.5)	0 (0)	1 (<1)
Prospective cohort study	6 (5)	1 (2)	0 (0)	7 (4)
Quasi-experiment	0 (0)	8 (14)	0 (0)	8 (4)
RCT/Experiment	0 (0)	4 (7)	1 (7)	5 (3)
Retrospective cohort study	1 (<1)	0 (0)	0 (0)	1 (<1)
Other	4 (3.5)	2 (3.5)	0 (0)	6 (3)
Age groups[d]				
Young children (<5 years)	8 (7)	5 (9)	1 (7)	14 (7)
Schoolchildren (5 – 11 years)	18 (16)	22 (38)	4 (29)	44 (24)
Early adolescents (12 – 14 years)	39 (34)	11 (19)	1 (7)	51 (27)
Older adolescents (15 – 18 years)	13 (11)	4 (7)	3 (21)	20 (11)
Mixed age groups	36 (32)	17 (29)	5 (36)	58 (31)

Psychological outcomes[e]				
Indicators of poor mental health	61 (53.5)	32 (55)	7 (50)	100 (54)
Indicators of positive mental health	47 (41)	29 (50)	8 (57)	84 (45)
Cognitive functioning	18 (16)	12 (21)	4 (29)	34 (18)
Academic achievement	26 (23)	13 (22)	1 (7)	40 (21.5)

Notes. Numbers exceed totals, and percentages exceed 100%, in some places because; [a]some studies involved multiple countries; [b]6 GT studies used whole school samples and did not report on final sample number, 1 ST study used whole families in their sample and did not report on final sample number; [c]8 studies involved both cross-sectional and longitudinal analyses; [d]1 GT study stratified results by young children and schoolchildren, and is therefore counted twice; [e]66 studies measured more than one type of psychological outcome.

3.3.1.1 Research by year and topic

Figure 3.2 displays the included studies by research topic and publication year (n = 186). The number of studies assessing ST, GT, or both has increased substantially over time. Overall, we identified almost double the number of studies assessing ST (n = 114; 61%) than GT (n = 58; 31%), with only 14 studies (7.5%) assessing both exposures; of these, most were published in the last five years.

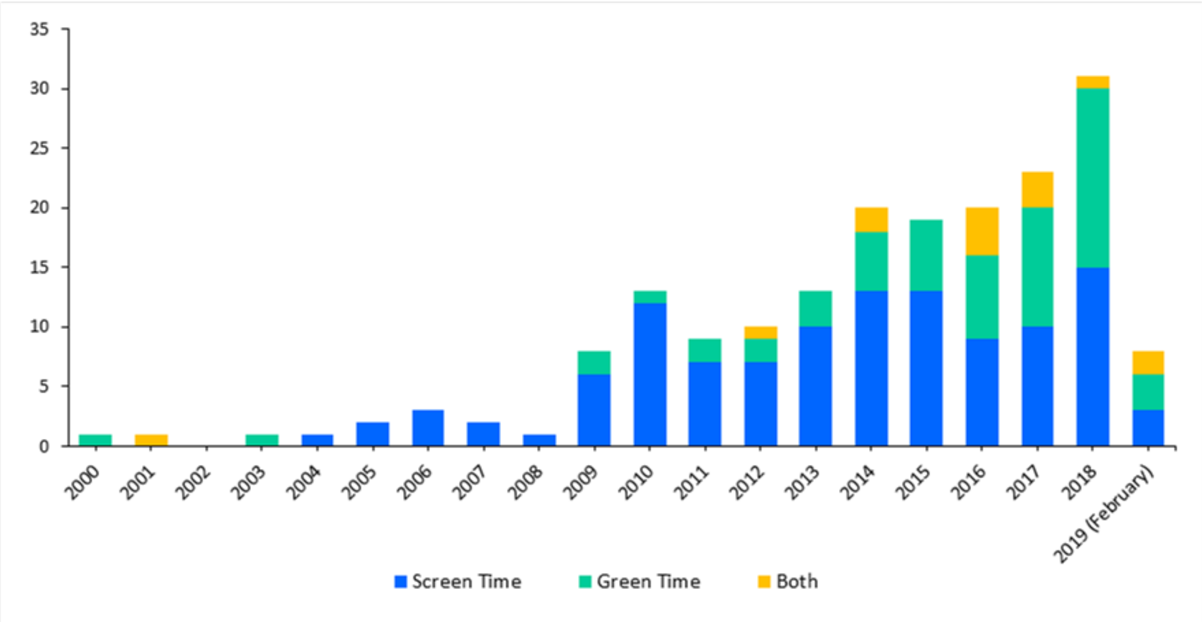

Figure 3.2 Included studies by research topic and year of publication

3.3.1.2 Geographic distribution of study samples

Children and adolescents in high-income countries such as the United States (n = 58), the United Kingdom (n = 37), Australia and New Zealand (n = 25), Canada (n = 17), and across Europe (n = 61) were most commonly represented in the literature (Table 3.2).

3.3.1.3 Study setting and sample sizes

Sample sizes ranged from 11 to 388,275 participants, with a median of 969. Of the included studies, three (<2%) involved multiple countries, 40 (21%) comprised nationally representative samples, seven (4%) were representative of a state or similar jurisdiction within a country, and the remainder either represented a smaller area such as a region or city, or utilised participants in selected schools, organisations, or with particular characteristics (e.g., obese youth).

3.3.1.4 Study designs

Cross-sectional studies were by far the most common study design, accounting for 74% of ST studies (n = 85), 42% of GT studies (n = 24), and 57% of the studies that examined both ST and GT (n = 8). Longitudinal studies were relatively more common in the ST literature (n = 26; 23%), while the GT study designs were considerably more variable, due to utilisation of a variety of pretest-posttest (mostly without a control group) and quasi-experimental designs (Table 3.2).

3.3.1.5 Age groups

Early adolescents were most commonly studied (n = 51 studies; 27%), followed by schoolchildren (n = 44 studies; 24%), older adolescents (n = 20 studies; 11%), and young children (n = 14 studies; 7%).

3.3.1.6 Psychological outcomes measured

Over half of the included studies investigated indicators of poor mental health (n = 100; 54%), followed by indicators of positive mental health which were assessed in 45% of studies (n = 84). Indicators of both poor and positive mental health were explored in 25% of studies (n = 46). Fewer studies concerned outcomes related to academic achievement (n = 40; 21.5%) or cognitive functioning (n = 34; 18%). Three studies (<2%) also examined other variables measuring nature connectedness or relatedness, which did not fall into the four categories.

3.3.1.7 Conceptualisation and measurement of ST and GT in the literature

Figure 3.3 illustrates the language used to conceptualise and measure ST (coloured in blue) and GT (coloured in green) in the included studies. As shown by the larger text, ‘traditional’ screen-based activities such as television watching, videogaming, and computer use are highly represented in the literature. The terminology used for ST is varied, with regular reference to ‘screen time’, ‘sedentary behaviour’, and ‘media use’. Parks, greenspace, and outdoor play were commonly assessed in the GT literature, along with the use of the Normalised Difference Vegetation Index (NDVI) which measures greenness of an area via satellite images (202). Environmental variables were often measured in and around neighbourhoods, schools, or homes.

Figure 3.3 Word cloud of the language used to conceptualise and measure ST and GT in the included studies (ST = 114 studies; GT = 58 studies; Both = 14 studies)

3.3.2 The current evidence – associations between ST, GT, and psychological outcomes

An overview of the associations between ST or GT and psychological outcomes in the included studies is presented below. Section 3.3.2 investigates the overall consistency of findings by age group. This section does not distinguish between study designs, although that information can be found in the tables. Detailed consideration of studies with a longitudinal, experimental, or intervention component, where these permitted examination of causal linkages (e.g., had comparable groups, included baseline psychological profiles, and considered competing explanations or confounding variables), are presented in section 3.3.3.

3.3.2.1 Young children (<5 years)

Table 3.3 presents the results for studies looking at associations between ST (8 studies) or GT (5 studies) and psychological outcomes in young children (134, 203-214). Studies of young children comprised a total of 30,476 participants in ST studies (plus 483 families with unspecified numbers), 2,836 participants in GT studies, and 575 participants in studies exploring both ST and GT together.

Table 3.3 Results from studies including young children (aged <5 years) (ST = 8 studies; GT = 5 studies)

		Screen Time Exposures							Green Time Exposures						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Psychological Outcomes Measured		Hand-held Game Use	ICT Time	Media Exposure	Screen Time	Tablet Use	TV Watching	TV/Video Time	Distance to Greenspaces	Natural Play Environment at Childcare	Outdoor Education / Classroom	Residential Greenness (as measured by the NDVI)	Satisfaction with Greenspaces	Time Spent Outside	Walk in Nature
Indicators of Poor Mental Health	Aggression									(134)PP					
	Behaviour Problems				**(206)CS**										
	Conduct Problems (SDQ)									(134)PP					
	Depressed Affect									**<u>(134)PP</u>**					
	Emotional Problems (SDQ)									(134)PP					
	Externalising Problems								(207)CS			(207)CS	(207)CS	(207)CS	
	Hyperactivity/Inattention (SDQ)									(134)PP					
	Internalising Problems								(207)CS			(207)CS†; **<u>(207)CS‡</u>**	(207)CS†; **<u>(207)CS‡</u>**	(207)CS	
	Peer Problems (SDQ)									**<u>(134)PP</u>**					

		Screen Time Exposures							Green Time Exposures						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Self-Regulation							**(211)RCS**							
	Social-Emotional Delay				(206)CS										
	Total Difficulties (SDQ)				**(213)CS**				(207)CS			(207)CS†; **(207)CS‡**	(207)CS†; **(207)CS‡**	(207)CS	
Indicators of Positive Mental	Emotional Development										**(203)LC***				
	Happiness/Well-being										(205)EC				
	Prosocial Behaviour (SDQ)				**(213)CS**				(207)CS	(134)PP**		(207)CS	(207)CS†; **(207)CS‡**	(207)CS	
	Social Development										**(203)LC***				
Cognitive Functioning	Attention														(214)EC
	Cognitive Development		**(210)CS**	**(212)L**							**(203)LC***				
	Communication Scores						**(204)L**; **(204)CS**								
	Effortful Control	**(209)CS**				**(209)CS**									
	Expressive Language			(208)L											
	Inhibitory Control														(214)EC
	Language Development		**(210)CS**								**(203)LC***				
	Language Scores			**(208)L**; **(212)L**											

		Screen Time Exposures							Green Time Exposures						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Receptive Language			**(208)L**											
	Spatial Working Memory														**(214)EC**
Academic Achievement	Not Assessed	Not Assessed													

Notes. Study reference number and study design in brackets. Studies reporting an **unfavourable** association between the exposure and outcome are bolded. Studies reporting a **favourable** association between the exposure and outcome are bolded and underscored. Studies reporting no statistically significant association are not bolded. *Study Designs:* CS = Cross-sectional; PP = Pretest posttest; RCS = Retrospective cohort study; L = Longitudinal; LC = Longitudinal with comparison; EC = Experimental crossover. *Psychological Outcomes*: SDQ = Strengths & Difficulties Questionnaire. *Where results differ for subgroups*: † = association for White British children; ‡ = association for South Asian British children; * = significant at measurement time 1 and 2, but not 3 and 4; ** = difficult to determine whether effects were due to intervention. *Other*: ICT = Information & Communications Technology; NDVI = Normalized Difference Vegetation Index.

In this age group, ST exposures were most commonly explored in relation to cognitive functioning and, overall, appeared to show deleterious associations with cognitive development (210, 212), effortful control (209), language (204, 208, 210, 212) and communication (204) abilities. Unfavourable associations between ST and behaviour problems (206), total difficulties (213), self-regulation (211), and prosocial behaviour (213), were also demonstrated across a range of cross-sectional and longitudinal studies. Only two studies in this age group did not report a statistically significant association between a ST exposure and a psychological outcome (206, 208).

The GT research was less consistent, with some studies reporting no statistically significant association between GT exposures and psychological outcomes (134, 205, 207, 214) alongside favourable associations (134, 203, 207, 214). In one study, incidental GT, such as distance to greenspaces, was not associated with young children's mental health (207). However, in this and other studies, green educational contexts (134, 203), satisfaction with greenspaces (207), and residential greenness (207) were favourably associated with a range of psychological outcomes. This included reduced depressed affect, internalising problems, peer problems, and total difficulties, as well as superior prosocial behaviour, cognitive, language, emotional, and social development. Further, one study reported that certain sub-groups, such as young children from ethnic minorities (South Asian British children), benefited from these GT exposures to a greater degree than White British children (207). Lastly, an experimental study showed that compared to walking in an urban area, going for a walk in nature led to higher spatial working memory for young children (214).

3.3.2.2 Schoolchildren (5 – 11 years)

Table 3.4 presents the results for studies looking at associations between ST (18 studies) or GT (22 studies) and psychological outcomes in schoolchildren (99, 100, 102, 106, 113, 130, 135, 137, 140, 182, 214-243). Studies of schoolchildren comprised a total of

58,861 participants in ST studies, 252,826 participants in GT studies (plus 1,940 schools with unspecified student numbers), and 15,356 participants in studies exploring both ST and GT together.

Table 3.4 Results from studies including schoolchildren (aged 5 – 11 years) (ST = 18 studies; GT = 22 studies)

		Screen Time Exposures							Green Time Exposures																				
Psychological Outcomes Measured		1 Computer Use	2 Electronic Device Use (tablets, phones, games)	3 Playing Non-Sedentary Videogames	4 Playing Sedentary Videogames	5 Total Screen Time / Total Sedentary (Screen) Time / Media Use / Screen Entertainment	6 Video/Electronic Game Playing	7 Watching TV/VCR Videos	8 Access to Greenspace	9 Agricultural Land around School	10 Beach Attendance	11 Education Outside the Classroom / Forest School	12 Residential/Home, School & Commuting Greenness (as measured by the NDVI)	13 Greenspaces in the Neighbourhood or School	14 Greenspace Playing Time	15 Grass or Shrub Cover	16 Nature Orienteering Intervention	17 Outdoor Play Environment	18 Park/Playground Use	19 Perceived Restorativeness of School Playground	20 Private Garden Access	21 Residential Greenspace Quantity	22 Residential Naturalness	23 Residential Proximity to Major Greenspaces	24 Schoolyard Greening Intervention	25 Trees / Tree Canopy Cover	26 Urban Water Cover	27 Use of Greenspace	28 Walk in Nature
Indicators of Poor Mental Health	Anger											**(236)PPC**																	
	Conduct Problems (SDQ)	(231)CS				**(234)L**; **(219)CS**; (224)CS[B]; **(224)CS[G]**	(234)L; **(231)CS[B]**; (231)CS[G]	**(234)L**; (231)CS			(137)CS		(137)CS[RS]; (137)CS[SS]; (137)CS[HS]	(135)L[N]	(137)CS				**(135)L**		**(135)L**			(137)CS					
	Cortisol Levels											**(182)LC**																	
	Depression	**(232)CS**					**(232)CS**	(232)CS																					
	Depressive Symptoms	**(99)CS[WE]**; (99)CS[WD]	**(99)CS**	(99)CS	**(99)CS[WE]**; (99)CS[WD]	**(106)CS**; **(99)CS[WE]**; (99)CS[WD]		**(99)CS[WE]**; (99)CS[WD]																					
	Emotional Problems (SDQ)	(231)CS				(234)L; (219)CS[B]; **(219)CS[G]**; (224)CS[B]; **(224)CS[G]**	(234)L; **(231)CS[B]**; (231)CS[G]	(234)L; (231)CS			(137)CS	(217)QE	**(137)CS[RS]**; (137)CS[SS]; (137)CS[HS]	(135)L[N]	**(137)CS**				(135)L		(135)L			(137)CS					
	Hyperactivity / Impulsivity										(137)CS		(137)CS[RS]; (137)CS[SS]; (137)CS[HS]		(137)CS			(229)CS[SV]; (229)CS[Q]						(137)CS					
	Hyperactivity Inattention (SDQ)	(231)CS				(219)CS; (224)CS; (234)L	(234)L; (231)CS[G]; **(231)CS[B]**	(234)L; **(231)CS[B]**; (231)CS[G]	**(243)CS**		(137)CS	(217)QE	**(137)CS[RS]**; **(137)CS[HS]**; (137)CS[SS]	(135)L[N]	(137)CS				**(135)L**		**(135)L**			(137)CS					

	Screen Time Exposures							Green Time Exposures																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Mental Health											**(225)QE^{B}**; (225)QE^{G}																	
Negative Affect	**(232)CS**																		(215)PP									
Negative Thinking						**(232)CS**	(232)CS																					
Peer Problems (SDQ)	(231)CS				(219)CS; (224)CS; (234)L	(234)L; (231)CS	(234)L; (231)CS			**(137)CS**	(217)QE	(137)CS^{RS}; (137)CS^{SS}; (137)CS^{HS}	(135)L^{N}	**(137)CS**				**(135)L**		**(135)L**			(137)CS					
Perceived Stress					(219)CS																							
Psychological Distress																						**(241)CS**						
Short-tempered	**(232)CS**					**(232)CS**	**(232)CS**																					
Sleeplessness	**(232)CS**					**(232)CS**	**(232)CS**																					
Somatic Complaints	**(232)CS**					**(232)CS**	(232)CS																					
Stress											(236)PPC																	
Total Difficulties (SDQ)	**(233)CS**				(224)CS; **(102)CS**		**(233)CS**	**(243)CS**		**(137)CS**		**(137)CS^{RS}**; **(137)CS^{HS}**; (137)CS^{SS}		**(137)CS**									(137)CS					
Emotional Functioning (HRQoL)																					(140)CS			(240)QE			(140)CS	
Energy											**(236)PPC***																	

		Screen Time Exposures							Green Time Exposures																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Indicators of Positive Mental Health	Global Self-Worth																						**(241)CS**						
	Happiness	**(100)CS**				**(100)CS**	**(100)CS**	**(100)CS**				**(236)PPC**																	
	Health-Related Quality of Life					(235)CS																(140)CS						**(140)CS**	
	Positive Affect																			**(215)PP**									
	Prosocial Behaviour (SDQ)					(219)CS; (224)CS; (234)L	(234)L	(234)L			**(137)CS**	**(217)QE**	(137)CS^{RS}; (137)CS^{SS}; (137)CS^{HS}		(137)CS									(137)CS					
	School Functioning (HRQoL)																					(140)CS						(140)CS	
	Self-Esteem					(226)CS											(216)PP					(140)CS						**(140)CS**	
	Self-Rated Health					(219)CS																							
	Social Perception	**(237)CS**						**(237)CS**																					
Cognitive Functioning	Attention	(237)CS				**(223)PS†; (238)CS; (238)L**	**(238)CS; (238)L**	**(237)CS; (238)CS;** (238)L			(137)CS		**(137)CS^{RS}**; (137)CS^{SS}; (137)CS^{HS}; (221)L^{RS}; (221)L^{C}; **(221)L^{S}**; **(221)L^{T}**		(137)CS			(229)CS^{SV}; **(229)CS^{Q}**						(137)CS					**(214)EC**
	Attention Restoration																								**(240)QE**				
	Executive Functioning	(237)CS						**(237)CS**																					
	Inhibitory Control																												(214)EC

		Screen Time Exposures							Green Time Exposures																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	Language, Memory & Learning	**(237)CS**						**(237)CS**																					
	Spatial Working Memory																												(214)EC
	Superior Working Memory												(221)L^{RS}; (221)L^{C}; **(221)L^{S}**; **(221)L^{T}**																
	Visuospatial Processing	(237)CS						**(237)CS**																					
	Working Memory												(221)L^{RS}; **(221)L^{C}**; **(221)L^{S}**; **(221)L^{T}**																(214)EC
Academic Achievement	Language / Arts Scores	**(218)CS^{PR}**; (218)CS^{SR}; **(113)L**					(218)CS	TV: (218)CS^{PR}; **(218)CS^{SR}** VCR: (218)CS^{PR}; **(218)CS^{SR}**; (113)L					**(242)CS^{SS}**																
	Mathematics Scores	**(218)CS^{PR}**; (218)CS^{SR}; (113)L					(218)CS	TV: (218)CS^{PR}; **(218)CS^{SR}** VCR: (218)CS^{PR}; **(218)CS^{SR}**; (113)L					**(242)CS^{SS}**	**(130)CS^{S}**		(227)CS^{U}; (228)CS^{U}; (228)CS^{S}										(227)CS^{U}; **(228)CS^{S}**; (228)CS^{N}	(227)CS		
	Reading Scores	**(218)CS^{PR}**; **(218)CS^{SR}**					(218)CS	TV: (218)CS^{PR}; **(218)CS^{SR}** VCR: (218)CS^{PR}; **(218)CS^{SR}**						**(130)CS^{S}**		(227)CS^{U}; (228)CS^{U}; (228)CS^{S}										**(227)CS^{U}**; (228)CS^{S}; (228)CS^{N}	(227)CS		
	School Grades/ Performance					**(222)PS**; **(113)CS**																							
	Science Grades	(113)L						(113)L																					
	School Test Scores									(239)CS			(239)CS^{SS}			(239)CS^{SS,RUS}; **(239)CS^{SS,US}**										(239)CS^{SS,RUS}; **(239)CS^{SS,US}**			
	Writing Scores													**(130)CS^{S}**															

Notes. Study reference number and study design in brackets. Studies reporting an **unfavourable** association between the exposure and outcome are bolded. Studies reporting a **favourable** association between the exposure and outcome are bolded and underscored. Studies reporting no statistically significant association are not bolded. *Study Designs:* CS = Cross-sectional; CSC = cross-sectional with comparison; EC = experimental crossover; LC = longitudinal study with comparison; L = Longitudinal; PP = pre-post-test design; PPC = pre-post-test design with comparison; PS = prospective study; QE = quasi-experimental. *Where results differed for subgroups:* B = result for boys; G = result for girls; WE = ST on weekend days; WD = ST on weekdays; PR = when ST is parent-reported; SR = when ST is self-reported by child; RUS = rural schools; US = urban schools; * = results were strongest for students with poor behaviour. *Green Time Exposure Details:* RS = Residential surrounding; SS = Surrounding school; HS = Home-school; C = Commuting; S = School; T = Total surrounding (home, school & commuting); SV = Sky view; Q = Quality; U = Urban; N = Neighbourhood; NDVI = Normalized Difference Vegetation Index. *Psychological Outcomes:* SDQ = Strengths & Difficulties Questionnaire; HRQoL = Health-related Quality of Life subscale; † = association mediated by reduced sleep. *Study Notes:* Studies (220)CS and (230)L were not included in this table due to unclear reporting of results.

Overall, study results were inconsistent, with 11 ST studies (99, 218, 219, 224, 226, 231, 232, 234, 235, 237, 238) and 15 GT studies (135, 137, 140, 214-217, 221, 225, 227-229, 236, 239, 240) reporting no statistically significant association between at least one exposure and psychological outcome variable measured. However, where statistically significant associations were reported, ST exposures were generally associated with unfavourable psychological outcomes (*n* = 16 studies), while GT exposures were typically associated with favourable psychological outcomes (*n* = 18 studies).

The majority of studies explored the impacts of total ST and it was not clear whether a particular type of screen activity was most influential for schoolchildren in the available literature. ST was most commonly associated with unfavourable outcomes on measures of poor mental health, such as depression/depressive symptoms (99, 106, 232), conduct problems (219, 224, 231, 234), emotional problems (219, 224, 231), negative affect (232), total difficulties (102, 233), and being short-tempered, experiencing sleeplessness, and voicing somatic complaints (232). In some studies, stratifying ST by weekend and weekday use, child- and parent-report, or by gender, revealed differential psychological associations. In general, weekend (99) and self-reported ST (218) were associated with a wider range of adverse psychological outcomes, however this varied significantly by gender. ST was also associated with various measures of cognitive functioning, including poorer attention (223, 237, 238), and executive functioning, language, memory, learning and visuospatial processing (237) for schoolchildren. Further, higher ST was associated with reduced happiness (100) and poorer academic outcomes (113, 218, 222) in some studies.

A wide range of GT exposures were considered for schoolchildren. Education outside the classroom and forest schools (n = 4 studies) were reported as largely beneficial, being associated with reduced anger (236), healthier cortisol profiles (indicative of reduced stress) (182), increased energy (236), happiness (236), and prosocial behaviour (217), along with improved overall mental health for boys (225). In one study, schoolchildren who perceived their schoolyard as more restorative experienced greater positive affect following recess time (215). A schoolyard greening intervention resulted in increased attention restoration (240), while an experiment demonstrated that a brief walk in nature was associated with increased attention (214).

In some studies, higher surrounding greenness in a child's environment, as measured by the NDVI, was associated with better mental health (lower emotional problems, hyperactivity/inattention problems, and total difficulties (137)), greater cognitive functioning (improved attention (137, 221), superior working memory (221), and working memory (221)), and better language/arts and math performance at school (242). However, these associations differed by residential and school surrounding greenness. Furthermore, one study highlighted that greener environments appeared to benefit children academically in urban schools but not rural schools (239). One study found that higher greenness was associated with poorer school performance (130); however, this was proposed to be reflective of greenspace being associated with lower SES communities in New Zealand.

Residential proximity to major greenspaces was not associated with any psychological outcomes in one cross-sectional study (137), whereas having access to a private garden and park use were associated with lower conduct, hyperactivity/inattention, and peer problems, in a longitudinal study (135). In the same cross-sectional study (137), greenspace playing time was associated with lower emotional problems, peer problems, and total difficulties.

3.3.2.3 Early adolescents (12 – 14 years)

Table 3.5 presents the results for studies looking at associations between ST (39 studies) or GT (11 studies) and psychological outcomes in early adolescents (90, 93, 95, 97, 98, 107, 108, 111, 124, 141, 244-283). Studies of early adolescents comprised a total of

97,820 participants in ST studies, 4,100 participants in GT studies, and 20,122 participants in studies exploring both ST and GT together.

Table 3.5 Results from studies including early adolescents (aged 12 – 14 years) (ST = 39 studies; GT = 11 studies)

		Screen Time Exposures												Green Time Exposures								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Psychological Outcomes Measured	Computer Use	Gaming (video and computer)	Internet Use	Media Multitasking	Playing Video Games	Recreational Screen Time	Screen Time for Homework	Screen Time/Media Use/ Screen-Based Media Time	Small Screen Recreation	Social Media Use	Tablet/ Mobile/Cell Phone Use	Watching TV/ Videos/ DVDs	Greening Schoolyards	Greenspace	Hiking Camp	Indoor Plants	Outdoor Education Program	Outdoor Learning	Percentage Parkland in Neighbourhood	Surfing Program Participation	Viewing Natural Environmental Scenes
Indicators of Poor Mental Health	Anxiety										(252)CS						(256)QE					
	Anxiety Symptoms	(93)CS				**(93)CS**			**(97)CS**; **(93)CS**				(93)CS									
	Conduct Problems (SDQ)			(246)CS		**(246)CS**							(246)CS									
	Demand (PSQ)															**(269)PP**						
	Depressed Affect								(279)CS^{B}; **(279)CS^{G}**													
	Depression	(254)CS^{B}; **(254)CS^{G}**							**(95)CS**; (254)CS				(254)CS									
	Depressive Symptoms	**(93)CS**				**(93)CS**			**(97)CS**; **(258)CS**; **(93)CS**		(252)CS		(93)CS		(255)L^{QL}; (255)L^{QN}							
	Emotional Problems (SDQ)			(246)CS		(246)CS							(246)CS									
	Externalising Problems								**(274)CS**						**(141)CS^{QL,CR}**; **(141)CS^{QL,PR}**; (141)CS^{QL,TR}; (141)CS^{QN}							

	Screen Time Exposures												Green Time Exposures								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Health Complaints								**(259)CS**													
Hyperactivity/ Inattention (SDQ)			**(246)CS**		**(246)CS**							(246)CS									
Internalising Problems			(247)CS		(247)CS[CR]			**(274)CS**						**(141)CS[QL,CR]**; **(141)CS[QL,PR]**; (141)CS[QL,TR]; (141)CS[QN,CR]; **(141)CS[QN,PR]**; (141)CS[QN,TR];							
Major Depressive Disorder			(272)CS		(272)CS							(272)CS									
Mental Health Diagnosis			(247)CS		(247)CS																
Mental Health Problems								**(274)CS**													
Mood									(275)ES												
Negative Affect																				(257)PP	
Peer Problems (SDQ)			(246)CS		(246)CS							(246)CS									
Perceived Stress																			**(251)CS**		
Physiological Stress													**(263)QE**								
Total Difficulties (SDQ)	(90)L		(246)CS; (247)CS[PR]		(246)CS; (247)CS[PR,B]; **(247)CS[PR,G]**	(90)L; (264)CS	(90)L				(90)L	(246)CS; **(90)L**		**(141)CS[QL,CR]**; **(141)CS[QL,PR]**; (141)CS[QL,TR]; (141)CS[QN,CR]; **(141)CS[QN,PR]**; (141)CS[QN,TR]			(267)PPC				
Worries (PSQ)															(269)PP						

		Screen Time Exposures												Green Time Exposures								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Indicators of Positive Mental Health	Connectedness Towards School																				**(257)PP**	
	Emotional Functioning (HRQoL)		**(98)CS**						(253)CS^{B}; **(253)CS^{G}**													
	Extrinsic Motivation																		(250)QE			
	General Health (HRQoL)		**(98)CS**																			
	Happiness														**(282)OS^{E}**	(269)PP						
	Health Status								**(259)CS**													
	Health-related Quality of Life		**(98)CS; (107)CS**						**(107)CS; (268)CS^{BS}**			**(268)CS^{BS}**	**(107)CS;** (268)CS^{BS}									
	Intra-Psychic Balance (Well-being)													**(263)QE**								
	Intrinsic Motivation																		(250)QE			
	Mindfulness															**(269)PP**						
	Mood																					(283)RCT
	Positive Affect																				(257)PP	
	Prosocial Behaviour (SDQ)			(246)CS		(246)CS							(246)CS					(267)PPC^{BG}; **(267)PPC^{WG}**				

	Screen Time Exposures												Green Time Exposures								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Psychological Well-being	**(90)L**					**(90)L**	(90)L				(90)L	(90)L									
Psychosocial Functioning (HRQoL)		**(98)CS**																			
Quality of Life								**(259)CS**													
Satisfaction with Appearance																				**(257)PP**	
Satisfaction with Life								(266)CS		**(252)CS**; (252)L		(252)CS; (252)L		**(282)OS[E]**	**(269)PP**		(267)PPC[BG]; **(267)PPC[WG]**			(257)PP	
School Functioning (HRQoL)		**(98)CS**						**(253)CS**													
School Life Satisfaction								**(97)CS**													
Self-Concept																		(250)QE			
Self-efficacy			(246)CS[B]; **(246)CS[G]**		(246)CS							(246)CS			(269)PP						
Self-esteem	**(270)CS**		(260)CS; (261)CS		**(260)CS**; (261)CS			(253)CS[B]; **(253)CS[G]**; **(270)CS**; **(279)CS[B]**; **(279)CS[G]**			(260)CS; (261)CS	**(270)CS[DVD]** (270)CS[TV]					**(267)PPC[BG]**; **(267)PPC[WG]**				(283)RCT
Self-perceived Health	(265)CS[WE]; **(265)CS[WD,B]**; (265)CS[WD,G]											(265)CS									
Self-rated Health								(266)CS													
Well-being	(265)CS											**(265)CS[WE,B]**; (265)CS[WE,G]; (265)CS[WD]	(263)QE	**(282)OS[E]**		(256)QE					

		Screen Time Exposures												Green Time Exposures								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Cognitive Functioning	Attention				**(245)L**	(124)CS			(281)CS				(124)CS									
	Attention Shifting	**(281)CS**	(281)CS										(281)CS									
	Cognitive Development														(282)OS^{E}							
	Creative Thinking & Problem Solving																	(267)PPC^{BG}; **(267)PPC^{WG}**				
	Executive Function								(281)CS					(263)QE								
	Flexibility of Attention	**(281)CS**	(281)CS										(281)CS									
	Inhibition				(244)CS^{EFT}; **(244)CS^{CR}**																	
	Shifting				(244)CS^{DTT}; **(244)CS^{CR}**																	
	Visual Memory								(281)CS													
	Visual-Spatial Abilities			(261)CS; (262)L		**(261)CS**; **(262)L**						(261)CS										
	Visuospatial Working Memory	(281)CS	**(281)CS**										(281)CS									
	Working Memory				(244)CS^{DST}; **(244)CS^{CR}**																	
	Academic Achievement		(248)PC	**(248)PC**		(277)CS			**(108)CS**; **(248)PC**; **(111)CS**; **(276)L^{+}**				**(248)PC**; (277)CS^{WE}; **(277)CS^{WD}**				(256)QE					
	Arithmetic Skills																		(250)QE$^{\pm}$			

		Screen Time Exposures												Green Time Exposures								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Academic Achievement	GPA		(249)CS	**(249)CS**; (261)CS; (262)L		(124)CS; **(261)CS**; **(262)L**		(249)CS*	**(280)CS**			(261)CS	(249)CS; (124)CS									
	Language Achievement/ Scores	(271)L	(249)CS; (271)L	**(249)CS**; (271)L				(249)CS*	**(271)CS**; (271)L			(271)L	(249)CS; (271)L									
	Math Achievement/ Ability/ Scores	**(271)L**	(249)CS; (271)L	(247)CS; **(249)CS**; (261)CS; (262)L; **(271)L**		(247)CS; (261)CS; (262)L		(249)CS*	**(271)CS**; **(271)L**			(261)CS; (271)L	(249)CS; (271)L									
	Reading Ability			(261)CS; **(262)L**; (247)CS^{B}; **(247)CS^{G}**		(261)CS; (262)L; (247)CS^{B}; **(247)CS^{G}**						(261)CS										
	School Grades			(261)CS; **(262)L**		(261)CS; **(262)L**						(261)CS										
Other	Nature Connectedness																				(257)PP	

Notes. Study reference number and study design in brackets. Studies reporting an **unfavourable** association between the exposure and outcome are bolded. Studies reporting a **favourable** association between the exposure and outcome are bolded and underscored. Studies reporting no statistically significant association are not bolded. *Study Designs:* CS = cross-sectional; ES = ecological momentary assessment study; L = longitudinal; OS = observational study; PC = prospective cohort; PP = pre-post test design; PPC = pre-post with comparison; QE = quasi-experimental; RCT = randomised controlled trial. *When results differ for subgroups:* B = results for boys; G = results for girls. *Green Time Exposure details:* QL = quality; QN = quantity; E = exposure; ± = both the outdoor group and traditional classroom group improved significantly over time, but it is not clear whether these improvements differed by group. *Screen Time Exposure details:* BS = before sleep; WE = weekend screen time; WD = weekday screen time; DVD = for DVD viewing only; TV = for TV viewing only; * = studying with a computer was not significant, but studying without a computer was favourable; $^{+}$ = association was mediated by an increase in sensation seeking. *Psychological Outcomes:* CR = child-reported; PR = parent-reported; TR = teacher-reported; BG = between-group difference; WG = within-group difference; EFT = measured with the Eriksen Flankers Task; DTT = measured with the Dots-Triangle Task; DST = measured with the Digit Span Task; SDQ = Strengths & Difficulties Questionnaire; HRQoL = Health-related Quality of Life subscale; PSQ = Perceived Stress Questionnaire. *Study Notes:* Study (273)CS was not included in the table due to unclear reporting of results; Study (278)CS is described in text due to comparison of cluster types.

Twenty-four ST studies (90, 93, 124, 244, 246-249, 252-254, 260-262, 264-266, 270-272, 275, 277, 279, 281) and 10 GT studies (141, 250, 255-257, 263, 267, 269, 282, 283) reported at least one association with a psychological outcome that was not statistically significant. However, where statistically significant associations were reported, ST exposures were generally associated with unfavourable psychological outcomes (*n* = 32 studies), while GT exposures were typically associated with favourable psychological outcomes (*n* = 8 studies).

TV watching time was largely unrelated to all psychological outcomes in this age group. Studies measuring total ST were most common and generally reported unfavourable associations with a range of psychological outcomes. Total ST was associated with indicators of poor mental health such as higher anxiety symptoms (93, 97), depression/depressive symptoms (93, 95, 97, 258), depressed affect (in girls) (279), externalising problems (274), internalising problems (274), health complaints (259), and overall mental health problems (274).

Total ST was also associated with reduced positive mental health such as lower health status (259), health-related quality of life (107, 268), quality of life (259), psychological well-being (90), school functioning (253), school life satisfaction (97), and lower emotional functioning (253) and self-esteem (270) (particularly for girls (253, 279)). Two studies reported an important distinction between *screen* sedentary behaviour and *non-screen* sedentary behaviour (e.g., reading), whereby screen sedentary behaviour was associated with lower self-esteem, but non-screen sedentary behaviour was not (270, 279). Furthermore, a study which compared ‘clusters’ of different types of technology users (278) found that early adolescents who were labelled as ‘instrumental computer users’ (characterised as high email and general computer users) had more favourable self-efficacy and mood scores when compared to ‘multi-modal e-gamers’ and ‘computer e-gamers’, although some gender differences were present.

Overall, higher total ST was associated with lower academic achievement (108, 111, 248, 276), GPA (280), language achievement (271), and math achievement (271). While associations between ST and measures of cognitive functioning were less clear, playing video games was associated with better visual-spatial abilities in two studies, cross-sectionally (261) and longitudinally (262), for early adolescents. In other studies, computer use was associated with poorer attention measures cross-sectionally (281), while media multitasking was associated with poorer attention longitudinally (245). In the same longitudinal study, no reversed effects from attention problems, on media multitasking over time, were found (245). In a cross-sectional study, media multitasking was not associated with inhibition, attention shifting, or working memory when measured by objective cognitive tests; however, when early adolescents reported their daily difficulties in these subcomponents of executive function, it was found that media multitasking was unfavourably associated with these self-reports (244).

Inconsistent findings for the GT exposures were found in this age group. Outdoor education programs and hiking camps were associated with increased satisfaction with life (269), mindfulness (269), and self-esteem (267). A schoolyard greening intervention was associated with decreased physiological stress and increased well-being (263), whereas introducing plants into classrooms did not alter early adolescents’ anxiety, well-being, or academic achievement in another study (256). Outdoor learning was associated with greater improvement of math skills in a quasi-experiment (250), but these results should be interpreted with caution due to significant baseline differences between groups.

A higher percentage of parkland in neighbourhoods was associated with lower perceived stress for early adolescents in a cross-sectional geographic study (251), but in an RCT, viewing scenes of natural environments on a screen was not associated with changes in mood or self-esteem (283). Findings pertaining to early adolescents' greenspace exposure and psychological outcomes were inconsistent, with results varying according to greenspace quality and quantity, and whether psychological variables were self-, parent- or teacher-reported (141, 255, 282). Overall, few studies looking at the effects of GT on cognitive functioning and academic achievement were identified for this age group.

3.3.2.4 Older adolescents (15 – 18 years)

Table 3.6 presents the results for studies looking at associations between ST (13 studies) or GT (4 studies) and psychological outcomes in older adolescents (92, 105, 112, 115, 177, 191, 284-294). Studies of older adolescents comprised a total of 155,418 participants in the ST studies, 1,053 participants in the GT studies, and 2,065 participants in studies exploring both ST and GT together.

Table 3.6 Results from studies including older adolescents (aged 15 – 18 years) (ST = 13 studies; GT = 4 studies)

		Screen Time Exposures												Green Time Exposures	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Psychological Outcomes Measured	Accessing e-news or study materials online	Computer Use	Electronic Media Use Before Bed / Sleep	Gaming (Video, Computer, Internet, e-games)	Being Online in Bed (Facebook, Chat, etc)	Internet Time	Playing Video Games	Social Media Sites/Apps	Telephone/Smartphone Use/Texting	Total Screen Time / Media Use	Watching TV	Watching Videos	Outdoor Program / Camp Experience	Wilderness Expedition
Indicators of Poor Mental Health	Aggression													(291)PP	
	Anxiety	**(294)CS**[s]			**(288)CS**[*]; (294)CS				**(294)CS**			**(288)CS**[M]; (288)CS[F]	(294)CS	(293)QE; <u>**(291)PP**</u>	
	Anxiety Symptoms										**(105)CS**				
	Conduct Problems				**(288)CS**							(288)CS			
	Depression				**(288)CS**							**(288)CS**		(293)QE; (291)PP	
	Depressive Symptoms		**(92)CS**; **(287)CS**	**(115)CS**		**(115)CS**		**(115)CS**[IB]; **(92)CS**		(115)CS[IB]	**(92)CS**; **(105)CS**; **(292)CS**; (285)CS[M]; **(285)CS**[F]	(92)CS; (287)CS; (115)CS[IB]			
	General Emotional, Behavioural & Social Problems				**(288)CS**							(288)CS[M]; **(288)CS**[F]			

		Screen Time Exposures												Green Time Exposures	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Oppositional Defiant Problems				**(288)CS**							(288)CS^{M}; **(288)CS^{F}**			
	Psychological Distress		**(289)CS**					**(289)CS**		(289)CS	(289)CS; **(292)CS**	(289)CS			
	Somatic Symptoms/ Complaints										(105)CS				
	Total Difficulties (SDQ)		(289)CS					(289)CS		(289)CS	**(289)CS**	(289)CS		**(293)QEST**; <u>**(293)QE^{LT}**</u>	
Indicators of Positive Mental Health	Emotional Functioning (HRQoL)		**(284)CS**				(286)CS	**(284)CS**; (286)CS			**(284)CS**; (286)CS	(284)CS; (286)CS			
	Global Health		(289)CS					**(289)CS**		(289)CS	(289)CS	(289)CS			
	Health-related Quality of Life		**(284)CS**; (289)CS				(286)CS	**(284)CS**; **(289)CS**; (286)CS		(289)CS	**(284)CS**; **(289)CS**; (286)CS	(284)CS; <u>**(289)CS**</u>; (286)CS			
	Mental Well-being									**(177)CS**					
	Positive Identity														<u>**(290)PP**</u>
	Psychological Strengths													(293)QE	

		Screen Time Exposures												Green Time Exposures	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Psychosocial Score (HRQoL)		**(284)CS**					**(284)CS**			**(284)CS**	(284)CS			
	Quality of Life		(289)CS					**(289)CS**		(289)CS	**(289)CS**	(289)CS			
	Satisfaction with Life	(294)CS			(294)CS				(294)CS		**(105)CS**	**(294)CS**^{S}	(294)CS		
	School Functioning (HRQoL)		(284)CS				**(286)CS**^{SP,M}; (286)CS^{SP,F}; (286)CS^{VP}	**(284)CS**; **(286)CS**^{SP,M}; (286)CS^{SP,F}; (286)CS^{VP}			**(284)CS**; **(286)CS**^{SP,M}; (286)CS^{SP,F}; (286)CS^{VP}	(284)CS; (286)CS			
	Self-Efficacy													**(291)PP**	
	Self-esteem	(294)CS			(294)CS				(294)CS		**(105)CS**; **(292)CS**	**(294)CS**^{S}	(294)CS		
	Social Functioning (HRQoL)		**(284)CS**				(286)CS	(284)CS; (286)CS			**(284)CS**; (286)CS	(284)CS; (286)CS^{SP}; **(286)CS**^{VP,M}; (286)CS^{VP,F}			
	Well-being													(291)PP	
Cognitive Functioning	Attention				**(288)CS**							(288)CS			

		Screen Time Exposures												Green Time Exposures	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Academic Achievement	Academic Achievement	(294)CS	**(112)CS**		(294)CS			**(112)CS**	**(294)CS**		**(292)CS**	**(112)CS**; **(294)CS**[S]	(294)CS		
Other	Nature Relatedness													(293)QE; (291)PP	

Notes. Study reference number and study design in brackets. Studies reporting an **unfavourable** association between the exposure and outcome are bolded. Studies reporting a **<u>favourable</u>** association between the exposure and outcome are bolded and underscored. Studies reporting no statistically significant association are not bolded. *Study Designs*: CS = cross-sectional; QE = quasi-experimental; PP = pre-post test design. *Where results differed for subgroups*: M = result for males; F = result for females; * = In study (288)CS, only high levels of gaming were associated with anxiety for males, while any amount of gaming was associated with anxiety for females; S = for ST exposure on school days only; [+] = In study (289)CS, low levels of computer use were better than no computer use, but high levels of computer use demonstrated no association with Total Difficulties. *Screen Time Exposure Details*: IB = In Bed; SP = Screen Time During School Period; VP = Screen Time During Vacation Period. *Psychological Outcomes*: ST = Short-term; LT = Long-term; SDQ = Strengths & Difficulties Questionnaire; HRQoL = Health-related Quality of Life subscale. *Study Notes*: Studies (191)CS and (177)CS are described in text due to the non-linear nature of the results. Study (286)CS results refer to self-reported HRQoL – all associations were non-significant when parent-reported HRQoL.

Ten ST studies (92, 105, 115, 284-289, 294) and two GT studies (291, 293) reported no statistically significant association between at least one exposure and psychological outcome measured. Where statistically significant associations were reported, they were typically unfavourable for ST (*n* = 13 studies) and favourable for GT (*n* = 3 studies).

ST was mostly examined in relation to indicators of poor mental health for older adolescents. The results of studies demonstrating an association between ST exposures and psychological outcomes primarily suggest that high levels of ST are associated with poorer mental health across a range of exposures and outcomes. In particular, high ST was mostly associated with higher levels of depression/depressive symptoms (92, 105, 115, 285, 287, 288, 292) and anxiety/anxiety symptoms (105, 288, 294) for older adolescents. One study found a non-linear, U-shaped association between ST and mental health, whereby TV watching, gaming, using computers, and using smart phones above inflection points was associated with poorer mental health, but engaging with ST activities within moderate ranges appeared to be linked to mental well-being (177). The only exception in the same study was weekend smartphone use, which was associated with poorer mental well-being at all usage levels (177).

Overall, the results for indicators of positive mental health were less clear; however, it appears as though certain activities, such as TV watching (284, 286, 289), were less important than others. For example, studies reported that high levels of video game playing were associated with lower emotional functioning (284), health-related quality of life (284, 289), psychosocial scores (284), and quality of life (289). It was also associated with poorer school functioning for boys who videogamed more during school terms (286). Contrastingly, one study suggested that more TV watching was associated with better health-related quality of life (289). Studies seldom considered the impact of ST on cognitive functioning in this age group, with only one study suggesting an unfavourable association between gaming and attention for older adolescents (288). Of the three studies examining academic achievement, most ST exposures, including social media use, were associated with poorer achievement (112, 292, 294).

Outdoor programs, camp experiences, and wilderness expeditions were investigated in this age group. While largely unrelated to most psychological outcomes, these GT experiences were found to increase self-efficacy (291) and positive identity (290), and decrease long-term total difficulties (293) and anxiety (291). Another study (191) summarised 126 approaches to modelling pathways linking greenspace variables to mental health outcomes for adolescents, through a combination of single mediation, parallel mediation, and serial mediation analyses, highlighting the complexity of the relationship between the natural environment and mental health.

3.3.2.5 Studies of mixed age groups

As previously mentioned, each study was allocated to an age group category; however, some studies included wide age ranges of participants, with no indication of a dominant age group. They were consequently classed as studies of mixed age groups (94, 96, 103, 110, 139, 142, 295-341). Thirty-six studies with mixed age groups investigated ST as an exposure, while 17 such studies looked at GT as an exposure. Studies of mixed age groups comprised a total of 883,732 participants in ST studies, 68,783 participants in GT studies (plus 320 schools with unspecified student numbers), and 7,468 participants in studies exploring both ST and GT.

Individual characteristics of these mixed age groups studies can be found in Appendix 7. Results for these mixed age groups studies are presented in Appendix 8. Overall, few of these studies contradicted previously presented associations between ST, GT, and psychological outcomes. Results of mixed age group studies with a longitudinal, experimental, or intervention component are considered in more detail in sections 3.3.3.1 and 3.3.3.2 as they permit examination of causal linkages.

3.3.3 Exploring the basis for causal links

In exploring whether associations between ST, GT, and psychological outcomes are likely to be causal (Aim 2), elements of study designs and key variables used in analyses were considered (as outlined in section 3.2.4). Whether or not associations between ST, GT, and psychological outcomes are causal is an important question, for example, to justify investment in GT to promote psychological well-being. The key consideration is not the direction of causation, but whether there is evidence of causation. Psychological well-being may be affected by both ST and GT, and in turn psychological well-being may affect an individuals' engagement with ST and GT to some degree. While bidirectionality offers opportunities for health promotion by intervening in the feedback loop, if the associations are artefacts produced by bias or confounding this would not be a worthwhile line to pursue for health promotion.

Although experiments and randomized controlled trials are upheld as the gold standard for demonstrating causation in psychology, they are not always feasible or ethical when investigating environmental exposures. As such, there has been renewed discussion in environmental epidemiology about how to make causal inferences from observational studies (e.g., (342-344)). There are previous examples of serious threats to health and the environment for which prudent action was delayed when, in hindsight, there were early warnings in observational data (e.g., the legacy of health (respiratory illness) and environmental (forest degradation) costs associated with sulphur contamination through 'acid rain' (345)). This reflects a need to make best use of imperfect data when assessing relationships between the environment and human health.

Determining causation does not necessarily depend on a single method, but can involve integrating evidence from a range of methods and data sources; this has been framed as ‘triangulation of evidence’ (344). If the majority of evidence points to the same conclusion, there is a strong likelihood that a relationship is casual. In this realm, it is valuable to pay attention to studies in which sources of bias are distinctive and potentially influence the outcome in atypical directions. With this in mind, despite making synthesis of evidence challenging, heterogeneity in the ways ST and GT were conceptualised and measured is a useful aspect of the literature. Likewise, the myriad of different contexts in which associations were examined is a strength, and provides some grounds for accepting that the associations are not artefacts, despite formal consideration of bias and confounding being erratic in this literature. Together, the abundance of findings and their relative consistency in terms of mostly favourable associations between GT and psychological outcomes and mostly unfavourable associations between ST and psychological outcomes, suggest that the associations are (a) not chance findings, (b) not attributable to publication bias (even though a degree of that may have occurred), and (c) possibly causal.

Family disadvantage remains the most important source of confounding and is likely to apply in almost all settings. Our planned focus on exploring differential impacts by SES within studies (Aim 3, section 3.3.4) represents both an assessment of confounding (addressed by stratification) and a question with social justice implications. However, before scrutinizing this aspect of the literature, we will provide an account of the studies that have a longitudinal, experimental, or intervention component, and consider how these support or oppose the case for causation. Cohort studies have the ability to demonstrate that an exposure is associated with an outcome that covaries over time. If the outcome variable is measured at baseline, then the *change* in outcome for different levels of exposure can be assessed, and a ‘dose-response’ effect can provide support for causation after addressing sources of bias and confounding. In theory, confounding is eliminated in intervention studies and experiments through random allocation of participants to groups. In practice, systematic differences may still be present, especially in relatively small studies, so it is important to examine whether groups were similar at baseline.

3.3.3.1 ST studies

Nineteen longitudinal ST studies included in this systematic scoping review provided an indication of baseline psychological profiles and accounted for these appropriately in analyses (e.g., psychological profiles had been factored in, through using change from baseline or equivalent approaches). These studies permit examination of causal linkages between ST and psychological outcomes. A brief description of each study is provided below.

Two of these longitudinal ST studies considered associations with indicators of positive mental health. One demonstrated that ST was not associated with life satisfaction over a 6-month period for 10 – 17-year-olds, after controlling for baseline life satisfaction (252). The other reported that computer use and recreational ST were associated with decreases in psychological well-being across 7th grade (90). One time-lag study assessed associations between ST and psychological well-being (as measured by self-esteem, life satisfaction, and happiness) for 8th, 10th, and 12th grade students between 1991 and 2016 (312). Using Granger causality analyses (which allows for assessment of whether the ST exposure changed before psychological well-being, or the converse), the study reported that increases in social media use, Internet use, texting, and gaming led to lower levels of adolescent psychological well-being over time (312).

Six longitudinal ST studies considering cognitive functioning had mixed findings. Three studies with follow up after one year reported that ST was associated with increased attention problems. These studies included 6 – 12-year-olds (238), 9 – 10-year-olds (223), and early adolescents (245). One study using data for children from age 3 – 11 years reported no statistically significant association between ST and general cognitive functioning over time (316). Two other studies reported varying results, both unfavourable and favourable, across different screen activities, genders, ethnicities, and specific cognitive tasks (336, 337). Specifically, one study suggested that between the ages of 6 – 12 years, girls benefited cognitively from computer use more than boys, and Black children benefited more than White children (336). Contrastingly, increased video game playing was associated with an improved ability to solve applied problems for Black girls over time, but was associated with reduced verbal task achievement for girls of all included ethnicities (336). Over a 5-year follow up period, greater online communications and Internet use were detrimental to vocabulary and reading abilities for 10 – 18-year-olds in another study (337). Contrastingly, computer gaming was associated with increased reading and problem-solving scores, particularly for girls and minority children (337). Furthermore, greater computer use for studying was associated with increased test scores for girls but not boys in the same study (337).

Results were also inconsistent across seven longitudinal ST studies assessing indicators of poor mental health. When looking at outcomes assessed by the Strengths and Difficulties Questionnaire (SDQ), higher weekday computer use at approximately 4 years of age was associated with an increased risk of emotional problems in girls at age 6, while other screen activities were not associated with SDQ scores over time (320). In a study of 14-year-olds, only TV viewing was associated with increased psychological difficulties (total SDQ scores) over a school year (90). Two additional studies, assessing 5 – 7-year-olds (234) and

10 – 18-year-olds (307), reported differences in the longitudinal effects of various screen activities on SDQ scores. The study of 5 – 7-year-olds reported that higher TV watching time was associated with increases in conduct problems, but electronic game use was not associated with any SDQ scores over time (234). On the other hand, the study of 10 – 18-year-olds found that higher computer and Internet use was associated with increased emotional problems, peer relationship problems, and total difficulties over time (307). These studies suggest that different screen activities may affect different aspects of psychological functioning for children and adolescents of different life stages.

When considering measures of common psychological disorders, one study reported that initial ST at 13 years of age did not predict changes in depression or anxiety symptoms, and vice versa, up to approximately 20 years of age (298). In a study of 12 – 16-year-olds, baseline videogaming and computer use were not associated with increased depression scores at 1-year follow up, but higher mobile phone use and television viewing were (96).

Mixed results were also reported in the five longitudinal ST studies which investigated academic achievement. One prospective study reported that for 10 – 14-year-olds, higher ST was associated with deteriorating school performance over 2 years (276). Math achievement was reported to be negatively affected by TV (110, 319), communication-based ST (299), PC/Internet use (271) and total ST (271) across 4 studies. Measures of math achievement were not associated with Internet use (299, 319), video/computer game use (110, 271, 299), mobile phone use (271), texting, emailing, or instant messaging (299), TV/video time (271), or total ST (299) in the same studies. Contrastingly, Internet use (319) and watching/streaming TV shows or movies (299) were reported to be associated with greater math achievement in two studies. These studies mostly concerned adolescents (110, 271, 299), with one study following children from 4 – 8 years of age (319). Follow up periods ranged from 3 (110, 299) to 6 (271) years.

Concerning reading and language subjects, watching/streaming TV shows or movies and surfing the Internet were reported to be associated with poorer achievement for high school students over 3 years (299). Other ST activities such as video/computer games and communication-based ST (299), and Internet and TV time (319), were not associated with reading or language achievement for primary (319) or high school (299) students over time.

In examining key variables used in ST analyses, a number of studies reported that poor sleep (115, 209, 213, 223), reduced physical activity (97, 102, 292, 318), and less in-person social interactions (208, 213, 312) were potential mediators between ST and a range of psychological outcomes. Furthermore, a number of studies reported that associations were found to differ by child sex (103, 107, 219, 224, 231, 238, 245-247, 253, 254, 258, 265, 277-279, 285, 288, 292, 295, 305, 311, 320, 329, 333, 336, 337) and age (94, 106, 135, 245, 301, 335). As summarised in Figure 3.4, age and sex potentially confound associations as they independently affect both ST and psychological well-being, while the lifestyle variables are thought to be pathways through which elevated ST operates to impact on psychological well-being. Despite this evidence, these demographic (age, sex) and lifestyle variables were generally controlled (adjusted) for in analyses and examination of mediation or effect modification was limited. If simply controlled for, results will only reflect one pathway between ST and psychological well-being (as shown by the dashed line in Figure 3.4). This means that potential mechanisms and effect sizes of relationships could be concealed or diminished across the literature.

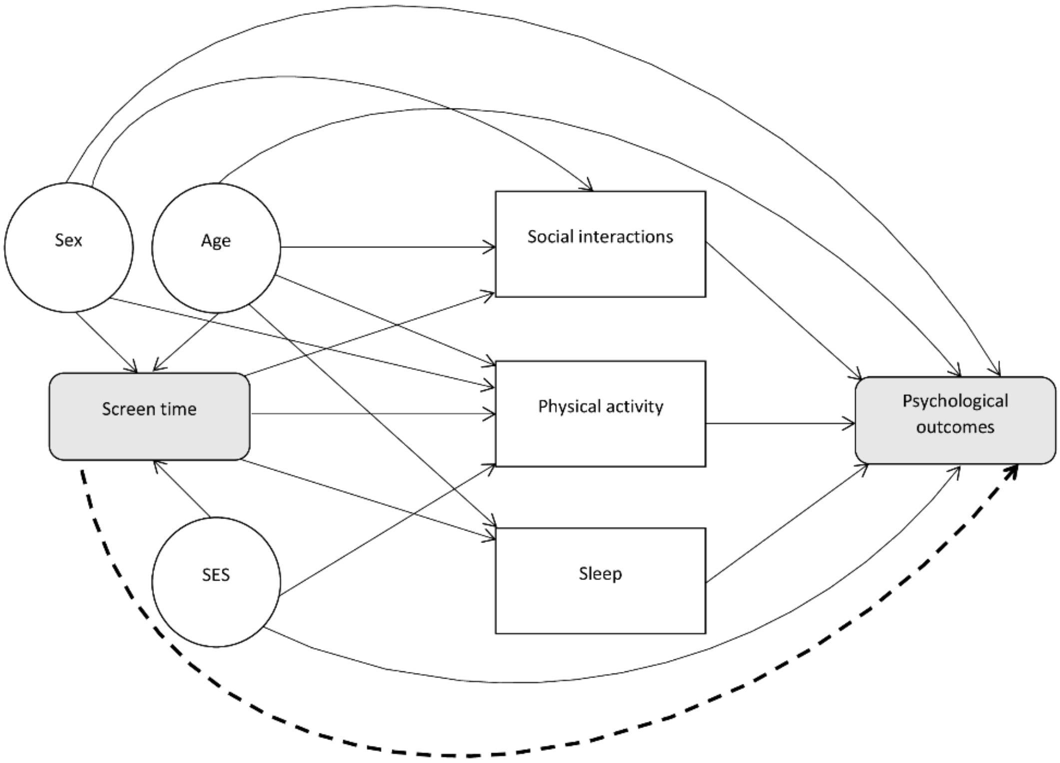

Figure 3.4 Pathways between ST and psychological outcomes (potential confounding and mediation by demographic and lifestyle variables)

3.3.3.2 GT studies

There were ten GT studies which permitted the examination of causal linkages (according to the criteria outlined in section 3.2.4) between GT and psychological outcomes in this systematic scoping review. Five were longitudinal GT studies which provided an indication of, and took into account, baseline psychological profiles. The other five studies had an experimental or intervention component, as well as equivalent comparison groups. A brief description of each study is provided below.

Two longitudinal studies examined psychological effects of nature in educational contexts. A prospective longitudinal study of 11-year-olds, including a comparison group with similar baseline profiles, reported that outdoor learning in a forest setting was associated with a steeper daily decrease in cortisol levels (e.g., superior profiles indicative of reduced stress) across the school year, when compared to traditional indoor classes (182). A 4-year longitudinal study of young children found that attending a nature-based day-care centre (as compared to a conventional day-care centre) at age 3 years was associated with lower inattention/hyperactivity problems at ages 4 and 6 years (323). Children exposed to high levels of outdoor time in day-care (as reported by day-care managers) also showed fewer inattention/hyperactivity problems at ages 4, 5, 6 and 7 years (323). These children with higher levels of outdoor play showed significant declines in inattention/hyperactivity symptoms from age 3 – 5 years, retaining low levels at age 6 years, but increasing again as they entered school at 7 years of age. In the same study, children with low and high levels of outdoor hours in day-care did not differ in performance on the digit span task at age 3 years; however, the latter group showed consistently higher performance from age 4 – 7 years (323).

Three additional longitudinal studies, with a focus on incidental GT, contributed to the case for causal relationships through sound design and analysis. In a prospective cohort study, higher surrounding greenness in childhood/adolescence was associated with lower incidence of depressive symptoms later in life (324). Stratified models suggested that this association was slightly stronger for young people with onset of depression before 18 years of age (324). In another study, residential greenspace at age 4 – 5 years was associated with well-being at age 12 – 13 years (325). Higher levels of well-being were associated with larger green space quantities; however, moderate quantities of greenspace, which were highest in quality, appeared to be most beneficial. Higher greenspace quality in early years was associated with lower internalising problems, but not externalising problems or total difficulties, in early adolescence. Furthermore, age-effects suggest that well-being benefits from greenspace quality seemed to intensify as children got older, while the well-being benefits gained from greenspace quantity seemed to weaken at age 10 years. In a pre-move post-move longitudinal study of 7 – 12-year-olds, moving to a new home environment with increased naturalness was associated with increased directed attention capacity post-move (332). The change in naturalness score from previous to new home environments explained 19% of the variance in post-move attentional capacity, beyond the variance explained by pre-move attentional capacity (332).

Besides studies with a longitudinal component, several studies with an experimental or intervention component assessed the psychological effects of natural content in school environments, such as indoor plants (256) and green classroom views (302). In the study looking at indoor plants, measures of academic achievement, anxiety, and well-being did not differ between 13-year-olds in non-randomised control and intervention classrooms which received indoor plants for a semester (256). Contrastingly, in a randomised controlled experiment with comparable groups at baseline, natural classroom window views were associated with increased attention restoration and stress recovery for high school students (302).

Beyond the schoolyard, one study examined the psychological effects of walking in natural versus urban settings for children (214); control groups were not used in this study as participants completed both study conditions. Following the nature walk, young children experienced increased spatial working memory and schoolchildren experienced increased attention, when compared to the urban walk (214). A final study reported almost no differences in measures of well-being between high school students who participated in week-long outdoor adventure programs, and those who did not (293). Despite being quasi-experimental, the results were considered reliable as matched control groups were utilised (293).

While a wider range of study designs were utilised in the GT literature there were methodological shortcomings in some studies which limit causal inferences. A lack of control group in pre-post studies (134, 142, 215, 216, 257, 269, 290, 291), significant baseline differences between groups (217, 240, 250, 267), and procedural issues (217, 225, 334) were common across studies. For example, the educational and well-being effects of education outside the classroom for schoolchildren may have been underestimated in three studies as the control groups were either ‘contaminated’ with education outside the classroom (217, 334), or the intervention schools had a pre-established interest in, and use of, education outside the classroom (225). Furthermore, potential psychological effects of schoolyard greening interventions may have been underestimated in two studies, as students in a greening intervention school had higher baseline executive functioning than control school students in one study (263), while intervention students in another study reported liking their schoolyard to a greater extent at baseline than students in control schools (240). Another study reported no difference in high school students’ scores on measures of self-esteem and mood after viewing natural environmental scenes and built environmental scenes on a screen (283). Given the technologically-mediated GT experience presented in this study, it was difficult to compare with other studies offering full GT sensory experiences.

Studies frequently claimed that GT was associated with favourable psychological outcomes as a result of increased physical activity; however, this claim was not formally investigated in most instances. Only two studies demonstrated that the associations between various GT exposures and psychological outcomes were mediated by physical activity (137, 191), while two other studies reported that physical activity did not mediate associations between GT exposures and psychological outcomes (135, 182). Relatively few studies performed adjustment for physical activity when this did not appear to be warranted. The association between superior cognitive functioning and higher GT was mediated by reduced traffic-related air pollution in one study (221). Similar to the ST literature, associations between GT and psychological outcomes were found to differ by child sex (130, 214, 225, 291, 339) and age (214, 325), but in many studies these variables were often adjusted for rather than forming the basis for stratified analyses or investigation of interactions.

3.3.4 Exploring the extent to which associations hold across the spectrum of socioeconomic status

We were especially interested in exploring the influence of socioeconomic status (SES) on the associations between ST, GT, and psychological outcomes (Aim 3). On the one hand, as a marker of access to material and community resources and social support, SES could confound associations between high ST, low GT, and psychological well-being. It is also possible that these relationships may differ by SES, which could have important policy and social justice implications. Thus, careful attention to the role of SES is required in the design of studies and statistical analyses. An example of how confounding by SES could influence results was provided by a study which reported that being from a low SES background determined both whether a child's preschool was classified as high or low quality on outdoor play environment categories and whether children had attention problems (229).

Overall, children and adolescents from low SES backgrounds were underrepresented in the included studies (see Appendix 7 for indicators of SES in each individual study). Where studies reported on differences between participants and non-participants, participants were more likely to come from higher SES backgrounds (231, 237, 246, 282, 322, 335). Participants lost to follow up, or excluded due to incomplete data, were commonly reported to be from low SES backgrounds, ethnic minorities, or families with lower education, employment, and income (101, 136, 206, 233, 234, 247, 248, 253-255, 264, 276, 277, 289, 307, 317, 340, 346, 347). In some cases data were available to show that lost or excluded participants also had poorer psychological outcomes, lower levels of physical activity, higher levels of ST, and lower levels of GT (101, 233, 237, 245, 254, 276-278, 307, 338, 348). The feasibility of recruitment and follow up for longitudinal studies often motivates use of middle-to-high SES samples, with high quality data that is as complete as possible being sought (349). This may be considered an advantage for the purposes of this systematic scoping review in that it limits the extent to which findings are confounded by SES, given the relative similarity of psychological profiles among middle-to-high SES youth. To explain, this is because the association between SES and psychological outcomes is not linear: there is a steep gradient between the lowest and next SES category in terms of psychological problems, but a flatter gradient across subsequent SES increments (350, 351).

On the other hand, the underrepresentation of children and adolescents from low SES backgrounds in this literature means that evidence to assess possible *differential* effects by SES is lacking. There were four ST studies and five GT studies which performed internal comparisons of children and adolescents from different SES backgrounds; these are considered below.

Overall, in these four studies high levels of ST appeared to have a stronger link with poor psychological outcomes for children and adolescents from low SES backgrounds. For example, one study reported that the association between high ST and poor SDQ outcomes was strongest for children in low income families (94). Similarly, when primary analyses were stratified by SES, unfavourable associations between media consumption and self-regulation were strongest for toddlers from low SES families (211). In another study, more television watching was associated with poorer math test scores only for students in the second lowest SES quartile (110). Significant SES and racial differences in both ST and psychological outcomes were reported in a U.S. study, which in some cases led to differential associations between ST and psychological outcomes by SES (247).

Similar patterns emerged in the five GT studies which performed internal comparisons of children and adolescents from different SES backgrounds, with associations between GT and psychological outcomes appearing to be strongest for children and adolescents from low SES backgrounds. One study found that high SES was protective against the development of emotional problems for young children from age 3 – 5 years (135). The same study reported that in the absence of socioeconomic advantage, neighbourhood greenspace could protect against the development of emotional problems (135). Specifically, disadvantaged children with a higher percentage of greenspace in their neighbourhood had fewer emotional problems from age 3 – 5 years, relative to disadvantaged children in less green neighbourhoods (135). Another study reported that living further away from a park was associated with worse mental health outcomes for 5 to 6-year-old children whose mothers had a low education level, but not for children whose mothers had a higher education level (318).

A study examining the psychological effects of an education outside the classroom program found that children from lower SES backgrounds had greatest improvements in SDQ scores, although this finding did not reach statistical significance which the authors attributed to a lack of power (217). Contrastingly, in another study, time spent in outdoor play was associated with poorer school grades and higher conduct problems in 10 – 12-year-olds from low SES backgrounds (125). That study reported that outdoor play was typically reflective of unstructured play when they were “not really doing any activities, just hanging around” (125). When investigating associations between residential/school greenspace and academic performance, one final study reported that stratification by household income did not reveal any effect modification (327). The study authors commented that low income families were underrepresented in their analytical samples, which may have led to underestimates of associations. Overall, these studies suggest there is a possibility that high levels of ST and inadequate access to, or time spent in nature, may disproportionately affect children and adolescents from low SES backgrounds. These findings are based on a limited number of studies and should be interpreted within those constraints.

3.3.5 Delineation of reciprocal effects of ST and GT on psychological outcomes

ST and GT appear to be associated with psychological outcomes in contrasting ways; ST is mostly associated with unfavourable psychological outcomes, while GT is mostly associated with favourable psychological outcomes. The *combination* of high ST and low GT observed in contemporary children and adolescents may be particularly harmful to their psychological well-being (87, 131). As such, it is important to consider the reciprocal effects of both ST and GT on children and adolescents' psychological outcomes (Aim 4).

Fourteen studies identified in this systematic scoping review measured both ST and GT (101, 125, 136, 138, 346-348, 352-358). It is important to note that these studies did not necessarily measure both exposures with the intention of delineating the effects of high ST and low GT on psychological outcomes in children and adolescents, and it was not always possible to determine the reciprocal effects of both exposures. For the most part, these studies were interested in either ST or GT, with the alternate exposure being measured as a secondary variable.

Of the 14 studies, two provided some insight into associations between psychological outcomes and ST, in the presence of GT, and vice versa. In one pre-post study (353), German adolescents took part in a 10-day Outdoor Adventure Program, with no access to technology. They also self-reported the average daily time they typically spent on various screen activities in their leisure time. The study found that the psychological benefits gained from the outdoor adventure program were moderated by adolescents' reported level of typical daily screen time (high (>3 hours/day) or low/moderate (≤3 hours/day)). Participation in the outdoor adventure program resulted in improved mental health across a range of measures for both low/moderate and high ST users but effect sizes were larger for high ST users, suggesting they may have reaped greater benefits from the outdoor adventure program. There was also a significant time by group interaction for life satisfaction scores, with increases in life satisfaction post-outdoor adventure program being significantly higher for adolescents who regularly engaged in high levels of ST. This illustrates potential psychological benefits of GT for high ST users in particular (353).

A randomised experiment of adolescents from England also provided potential to delineate the psychological impacts of ST and GT (352). Participants completed a series of stressor tasks before being randomly assigned to an outdoor or indoor environment, with a friend or alone with a mobile phone. Following a period of rest in their assigned environment, participants completed a series of cognitive and mood measures. Attention restoration and positive affect was found to be greater for participants who rested in an outdoor environment, compared to those who rested in an indoor environment. Furthermore, being with a friend was found to be more beneficial than playing a game on a mobile phone. Self-reported attentiveness decreased more rapidly when playing on a mobile phone compared to being with a friend, but this only occurred for adolescents in the indoor environment. Being outdoors may buffer the psychological effects of playing on a mobile phone to some degree, but more research is needed to support this (352).

Three additional studies measuring both ST and GT allowed their reciprocal effects to be probed to some extent. One study demonstrated the psychological benefits offered by the outdoors, above and beyond physical activity, for Canadian early adolescents (346). Survey respondents reported on their time spent (a) playing sedentary video games, (b) playing active video games, and (c) in active outdoor play. Isotemporal substitution models were used to estimate whether replacing time spent in sedentary videogames and active outdoor play, with active videogames, would be associated with changes in emotional problems, prosocial behaviour, and life satisfaction. The study found that active videogames were associated with better mental health than sedentary videogames, but active outdoor play was superior to active videogames. This provides some limited evidence to suggest that the association between ST and mental health goes beyond displacement of physical activity and that outdoor environments may provide unique benefits to mental health. Another study demonstrated that TV viewing was inversely associated with the compliant subscale of the Adaptive Social Behaviour Inventory, while outdoor play time was positively associated with the same measure (in the same model) for children aged 2 – 5 years (356). Similarly, another study showed that TV watching on the weekend was inversely associated with health-related quality of life for children aged 9 – 11 years, while a range of greenspace indices (such as percentage of landscape and number of green patches within half-a-mile of children's homes) were positively associated with health-related quality of life (in the same model) (347).

The analysis plans of the remaining nine studies did not entail delineating the reciprocal effects of ST and GT on psychological outcomes, and it was not possible to investigate this based on the results presented within these studies. Studies either assessed the effects of the exposures in separate models (101, 358), adjusted for either ST (136, 354, 357) or GT (348, 355) in analyses, or did not report relevant associations for determining reciprocal effects of ST and GT on psychological outcomes (125, 138, 348). This highlights the complexity of gaining understanding of the reciprocal psychological effects of ST and GT. Studies reporting statistically significant associations typically found that independent associations between ST or GT and psychological outcomes were consistent with earlier findings (sections 3.3.2.1 to 3.3.2.4).

3.4 Discussion

We set out to collate and critically discuss the available literature on associations between ST, GT, and psychological outcomes in children and adolescents. The body of research has expanded greatly in recent years, especially in relation to ST, with the majority of available evidence coming from high-income countries. We identified 186 eligible studies for inclusion in the systematic scoping review and discuss our key findings below.

3.4.1 ST and GT have contrasting relationships with psychological outcomes

Many cross-sectional studies reported associations between ST or GT exposures with some, but not necessarily all, of the psychological outcomes assessed. There was no obvious pattern to the null findings and there were relatively few opposing results. What was clear was that higher ST tended to be associated with unfavourable psychological outcomes while greater GT tended to be associated with favourable psychological outcomes.

The longitudinal ST studies which permitted examination of causal linkages (according to the criteria outlined in section 3.2.4) were difficult to compare. However, observed statistically significant associations provided some support for unfavourable causal relationships, consistent with the multitude of cross-sectional studies. There were no experimental or intervention studies to draw on in relation to ST. For GT, in addition to some longitudinal studies which permitted examination of causal linkages, a small number of studies with an experimental or intervention component also demonstrated favourable relationships between GT and psychological outcomes, building the case for causal linkages.

3.4.2 There are limitations in existing study designs and analysis

Although there is a sizeable literature concerning ST or GT and psychological outcomes in children and adolescents, the majority of studies used cross-sectional designs. While the great volume and variety (e.g., heterogeneous ST and GT measures, diverse study samples and contexts) of cross-sectional studies is useful for demonstrating general consistency in results, the research now needs to move beyond this. Investment in study designs which permit examination of causal linkages is important for advancement of both fields.

Studies with a longitudinal component are an example of superior study designs. In particular, comprehensive longitudinal studies which take baseline psychological profiles into account and consider competing explanations are needed to understand the potential bi-directional and reciprocal relationships between ST, GT, and psychological outcomes (106). In addition, more short-term intervention studies, preferably randomised controlled trials with comparable baseline groups, would be particularly persuasive in making the case for (or against) causality and could allow a better understanding of mechanisms (359).

In considering competing explanations, potential confounding and mediating variables should be treated appropriately in analyses (see Figure 3.4 in section 3.3.3.1). For children and adolescents of all ages, the displacement hypothesis was regularly put forth as a potential mechanism underlying unfavourable associations between ST and psychological outcomes. Displaced behaviours raised included getting adequate sleep (93, 101, 204, 208, 209, 212, 223, 232, 268), engaging in physical activity (93), experiencing in-person social interactions (99, 106, 107, 231), and dedicating time to academic activities (108, 111, 248, 280). However, few studies examined mediation formally. Across the identified literature these important variables were frequently treated as confounders, despite their potential role on the causal pathway. Unless the aim is to isolate the direct independent effect of ST or GT, these factors should not be treated as confounders in analyses. Furthermore, exploration of effect modification by age, sex, and SES was relatively rare, despite the potential for these variables to interact with ST, GT, and psychological outcomes.

In addition to claims that enhanced protective behaviours (e.g., more physical activity and socialisation) operating through GT contributed to favourable psychological outcomes, many GT studies made appeals to the intrinsic qualities of nature that theoretically enhance psychological well-being. In particular, frequent reference was made to Kaplan’s Attention Restoration Theory (146), which postulates that spending time in nature can improve cognitive functioning by restoring direct attention abilities, enabling individuals to consequently perform better on tasks that depend on directed attention. Two intervention studies provided strong support for this, suggesting that outdoor education (182) and natural classroom window views (302) are beneficial for students’ attention restoration and stress recovery. Whether GT can assist in recovery of attention and reduction of stress following ST is not known, but is an interesting prospect.

3.4.3 Considering different developmental stages is important

This review highlights the importance of considering the way in which specific screen-based technologies and GT exposures affect children and adolescents, depending on social and biological factors unique to their developmental stage of life.

For example, for young children, cognitive and language development are profound. As such, ST was most commonly explored in relation to these domains in children under 5 years of age, and was typically associated with poorer cognitive and language development (204, 208, 209, 212). These findings are possibly owing to displacement of parent-child interactions and reduced quantity and quality of child play (204, 208, 209, 212).

Early adolescence is another period defined by significant biological and social development. It is characterised by hyper-responsive neural reward systems (360), along with the pursuit of autonomy from family, and peer social acceptance (122, 180, 181, 361); all in the absence of reliable behavioural inhibition (362) and reduced parental control. Therefore, the domains of greatest interest and the potential mechanisms proposed to link high ST to poor psychological outcomes in this age group are more complex than that of younger children. For example, it is proposed that social media, which is popular among adolescents, can contribute to poor mental health as it offers the opportunity for constant social comparison. Photographs on social media broadcast certain ideals and encourage young people to compare themselves to their peers with respect to their body image, life experiences, and abilities (90, 279). This not only inflates social pressure to conform (90), but can also cause distress for young people when there are discrepancies between these publicised ideals and the self (279). While real-world social acceptance has historically been open to interpretation for adolescents, social media overtly quantifies levels of social acceptance through numbers of “friends” and “likes” attained by users (363).

When considering the GT literature, associations between different types of GT and psychological outcomes were also dependent on the participant age group. For example, having access to private gardens or natural environments at home appeared to be important for pre- and school-aged children (135) (who are dependent on caregivers for access or transportation to public green spaces and parks) as it can increase opportunities for engagement in deep and complex play in nature, which is thought to be essential for healthy development (134). In another study, greenspace *quantity*, over quality, was reported to be more important for young children (325). Younger children may reap psychological benefits from large greenspaces as they afford the opportunity to socialise through group sports, games, and exploration, which are key for psychological well-being. However, given physical activity declines from childhood through to early adolescence, particularly for girls (109), the quantity of greenspace may become less important with older age.

Some evidence suggests that broader environments may be more important to early adolescents, who begin to gain a level of independence from their parents/caregivers. For example, greater neighbourhood greenspace was reported to buffer against perceived stress for early adolescents (251) and was associated with higher emotional well-being (282). In another study, greenspace *quality* was reported to be more important than quantity for older children (325). As mentioned above, physical activity declines from childhood to adolescence (109), while rumination may increase concurrently (364). Therefore, high quality natural environments which are restorative (e.g., provide a feeling of 'getting away'), may be more important for early-to-late adolescents because they provide opportunities for respite and mind-wandering (146).

Overall, little GT research related to cognitive functioning was available for early adolescents, and little GT research related to mental health was identified for older adolescents. Given early adolescence is a critical period associated with the development and consolidation of complex cognitive processes, and adolescence is a peak age for the emergence of common psychological disorders (365), more research in these areas is warranted.

3.4.4 Certain screen technologies are most relevant when considering psychological outcomes

A lack of consistency in the conceptualisation and measurement of ST considerably limits our ability to make detailed comparisons between studies, synthesise the existing evidence, and ultimately make broader conclusions. This includes varying measurement units (e.g., hours versus minutes of ST), and exposure variables being treated as either binary (e.g., high versus low ST) or continuous (e.g., minutes or hours of ST), with mixed data transformation methods and cut-off points (e.g., >2 hours ST per day) used across studies.

Historically, ST received attention as an important modifiable determinant of childhood obesity (366), which led to ST guidelines recommending that children and adolescents limit their ST to two hours per day (89) in order to reduce sedentary leisure time. Consideration of psychological impacts of ST invites further distinctions between types of ST, notably passive (e.g., television watching) versus interactive or stimulating ST (e.g., gaming, social networking), in view of their different psychological demands. For example, a recent systematic review reported that passive ST, like television watching, was less likely to be associated with poor sleep outcomes compared to more interactive screen-based activities including computer use, video gaming, and mobile device use (114). Similarly, when TV exposure was assessed alone, it was mostly unrelated to psychological outcomes for adolescents in the studies included in this systematic scoping review.

ST within the included studies most commonly included television watching, followed by videogaming, and computer use. Not surprisingly, older studies do not feature contemporary interactive and stimulating technologies, such as portable small-screen devices like iPads, tablets, and smart phones. With approximately three quarters of adolescents now reporting smartphone ownership, and almost one quarter describing themselves as "constantly connected" to the Internet (367), future research should move towards focusing on the psychological impacts of these contemporary technologies which keep young people connected and make it difficult to 'switch off'.

3.4.5 It is not clear what constitutes the most beneficial GT

Conceptualisations of GT in the included studies varied markedly. As per the ST literature, varying measurement units (e.g., Euclidean distance to greenspace versus greenspace within diverse buffer sizes), variables being treated as both binary (e.g., no exposure versus some GT exposure) and continuous (e.g., NDVI of greenness), with mixed data transformation methods and cut-off points used (e.g., 100m versus 500m buffers), once again limits our ability to make comparisons between studies, synthesise the existing evidence, and ultimately make broader conclusions. While some studies focussed on incidental exposure to urban greenspaces or residential greenness, others investigated the effects of more purposive exposure, such as outdoor play, private garden access, outdoor adventures, or education outside the classroom. It is important to note that residential proximity to greenspaces does not necessarily reflect use, and outdoor play is not guaranteed to take place in natural surroundings. Carefully planned studies are needed which determine whether incidental exposure to nature, and purposive use of natural spaces, yield similar psychological benefits. Currently, the literature fails to make a distinction between these GT exposures and the different psychological benefits they may afford individuals of different ages.

3.4.6 Youth from low SES backgrounds may be disproportionately affected

Children and adolescents from middle-to-high SES backgrounds were most commonly recruited and retained in studies. While this provides reassurance that findings are not driven by the SES gradient, current evidence pertaining to higher SES samples may be underestimating the psychological effects of ST and GT on young people as a whole. The use of high SES samples with higher baseline well-being may lead to ‘floor’ and ‘ceiling effects’, as was suggested in a study which reported non-significant findings related to well-being following an outdoor camp and wilderness experience with a sample of high SES adolescents (293).

As presented in section 3.3.4, in some studies the negative psychological effects of ST, and benefits gained through GT, have been found to be stronger in individuals from low SES backgrounds. On theoretical grounds, associations between ST and cognitive development may be particularly important for young children from low SES backgrounds. In combination with higher average ST (193-196), these children can experience lower levels of directed parental language (212), and may also face issues with neighbourhood safety, social isolation, and other life stressors which play a key role in parents' decisions around media use at home (204) and access to local greenspaces (368). Given the potential to provide community amenities in the form of additional green spaces, which could address some inequities in youth mental health, future research in this area should prioritise youth from low SES backgrounds.

3.4.7 There is value in considering both ST and GT in future research

Very few studies considering both ST and GT together were identified and included in this systematic scoping review. Given the lack of available evidence, it is difficult to determine whether individuals who demonstrate improvements in psychological functioning following exposure to a natural environment experience such improvements purely as a result of nature exposure, or whether reduced exposure to screen-based technologies in such environments contributes to their observed improvements. Equally, it is difficult to determine whether the psychological consequences of ST arise exclusively from the screen-based technologies themselves, or whether the observed psychological outcomes are also associated with the concurrent deficit in exposure to natural environments whilst an individual is engaging with screen-based technologies.

This lack of available evidence warrants further research which considers the psychological effects of both ST and GT on children and adolescents. Given the opposing ways in which technology and nature arguably influence the brain and human lifestyles, it is important to delineate their reciprocal effects to ensure accurate recommendations are made regarding appropriate ST and GT for optimal psychological well-being. Such delineation may assist in determining the ability of nature to act as a buffer against negative psychological effects of ST in a high-tech era.

On theoretical grounds, investigating the potential role of GT as an ameliorator to the consequences of extensive ST, is an interesting prospect. Paying constant directed attention to screen-based technologies can lead to directed attention fatigue. Attention Restoration Theory postulates that when direct attention mechanisms are fatigued, they can be restored in natural environments because they employ involuntary attention, which is not tiring or effortful (146, 192). Similarly, Stress Reduction Theory contends that due to extensive human evolution in natural environments, modern humans may have a biologically prepared readiness to quickly and readily acquire restoration from stress in natural settings, but have no such preparedness for highly stimulating technological environments (147, 369, 370). Given the psychological demands contemporary interactive and stimulating technologies place on children and adolescents, research looking at the restorative role of GT is warranted.

With an estimated 47% of total U.S. employment classified as at high risk of computerisation in coming years (371), modern technologies are here to stay, and it is important for young people to be tech-literate; however, determining activities which assist in preventing mental illness and promoting mental well-being, to ultimately reduce continued burden of youth mental health problems, is crucial. In a high-tech era, further research is required to properly measure and understand practical ways for ameliorating any detrimental impacts ST may be having on children and adolescents (363).

3.4.8 Limitations of the current systematic scoping review & recommendations for future research

A limitation of this systematic scoping review may be the inability to fully synthesise and systematically appraise included studies, due to substantial heterogeneity across included studies. However, it is important remember that the purpose of a scoping review is to describe the available literature broadly, including diverse study designs and methods with no requirement for an evaluation of the quality of the evidence.

Given our aim was to provide a broad overview of existing evidence, it was also beyond the scope of this review to discuss the magnitude of the effects of ST and GT on psychological outcomes. The disparate ways exposure variables were measured in the included studies made it difficult to make these comparisons. More focussed systematic reviews with meta-analyses should be undertaken in the future, to pool data for studies that conceptualised and measured exposures in similar ways. We believe that the body of evidence pertaining to outcomes such as depression, anxiety, psychological difficulties (as measured by the SDQ), attention, and academic achievement may be wide enough to allow the conduct of a focussed systematic review. Such a review, presenting magnitude of effects, would be beneficial in commenting on the practical and clinical significance of associations across the literature.

The current review focused upon ST duration rather than content; therefore, it was not possible to comment on the differential effects of specific content, such as violent videogames and educational TV programs. In general, recreational and educational ST were combined in study responses, which made it difficult to explore differential impacts. The Canadian Pediatric Society recently released new ST guidelines suggesting that ST content is equally as important as ST duration (372); therefore, future research should aim to synthesise evidence reporting the effects of ST duration and content (specifically distinguishing between recreational and educational ST) on psychological outcomes in children and adolescents.

A further limitation is that the review was limited to articles published in English. We may not have identified all relevant studies, despite attempts to be as comprehensive as possible. This may be due to the inconsistent terminology used in describing and indexing ST and GT. For example, most studies sourced from reference lists were not captured in the original search because they referred to time in screen-based activities as ‘sedentary time’; however, as highlighted in the literature, sedentary time that is not spent using electronic devices has significantly different psychological effects than sedentary time spent with screens (270, 279). Therefore, rather than considering screen time as an interchangeable term with sedentary time, as it typically is in obesity research, a distinction needs to be made in the literature when considering psychological impacts.

Despite the aforementioned limitations, the approach used in this study provides a comprehensive overview and description of the current state-of-the-evidence. Overall, we recommend that: (a) a focused systematic review of only studies with a longitudinal, experimental, or intervention component be undertaken in the future, (b) specific attention be paid to the psychological benefits of purposive versus incidental GT for children and adolescents of different ages, (c) interactive ST activities and different ST content be considered, and (d) derivation of effect magnitudes occur where studies can be pooled. Further, we recommend that starting dates for searches commence around the time when contemporary technologies, such as smart phones, were introduced. Older research pertaining to previous generations with older technology use and different socialisation patterns should be drawn on judiciously. In addition, a narrow range of operationalisations of ST and GT will need to be employed to limit heterogeneity and allow for more fine-grain analysis.

3.5 Conclusion

While moderate ST can be beneficial for young people in a connected world, it is widely speculated that the concomitant trends of increasing ST and decreasing GT among children and adolescents may be social determinants of trends in youth mental health problems. However, research rarely considers the reciprocal effects of extensive ST (which is arguably detrimental) and GT (which is arguably protective) on children and adolescents' psychological well-being. Researchers should move beyond cross-sectional studies, to longitudinal and intervention studies which are designed to investigate the psychological effects of both ST and GT, with careful specification of the extent and type of exposure. Research should consider specific developmental ages of children and adolescents, young people from low SES backgrounds, and consider the specific contribution of other lifestyle variables. GT presents as a potentially novel strategy to ameliorate high levels of ST; however, robust evidence is needed to guide policies and recommendations for exposure at critical life stages in childhood and adolescence. Nature may currently be an under-utilised public health resource, and it could potentially function as an upstream preventative and psychological well-being promotion intervention for children and adolescents in a high-tech era.

CHAPTER FOUR: PAPER 2 – NATIONAL CROSS-SECTIONAL STUDY (PUBLISHED)

Mental Health of Young Australians during the COVID-19 Pandemic: Exploring the Roles of Employment Precarity, Screen Time, and Contact with Nature

(Publication preview presented in Appendix 9)

Tassia K. Oswald[1,2*], Alice R. Rumbold[2,3], Sophie G. E. Kedzior[2], Mark Kohler[4,5] and Vivienne M. Moore[1,2] (2021). *International Journal of Environmental Research and Public Health*, *18*, 5630. doi: https://doi.org/10.3390/ijerph18115630

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Contribution to the Paper	Conceptualised research questions, generated and submitted ethics application and related amendments, set up the survey and liaised with *Qualtrics* for participant recruitment, conducted data cleaning, management, and analysis, wrote manuscript, acted as corresponding author.		
Overall percentage (%)	85%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	19/01/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the thesis; and
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

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4.0 Abstract

The coronavirus disease 2019 (COVID-19) pandemic is widely understood to have contributed to mental health problems. In Australia, young people (18 – 24 years) have been disproportionately affected. To date, research has predominantly focused on the presence or absence of mental illness symptoms, while aspects of mental well-being have been overlooked. We aimed to explore associations between potential risk and protective factors and mental health more comprehensively, using the Complete State Model of Mental Health. An online survey of 1,004 young Australians (55% female; M age = 21.23) was undertaken. Assessment of both mental illness and mental well-being enabled participants to be cross-classified into four mental health states. Those with 'Floundering' (13%) or 'Struggling' (47.5%) mental health reported symptoms of mental illness; a 'Languishing' group (25.5%) did not report symptoms of mental illness but mental well-being was compromised relative to those who were 'Flourishing' (14%) with high mental well-being. Multinomial logistic regressions were used to examine associations, adjusting for socio-demographic confounders. Protective factors associated with Flourishing mental health included being in secure employment, using screen time to connect with others, and reporting high levels of hope. Both incidental and purposive contact with nature were also associated with Flourishing, while a lack of green/bluespace within walking distance was associated with Languishing, absence of outdoor residential space was associated with Floundering, and lower neighbourhood greenness was associated with all three suboptimal mental health states. Precarious employment, financial stress, living alone, reporting decreased screen time during lockdowns, lower levels of hope, and high disruption of core beliefs were also associated with Struggling and Floundering mental health. Those who were Languishing reported somewhat less hardship and little disruption to core beliefs, but lower levels of hope compared to young people who were Flourishing. This study highlights that young adults

require dedicated mental health services to deal with current burden, but should also be supported through a range of preventive strategies which target mental health risk factors, like precarious employment, and enhance protective factors, such as urban green infrastructure.

4.1 Introduction

Impacts of the coronavirus disease 2019 (COVID-19) pandemic have been wide and varied, altering most aspects of daily life. Necessary attempts to curb the spread of COVID-19 through lockdowns, requirements for physical distancing, and restrictions on social gatherings have caused disruptions to employment, education, usual healthcare, and leisure activities (373, 374). Aside from the direct health effects of COVID-19, the mental health consequences of these restrictions and disruptions may be one of the greatest public health impacts of the pandemic (375-377). In Australia, mental health crisis lines have seen significant elevations in calls since the pandemic began and waiting times for mental health services have increased considerably (49-51).

The mental health implications of the pandemic appear to be particularly salient for young adults (18 – 24 years), who are at an important transitional stage of life and face a unique set of challenges (378, 379). They may be in their final year at school, starting or completing tertiary education, and are also more likely to be in precarious employment (380-382), so they are at a greater risk of job losses under economic crises like pandemics (383). Young adults each experience these transitions along different pathways and timelines (384), meaning their social supports and economic circumstances are diverse and fluctuating. For some, this is a time when financial autonomy is established, while for others study or economic insecurity can increase dependence on parental support (385). Indeed, where pandemic-related research has focused on young adults exclusively, or results have been stratified by age in population-wide surveys, young adults are shown to have experienced higher levels of psychological distress than other age groups during the pandemic, both internationally (386-390) and in Australia (383, 391-393).

To date, research has highlighted a number of behavioural, lifestyle, socioeconomic, and environmental risk and protective factors for mental illness in the context of the COVID-19 pandemic. These risk and protective factors reflect the daily activities and resources typically available or relevant to young people, but have yet to be fully explored in relation to young adults. In general, unemployment, job loss, and financial stress have consistently shown associations with poorer mental health during the COVID-19 pandemic (374, 377, 383, 391, 392, 394), but less is known about the influence of job precarity, which, as described earlier, disproportionately affects young people. With more time being spent at home, increased screen time during COVID-19 lockdowns has been reported consistently (388, 394, 395). In some studies, this has been associated with poorer mental health (386, 396-398), with explanations centering around excessive exposure to news cycles, blurred work-life balance as a result of working-from-home, or passive media use leading to lower social support seeking (374, 388, 395, 399). In other cases, screen time has been linked with better mental health during the COVID-19 pandemic and labelled as a positive coping mechanism which helps individuals stay connected with their communities and social networks (387, 395). Only two of these studies explored the impact of increased screen time among young people specifically (386, 387), but both were limited to samples of American college students.

Mobility and other restrictions at different points during the pandemic have also meant that peoples' immediate physical surroundings are likely to have greater influence on mental health (400). In particular, having access to public urban greenspaces (401-403) and private outdoor spaces (404, 405), living in greener neighbourhoods (389, 406, 407), and having 'natural' views from home (405, 406, 408) have been linked with better mental health across a range of populations during the pandemic. Beyond access and incidental exposure to nature, purposive time spent in nature during the COVID-19 pandemic has also been linked with better mental health (386, 389, 395, 400, 403, 404, 407-410). Only two of these studies exploring the influence of nature focused on young people specifically, and were limited to student samples in the USA (386) and Bulgaria (406).

In addition to the aforementioned risk and protective factors, other psychological constructs related to mental health during the COVID-19 pandemic should also be considered. For example, the protective role of hope against anxiety and stress during the pandemic has been demonstrated in research among adults (sample mean age = 37 years) (411). Contrastingly, in other research among similar aged respondents, the degree to which an individuals' core beliefs were disrupted by the pandemic explained experiences of depressive and anxiety symptoms to a greater degree than direct (e.g., receiving a COVID-19 diagnosis) and indirect (e.g., loss of child care) pandemic stressors combined (412). The role of these psychological constructs in young adults' mental health during the COVID-19 pandemic are not known.

Explorations of risk and protective factors in the context of the COVID-19 pandemic have predominantly focused on the presence or absence of mental illness symptoms, like anxiety and depression. However, mental health does not exist on one continuum with mental illness and mental well-being (absence of mental illness) sitting at opposite ends of the same spectrum. Rather, as the dual-continua model of mental health suggests, mental illness and mental well-being exist on two distinct continua (162, 413) and changes in levels of mental well-being are a predictor of future risk of mental illness (e.g., losses of mental well-being predict increases in mental illness, while gains in mental well-being predict declines in mental illness) (414). Failure to consider this complexity in mental health may mean that adverse consequences for mental well-being, that undermine quality of life without rendering a person mentally ill at the time, are overlooked. As such, there is a need to assess the mental health impacts of the COVID-19 pandemic from a more holistic point-of-view and consider both symptoms of mental illness and symptoms of well-being in conceptualizations of mental health (415). The Complete State Model of Mental Health provides a more comprehensive perspective of mental health, as it categorizes individuals into four states of mental health: Flourishing (no-to-low mental illness, with high levels of mental well-being), Languishing (no-to-low mental illness, with low levels of mental well-being), Struggling (moderate-to-high mental illness, with high levels of mental well-being), or Floundering (moderate-to-high mental illness, with low levels of mental well-being) (415, 416).

Given the independent role of mental well-being, this model is increasingly being applied to study the mental health of young people (415-426), but to date has not been applied to understand the impacts of the COVID-19 pandemic on young people's mental health. The aim of the current study was to explore associations between the four states of mental health and potential risk and protective factors relevant to young Australians and their mental health in the context of the COVID-19 pandemic. We specifically considered factors related to employment and financial security, living arrangements, use of screen time and contact with nature, as well as psychological factors such as level of hope and disruption of core beliefs.

4.2 Materials and Methods

4.2.1 Participants

Participants were recruited through Qualtrics Panels to complete a once-off online survey. To be eligible to participate, individuals had to be living in metropolitan areas of Australia, aged between 18 and 24 years, and proficient in English. The sample was limited to young Australians living in metropolitan areas because impacts of the pandemic, as well as risk and protective factors, are likely to differ considerably for young people living in rural areas. Quota sampling was used in an attempt to capture a sample which covered a spectrum of parameters balanced by gender, state/territory, and socioeconomic status. An area-level indicator of participants' socioeconomic status (SES), based on residential postcode, was assigned using the Australian Bureau of Statistics (ABS) Socio-Economic Indexes for Areas Index of Relative Advantage and Disadvantage (427). The ABS scores and ranks geographic areas in Australia on indicators of socioeconomic advantage and disadvantage, based on information gathered in a 5-yearly census. For the purposes of this study, participants were split into quintiles based on these area-level scores (1 = most disadvantaged, 5 = most advantaged).

4.2.2 Measures

4.2.2.1 Sociodemographic Measures

Participants were asked to provide their age, gender, birthplace, residential postcode, and information about their living arrangement, including type of dwelling (house, townhouse, apartment/unit in single or multi-storey group) and household co-inhabitants (living alone, with a partner, dependent child(ren), parent(s), sibling(s), friend(s) or housemate(s), or others (e.g., extended family members)). Participants indicated whether or not they were doing any formal study or training in 2020 (Year 11 or 12; high school), vocational education and training (VET; workplace-specific often involving apprenticeship), professional development (PD), or university studies. Participants also reported which months of the year they experienced COVID-19 lockdowns.

4.2.2.2 Mental Well-Being Symptoms

Mental well-being symptoms were measured via the 14-item self-report Mental Health Continuum-Short Form (MHC-SF). The MHC-SF is based on Keyes' dual continuum theory and measures the three dimensions of well-being: emotional (items 1 – 3), social (items 4 – 8), and psychological well-being (items 9 – 14) (428, 429). Using a 6-point Likert scale (0 = never, 1 = once or twice, 2 = about once a week, 3 = 2 or 3 times a week, 4 = almost every day, 5 = every day), participants indicated how often they had experienced each of the items listed over the last month. Examples of items included feeling “happy”, “satisfied with life” and “that your life has a sense of direction or meaning to it”. Scores on the MHC-SF range from 0–70 and higher scores indicate greater well-being. The scale had a Cronbach’s alpha score of 0.94 in this study.

4.2.2.3 Mental Illness Symptoms

Mental illness symptoms were measured via the self-report Kessler Psychological Distress Scale (K-10; (430)). This 10-item scale yields a global measure of distress based on questions about depression and anxiety which the respondent has experienced in the past 30 days. Examples of questions include “During the last 30 days, about how often did you feel so nervous that nothing could calm you down?” or “about how often did you feel that everything was an effort?” Response options range from 1 (None of the time) to 5 (All of the time). Scores on the K-10 range from 10–50 and categorise respondents as likely to be well (<20), or having a mild (20 to 24), moderate (25 to 29), or severe (≥30) psychological distress. The K-10 is a widely used measure of psychological distress with high validity, as evidenced in the Australian context (431). The scale had a Cronbach’s alpha score of 0.92 in this study.

4.2.2.4 Complete Mental Health States

Each participant was cross-classified into a Complete Mental Health State based on their MHC-SF and K-10 scores (see Table 4.1 for criteria). As undertaken in previous work by Venning and colleagues (415), pre-determined cut-off scores were used to classify participants as either Flourishing, Languishing, Struggling, or Floundering in life, based on the relative proportion of mental well-being and mental illness symptoms reported. To adapt to the short-form measures used in the current study (in which respondents are positioned within a more compressed range), minor modifications were made to the criteria used by Venning and colleagues (415). Participants were categorised as (1) *Flourishing in life* if they reported high levels of mental well-being alongside no-to-mild mental illness symptoms; (2) *Languishing in life* if they reported low levels of mental well-being alongside no-to-mild mental illness symptoms; (3) *Struggling in life* if they reported high levels of mental well-being alongside moderate-to-severe mental illness symptoms; or (4) *Floundering in life* if they reported low levels of mental well-being alongside moderate-to-severe mental illness symptoms.

Table 4.1 Criteria used to categorise participants into complete mental health states

Mental Health State	K-10 [a]	MHC-SF [b]
Flourishing (Complete Mental Health)	Likely to be well (<20) or mild (20–24) psychological distress	Feels 1 of the 3 emotional well-being symptoms "every day" or "almost every day" and feels 6 of the 11 social/psychological symptoms "every day" or "almost every day"
Languishing (Incomplete Mental Health)	Likely to be well (<20) or mild (20–24) psychological distress	Not compatible with Flourishing
Struggling (Incomplete Mental Illness)	Moderate (25–29) or severe (30+) psychological distress	Not compatible with Floundering
Floundering (Complete Mental Illness)	Moderate (25–29) or severe (30+) psychological distress	Feels 1 of the 3 emotional well-being symptoms "never" or "once or twice" and feels 6 of the 11 social/psychological well-being symptoms "never" or "once or twice"

Notes. [a]Kessler Psychological Distress Scale; [b]Mental Health Continuum-Short Form.

4.2.2.5 Employment and Financial Variables

Participants were asked to indicate their level of employment precarity in 2020 (permanent, fixed-term contract, regular casual hours, irregular casual hours, receiving JobKeeper payments (welfare support for selected jobs affected by COVID-19 restrictions), or not employed). Individuals who were employed were asked whether they moved to working from home and, if yes, they were asked to indicate on a 5-point Likert scale (1 = Strongly disagree, 5 = Strongly agree) the extent to which they agreed or disagreed with the statement "Working from home has been stressful compared to my usual working arrangements". Participants were also asked to indicate whether their income and working hours had increased, stayed the same, or decreased as a result of the COVID-19 pandemic.

The InCharge Financial Distress/Financial Well-Being Scale (432) was used to measure participant financial stress. Using a 10-point visual analogue scale (VAS), participants were asked to respond to the question "What do you feel is the level of your financial stress today?" Response options ranged from "No stress at all" to "Overwhelming stress". Categories were then created to classify participants as having no-to-low financial stress (1–4), moderate financial stress (5–6), or high-to-overwhelming financial stress (7–10).

4.2.2.6 Screen Time Variables

Participants were asked to indicate whether their overall screen time had increased, stayed about the same, or decreased during COVID-19 lockdowns/restrictions. This was repeated for six specific screen time activities: social media use, video-chatting (e.g., FaceTime, Zoom), streaming services (e.g., Netflix, Stan), video-gaming, phone use, and laptop/computer use. On a 5-point Likert scale (1 = Strongly disagree, 5 = Strongly agree), participants were asked to what degree they agreed with the following statements: "During COVID-19 lockdowns/restrictions: (1) I found technology helpful for staying connected with family and friends, (2) I found myself disengaging from social media or communications over technology (e.g., slower replying to text messages), (3) I felt fatigued by screen time, (4) I felt that technology helped me to cope, (5) I needed to restrict my exposure to news stories in the media."

4.2.2.7 Nature Variables

Given there is currently no gold standard for measuring contact with nature (151), access to and incidental contact with nature was gauged through three questions designed specifically for this study. Participants were first asked to indicate whether they had access to a residential outdoor space (no access, balcony, courtyard, or yard). Participants were also asked to indicate whether they lived within walking distance (300 metres according to the World Health Organization (433)) of a greenspace (park, oval, national park) or bluespace (beach, river, lake), and how "green or natural" they perceived their neighbourhood to be on a 10-point VAS (1 = completely urban/built, 10 = completely green/natural).

Purposive contact with nature during COVID-19 lockdowns/restrictions was determined via four questions designed for this study. Participants were first asked to report whether their overall contact with nature had increased, stayed about the same, or decreased during COVID-19 lockdowns/restrictions. This was then repeated for three specific activities: (1) going out in the neighbourhood (walking, jogging, wandering), (2) spending time in a local park, and (3) planning activities in nature (e.g., hiking, picnic, beach walk). Participants were asked to indicate on a 5-point Likert scale (1 = Strongly disagree, 5 = Strongly agree) whether spending time in nature during COVID-19 lockdowns/restrictions (1) gave them a feeling of "getting away", and whether it (2) felt uncomfortable.

4.2.2.8 Other Psychological Constructs

Participants' level of hope was measured via the 12-item Adult Hope Scale (AHS; (434)). Respondents indicate the degree to which each statement describes themselves on an 8-point Likert scale (1 = Definitely false, 8 = Definitely true). Examples of statements include "There are lots of ways around any problem" and "I usually find myself worrying about something." Scores on the AHS range from 8 to 64 and higher scores indicate a higher level of hope. The scale had a Cronbach's alpha score of 0.79 in this study.

Individuals each have a broad set of core beliefs which relate to the assumptions they have about themselves, others, the world, and the future. These core beliefs influence how an individual believes others will behave, how events should unfold, and their ability to influence events (435). Stressful events can sometimes challenge, and cause people to re-examine, their core beliefs. The Core Beliefs Inventory measures the degree to which an individuals' core beliefs have been disrupted by a stressful event, like the COVID-19 pandemic (CBI; (435)). Participants were asked to reflect upon the COVID-19 pandemic and indicate the extent to which it led them to seriously examine nine core beliefs, on a 6-point Likert scale (0 = Not at all, 5 = To a very great degree). An example of an item is, "Because of the COVID-19 pandemic, I seriously thought about whether things that happen to people are controllable." Participants' responses are summed and averaged (final scores ranging from 0 to 5) and higher scores indicate greater disruption of core beliefs. The scale had a Cronbach's alpha score of 0.87 in this study.

4.2.3 Procedure

The online survey was launched on the 17th of November 2020 and was open until the 9th of January 2021. The survey link was disseminated by Qualtrics to eligible individuals in their double-opt-in research panels. Participants could complete the survey on either a mobile phone or computer device at a time and location of their choice; they were advised that the survey would take 10 to 15 minutes to complete. All participants provided consent prior to commencing the survey and earned incentive points via Qualtrics Panels for their participation. To guard against duplicate responses, IP filtering was used by Qualtrics. This study was approved by the University of Adelaide School of Psychology Research Ethics Committee (approval number 20/85) (Appendix 10).

4.2.4 Context

In the lead-up to and during the study period, restrictions were continually changing in Australia in response to the public health recommendations which accompanied COVID-19 outbreak clusters (373). In the early stages of the pandemic, Australia worked towards reducing the incidence of COVID-19 and "flattening the curve". In doing so, from March 2020 most states and territories in Australia introduced border restrictions which limited travel across the country, temporary closure of non-essential activities, gatherings and businesses, and people were encouraged to work from home and only go out when essential. Between May and June of 2020, restrictions began to ease across Australia and non-essential services were permitted to operate under new conditions. In late June 2020, stay at home restrictions were reintroduced in the state of Victoria, following a second wave of COVID-19. These restrictions were lifted almost 5 months later in late November 2020, during the study period. Just as this occurred, a cluster outbreak occurred in South Australia which resulted in a 3-day hard lockdown and the closure of several state and territory borders during the study period. A cluster in Northern Sydney (New South Wales) then occurred in December 2020, which resulted in a stay at home order for those areas, new restrictions on social gatherings and non-essential services, and border closures over the week of Christmas. Relative to other countries, Australia has had very few deaths and limited community transmission of COVID-19.

4.2.5 Statistical Analysis

All data were analysed using STATA software version 15.1. Descriptive and bivariate analyses were first conducted to examine relationships between variables. Responses on 5-point Likert scales were recategorized as: "agree" (strongly agree and agree), "neutral" (neither disagree nor agree), and "disagree" (strongly disagree and disagree). Variables were then analysed in a series of multinomial logistic regressions to assess associations between mental health state and factors related to living arrangement, employment, finances, screen time, contact with nature, and hope and core beliefs. Flourishing was used as the outcome reference category and relative risk ratios (RRR) with 95% confidence intervals (95% CI) were calculated. Important relationships between variables were presented in figures.

4.3 Results

4.3.1 Descriptive Statistics

A total of 1,004 participants were recruited across seven states and territories in Australia (55% female; M age = 21.23, SD = 1.93). The sample was reasonably well distributed across SES quintiles and 80% of participants were born in Australia. Table 4.2 presents a summary of sociodemographic variables by mental health state, with bivariate associations shown. Descriptive statistics for all other study variables can be found in the Main Analysis and Appendix 11.

Results on the K-10 indicated that almost one quarter of the sample were likely to be well (n = 228; 23%), while 17% (n = 171), 20% (n = 205), and 40% (n = 401) of participants were classified as experiencing mild, moderate, and severe psychological distress, respectively. Results on the MHC-SF indicated that participants had moderate levels of well-being symptoms on average (M = 36.5, SD = 14.6). After calculating the relative proportion of mental illness and mental well-being symptoms, the largest group in the sample was classified as Struggling in life (n = 477; 47.5%), followed by Languishing (n = 257; 25.5%), Flourishing (n = 142; 14%), and Floundering (n = 128; 13%) (see Figure 4.1).

Table 4.2 Sociodemographic variables by mental health state

Study Variable	Total n (%)	Flourishing n (%)	Languishing n (%)	Struggling n (%)	Floundering n (%)	*p*-value
Age (years)						0.69
	M = 21.23 (SD 1.93)	M = 21.37 (SD 1.90)	M = 21.37 (SD 1.87)	M = 21.14 (SD 1.20)	M = 21.09 (SD 1.92)	
Gender						0.19
Male	450 (45%)	61 (43%)	226 (47%)	115 (45%)	48 (38%)	
Female	548 (55%)	81 (57%)	246 (52%)	141 (55%)	80 (62%)	
Gender Diverse/Non-Binary*	6 (<1%)	0 (0%)	5 (1%)	1 (<1%)	0 (0%)	
Birthplace						0.36
In Australia	801 (80%)	113 (80%)	391 (77%)	197 (82%)	100 (78%)	
Outside Australia	203 (20%)	29 (20%)	86 (23%)	60 (18%)	28 (22%)	
State/Territory of Residence						0.98
Australian Capital Territory	15 (1%)	2 (1%)	7 (1%)	4 (2%)	2 (2%)	
New South Wales	330 (33%)	47 (33%)	161 (34%)	87 (34%)	35 (27%)	
Queensland	160 (16%)	22 (15%)	70 (15%)	43 (17%)	25 (20%)	
South Australia	79 (8%)	9 (6%)	40 (8%)	19 (7%)	11 (9%)	
Tasmania	39 (4%)	9 (6%)	16 (3%)	9 (3%)	5 (4%)	
Victoria	274 (27%)	35 (25%)	133 (28%)	68 (26%)	38 (30%)	
Western Australia	107 (11%)	18 (13%)	50 (10%)	27 (11%)	12 (9%)	
Area-Level Socioeconomic Status Quintile						0.57
1 (most disadvantaged)	191 (19%)	24 (17%)	101 (21%)	39 (15%)	27 (21%)	
2	149 (15%)	19 (13%)	71 (15%)	39 (15%)	20 (16%)	
3	205 (20%)	32 (23%)	97 (20%)	50 (19%)	26 (20%)	
4	224 (22%)	31 (22%)	93 (20%)	68 (26%)	32 (25%)	
5 (most advantaged)	235 (23%)	36 (25%)	115 (24%)	61 (24%)	23 (18%)	
Studying in 2020						0.04
Not studying	343 (34%)	54 (38%)	92 (36%)	153 (32%)	44 (35%)	
Year 11 or 12 (high school)	71 (7%)	7 (5%)	14 (5%)	44 (7%)	6 (5%)	
VET or PD	208 (21%)	27 (19%)	38 (15%)	110 (21%)	33 (26%)	
University	381 (38%)	54 (38%)	112 (44%)	170 (38%)	45 (35%)	
Type of Residential Dwelling						0.47
Apartment/Unit (Multi-Storey Group)	135 (13%)	15 (11%)	37 (14%)	73 (15%)	19 (15%)	
Unit (Single-Storey Group)	144 (14%)	16 (11%)	37 (14%)	72 (15%)	10 (8%)	
Town house	88 (9%)	12 (9%)	20 (8%)	44 (9%)	12 (10%)	
House	634 (63%)	98 (69%)	163 (63%)	287 (60%)	86 (68%)	
Months in COVID-19 lockdowns						0.34
	M = 3.57 (SD 2.74)	M = 3.73 (SD 2.80)	M = 3.68 (SD 2.69)	M = 3.29 (SD 2.63)	M = 4.20 (SD 3.04)	

Notes. M = mean; SD = standard deviation; VET = vocational education and training; PD = professional development; *gender diverse/non-binary participants were not included in gender analysis due to small cell size.

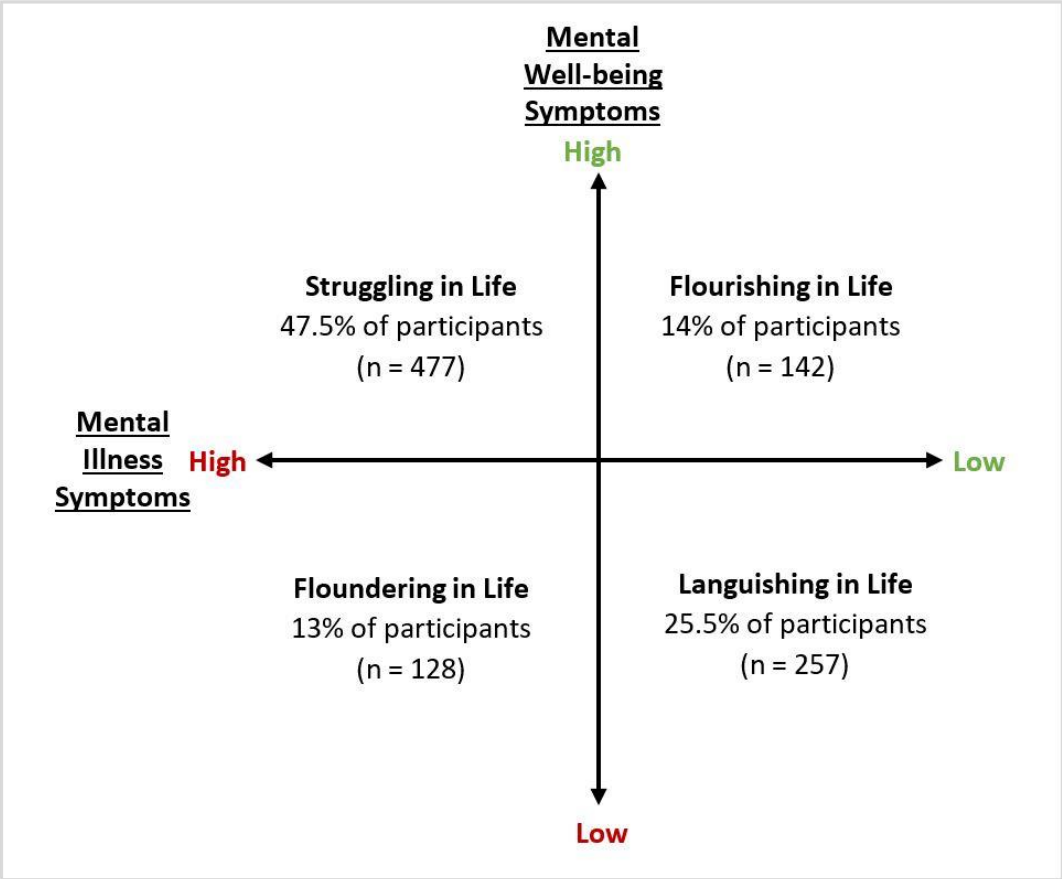

Figure 4.1 Proportion of sample cross-classified into each of the *Complete State Model of Mental Health* (162, 413, 415, 416) mental health states during the COVID-19 pandemic

4.3.2 Main Analysis

4.3.2.1 The Role of Living Arrangement, Employment Precarity and Financial Stress

Almost half of participants reported living with parent(s) and/or sibling(s) during 2020 (n = 493; 49%), while only 9% (n = 94) reporting living alone. Associations between young peoples' living arrangement during the COVID-19 pandemic and mental health state are shown in Table 4.3. After adjusting for gender, whether young people were studying or employed, and SES, those who lived with their parent(s) and/or sibling(s) or with dependent child(ren) (with or without a partner), were 69% less likely to be Struggling than those who lived alone.

Across the sample, 29% (n = 288) of participants had permanent employment, while 9% (n = 89) were on fixed-term contracts, 20% (n = 200) worked regular casual hours, and 10% (n = 98) worked irregular casual hours. Five percent (n = 54) of the sample reported that they were on JobKeeper (COVID-19 welfare payments) and 27% (n = 266) reported that they were not employed (n = 176; 66% of those not employed being students). As shown in Figure 4.2, young people with permanent employment were predominantly Flourishing. In contrast, those who were not employed were predominantly Floundering. Of note, this was also the case for those with irregular casual work and those on JobKeeper.

Associations between employment and financial variables with mental health state are presented in Table 4.3. Compared to those who had permanent employment, those who were on fixed-term contracts were more than 3 times as likely to be Languishing and Struggling. Young people who worked irregular casual hours were 4 times more likely to be Floundering. Those who were on JobKeeper payments were more than 4 and almost 8 times more likely to be Struggling and Floundering, respectively.

Young people who agreed that working from home was stressful were almost 3 and 5 times more likely to be Struggling and Floundering. Experiencing a decrease or increase in working hours as a result of the COVID-19 pandemic was associated with approximately 2–3 times the risk of Struggling or Floundering, compared to no change in working hours. Compared to reporting no change in income, reporting decreased income as a result of the COVID-19 pandemic was associated with 2.5 times the risk of Struggling and Floundering, while reporting an increase in income was also associated with more than 2 times the risk of Struggling.

Overall, 48% (n = 478) of the sample reported experiencing high-to-overwhelming levels of financial stress, while 22% (n = 218) reporting experiencing no-to-low financial stress and 31% (n = 308) reported experiencing moderate financial stress. As shown in Figure 4.3 and

Table 4.3, compared to young people with no-to-low financial stress, those who reported moderate financial stress were over 1.5 times more likely to be Languishing, 2 times more likely to be Struggling, and greater than 5 times more likely to be Floundering. Participants who reported experiencing high-to-overwhelming financial stress were over 7 times more likely to be Struggling and had 15 times the risk of Floundering.

Table 4.3 Associations between living arrangement, employment, and financial variables with mental health state during the COVID-19 pandemic

Variables	Languishing vs. Flourishing	Struggling vs. Flourishing	Floundering vs. Flourishing
Living arrangement	RRR[a] (95% CI)	RRR[a] (95% CI)	RRR[a] (95% CI)
Alone	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Couple	0.58 (0.20–1.70)	0.51 (0.19–1.35)	0.67 (0.20–2.19)
Parent(s) and/or sibling(s)	0.55 (0.22–1.37)	**0.31 (0.13–0.71)**	0.43 (0.16–1.19)
Dependent child(ren) (with or without partner)	0.39 (0.11–1.30)	**0.31 (0.11–0.92)**	0.36 (0.09–1.47)
Housemate(s)/Friend(s)	0.85 (0.30–2.46)	0.42 (0.16–1.11)	0.66 (0.20–2.14)
Other mix	0.85 (0.29–2.52)	0.51 (0.19–1.38)	0.66 (0.20–2.23)
Employment precarity	RRR[b] (95% CI)	RRR[b] (95% CI)	RRR[b] (95% CI)
Permanent	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Fixed-Term	**3.32 (1.27–8.71)**	**3.52 (1.42–8.68)**	2.92 (0.88–9.67)
Regular Casual Hours	1.40 (0.77–2.53)	1.50 (0.88–2.53)	1.65 (0.77–3.55)
Irregular Casual Hours	1.39 (0.62–3.12)	1.39 (0.68–2.86)	**4.02 (1.67–9.67)**
JobKeeper (COVID-19 welfare support)	2.84 (0.74–10.88)	**4.27 (1.25–14.60)**	**7.89 (1.97–31.51)**
Not Employed	**1.99 (1.17–3.38)**	1.17 (0.71–1.93)	**3.22 (1.67–6.23)**
Working from home was stressful	RRR[b] (95% CI)	RRR[b] (95% CI)	RRR[b] (95% CI)
Disagree	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Neutral	1.07 (0.38–3.00)	1.31 (0.50–3.41)	2.67 (0.51–14.00)
Agree	1.07 (0.44–2.56)	**2.98 (1.35–6.56)**	**4.58 (1.10–19.06)**
Change in work hours during COVID-19	RRR[b] (95% CI)	RRR[b] (95% CI)	RRR[b] (95% CI)
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	0.96 (0.57–1.61)	**2.61 (1.62–4.20)**	**3.21 (1.61–6.41)**
Increased	0.96 (0.45–2.06)	**3.01 (1.54–5.88)**	**3.47 (1.39–8.64)**
Change in income during COVID-19	RRR[b] (95% CI)	RRR[b] (95% CI)	RRR[b] (95% CI)
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	1.28 (0.74–2.21)	**2.53 (1.54–4.15)**	**2.54 (1.32–4.89)**
Increased	1.19 (0.63–2.26)	**2.11 (1.19–3.75)**	1.09 (0.47–2.57)
Financial Stress	RRR[b] (95% CI)	RRR[b] (95% CI)	RRR[b] (95% CI)
No-to-Low	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Moderate	**1.63 (1.01–2.64)**	**2.10 (1.29–3.40)**	**5.33 (2.35–12.10)**
High-to-Overwhelming	1.66 (0.98–2.82)	**7.27 (4.42–11.97)**	**15.28 (6.81–34.30)**

Notes. RRR[a] = relative risk ratio adjusted for gender, studying (yes/no), employed (yes/no), and socioeconomic status (SES); RRR[b] = relative risk ratio adjusted for gender, studying (yes/no), and SES; 95% CI = 95% confidence interval; statistically significant associations bolded.

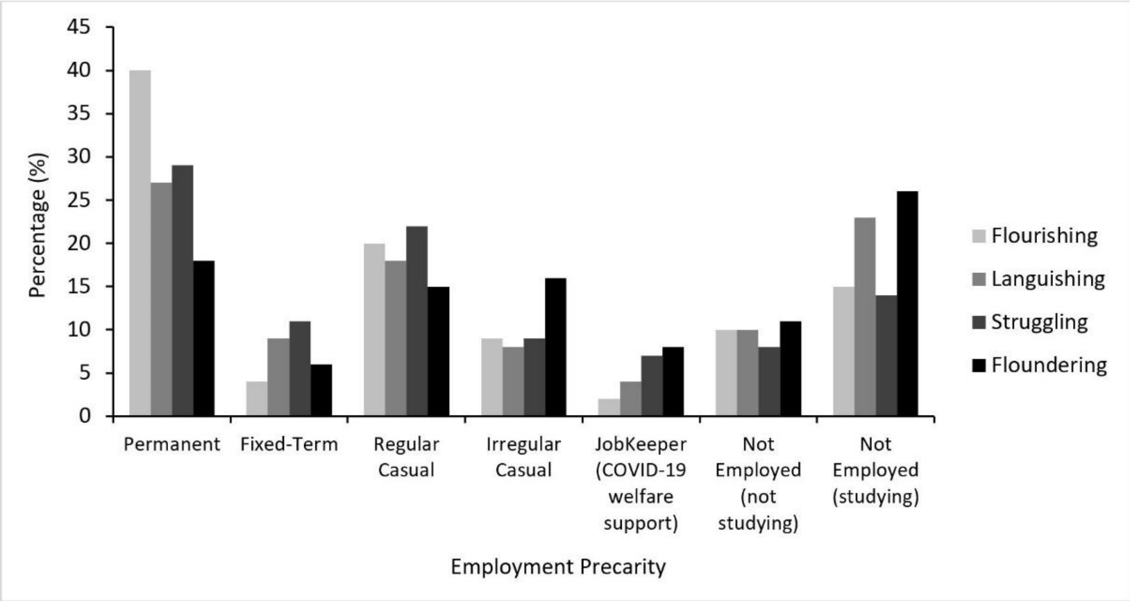

Figure 4.2 Employment precarity by mental health state during the COVID-19 pandemic

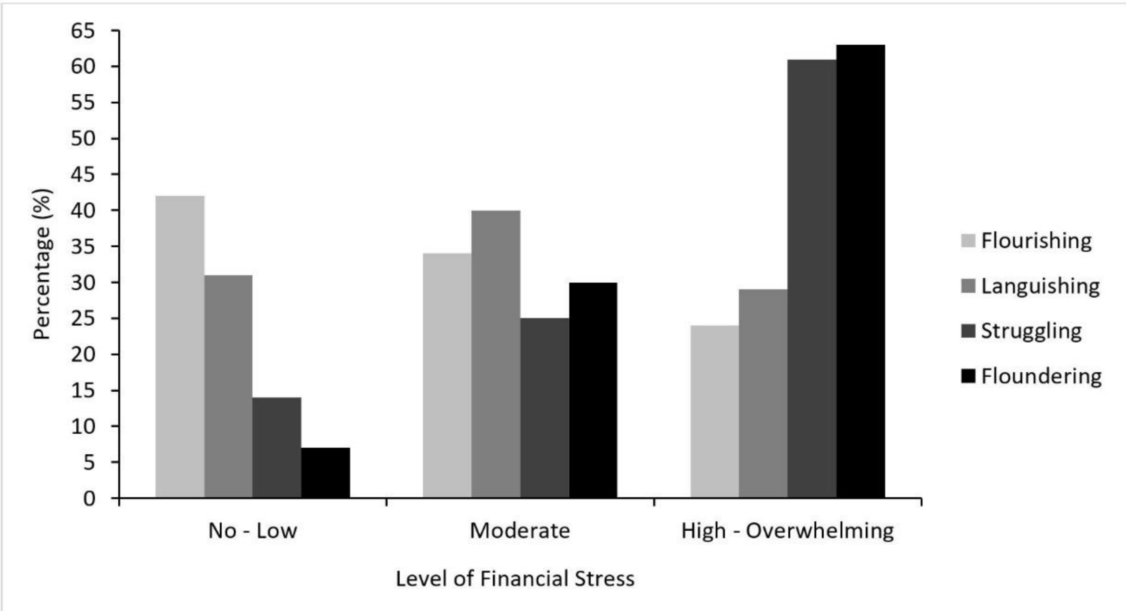

Figure 4.3 Financial stress by mental health state during the COVID-19 pandemic

To summarise, living with family, being in permanent employment, and having stable income and working hours were protective factors associated with better mental health during the COVID-19 pandemic (Flourishing). By contrast, living alone, being in precarious employment, experiencing a change in income or working hours, reporting financial stress and stress linked to working from home, were risk factors associated with poor mental health during the COVID-19 pandemic (Languishing, Struggling or Floundering).

4.3.2.2 The Role of Screen Time

The majority of participants reported that their overall screen time had increased during COVID-19 lockdowns/restrictions compared to their typical screen time (77%; n = 769), while 14% (n = 144) reported that their overall screen time stayed about the same. As shown in Figure 4.4, a small minority of the sample reported decreased screen time (n = 91; 9%). Compared to experiencing typical amounts of screen time during the COVID-19 pandemic, reporting a decreased amount of screen time was associated with almost 24 times the risk of Struggling (see Table 4.4). Reporting an increased amount of screen time compared to usual was also associated with more than 2 times the risk of Struggling. Similar results were reflected in analyses looking at the different types of screen activities; decreases in each type of screen activity were associated with a greater risk of Struggling, but increases were not (presented in Appendix 12).

Young people who agreed that screen time helped them connect with family and friends during COVID-19 lockdowns/restrictions were 81% and 76% less likely to be Struggling and Floundering, respectively. Young people who found themselves disengaging from technology-mediated communications were almost 2 times as likely to be Struggling and Floundering. Not feeling fatigued by screen time was associated with Flourishing (50–53% less risk of Languishing and Struggling). Young people who felt as though technology did not help them cope were more than 2.5 times as likely to be Floundering. Feeling the need to restrict exposure to news during COVID-19 lockdowns/restrictions was not independently associated with mental health state.

To summarise, young people with the best mental health (Flourishing) reported that technology helped them cope and connect with family and friends during the pandemic. By contrast, young people with poor mental health reported decreasing their overall screen time during lockdowns (Struggling), alongside experiences of screen time fatigue (Languishing and Struggling) and disengagement from technology-mediated communications (Struggling and Floundering).

Table 4.4 Associations between screen time variables and mental health state during COVID-19 lockdowns/restrictions

Variables	Languishing vs. Flourishing	Struggling vs. Flourishing	Floundering vs. Flourishing
Change in screen time	RRR[a] (95% CI)	RRR[a] (95% CI)	RRR[a] (95% CI)
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	4.53 (0.95–21.72)	**23.85 (5.44–104.41)**	3.27 (0.58–18.37)
Increased	1.42 (0.83–2.37)	**2.20 (1.32–3.65)**	1.18 (0.65–2.17)
Experience variables	RRR[b] (95% CI)	RRR[b] (95% CI)	RRR[b] (95% CI)
Screen time helped connect with family and friends			
Neutral	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Disagree	0.56 (0.18–1.76)	0.55 (0.19–1.56)	0.72 (0.22–2.34)
Agree	0.55 (0.22–1.36)	**0.19 (0.08–0.43)**	**0.24 (0.09–0.62)**
Found myself disengaging from technology communications			
Neutral	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Disagree	1.12 (0.66–1.91)	0.74 (0.44–1.25)	**0.43 (0.20–0.90)**
Agree	1.15 (0.67–1.99)	**1.76 (1.07–2.89)**	**1.92 (1.05–3.51)**
Screen time was fatiguing			
Neutral	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Disagree	**0.50 (0.26–0.97)**	**0.47 (0.25–0.89)**	0.51 (0.22–1.16)
Agree	1.11 (0.63–1.96)	1.67 (0.97–2.88)	1.29 (0.66–2.51)
Technology helped me cope			
Neutral	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Disagree	1.24 (0.57–2.72)	1.44 (0.67–3.09)	**2.56 (1.06–6.14)**
Agree	0.65 (0.39–1.07)	1.08 (0.67–1.76)	0.96 (0.52–1.76)
Needed to restrict exposure to news			
Neutral	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Disagree	0.96 (0.52–1.76)	0.69 (0.38–1.24)	0.60 (0.28–1.27)
Agree	1.05 (0.61–1.84)	1.08 (0.64–1.82)	0.78 (0.41–1.48)

Notes. RRR[a] = relative risk ratio adjusted for gender, studying (yes/no) and SES; RRR[b] = relative risk ratio adjusted for gender, studying (yes/no), SES, and other screen time experience variables in the table; 95% CI = 95% confidence interval; statistically significant associations bolded.

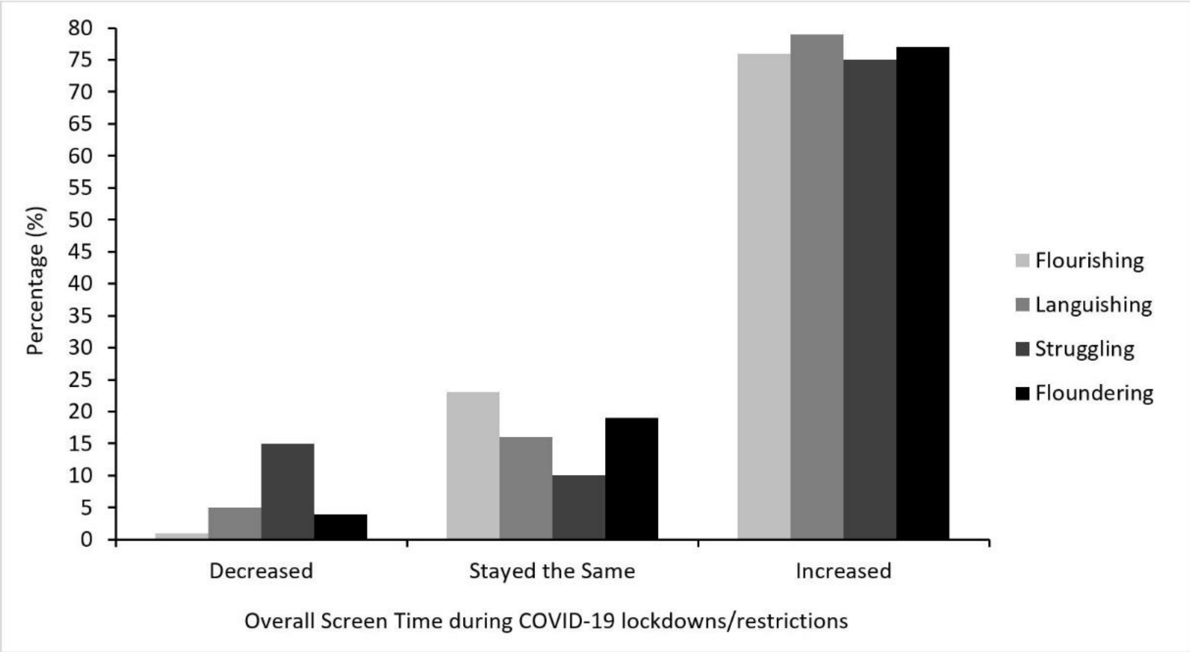

Figure 4.4 Changes in overall daily screen time during COVID-19 lockdowns/restrictions by mental health state

4.3.2.3 The Role of Nature

The majority of the sample had access to nature during the COVID-19 pandemic, with 95% (n = 951) reporting access to a residential outdoor space and 77% (n = 777) having a greenspace or bluespace within walking distance of their home. While 9% (n = 88) of the sample perceived their neighbourhood to be highly natural/green, and 5% (n = 54) perceived their neighbourhood as highly built/urban, the majority of participants reported living in neighbourhoods between the two extremes (e.g., moderately natural, even mix, or moderately built).

Associations between access to nature, incidental contact with nature, and mental health state during the COVID-19 pandemic are shown in Table 4.5. Compared to having access to a residential outdoor space, young people with no access were 5 times more likely to be Floundering. Living in a neighbourhood which was perceived to be highly built was associated with over 4 times the risk of Floundering, while living in a neighbourhood that was perceived to be highly green/natural was associated with 65% and 75% less risk of Languishing and Floundering, respectively. Compared to having a greenspace and/or bluespace within walking distance of the home, not having this was associated with 1.77 times the risk of Languishing.

The majority of young people reported that their contact with nature stayed about the same during COVID-19 lockdowns/restrictions (43%; n = 407), while 26% (n = 249) reported that their contact with nature increased and 31% (n = 288) reported a decrease in their contact with nature. As shown in Figure 4.5, Floundering was the predominant mental health state among those who reported decreased contact with nature, while Flourishing was predominant among those who reported an increase.

Compared to reporting no change in contact with nature during COVID-19 lockdowns/restrictions, young people who reported a decreased amount of contact were almost 2 times more likely to be Floundering, while young people who reported an increased amount of contact with nature were 51% less likely to be Floundering (see Table 4.6). These results were largely reflected in analyses looking at different types of nature activities (presented in Appendix 13).

Compared to those who agreed that spending time in nature during COVID-19 lockdowns/restrictions felt like "getting away", those who disagreed were more than 3 times as likely to be Languishing, more than 4 times as likely to be Struggling, and almost 6 times as likely to be Floundering. Those who endorsed the statement that spending time in nature during COVID-19 "felt uncomfortable" were over 5 times more likely to be Struggling, compared to those who disagreed.

To summarise, having access to a residential outdoor space, living in a neighbourhood which was perceived to be highly green/natural, reporting increased contact with nature during COVID-19 lockdowns, and experiencing feelings of "getting away" in nature, were protective factors associated with the best mental health during the COVID-19 pandemic (Flourishing). Contrastingly, having no access to a residential outdoor space, living in a neighbourhood which was perceived to be highly built/urban, and reporting decreased contact with nature, were risk factors associated with the worst mental health (Floundering). Those who did not have a greenspace and/or bluespace within walking distance of their home were more likely to be Languishing (no mental illness, but low mental well-being), while those who were Struggling reported feeling uncomfortable in nature.

Table 4.5 Associations between access to nature, incidental contact with nature, and mental health state during the COVID-19 pandemic

Variables	**Languishing vs. Flourishing**	**Struggling vs. Flourishing**	**Floundering vs. Flourishing**
Access to residential outdoor space	RRR[a] (95% CI)	RRR[a] (95% CI)	RRR[a] (95% CI)
Yes	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
No	0.98 (0.24–4.05)	3.22 (0.95–10.86)	**5.02 (1.35–18.63)**
Perceived neighbourhood naturalness	RRR[a] (95% CI)	RRR[a] (95% CI)	RRR[a] (95% CI)
Highly built	1.95 (0.61–6.25)	2.00 (0.65–6.12)	**4.05 (1.24–13.27)**
Moderately built	1.34 (0.71–2.54)	1.11 (0.60–2.06)	1.31 (0.62–2.74)
Even mix of built and natural	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Moderately green/natural	1.21 (0.74–1.97)	**1.67 (1.07–2.65)**	1.12 (0.63–2.01)
Highly green/natural	**0.35 (0.14–0.85)**	1.56 (0.82–2.98)	**0.25 (0.07–0.91)**
Greenspace and/or bluespace within walking distance	RRR[a] (95% CI)	RRR[a] (95% CI)	RRR[a] (95% CI)
Yes	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
No	**1.77 (1.02–3.06)**	1.62 (0.97–2.73)	1.47 (0.78–2.77)

Notes. RRR[a] = relative risk ratio adjusted for gender, SES and other nature variables in the table; 95% CI = 95% confidence interval; statistically significant associations bolded.

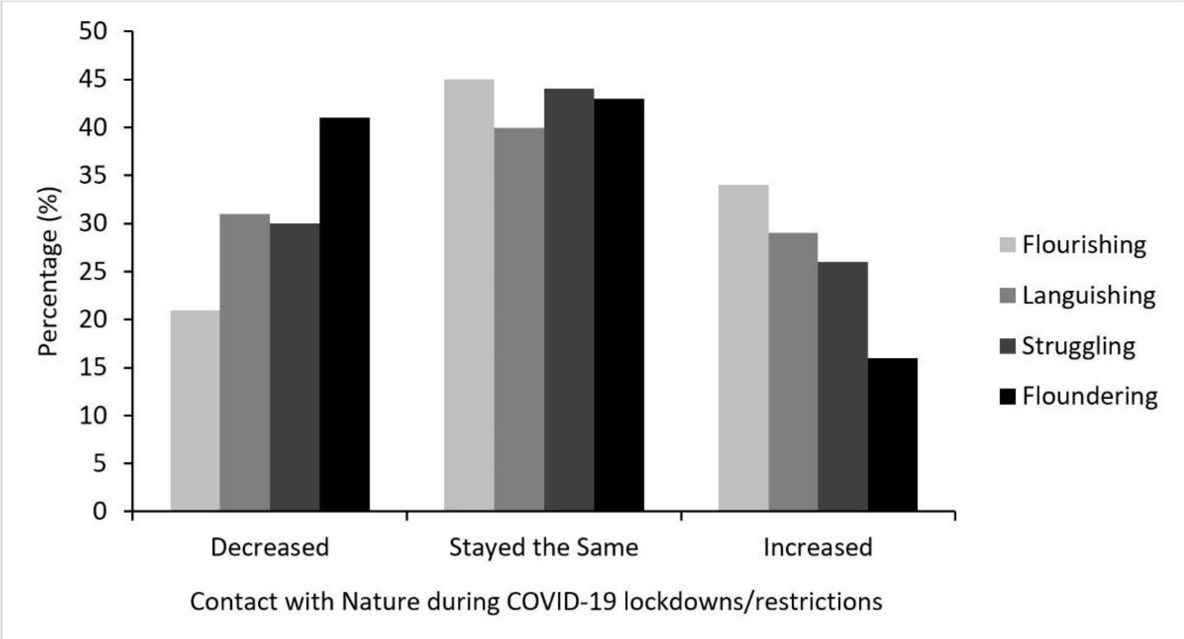

Figure 4.5 Purposive contact with nature during COVID-19 lockdowns/restrictions by mental health state

Table 4.6 Associations between purposive nature contact/experiences and mental health state during COVID-19 lockdowns/restrictions

Variables	Languishing vs. Flourishing	Struggling vs. Flourishing	Floundering vs. Flourishing
Change in contact with nature during COVID-19	RRR[a] (95% CI)	RRR[a] (95% CI)	RRR[a] (95% CI)
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	1.66 (0.97–2.83)	1.46 (0.89–2.39)	**1.98 (1.09–3.58)**
Increased	0.96 (0.59–1.57)	0.79 (0.51–1.24)	**0.49 (0.26–0.95)**
Experience variables	RRR[b] (95% CI)	RRR[b] (95% CI)	RRR[b] (95% CI)
Spending time in nature felt like “getting away”			
Disagree	**3.22 (1.18–8.76)**	**4.35 (1.67–11.33)**	**5.92 (2.06–17.03)**
Neutral	1.70 (0.95–3.05)	1.51 (0.87–2.63)	1.88 (0.95–3.70)
Agree	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Spending time in nature felt uncomfortable			
Disagree	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Neutral	1.39 (0.74–2.59)	**2.61 (1.46–4.69)**	2.10 (1.03–4.25)
Agree	1.35 (0.69–2.63)	**5.51 (3.05–9.94)**	2.32 (1.10–4.89)

Notes. RRR[a] = relative risk ratio adjusted for gender and SES; RRR[b] = relative risk ratio adjusted for gender, SES, and nature experience variables; 95% CI = 95% confidence interval; statistically significant associations bolded.

4.3.2.4 The Role of Other Psychological Constructs

Overall the sample had a moderate level of hope (M = 42.50, SD = 9.40, range = 8 – 64) and experienced moderate disruption of core beliefs as a result of the pandemic (M = 2.83, SD = 0.95, range = 0 – 5). As shown in Figure 4.6, those who were Flourishing tended to have higher levels of hope (M = 49.83, SD = 7.42, range = 17 – 64) and lower disruption of their core beliefs (M = 2.80, SD = 1.08), while those who were Floundering tended to have lower levels of hope (M = 33.82, SD = 10.66, range = 8 – 57) and greater disruption of their core beliefs (M = 2.92, SD = 1.11).

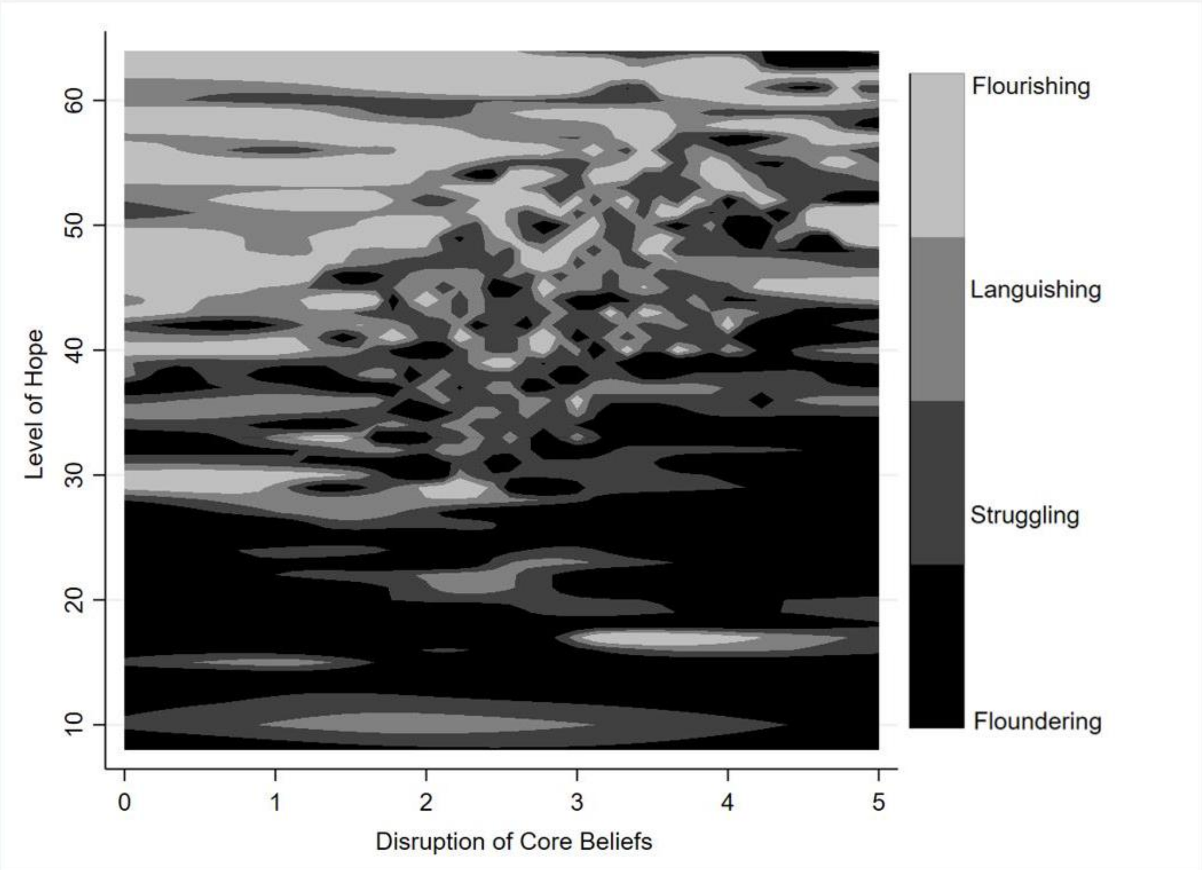

Figure 4.6 Level of hope and disruption of core beliefs by mental health state during the COVID-19 pandemic. Top left-hand corner corresponds to high levels of hope and low disruption of core beliefs. Bottom right-hand corner corresponds to low levels of hope and high disruption of core beliefs. Greyscale represents the four mental health states.

Associations between hope, disruption of core beliefs, and mental health state during the COVID-19 pandemic are shown in Table 4.7. Each unit increase in hope score was associated with 10%, 15%, and 24% less risk of Languishing, Struggling, and Floundering, respectively. Each unit increase in CBI score (indicating greater disruption of core beliefs as a result of the pandemic) was associated with almost double the risk of Struggling and almost three times the risk of Floundering.

Table 4.7 Associations between hope, disruption of core beliefs and mental health state during the COVID-19 pandemic

Variables	Languishing vs. Flourishing	Struggling vs. Flourishing	Floundering vs. Flourishing
	RRR[a] (95% CI)	RRR[a] (95% CI)	RRR[a] (95% CI)
Increasing Levels of Hope	**0.90 (0.87–0.92)**	**0.85 (0.83–0.88)**	**0.76 (0.73–0.79)**
Increasing Disruption of Core Beliefs	1.06 (0.85–1.32)	**1.97 (1.56–2.48)**	**2.83 (2.04–3.94)**

Notes. RRR[a] = Relative Risk Ratio adjusted for gender, SES, and either hope or disruption of core beliefs respectively; 95% CI = 95% confidence interval; statistically significant associations bolded.

4.4 Discussion

Using the Complete State Model of Mental Health, we explored associations between a number of risk and protective factors and mental health among over 1,000 young Australians in the context of the COVID-19 pandemic. A small proportion of this sample were considered Flourishing (14%), with high levels of mental well-being and low-to-mild levels of mental illness symptoms. The largest group in the sample (47.5%) were classified as Struggling, meaning they tended to have moderate-to-high levels of mental well-being, while also experiencing moderate-to-severe psychological distress. This is consistent with most international (386-389) and Australian (383, 391-393) literature, which indicates that young adults have experienced high levels of psychological distress during the pandemic. A smaller, yet sizeable proportion of the sample (25.5%), were found to be Languishing, meaning they reported no-to-mild levels of psychological distress, but they also reported low levels of mental well-being. Given levels of mental well-being have been found to predict future levels of mental illness (436), this may have implications for the mental health of this sub-group beyond the pandemic. Overall, the mental health profiles obtained in the current study suggest that young adults should be a target group for both provision of mental health services and preventive strategies in the immediate post-pandemic context.

In promoting the mental well-being of young adults, and reducing future burden of mental illness, this study has identified a range of relevant risk and protective factors. Foremost, advocating for job security is important for promoting mental well-being and preventing mental illness for young adults (437). While other research has highlighted the mental health impacts of unemployment and job loss during the COVID-19 pandemic (383, 394), our study extends this literature and demonstrates the mental health risks of precarious employment. Young people in our sample who had secure employment (e.g., permanent positions) had the best mental health (i.e., Flourishing). By comparison, those in less secure employment (e.g., casual workers) with fewer benefits like sick leave or paid time off for quarantine purposes, had poorer mental health (i.e., Languishing, Struggling, and Floundering). This is concerning for young people globally because they are more likely to be in precarious employment (381, 382).

While financial stress due to the pandemic, rather than job loss itself, was reported to be a key correlate of psychological distress in another Australian study (391), our study demonstrated that simply guaranteeing young adults' income (e.g., through government subsidies), or increasing their working hours, may not counteract distress around employment disruption. Young Australians in our sample who reported an increase in their income as a result of the pandemic were still 2 times more likely to be classified as Struggling than respondents who experienced no change in income. This is similar to those who reported reduced income due to the COVID-19 pandemic, and suggests that instability and changes out of one’s control may be a greater source of distress than currently recognised. Related to this, instability during the pandemic appeared to be associated with worst mental health for young people who were living independently and did not have the social supports or “buffers” available to those living with their parent(s) or partner.

Contemporary technologies have useful functions which can enable important aspects of our social, educational, and occupational lives to continue in the context of the pandemic (395). While excessive screen time has repeatedly been linked with poorer psychological outcomes in a pre-COVID world (151), a number of recent studies have found screen time to be a useful resource for adaptive coping during lockdowns, through positive escapism or community engagement, for example (387, 395). Young Australians in our sample tended to increase their screen time overall during lockdowns/restrictions, but those who decreased their screen time were significantly more likely to be Struggling with their mental health. When asked about their experiences of using screen time during COVID-19 lockdowns/restrictions, those who had the best mental health in our sample (i.e., Flourishing) appeared to view screen time as a useful resource which helped them cope during the pandemic and connect with family and friends (even when accounting for screen time fatigue). Contrastingly, young people who disagreed that screen time helped them cope during the pandemic were over 2.5 times more likely to have the worst mental health (i.e., Floundering) and appeared to experience screen time fatigue and difficulty engaging with technology-mediated communications during lockdowns/restrictions. Exposure to news stories in the media did not seem to independently affect mental health. In the case of the COVID-19 pandemic, it may be that higher levels of screen time reflect greater engagement and connection which supports mental health, while decreases in screen time indicate a group who may have become withdrawn. If this pattern of low engagement and withdrawal is generalizable, this would have important implications for public health messaging and community-based mental health services, which typically assume that people who are struggling can be reached via social media and media mental health campaigns.

Consistent with a growing body of other research, our results suggest that investment in green infrastructure is important for supporting young people's mental health "in place" during lockdowns (402, 438). A UK-based study reported that not having access to a private outdoor space during the pandemic was associated with greater psychological distress (389), while other studies have highlighted the mental health benefits offered by domestic gardens for both young and older individuals during lockdowns (404, 406, 439). Similarly, in our study, not having access to a residential outdoor space during the pandemic was associated with a 5-fold risk of worst mental health (i.e., Floundering) among young Australians. In contrast to residential outdoor space, not having a public green or bluespace within walking distance of the home was associated with a greater risk of Languishing only, suggesting that this type of green amenity may be particularly pertinent to promoting mental well-being. Across a number of studies, general neighbourhood greenery has also been linked with reduced psychological distress (406, 408) and greater positive emotions (405, 407, 408) during the COVID-19 pandemic. Consistent with this, the degree of neighbourhood naturalness was associated with mental health state in our sample, particularly at either extreme, with young Australians living in highly green/natural environments more likely to have the best mental health (i.e., Flourishing) and those living in highly built neighbourhoods more likely have the worst mental health (i.e., Floundering).

The mental health benefits of access to nature during the pandemic have been demonstrated, but this does not always reflect purposive engagement. While increased visitation to urban greenspaces during the pandemic has been reported across a number of studies internationally (403, 407, 440, 441), some studies have reported decreases in the time people spent in urban greenspaces during the COVID-19 pandemic (401, 409) due to mobility restrictions and fear of infection. Individuals who had greater nature engagement during the pandemic typically had better mental health (386, 389, 404, 407, 410) and often reported that nature was important for supporting their mental health (400, 409, 441), helping them cope with lockdowns (405, 407), and gave them feelings of "being away" (406). Similarly, in our study, young Australians who increased their time in nature and agreed that spending time in nature during COVID-19 lockdowns/restrictions felt like "getting away", had the best mental health (i.e., Flourishing). By contrast, young Australians in our study who "felt uncomfortable" in nature during COVID-19 lockdowns/restrictions were more likely to be Struggling, possibly reflecting similar fears about infection in other studies.

Given that urban greenspaces are not equitably distributed across Australia (197), with low-income neighbourhoods having the least access, the results in our study had the potential to be influenced by level of neighbourhood disadvantage. However, even after adjustment for area-level SES, these nature-mental health associations still persisted. Together, these findings highlight the potential mental health implications of high-density living, and emphasise social justice implications of inequitable access to urban greenspaces, especially under extenuating circumstances like pandemics.

The pandemic has shaken many young peoples' fundamental assumptions about the world, including their beliefs about their personal abilities, their relationships with other people, and their futures more broadly, which can cause considerable distress (412, 435). In times of hardship, hope is a psychosocial resource which can help provide individuals with a means of coping with circumstances out of their control (442). In our study and others (411, 443), hope has shown to be a powerful protective factor for mental health during the pandemic. This is an important public health finding and suggests that population-level mental health interventions should move beyond encouragement of self-care towards actively fostering hope in young people through evidence-based approaches (444).

4.4.1 Limitations

The results of this study must be considered while appreciating some limitations. First, it is not possible to generate a random sample of young adults for an online survey directly from electronic contact details, due to the lack of a sampling frame. While the electoral roll is a reliable sampling frame, this approach requires posting information to participants which is not the best avenue to engage young people (445). As such, a convenience sample was used. This approach is acceptable since our aim was to not to make prevalence estimates (168), but rather to explore inter-relationships between key variables. Quota sampling meant that the final sample had strengths in terms of size and diversity. It seems unlikely that the associations reported would be different among young people who did not participate. Research about social and mental health surveys indicates that individuals with severe mental illness are less likely to participate in online surveys than those without such conditions (168), nevertheless, some do so, and that was the case in our study.

Due to the cross-sectional nature of the data, the direction of associations remains uncertain, although in many cases it seems reasonable to presume that mental health state is the outcome. Likewise, causation cannot be claimed and there is likely bi-directionality. Furthermore, the changing context of the COVID-19 pandemic (including cluster outbreaks and snap-lockdowns), and the study period taking place over a holiday period (Christmas and the New Year) may have affected participants' mental health at the time of response. However, the latter may have had less influence, given the majority of data (98% of responses) were obtained before Christmas. Overall, longitudinal studies are required to investigate the potential direction of causation and to determine the long-term psychological effects of the pandemic.

This study may have been strengthened with additional information around the pre-existing mental health status of participants, as well as other lifestyle factors which impact mental health, such as alcohol consumption and smoking status. We also acknowledge that some relative risk ratio estimates should be interpreted with caution, where wide confidence intervals were present as a result of sparse data. Finally, while the results in our study mirror mental health experiences of young adults in similar high-income countries, it is important to note that our findings may not completely generalise to other contexts because COVID-19 infection rates during the study period were significantly lower in Australia than in other high-income countries such as the USA and UK (446). Given that Australia has been one of the countries least affected by COVID-19 in terms of morbidity and mortality [80], this makes the psychological impacts on young people all the more notable.

4.5 Conclusions

Young adults experience a variety of unique challenges specific to their transitional stage of life. The COVID-19 pandemic appears to have amplified many of these challenges, especially those around independence and security, which may explain why young adults have experienced disproportionate mental health impacts from the pandemic in Australia. Moving forward, young adults not only require focused funding for mental health services to deal with the current burden, but should also be supported through a range of preventive strategies which target mental health risk factors and enhance protective factors. This will involve not only individual-level intervention, but also support for significant structural changes around the way young people work, the environments in which they live, and the way they are able to participate in society more widely.

CHAPTER FIVE: PAPER 3 – THEORETICAL PAPER (MANUSCRIPT FORM)

Teens, screens, and a public health perspective: A developmental lens on how extensive use of digital technologies could affect self-regulation capabilities and undermine mental health of adolescents

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Statement of Authorship

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Publication Details	Not applicable.

Principal Author

Name of Principal Author (Candidate)	Tassia Kate Oswald		
Contribution to the Paper	Conceptualised research question, conducted literature review, created conceptual model, wrote manuscript, will act as corresponding author.		
Overall percentage (%)	70%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	19/01/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. The candidate's stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the thesis; and
iii. The sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of Co-Author	Associate Professor Alice Rumbold		
Contribution to the Paper	Supervised development of work, and contributed to manuscript evaluation and editing.		
Signature		Date	07/02/2022

Name of Co-Author	Professor Vivienne Moore		
Contribution to the Paper	Supervised development of work including conceptualisation of the paper, literature review, and contributed to manuscript evaluation and editing.		
Signature		Date	07/02/2022

5.0 Abstract

Adolescence is a period of profound development in which the onset of anxiety and depression peaks. A substantial body of literature has demonstrated associations between extensive digital technology use and poor mental health for adolescents, although debates are ongoing and cannot be settled unequivocally with available evidence. Following the precautionary principle, we argue that the pursuit for scientific certainty about the psychological impacts of screen time should not postpone preventive measures to protect adolescent well-being. In this theoretical paper, we integrate important segments of the literature relating to both cognition and emotion and offer a developmental perspective on how contemporary digital technologies could undermine adolescent mental health by impeding several critical neurological, cognitive, and social developments which are associated with self-regulation capabilities. Across adolescence, a suite of cognitive abilities and related neuroanatomical maturational changes, contributing to self-regulation, must be refined and strengthened through interactions with the external world. These capabilities enable cognitive control of emotions to protect against internalizing problems, for example, through reappraisal of threats and reducing rumination. A large amount of daily time devoted to digital technologies displaces opportunities for experience-dependent maturation of self-regulation capabilities, and also exploits immature neuroanatomy. We argue that use of digital technologies can foster cognitive and behavioural styles that are automatic or impulsive, rather than exercising forms of conscious control required for effective self-regulation. Variable-ratio reinforcement schedules embedded in digital technologies can interact with adolescents' overactive dopamine systems to encourage incentive-guided behaviour and disrupt goal-directed behaviour, especially in a context marked by reduced parental control. Habitual media-multitasking also reduces the capacity for self-regulation by promoting continuous partial attention, rather than sustained attention required to engage

cognitive control over emotions. We consider the asynchronous development of affective and cognitive systems in adolescence, and discuss how constant access to emotional content on social media can create demanding sources of stress; for example, through a perpetual need to remain in contact with larger social networks, experiencing overt quantification of social success, and celebration of unattainable lifestyles and beauty. Digital technologies are an inevitable part of young people's lives and we acknowledge that they afford young people many benefits. However, extensive use appears to possibly carry risks that affect a sizeable proportion of adolescents, so we conclude by discussing a range of actions for protecting adolescent psychological well-being. This could involve supporting young people to self-control screen time use whilst also encouraging their engagement in alternative activities to strengthen self-regulation. Concurrently, a greater focus on developing media literacy skills which emphasise autonomy and social justice will assist adolescents to gain agency and reduce their vulnerability to poor mental health.

5.1 Introduction: the problem and the precautionary principle

Early adolescence is a vulnerable period for the development of mental illness (361), with the onset of any mental health disorder peaking at 14 years of age (365, 447). The emergence of mental illness in adolescence is generally thought to reflect the profound physical, emotional, and social transformations experienced during this major stage of maturation, which brings about many challenges for young people as they transition from parental dependence to a more independent state of being (181, 361). The enhancement and coordination of neurological, cognitive, and emotional developments, as well as further skill acquisition, increased social affiliation with peers, and risk-taking, are all a necessary part of this transition (181, 448, 449). As a part of normative adolescent development, some of these domains mature earlier than others and this discordance in development, in the context of external stressors and social challenges, can create a heightened vulnerability to poor mental health (448).

As well as causing immediate distress and disruption to life, experiences of poor mental health in adolescence are associated with reduced quality of life and an elevated risk of poor mental health in adulthood (9, 27, 29, 30, 170), suggesting enduring consequences for well-being and functioning aross the lifespan. As such, treating mental health problems once they have developed is not the optimal approach – *prevention is required*.

The incidence of common psychological disorders, such as depression and anxiety, reported among adolescents has increased globally in recent decades (26, 34, 37), prompting debates about potential causes of, or contributors to, the observed increase. While this trend may, in part, reflect changes in the way mental health disorders are viewed and diagnosed, there have been notable changes in young people's social, cultural, and economic milieu, that affect the way contemporary cohorts of adolescents grow up, with potential consequences for their mental health (26).

While a plethora of upstream determinants of adolescent mental health exist, one proximal factor characterises contemporary adolescence as unique in comparison with previous generations: engagement with digital technologies. Smart phones, social media, and videogames are a pervasive feature of adolescent life, with new generations being dubbed "digital natives" (450). In a U.S. sample of 11-to-14 year olds, the average daily total screen time has been reported to be 9 hours (451). In a 2018 survey of U.S. teens and parents, 65% of parents reported worries about their teen spending too much time in front of screens, while 54%, 42% and 26% of teens reported that they felt they spent too much time on their phones, social media, and videogaming, respectively (452). The same survey estimated that 95% of U.S. teens have access to a smartphone and almost half (45%) reported that they are online “almost constantly” (453). Widespread integration of digital technologies in school curricula means that technology use is no longer confined to recreational use (454), making it an inevitable part of young peoples' lives. This media monopolisation of adolescents’ time arguably displaces opportunities for a wide range of other experiences and interactions that are considered important for development, such as structured extra-curricular activities (e.g., sport, art, etc) which expose young people to a variety of personal and interpersonal developmentally facilitative experiences (455).

Concerns have been raised about the psychological impacts of prolonged screen time for adolescents for some time (456), and research undertaken in a myriad of settings now provides evidence of reasonably consistent associations between high screen time and poor mental health, including a number of studies that are large and of high quality (151). For example, longitudinal research among U.S. adolescents showed that increases in contemporary digital technology use were associated with increases in depressive symptoms and suicidal thoughts across cohorts (311), as well as decreases in self-esteem, life satisfaction, and happiness (312). These associations persisted after fluctuating social and economic factors, such as unemployment, were taken into account.

Another pertinent finding was reported in a study about risk behaviours and associated mental illness, in over 12,000 15-year-old adolescents across 11 European countries (457). The risk behaviours assessed included excessive alcohol use, illegal drug use, heavy smoking, overweight, underweight, reduced sleep, sedentary behaviour, high use of Internet/TV/videogames (for reasons not related to school or work), and truancy. Latent class analysis was used to identify three groups of adolescents: (1) a group with low frequency on all risk behaviours; (2) a group that scored highly on all risk behaviours, and; (3) a group characterised by high engagement with the Internet, TV, and videogames, high sedentary behaviour, and reduced sleep. Notably, adolescents in this third group were considered an “invisible” risk group for mental health concerns as they were comparable to the high-risk adolescents with regard to prevalence of subthreshold depression (33% for the “invisible” risk group vs. 34% for the high-risk group), depression (13% vs. 15%), anxiety (8% vs. 9%), and suicidal thoughts (42% vs. 44%).

A number of systematic reviews have also reported on the negative psychological impacts of screen time for adolescents, across a range of exposures and outcomes. Systematic reviews by Hoare et al. (104), Suchert et al. (173), and Carson et al. (128) reported higher levels of total daily screen time were associated with lower self-esteem among adolescents, with the synthesised studies classified as moderate (104) and strong (173) quality. Other systematic reviews reported that high television watching and computer use specifically were also associated with lower self-esteem in adolescents (128, 175, 458). One review by Costigan and colleagues focussed on adolescent girls only and observed a positive association between total screen time and depression, and a negative association with psychological well-being, across 33 studies (172). Similarly, Suchert and colleagues reported that there was strong evidence that high levels of screen time were associated with poorer psychological well-being and perceived quality of life among adolescents, regardless of gender. Hoare and colleagues also reported consistent evidence, from studies classified as strong quality, for an association between high leisure screen time and depressive symptomology and psychological distress in adolescents, regardless of gender.

These studies have been countered by a number of additional reviews which report that findings pertaining to screen time (with a focus on social media) and adolescent mental health are less clear, with most associations being either not significant or small negative (e.g., harmful) effects. For example, a 2019 meta-analysis of 11 studies found a small but significant positive correlation between social media use and depressive symptoms ($r = .11$, $p<.01$) among adolescents (11 – 18 years old) (459). The authors noted that there was high heterogeneity (I2 = 95.22%), which indicated substantial variation among studies. A further two umbrella “reviews of reviews” published in 2020/2021 indicated that the associations between digital technology use (particularly social media use) and adolescent psychological well-being were mostly inconsistent or small negative effects (460, 461). Another 2020 study synthesised findings from a number of narrative reviews and meta-analyses, large-scale pre-registered cohort studies, and intensive longitudinal and ecological momentary assessment studies looking at the linkages between digital technology use and adolescent depression and anxiety (462). Overall, this study also reported that associations were either mixed or mostly small negative effects across the reviewed literature. Authors of these review studies regularly critiqued the existing evidence-base, stating issues around study designs (i.e., mostly cross-sectional) and the use of self-reported measures.

Recent work by Beyens (463), Valkenburg (464), and collegues suggests that the small and inconsistent findings across a range of screen time studies may be due to the typical between-adolescent approach used in analyses. They argue, in line with the proposition of media effects theories, that each adolescent may have a unique susceptibility to the effects of screen time activities like social media, meaning the effects will differ from adolescent to adolecent. They suggest that exploring whether increases in an adolescents’ screen time impacts their mental health through within-adolescent analyses, is more important than investigating whether adolescents who have higher levels of screen time experience poorer mental health (e.g., between-adolescent analyses).

This approach was adopted by Beyens et al. (463) in a study of 63 Dutch adolescents, which involved sampling adolescents’ experiences six times per day over one week, to explore differences in their susceptibility to the effects of social media on their momentary affective well-being (happiness). The study found that the association between passive social media use (mindlessly scrolling), but not active social media use (sending messages and engaging with others), and momentary happiness differed considerably from adolescent to adolescent. The person-specific effect sizes ranged from moderately negative (-0.24) to strongly positive (0.68). Overall, 44% of adolescents studied did not experience short-term changes in happiness if they had passively used social media, 46% experienced greater short-term happiness, while one in 10 adolescents reported feeling worse if they had passively used social media. While the authors describe the latter as "a small group", from a public health perspective (and despite this study being unable to generate prevalence estimates due to the lack of sampling frame), 10% would be seen to be a sizeable number of adolescents and call for concerns. It is important to note that this study recruited adolescents from one high school, who the authors characterised as "relatively happy, overall". The consent rate was 43% and 13 participants were excluded from some analyses due to insufficient data collection. This would suggest that a level of participant bias may have been present in the final sample, which could potentially limit the generalisability of the results to adolescents who may be more vulnerable. Nevertheless, it highlights the importance of person-specific approaches to research involving screen time and adolescent psychological well-being, as well as some insight into why overall effect sizes may be small in previous work (463, 464).

The lack of clear evidence, along with arguments that adults have historically been concerned with the impacts of new teen-embraced activities such as the telephone, rock'n'roll, comic books, and romance novels (465), has meant that concerns about screen time and youth psychological well-being have increasingly been viewed as alarmist (466). However, we wish to emphasise that these original adolescent leisure activities were characterised by very different patterns of diffusion and are unlikely to have consumed the number of daily hours, across most daily settings, which digital technologies do in contemporary society. Notably, a growing body of research highlights that the *type and content* of media activities young people engage with may be more important than the time spent (467). While we appreciate that different types of digital technologies and content have varying consequences, and address aspects of this throughout the paper (as well as in previous work (e.g., see (151)), we do not think that the immense time displaced, with few constraining factors, should be ignored (468). Therefore, this paper also discusses issues relating to screen time duration or frequency, despite some researchers in the field suggesting the abandonment of this approach (459, 462).

As demonstrated thus far, debates about the psychological impacts of screen time cannot be settled unequivocally with available evidence. Given current scientific debate and lack of consensus, specifying plausible mechanisms and reasoning about the possibilities is an important step forward to direct future research and give weight to policy initiatives, which is the aim of the current paper. Wayfinding of this kind is more familiar to researchers working in areas intersecting with environmental science or public health where judgements about causality have to be made in circumstances where randomized controlled trials are not possible; inferences must be drawn through integrating findings across methods and accepting imperfections in data (469). This is uncomfortable terrain, especially for those whose mainstay is clinical or laboratory research, where (as already alluded to) a tendency is to find fault with observational studies and self-reported measures. As will become clear, following the precautionary principle, we believe these well-worn criticisms should not prevent taking action (470). The precautionary principle is a concept which rose out of uncertainty about health risks pertaining to different exposures in environmental health and epidemiology research, and is useful for protecting population health against a backdrop of scientific uncertainty. It argues that the pursuit for scientific certainty should not postpone preventive measures and involves the creation of policies and preventive action to protect population health (471). Furthermore, under the precautionary principle, scientific uncertainty is tempered by community perspectives and encourages public participation in decision-making (471, 472).

In the case of screen time, it would be important to gauge the perspectives of young people themselves, whom the issue involves. For example, recent national U.S surveys show that 68% of adolescents believe that social media has a negative impact on people their age (473), while 41% worry that they spend too much time on social media (474) and over half (57%) have tried to cut back on their social media use (452), partially to get away from "digital drama" (473, 475). Qualitative research seeking the perspectives of adolescents themselves has also reported that young people view social media as a threat to mental well-being, identifying stress, low self-esteem, depression and suicidal ideation as likely negative consequences of social media use (476). Together, these findings suggest that ongoing inquiry into the psychological impacts of digital technologies is considered important by contemporary adolescents. The perspectives of other relevant community members, such as school staff, offers additional insight. For example, a 2021 qualitative study explored the topic of student social media use and its relation to mental health, from the perspectives of teachers and welfare staff in Norwegian high schools (477). While participants were asked about both positive and negative aspects of social media, the authors highlighted that "negative aspects dominated the discussions". In particular, school staff believed that social media could cause and exacerbate mental health problems in pupils, weaken their ability to delay gratification and concentrate, and lead to insufficient sleep (further contributing to potential mental health issues).

In specifying plausible mechanisms, recurring explanations for the association between high digital technology use and poor mental health invoked in the wider literature include general interference with important aspects of lifestyle, such as the displacement of physical activity and sleep (114, 128, 173, 175). While not dismissing these pathways, we argue that the field needs to move beyond these explanations. Similarly, Odgers, Jensen, Dahl and colleagues argue that there is currently a need for “a developmentally calibrated evaluation of the fit between the affordances and constraints of digital technologies and the core developmental tasks, competencies, and vulnerabilities that characterize the adolescent period more generally, and the transition to adolescence more specifically” (462, 478). Accordingly, in this theoretical paper we focus on the ways in which screen time may undermine the development of self-regulation capabilities in adolescence and why this is adverse for mental health. As articulated by Sameroff (479), acquisition of the ability to self-regulate is a fundamental component of adolescent development, and models of regulation specifically address the essential role of interactions between person and context for achieving this.

In this theoretical paper we draw together important segments of the developmental psychology literature, as well as related clinical psychology, cognitive psychology, and neuroscience literature, which point to underlying processes and mechanisms in the conceptual model shown in Figure 5.1. The conceptual model is underpinned by a public health perspective which follows the precautionary principle and is comprises of four main domains: (1) self-regulation and mental health, (2) normative adolescent development, (3) contemporary digital technologies, and (4) wider systems factors. We use this conceptual model to integrate findings about the ways in which adolescent development appears to be affected by digital technologies and highlight relevant synergies. In particular, as a part of normative adolescent development, self-regulation requires strengthening a suite of cognitive capabilities and we consider how this could be affected by (1) the addictive properties of digital technologies, (2) media multi-tasking, and (3) pervasive exposure to social and emotional content online, in a context in which these occupy significant time, daily. We consider these changes within the context of contemporary patterns of adolescent socialisation and, briefly, evolutionary neurobiology. We acknowledge the well-being benefits that digital technologies can afford adolescents and conclude with some suggestions to help develop and strengthen self-regulation, as well as support mental health in a high-tech era.

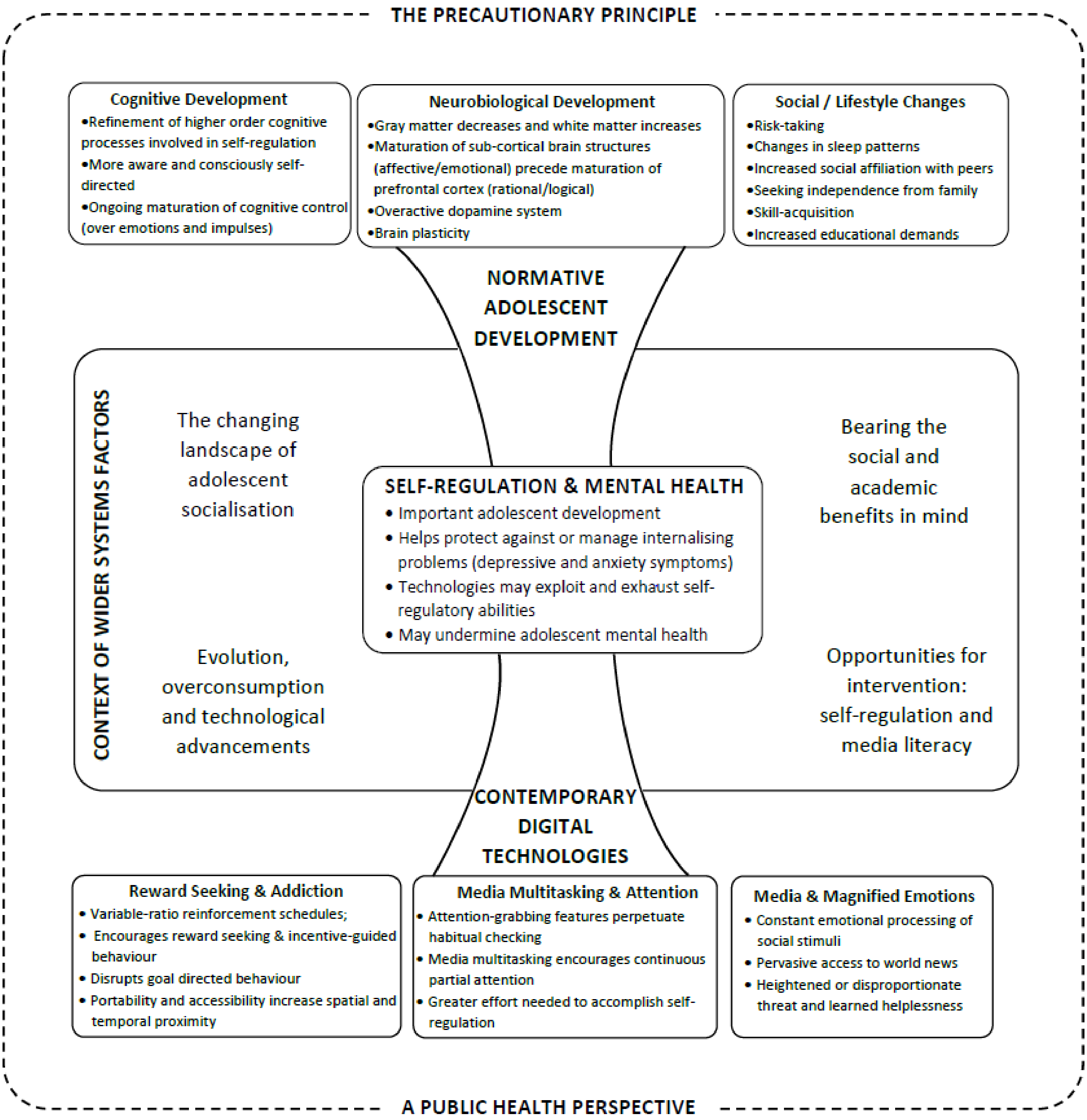

Figure 5.1 Conceptual model describing digital technology's potential to interfere with development of self-regulation in adolescents and potentially increase vulnerability to poor mental health

5.2 The Development of Self-Regulation in Adolescence

One of the most important developments in adolescence is the refinement of higher order cognitive processes that are required for effective self-regulation (12, 365, 480). Self-regulation refers to an individual's ability to regulate their emotions, cognitions (thoughts), and behaviour (12). This refinement arises through interactions with others and institutions (479) and entails assembly of an advanced "executive suite" of capabilities, through which a person becomes more self-aware and consciously self-directed (448). Within-group rankings of children and young adolescents in terms of self-regulation capabilities is only modestly stable over time, but absolute values and stability increase with age (481-483), supporting experiential processes of maturation (449, 479). Baumeister and colleagues (484, 485) conceptualise self-regulation as a capability which can be strengthened over time through regular use (practise) and depleted in the face of competing tasks (such as decision making, planning, and monitoring one's responses) (486-488) or when experiencing uncertainty (484, 489). The maturation and malleability of self-regulation create vulnerability to mental health problems but also present opportunities for improvement through intervention.

For the refinement of this advanced executive suite of self-regulatory capabilities to occur, experientially-dependent changes must take place in associated brain regions and systems, and adolescence is a time of heightened and robust brain plasticity (122, 490). For example, the prefrontal cortex undergoes considerable neural changes, with increased myelination and synaptic pruning underpinning increasingly efficient processing of information (448, 480, 491). Cortical grey matter gradually decreases, while white matter increases (361). In general, neural changes result in the maintenance and strengthening of regularly used (and thus presumably required) neural pathways, and the elimination of those which are not used regularly and lose relevance over time (361, 448, 492, 493). This is particularly important for the neural pathways implicated in self-regulation, for which it has been argued that adolescents need a variety of experiences for successful development and maintenance of brain architecture necessary for self-regulatory abilities and social skills (361, 449, 479). At the core of our arguments around digital technology's interference with the development of self-regulation, is the ways in which high screen time dramatically alters patterns of regular use of neural pathways, in the context of a high load of repetitive media activity.

Developmental psychologists refer to the construct underpinning self-regulation as effortful control (EC), while those within neuroscience or cognitive psychology use the term executive function (EF). EC refers to an individual's ability to focus attention and activate or inhibit behaviours as appropriate (12), including suppressing a dominant response in favour of a subdominant plan (494). Inhibitory control, activation control, and attentional control are all voluntary and effortful processes which make up EC, and load onto a single construct (12, 364), while EF includes abilities such as attention shifting, behavioural inhibition, and updating and monitoring information in working memory (12, 13). In a slight variation, Diamond (495) conceptualises self-regulation as substantially overlapping with inhibitory control, acknowledging that working memory is required for inhibitory control (and vice versa). Neurobiological evidence demonstrates notable similarities between EC and EF, with both governed by the executive attention network, which includes the anterior cingulate gyrus and the prefrontal cortex (12, 496, 497). While respecting the work undertaken to distinguish different constructs, we use the term self-regulation in the more general sense of Sameroff (479).

Poor self-regulation has an obvious role in externalizing problems (498). Of interest here, however, is the subtler role of self-regulation in internalizing problems, specifically the ability to protect against anxiety and depressive symptoms in adolescence (12, 15, 16, 364, 494, 499). Limitations in self-regulation are linked to an inability to control and shift attention away from threat stimuli, or away from negative thoughts, which can contribute to a greater cognitive vulnerability to anxiety and depression (364, 499). For example, Muris and colleagues (15) assessed whether attentional control influenced perceptions of threat among 9-to-13-year-olds by presenting them with a series of audiotaped vignettes about ambiguous social situations they may encounter, such as meeting a new neighbour or asking friends to one's birthday party. Participants listened to the stories sentence-by-sentence and were asked to indicate as soon as possible whether they thought the story would be "good" or "bad". Results indicated that lower levels of attentional control (as measured by the Attention Control Scale) were associated with greater perceptions of threat (rating the story as "bad" after fewer sentences). This and other evidence suggests a way that deficits in self-regulatory abilities (like attentional control) could contribute to cognitive biases (like greater threat perception) featured in anxiety disorders and depression (14-16).

Rumination, the tendency to repeatedly think about distress and the circumstances surrounding negative thoughts and feelings (500, 501), increases in early adolescence (364). Self-regulation aids in disengagement and redirection of attention away from threat stimuli and negative thoughts, enabling greater capacity to cognitively reappraise both thoughts and feelings (12, 364, 502, 503). Self-regulation may buffer against anxiety and depression through changing the emotional significance of a situation (12) and reducing ruminative and catastrophising thinking patterns.

Grahek and colleagues (504) recently argued that deficits in cognitive control processes can create a susceptibility to depression. They provided a framework which explained that these deficits can be learned through experiences in which the effort involved in exerting control does not lead to a positive outcome. While we find the arguments and evidence persuasive, we suggest that for adolescents there is now another pathway, that involves insufficient opportunities to practice deployment of cognitive control and therefore learn its value. Below we discuss the multi-faceted role of digital technology use in this pathway.

5.3 Contemporary digital technologies in the context of normative adolescent development

5.3.1 Short-Term Reward Seeking and Digital Technologies

Adolescence is a specific risk phase for excessive levels of engagement with digital technologies (505). This appears to be partly driven by neurological developments that are unique to adolescence, which result in an increased sensitivity to rewards (88), in conjunction with the exploitation of attention-grabbing features of contemporary technologies which perpetuate habitual checking behaviours (506).

As part of normal adolescent development, the dopamine system displays considerable overactivity relative to childhood and adulthood (180, 181). Dopamine, known as the "predominant molecular currency of the reward system" (122), increases adolescents' incentive-motivated risk-taking behaviour. This is thought to encourage independence from the family (365), an important transition for the survival of a species (181). An overactive dopamine system entails strong "go" impulses and weak "stop" signals involved in self-regulation (180, 181). This heightened dopamine activity precedes maturation of brain systems which are involved in cognitive control and engagement of approach behaviours (e.g., prefrontal cortex), that are adaptive for long-term goal achievement (88, 180, 181). This imbalance between heightened reward-seeking and under-developed cognitive control (88) is likely to exacerbate the consequences of tech-features which encourage excessive engagement.

The popularity of contemporary digital technologies reflects their ability to stimulate reward circuitries such as the dopamine system in the brain (122). Dopamine has been implicated in the process of checking a device and releasing ‘feel good’ chemicals in the brain, thereby perpetuating further reward-seeking (363, 507, 508). This cycle of stimulation is encouraged through variable-ratio reinforcement schedules whereby users receive pleasurable rewards at unpredictable frequencies and magnitudes, a schedule which strongly reinforces habitual checking and reward-pursuing behaviours (363, 508, 509). This phenomenon has been long exploited in gambling activities and used to be demonstrated in the classic operant conditioning ‘rat prac’ of first year psychology. Contemporary adolescents have been reported to experience heightened reward sensitivity for *social* rewards such as ‘likes’ on social media, similar to heightened reward sensitivity observed for *monetary* rewards obtained via gambling in previous adolescent cohorts (510). App designers explicitly include attributes in their platforms (such as the ‘Like’) which share features with monetary rewards as means of user feedback that shapes reinforcement learning and encourages ongoing user engagement (511).

In recent years, a perceived cultural shift towards a need for instant gratification has been reported, particularly among adolescents, and contemporary digital technologies are regularly argued to be (partly) responsible for this (490, 512). Delay of gratification refers to an individual’s willingness to delay rewards in the short-term in favour of greater benefits in the future (513). In the classic “Marshmallow Test” conducted by Mischel, Shoda and Peake (514), preschool children’s delay of gratification was assessed in the late 1960s and early 1970s by giving children the option of eating one marshmallow immediately or two marshmallows after a waiting period. Years later, children who were able to wait for longer were more likely to be academically and socially competent, attentive, and good at planning and dealing with frustration and stress in adolescence (514). Nevertheless, the ability to delay gratification is not fixed in childhood; rather, it can continue to develop throughout adolescence (515).

Recent research demonstrated that after a 3-month exposure to smartphones, previous non-users experienced a reduction in their ability to delay gratification when offered monetary rewards (490, 516). Overall, individuals who were heavier users of smartphones were more willing to accept a smaller, immediate monetary reward rather than wait for a more substantial monetary reward in the future (490, 516). Constant reward-seeking thus appears to encourage young people to be biased towards short-term pleasure-maximising goals, which can undermine endeavours that require sustained attention and persistence and contribute to well-being and success in the long-term (517). Relatedly, concerns have been expressed that adolescents may become dependent on the rapid pace and feedback that digital technologies provide (518), with their behaviour becoming controlled by extrinsic factors, ultimately undermining their ability to engage in internal goal-directed behaviours (505, 519).

During the adolescent period, reduced parental oversight means that adolescents have increased personal responsibility for limiting their technology use to some degree. The arguments above suggest this would be difficult for some, if not many, teens. Consistent with this, in a study of 12-to-17 year old Swiss adolescents, more than a third reported that they spend time online in bed during the night (115). In a study of American teenagers, objectively recorded text message data showed that 70% of participating adolescents sent at least one text message or tweet between 10:00pm and 6am each night across a week-long observation period (520). This scenario involves both a potential difficulty to disengage from smartphones and disruption of sleep, illustrating how adverse aspects may compound.

5.3.2 The Silent Adolescent Addiction or a Hard-to-Break Habit?

Adolescents' increased sensitivity to rewards can make them especially prone to addictive behaviours, including 'addictive' technology use (88, 505). Internet Gaming Disorder (IGD) has been studied extensively from the 1990s, and adolescence is known to be a peak period for experiencing IGD (88). Given the accompanying psychological, social, and functional impairments, gaming disorder is now included in the International Classification of Diseases-11, and is listed as a condition requiring further study by the Diagnostic and Statistical Manual of Mental Disorders-V (88, 521, 522). Criteria for the condition centre around symptoms which reflect addictive behaviours, such as preoccupation with gaming, withdrawal symptoms when gaming is not possible, or increased tolerance (the need to spend more time gaming to satisfy the urge).

IGD and other Internet addictions have been associated with structural or functional impairment in brain regions which are involved in reward processing and cognitive control (505, 523, 524). For example, one neuroimaging study showed that cortical thickness in the orbital prefrontal cortex, a region associated with inhibitory control (a self-regulation capability), was reduced in adolescents with IGD (525). Other studies of adolescents with IGD or other internet addictions have shown reduced gray matter in regions such as the anterior cingulate cortex, posterior cingulate cortex, dorsolateral PFC, OFC, and insula which allow for active control over impulses, attention and focussing of executive processes, and cognitive planning of complex behaviours (526-530). While only a small proportion of adolescents have IGD, the mechanisms which underpin IGD are arguably relevant to the effects of other contemporary digital technologies more broadly.

Increased sophistication of smart phones and social media platforms have increased their portability, accessibility, and pervasiveness (531), greatly increasing their spatial and temporal proximity to individuals compared with previous generations (181). This accessibility increases opportunities for adolescents to engage and reinforce cognitive and behavioural salience (the devices dominating their thoughts and behaviour), leading to a preoccupation with devices and replicating both symptoms of behavioural addiction (532, 533) and neuropsychological mechanisms underlying substance and gambling addictions (507, 534). In a study about desire and self-control, Hofmann and colleagues (535) reported that in daily life, people experienced the greatest difficulty resisting their desires to engage in media activities, compared with spending money or consuming alcohol and tobacco. Similarly, adolescents themselves have discussed social media as a kind of ‘addiction’ in qualitative research (476).

Others such as Tokunaga (536) and LaRose (2015) are cautious about using the term ‘addiction’, preferring to conceptualize the loss of conscious self-control that characterises much Internet use as a ‘media habit’. Arguably, there is a spectrum of technology use along which adolescents range; from being affected to some degree even when not reaching a point of clinical disordered use that (arbitrarily) separates the small minority with extreme manifestations. From a public health perspective (537), those with problematic but non-pathologised levels of use also warrant attention, due to the large size of this group and the important, though less severe, implications for psychological and social well-being.

5.3.3 One Brain, Too Many Tabs Open: Media Multi-tasking and Attention

Experimental studies have shown that general distraction from the mere presence of smartphones (490), receiving WhatsApp messages (538), or watching less than 10 minutes of fast-paced television shows (539), can impair cognitive functioning for young people. However, excessive use of contemporary digital technologies is further complicated by media multi-tasking (MMT). MMT refers to using more than one media device at any given time, such as using a smartphone while watching television. This has not been studied for as long as IGD so understandings of the cognitive consequences are ongoing.

MMT is pertinent to early adolescents, with a U.S. report revealing that 30% of the time young people use screen-based technologies, they simultaneously use more than one device (88). Individuals engaging in MMT can switch between media types as frequently as every 19 seconds (540). Evidence suggests that high media-multitaskers perform poorly on measures of sustained attention (363, 491, 534), as they are more susceptible to interference from irrelevant stimuli in their surrounding environment (541). A laboratory-based study demonstrated that a period of online shopping, as brief as 15-minutes, could reduce an individual's attentional scope, whereas alternative non-technologically-mediated activities (such as reading a magazine) did not produce these deficits (542). It has been argued that paying constant simultaneous attention to several media devices may lead to “breadth-biased” cognitive control, in which attention is scattered toward several sources of information. This is otherwise known as engaging in “continuous partial attention”, rather than sustained attention or focus (543, 544). Hypertext environments, characterised by increased browsing and scanning behaviours, may reduce cognitive resources available for sustained attention (542).

Higher MMT may predict the development of attention problems in adolescence. This was demonstrated in a longitudinal study of over 2,000 Dutch adolescents in which MMT and attention problems were assessed every quarter over one school year (545). Adolescents who engaged in MMT displayed increases in attention problems three months later, while no reverse effects (of attention problems on MMT) were identified. While it is not clear whether attentional capacity is diminished well beyond periods of active engagement with technologies such as smart phones (490), even acute effects are important to contemplate given they occur at such high frequency (363).

MMT amongst adolescents is associated with poorer performance on other measures of EF which rely upon attention, such as working memory capacity (as measured by the n-back task, in which progressively larger sets of letters or numbers must be remembered) (490) and greater impulsivity (assessed by questions about behaviours such as interrupting conversation, losing one's temper, or forgetting things needed for school) (546). Overall, evidence suggests that individuals who engage in high MMT are less able to filter irrelevant information from both external and internal sources (541, 547, 548). As such, concerns about how MMT might affect adolescents' brain development and cognitive functioning have been raised (491).

The effects of excessive digital technology use and MMT also correspond to structural and functional neuroanatomical changes. For example, a neuroimaging study of healthy college students showed that higher MMT scores were associated with decreased grey matter in the anterior cingulate cortex (549), a brain region responsible for emotional processing and regulation, and impulse, attentional, and cognitive control (363, 491, 509, 534). Emerging evidence suggests that contemporary digital technologies may induce these neurocognitive changes (363). For example, in a recent experimental study, gaming-naïve individuals were randomized to 6 weeks of daily "World of Warcraft" playing (an online, fantastical, role-playing game) or to a non-gaming condition (550). After six weeks, gaming participants experienced significant reductions in grey matter in the orbitofrontal cortex, which is involved in impulse control and decision making (550). Importantly, these neuroanatomical changes were observed following gaming conditions which arguably were not extreme (16.5 hours of gaming per week on average). It is not clear whether these neuroanatomical effects can be reversed by removal of exposure to gaming conditions or screen-based technologies. More research exploring the role of brain plasticity in these structural neuroanatomical changes is required.

5.3.4 From Cognition to Emotion: Media and Mental Health

The preponderance of recent research investigating consequences of high digital technology use has focussed on cognition, especially attention, memory and social cognition (363). This is the literature we have addressed above. However, it is the extension of this research to consider connections between cognition and emotion that is key to understanding possible mental health impacts for adolescents.

There is no doubt that media habits are a *consequence* of poor mental health in some adults (and likely some adolescents), who find digital technology a form of solace; this is an accepted casual sequence (e.g. (551)). However, a shift in focus to adolescents, combined with a developmental perspective, also invites consideration of alternative sequencing of the relationship and a different emphasis. This framing positions all adolescents as vulnerable to some degree; limitations in self-regulation abilities are present from the outset due to neurobiological immaturity and digital technology use can impede relevant skill acquisition and strengthening.

Consideration of self-regulation illuminates ways in which excessive technology use and MMT may undermine mental health. In essence, while spending large amounts of time on digital devices, and building skills such as MMT, adolescents are *not* strengthening skills in voluntary and effortful cognitive processes, such as sustained attention. This, and related cognitive skills, are required to manage emotions and counter the maladaptive thinking patterns which feature in anxiety and depression disorders. As described previously, in general, this may be achieved through (a) disengaging and redirecting attention away from threat stimuli and negative thoughts, (b) establishing greater capacity to cognitively reappraise thoughts and feelings, and (c) changing the emotional significance of a situation and reducing ruminative and catastrophising thinking patterns (12, 15, 16, 364, 494, 499, 502, 503). These strategies are demanding, requiring high levels of attentional control, and it is normal for adolescents to struggle with this somewhat, because the skills are acquired with age and through practice (491, 543, 552). However, the omnipresence of digital technologies would appear to add another dimension of complexity.

The added difficulty arises because adolescents who engage in high levels of technology use and MMT can become accustomed to task switching (*continuous partial attention)*, which consequently undermines their ability to apply necessary self-regulatory strategies in concertedly shifting attention away from perceptions of threat or negative thoughts, and engage *sustained attention* on active cognitive reappraisal (491, 534, 543, 552). With excessive screen time, attentional control may ultimately be outsourced to the media content provided by contemporary technologies (534, 553), habituating the mind to rely on external stimuli and consequently making internal stimuli, such as rumination and catastrophising, difficult to cope with (534, 547, 553). As a result, greater effort or attentional top-down control is needed to counter maladaptive thinking patterns and accomplish self-regulation (491). Diamond (495) and others (e.g., (554, 555)) argue that self-regulatory skills become second nature (or less effortful) through repeated practice and highlight that, with time and mastery, top-down control is used very little if at all as performance can be transferred from prefrontal to subcortical regions of the brain where performance is far more efficient (due to greater evolutionary tuning to perfect their functioning). However, evidence shows that individuals who engage in high technology use and MMT are less likely to engage top-down cognitive processing to improve their cognitive performance (547), which we argue may have implications for mastery of self-regulation.

Deficiencies in self-regulatory abilities are a theme in older literature about problematic Internet use. Individuals were understood to turn to online activities when experiencing loneliness, low mood or social anxiety, but their psychological problems meant they were unable to constrain the time spent in this way (e.g., (556-558). From this older line of research, there is evidence (from samples mostly comprising college students and adults) suggesting that problematic Internet use is a marker of deficient self-regulatory abilities (559). From this perspective, the focus is on the specific vulnerabilities of a small number of users that make it hard for them to moderate their use of digital technologies (551).

A focus on self-regulation also enables research on digital technologies and cognition to be united with research on digital technologies and sleep. Sleep is important for cognitive functioning and mental health in adolescence (560). Recent systematic reviews indicate that adolescents who get less sleep exhibit poorer information processing speed, memory encoding, working memory, and sustained attention (492, 561). Adolescents' cognitive performance is disproportionately affected by reduced sleep, relative to adults. For example, in a study involving one night of sleep deprivation, adolescents were found to have four times as many lapses in sustained attention the next day compared with adults under similar conditions (561-563). The ongoing maturation of sleep physiology and key neural systems (such as the prefrontal cortex) throughout adolescence are likely to interact with poor sleep to produce suboptimal cognitive performance (492). In the literature considering digital technology, sleep, and mental health, the correlations are clear (564) but the explanations have often been generic. However, research supports a pathway involving deficient self-regulation which is becoming more widely recognized (565-567). This provides some constructive avenues for intervention, beyond simply encouraging better sleep patterns, as we explain presently.

5.3.5 Media and Magnified Emotions

Adolescents typically process stimuli and incoming information in a more emotional manner than adults (361). This is thought to be a result of early maturation of sub-cortical brain structures which make up the affective (or emotional) system, superseding development of pre-frontal cortex brain regions which make up the cognitive (or logical / rational / reasoning) system, and are among the last areas of the brain to reach maturation (181, 361). As outlined above, high use of digital technology is likely to compromise the nascent ability to practice cognitive control over emotions. Not only that, digital technologies can be a source of frequent and intense emotional experiences.

Social media platforms provide adolescents with constant access to social stimuli such as photographs and messages. Neuroimaging studies have demonstrated that, when looking at social stimuli, brain regions implicated in emotional responding are activated for adolescents, and they can experience difficulty in switching from an emotional to a non-emotional assessment (365). Compared to children and adults, adolescents appear to be particularly affected by emotional faces, showing peak neural responsivity in the affective system when viewing them (510). The emotional content of messages shared on social media platforms can also influence the mood of the recipients, a phenomenon known as emotional contagion (544, 568). Constant emotional processing of their networks' social media content may be particularly demanding for adolescents, in view of the demands of managing others' emotions in addition to one's own, while lacking the full capacity to exert cognitive control over emotions (448).

Outside of social media, adolescents appear to be guided by their emotions in how they process news stories in the media (510, 569), which can lead to experiences of heightened or disproportionate threat perceptions. Adaptive emotion regulation strategies, such as threat reappraisal, rely on the use of the prefrontal cortex which is still developing in adolescence (510, 570, 571). Heightened emotional sensitivity, in the absence of fully developed cognitive control, may make early adolescents especially reactive to sensationalist media and contribute to blurring of fact and fiction (510, 569). Instant emotional responses may override individual opinion formation and critical thinking, meaning adolescents may accept that what they are presented with is their reality (510, 569). A constant influx of bad news stories, particularly with emotion-arousing "click-bait" titles, may lead to a learned helplessness and feeling of global "doom and gloom" among young adolescents, which can be a predecessor to experiencing depressive symptoms (572).

Contemporary cohorts of adolescents are historically the most exposed to global issues, via social media (573). In qualitative research, teens have described the news as "depressing" and "conflict-ridden" (573). Many of the issues which intrude into the lives of adolescents present genuine threats and probably warrant an emotional response, especially in view of repeated reporting that those with responsibility and power are failing to act. For example, contemporary adolescents express significant concern over environmental issues like climate change, pollution, and biodiversity loss, which have been promoted through online youth movements like the “School Strike for Climate” (574). These concerns are reflected in the emergence of new psychological phenomena that are uniquely related to feelings of distress around the state of the environment, such as eco-anxiety and eco-grief (574, 575).

Further complicating the emotional processing of constant social stimuli, adolescence is also arguably the first time that individuals experience co-occurring emotions. Unlike children, adolescents begin to understand that life is not exclusively good or bad, black or white, but rather it can be messy and contradictory (576). With little experience in conceptualising and managing co-occurring emotions, adolescents have low emotion differentiation abilities (576). Development of emotion differentiation abilities is non-linear and U-shaped across the lifespan, decreasing from childhood to adolescence as individuals begin moving away from experiencing emotions as mutually exclusive, and increasing from adolescence to adulthood as individuals gain greater experience in being able to identify emotions they co-experience (576). Low emotion differentiation ability, alongside greater co-experienced emotions, can contribute to an inability to select optimal strategies for regulating emotions, and may partially explain the common emergence of mental illnesses at this stage of life (576). It is clear to see how this can be exacerbated by the content provided by digital technologies.

5.4 Context of wider systems factors

5.4.1 The Changing Landscape of Adolescent Socialisation

Developmentally, peers become increasingly important to young adolescents as they seek autonomy from the family. Therefore, major changes in how adolescents socially interact (122) would seem to entail psychological consequences. Contemporary digital technologies, particularly smart phones in conjunction with social media, have significantly changed the nature of human socialisation since their introduction (577). Between 2002 and 2010, declines in face-to-face contact and increases in technology-enabled contact were observed in Australia (578), matching anecdotal reports in many other settings.

Social media use without real-world social connection and friendships may contribute to greater feelings of loneliness for 21st century adolescents (118). Loneliness is associated with increased risk of depression and anxiety for adolescents (579, 580). When in-person socialisation does occur, social media may unintentionally decrease the quality of these social interactions (532, 544). Naturalistic studies have demonstrated that when smartphones were present in social settings, such as over a meal in a café, individuals experienced greater distraction, which reduced their level of enjoyment of the company of friends and family (581). Similarly, during face-to-face interactions on campus, college students reported poorer affect in episodes where smartphones were present; they felt less socially connected and experienced less interest and enjoyment in social interactions (581). The negative experiences were not a result of opportunity costs (e.g. smartphones being used when individuals were bored), but rather were mediated by distraction (581). This suggests that smartphones can provide a constant co-presence of extended social networks which orients individuals away from their immediate social setting, interferes with the ability to engage fully in the present, and ultimately detracts from fulfilling in-person socialisation (581).

A fear of missing out, coined FOMO, is regularly posited as one of the causes of many individuals' perpetual need for contact with wider social media networks (544). Reporting the highest levels of FOMO, younger people also report checking in on their social networks more often than older generations (548). FOMO has been found to predict burnout, anxiety, and depression (544, 548). The pathway may involve communication overload and social media fatigue which are experienced by individuals of all ages, but are greatest among young people (544). For example, a study of high-paced families found that young adolescents with greater phone use, general media exposure, and larger Facebook networks, had poorer stress profiles, as measured by physiological markers (544). Specifically, young adolescents with higher technology use the preceding day experienced diminished or lower cortisol awakening responses the next morning, when compared to adults in the family (544). This is especially significant for young adolescents, for whom the neurological structures associated with the stress response, such as the hypothalamic-pituitary-adrenal axis, are still developing and are vulnerable to insult (122). Experiences of recurring daily stress as a result of a perceived need to sustain social relationships beyond a size that is maintainable, as well as experiencing ongoing access to others' personal information and emotions, may ultimately dysregulate adolescents' stress responses, making them more sensitive to, and less able to cope with, stress and challenges (544).

Social media arguably plays an important role in perpetuating "cultural fraud", which refers to the constant promotion of images and ideals of a "good life" that people should aspire to (70, 582-585). Photographs on social media can broadcast images of unrealistic (edited) physical beauty, material possessions, lavish locations, and showcase extraordinary achievements. This may offer adolescents the opportunity for constant social comparison and can lead to poor body image and lower general self-esteem when there are discrepancies between these publicised ideals and the self (90, 93, 107, 253, 279, 363). For many adolescents, the life being promoted is unattainable. Instead of creating a feeling of belonging, or speaking to other values that young people may have, cultural fraud can be alienating since such a life is not within reach in the absence of financial autonomy or for of those facing a precarious financial future. This "good life" is a fantasy grounded in a consumerism model and serves the economy, without meeting the psychological needs of young people or reflecting realities of socioeconomic inequalities (585).

In addition, social media can encourage young people to endlessly compare themselves to their peers with respect to other experiences and abilities (90, 279). At times, social media can be referred to as a "highlight reel", whereby users disproportionately represent positive aspects of their life but not their imperfections (586). The content adolescents post and view is often more "comparable" than "relatable", which may exacerbate distress around imperfections in one's own life or reduce life satisfaction by seeing peers seemingly enjoy a life with no stress or struggles (587). Furthermore, while real-world social accomplishment and acceptance has historically been open to interpretation, social media objectively quantifies social success of 21st century adolescents, through numbers of 'followers' and 'likes' attained by users across different platforms (363). This kind of social comparison will inevitably impact adolescents to varying degrees and may depend on pre-existing vulnerabilities and inequities (465).

Young people are particularly susceptible to peer influence and feel a strong need to follow social norms to show in-group adherence (90, 510). This peer influence can affect adolescents' decision-making and is implicated with increased risk-taking (448, 510). Given the pervasiveness of social media for adolescents, one may question whether they are ever really 'away' from their peers, and what effect the omnipresence of peers, albeit virtually, may have on adolescents. Susceptibility to heightened risk-taking by adolescents in the presence of their peers offline seems to hold in online environments as well, one example being the sharing of sexually explicit material (510). Rejection, exclusion, and bullying are also extended beyond traditional confines of the schoolyard, with cyberbullying well documented (90, 93). A recent systematic review and meta-analysis by Nesi and colleagues (588) reported that cybervictimisation was associated with suicidal and self-injurious thoughts and behaviours, with medium to large pooled effect sizes which were stronger for adolescents than adults.

The way in which social media has transformed the landscape of adolescent socialisation has recently been summarised by Nesi, Choukas-Bradley, and Prinstein (589), touching on many of the points raised above. They created a “transformational framework” which argues that social media has transformed dyadic adolescent peer relationships in five key ways. First, *by changing the frequency or immediacy of experiences*, meaning there is now potential for immediate support from friends through social media, but also increased reassurance-seeking, negative feedback-seeking, and co-rumination in friendships. Second, by *amplifying experiences and demands*, meaning there are increased expectations for relationship maintenance and accessibility. Third, by *altering the qualitative nature of interactions*, such that social support may be less rich, adolescents may experience increased comfort in interactions, and there are likely changes in conflict and interpretation bias. Fourth, by *facilitating new opportunities for compensatory behaviours*, including online exclusive friendships and connection with geographically distant friends, and, finally, by *creating entirely novel behaviours* such as the categorisation of “top friends” and public relationship displays. The authors also suggest that these five transformed peer experiences operate through group-level peer relations, and link with issues around peer victimisation, peer status, and peer influence (590).

5.4.2 Evolution and Overconsumption

Various strands of research in psychology (such as material engagement theory (591)), anthropology, technology and cultural studies consider how historical artefacts and innovations have changed the way we think, socialise, and understand what it means to be human (e.g. (592-594)). The development of mathematics and forms of written communication, for example, arguably changed cognitive abilities, social relations, and culture. Precursors of instant messaging include the telegraph, the semaphore flag system, and smoke signals, each requiring different symbolic logic, lore, and infrastructure. So, it is not surprising that digital technologies are reshaping cognition (595). Some authors are enthused by the opportunities this affords, for example, through the ‘extended mind’ (e.g., (596, 597)). We point out that previous technological developments that appear to have shaped profound changes, from the level of synapses to societies, did so on very different time scales with very different patterns of diffusion (as with various adolescent leisure activities historically).

The difficulty many people, not just adolescents, face in controlling their technology use may in part reflect an ancestral mismatch with the ecology of our evolutionary past (598, 599). Digital technologies appear to be exploiting brain structures and functions that evolved slowly in an environment without them (600). This evolutionary perspective resonates with explanations for the obesity epidemic in contemporary society (599-602). The argument is that humans have evolved to consume and store more food than is required to meet their immediate nutritional needs, when given the opportunity to do so, because most of human evolution has occurred in a nutritional environment characterised by sporadic feasting amidst food scarcity, uncertainty, and threat of famine (601, 602). While this behaviour was adaptive in our ancestral environment, it is maladaptive in high-income countries in the 21st century, where high-caloric foods are readily available and excessive consumption can lead to poor long-term health outcomes (601). While our “rational brain” (e.g., prefrontal cortex) may understand that resisting the temptation to eat a high-calorie take-out meal is beneficial for our long-term health, it is not so simple to enact this level of self-control given our disparate evolutionary past (598, 599, 601). Rapid change in the potential for overconsumption and the lack of strong satiety signals (599, 602) are features that obesity has in common with excessive use of digital technology. While we may understand that getting a good night’s sleep is important for our well-being, we may struggle to put down our smartphones at night in the absence of developed evolutionary experience to do so.

As Wells (603) has elaborated, products such as tobacco, coffee and sugar are the epitome of corporate commodities, since they are either overtly addictive or produce other pleasurable responses. Digital technologies have now ‘broken through the ceiling of physical consumption’ (p 338) realizing ‘the merchant’s dream’ of ‘unsatisfiable needs’ (p 326). It appears as though this overconsumption of digital technologies has been recognised by some adolescents, with a growing movement towards trying to be “unplugged”. In a recent survey of U.S. teens, over half of the respondents reported that they have tried to cut back the amount of time they spend in front of screens (452).

5.4.3 Bearing the Benefits in Mind

Digital technologies have become a necessary part of life for contemporary adolescents. With almost half of all jobs in the U.S. considered at high likelihood of computerisation in the near future (371), these technologies are here to stay and it is important that young people are tech-literate. There is also evidence that digital technologies can be beneficial for young people for a range of reasons (604). We summarise these below to underscore that we are not inciting the moral panic that often surrounds teens (466), nor are we opposed to digital technologies, rather we advocate for use in moderation to ensure adolescents have time for other opportunities which support experience-dependent maturation of self-regulation capabilities.

When social media is used to enhance existing relationships it can support social well-being and curb loneliness (605). For example, one study of more than 1,000 Canadian adolescents reported that greater use of instant messaging platforms over the course of a year was positively associated with romantic relationship and best friendship quality (606). This is because social media is thought to strengthen existing relationships through increased opportunity for self-disclosure of intimate information, with associated emotional support enhancing connections (607-609). Adolescents have referred to online peer forums as “supportive environments” for both promotion of mental health (610) and emotional support (611). Beyond self-disclosure of intimate information, sharing positive or entertaining updates on social media has also been reported to increase feelings of connectedness for young people (612). Further, social media may also help adolescents gain confidence in initiating new real-world friendships by allowing them to practice social skills with more diverse communication partners online (613).

Social media has also been found to be beneficial for safe identity exploration (178), allowing teens to develop their own interests and expertise in a private space (614). This is particularly important for minority groups, such as LGBTQ+ adolescents, who report turning to “safe spaces” online to seek acceptance from like-minded teens and role models (in the absence of representation in their real-world experiences) (178, 615). The Internet provides sexually and gender-diverse adolescents with opportunities to practise different aspects of their identities and align their inner selves with external self-presentation (615, 616). Research of over 5,000 American teens reported that LGBTQ+ adolescents were more likely than non-LGBTQ+ adolescents to find romantic partners online, once again highlighting the importance of social media for this group (617).

The importance of digital technologies for adolescents is particularly pertinent in the context of the COVID-19 pandemic. The enforced lockdowns and ongoing physical distancing to curb the pandemic has limited social connections, with feelings of loneliness increasing among young people (618). Given adolescence is a developmental period in which young people are biologically and psychologically driven to increase social affiliation with peers, forced isolation with families and social disconnection from peers presents a developmental mismatch which may disrupt normative adolescent development and is likely to have pronounced effects on adolescents' mental health (619, 620). Digital technologies may be used as a constructive coping strategy for adolescents to remain socially connected while they are physically distant from their peers during the COVID-19 pandemic (618, 619).

5.4.4 A Public Health Issue with Opportunities for Intervention

Adolescent development is a complex topic which is not fully understood, necessitating continued inquiry. Similarly, understandings of the psychological effects of contemporary digital technologies are continually expanding and changing alongside rapid technological developments. Historically, investigation of the psychological impacts of screen time on adolescents focussed on television watching, then video gaming, and we are only just beginning to pay attention to portable technologies like smartphones (151).

While it is understandable why other authors (e.g. (621) suggest that better data around screen time exposures is needed to make more concrete claims about psychological impacts, as previously stated we argue in line with the precautionary principle, that taking action on this public health issue cannot wait until this is achieved. Not only is screen time a unique exposure, but as highlighted by others (622, 623) it is the single activity which dominates our waking hours. It is this pervasiveness and volume of use that mean any potential influences should not be trivialised.

Many societies have reached consensus that, due to the risks presented, young adolescents should not have access to cigarettes and alcohol. Use of digital technologies is different, and perhaps has more in common with learning to driving a motor vehicle, in terms of the mix of benefits and harms. Driving provides independence and status to teenagers, but is a complex task. Adolescents are at an elevated risk of involvement in road traffic crashes due to their lack of experience, and thus lack of skills, as well as tendencies to over-estimate their abilities, take risks, and be influenced by their peers. The adolescent road toll has been reduced through a series of public health measures, notably graduated licensing. Under such a licensing regimen, driving is initially supervised and there are restrictions on the circumstances under which driving is permitted that are progressively lifted, including curfews and passenger numbers (624). The emotional and cognitive limitations of adolescence are recognized as underlying considerations that justify robust intervention (625). Of interest in the present context, enforced laws about distracted driving, in which hand-held devices like smartphones are banned, have recently to be shown to have benefits for teenage drivers (626).

Given the cognitive and emotional limitations of adolescence also apply in the case of digital technology use, it is arguably time to think about restrictions on screen time. But, unlike driving, use of digital technologies is not a public activity amenable to regulation, and imposing restrictions is not the same as encouraging adolescents to develop internalised reasons for controlling their digital technology use (475). This situation calls for a need for young people to reduce screen time themselves, however, the onus to achieve this should not be placed on young people alone, especially not in the absence of appropriate supports across social and educational landscapes. Equally important is the need to identify strategies and activities to strengthen self-regulation, which could be implemented in a variety of settings including the home, school, and during further education and training opportunities. While it is beyond the scope of this paper to comprehensively discuss strategies and activities to strengthen self-regulation in young people, we briefly outline some general approaches below.

Like a muscle, self-regulation can be strengthened and depleted (484). Interventions may be used to strengthen adolescents' self-regulation capabilities and counteract the lack of exertion and depletion experienced through excessive digital technology use and MMT. Many studies have shown that practising arbitrary exercises of self-control can lead to observed improvement on unrelated tasks which also require self-regulation (484). For example, in a study by Finkel and colleagues (627), following 2 weeks of using one's non-dominant hand to open doors (motor control) or avoiding abbreviations and cursing (verbal control), there was a reduction in the likelihood that individuals would respond with aggression to provocative behaviour by partners. Simple tasks like this to improve self-regulation may easily be implemented in the school or home environment, perhaps made into a fun self-challenge.

To achieve wider transference of self-regulation training, Diamond (495) argues that programs or interventions should follow a few simple principles. First, instead of activities which narrowly focus on one aspect of EF (e.g., through a computerised task), activities should address EFs more globally by involving a *combination* of EFs like task switching, inhibition, and working memory. Second, the EF demands of an activity must continually incrementally increase, otherwise notable improvements will not be seen. Finally, repeated practice of EFs is key for improving self-regulation and mental health.

Traditional martial arts and formal dance training are examples of activities which address each of these principles (495). Both activities involve EFs more globally; switching between sets of moves or choreography, controlling one's body and being aware of others in the space, as well as remembering and updating instructions as they are given. Over time, martial artists graduate to new belt colours and dancers move up through levels or grades, which incrementally increases the difficulty of the required activities. Both martial arts and dance require repeated practice to improve, maintain, and master skills.

Research has demonstrated the self-regulation benefits of both martial arts and dance for children and adolescents. For example, after a 3-month school-based martial arts intervention, Lakes and Hoyt (628) found that students randomised into a martial arts group demonstrated greater improvements in areas of cognitive and affective self-regulation than students in a control group. Similarly, after a 1-month school-based dance intervention, Anderson (629) reported improvements in student attention and self-regulation.

Beyond martial arts and dance, there is a significant literature around how activities which target EFs more globally can improve self-regulation in young people. For example, a recent systematic review and meta-analysis of universal self-regulation-based interventions found that a wide range of intervention types, including mindfulness and yoga, were successful in improving self-regulation in children and adolescents (630). Importantly, these improvements have also been reported to translate to improvements in distal academic, health, and behavioural outcomes, highlighting the wider well-being benefits of self-regulation practice (630).

In addition to improving self-regulation more broadly, understanding important features of contemporary digital technologies can also help young people to gain greater agency and reduce their vulnerability to poor mental health in a high-tech era. This includes knowledge about the addictive properties of social media and gaming, as well as algorithm bias, consumerist models underpinning promoted ideals, and the “highlight reel” nature of social media platforms (631). Indeed, experimental research with middle-school adolescents by

Galla and colleagues (475) found that leveraging adolescents' drives for *autonomy* and *social justice* is an important way to motivate self-regulation of social media use. Specifically, the authors developed a values-alignment education approach, which taught adolescents about the addictive designs of social media platforms (thus jeopardising their autonomy), as well as emphasising the social justice implications of these companies financially profiting from technologies which are engineered to be hard to resist. This values-alignment approach led to greater internalised reasons and motivation for adolescents to self-control their social media use when compared to those who received no education or traditional educational which highlighted the benefits of avoiding social media.

Research has also shown that having high media literacy can mitigate negative associations between social media use and body image for young teenage girls, as it can help them to appreciate the ideals disseminated online and maintain their confidence in the face of real-world differences (632). Other research has also shown that spending even just one day "unplugged" from all media can help young people become more cognizant of their media use and teach them to be more mindful of their media consumption patterns (633).

Supportive school environments and positive parental influences play an essential role in nurturing adolescents' media literacy (632). The work by Galla and colleagues provides some guidance for effective education and school-based interventions to support adolescents to control their screen time. In addition, the documentary 'The Social Dilemma', which explores the aforementioned features of social media platforms from the perspective of the original developers, is an example of a media literacy resource which may be useful for introducing concepts and facilitating conversations with students in schools and at home (634). To date, family-based interventions have mostly focussed on young preschool children and parental monitoring of technology use, with the aim of reducing sedentary behaviour and preventing obesity (635, 636). There is currently a need for more novel family-based interventions which focus on adolescent screen time and mental health.

5.5 Conclusion

Adolescence is a period of profound biological, neurological, psychological, and social developments which are shaped by context, culture, and environment, making it a period teeming with both risks and opportunities for lifelong well-being. The refinement of higher order cognitive processes involved in self-regulation is central to normative adolescent development, increasing young peoples' ability to consciously regulate their cognitions, emotions, and behaviour.

While the majority of previous research has focussed exclusively on either cognitive or mental health outcomes related to screen time, we have integrated this literature using a developmental lens, to understand the impacts of excessive technology use for adolescents. Features embedded in contemporary digital technologies can exploit the immature, yet fast developing, neuroanatomy associated with self-regulation, and important cognitive processes may be exhausted or hindered by high technology use. Given aspects of self-regulation are important for preventing or managing internalizing symptoms, this could ultimately undermine mental health of adolescents. Adolescence is a critical period which can determine the trajectory of any individuals' mental health across the lifespan; as such, it is important to identify risk factors that can be addressed to *prevent* mental illness during this developmental phase, rather than focus on allocation of funds to *treat* mental illness once it has already developed.

Despite the imperfect evidence available, following the precautionary principle, we need to consider robustly supporting young people in reducing their screen time to hopefully decrease their vulnerability to poor mental health. Encouraging young people to engage in diverse activities which strengthen self-regulation is one important aspect of this, which could be supported in a variety of settings. Media literacy should also be considered a central part of health literacy for young people.

CHAPTER SIX: PAPER 4 – RANDOMISED PRE-POST PILOT STUDY (MANUSCRIPT FORM)

Buffering "screen time" with "green time" in adolescence: A randomised pre-post pilot study exploring the acute psychological effects of screen-based technologies and the restorative potential of nature immersion

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Overall percentage (%)	80%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	19/01/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. The candidate’s stated contribution to the publication is accurate (as detailed above);
ii. Permission is granted for the candidate to include the publication in the thesis; and
iii. The sum of all co-author contributions is equal to 100% less the candidate’s stated contribution

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Contribution to the Paper	Supervised development of work including conceptualisation of the research questions and study design, provided guidance on randomisation methods, provided access to statistical support, contributed to manuscript evaluation and editing.		
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6.0 Abstract

Increases in time spent engaging with screen-based technologies ("screen time") and decreases in time spent in natural environments ("green time") are regularly argued to contribute to the observed increase in mental illness among contemporary adolescents. Excessive screen time can deplete the cognitive resources required for effective emotion regulation, such as sustained attention and inhibitory control, which cumulatively increases the risk of internalising problems. Contrastingly, time spent in natural environments encourages attention restoration and stress reduction. Therefore, green time may be important for buffering the psychological consequences of screen time. A randomised pre-post pilot study was undertaken to investigate the acute psychological effects of screen time in adolescents, and to explore the restorative potential of nature immersion. Eighty-seven adolescents (52% female, mean age = 15.5 years) participated in the study. Participants completed measures of mood, sustained attention capacity (Sustained Attention to Response Task), and inhibitory control (Stop-Signal Task) at three time-points: (1) at baseline, (2) after a period of screen time, and (3) after a period of rest. Participants were randomised to either an indoor setting or an outdoor environment (Botanic Gardens) for the rest period. Linear mixed modelling was used to examine the effect of time and resting condition on the outcome variables, with sex and age included as fixed effects. There were no statistically significant changes from baseline in mood ($F(1) = 1.11$, $p = 0.29$), sustained attention capacity ($F(1) = 0.20$, $p = 0.65$), or inhibitory control ($F(1) = 3.37$, $p = 0.07$) following the screen time period. This meant that the second aspect of the study, around the restoration potential of nature immersion, could not be adequately tested. Important conceptual and methodological lessons were learned through this study, particularly around potentially useful screen time activities for experimental studies and meaningful emotion regulation measures which are more applicable to real-world scenarios, which should be addressed with further empirical studies.

6.1 Introduction

Mental illness is increasing among adolescents, with depression and anxiety being leading causes of disability among young people worldwide (19, 34). Given adolescence is a critical developmental period which can determine an individuals' mental health trajectory across the lifespan (9, 27, 29, 30, 170), there is a pressing need to prevent mental illness and promote mental well-being by identifying and addressing risk and protective factors. While many determinants of youth mental health exist, two trends characterise contemporary adolescence as markedly different from previous generations, and are regularly argued to contribute to the observed increase in mental illness (128, 173, 175). These are increases in time spent engaging with screen-based technologies ("screen time") and decreases in time spent in natural environments ("green time") (151).

Contemporary technologies, such as smart phones, social media, and videogames, are a pervasive feature of adolescent life, with new generations being dubbed "digital natives" (450). The average total screen time for young people in the U.S. has been reported at 7.5 hours a day (451, 637), and 30% of the time young people use screen-based technologies they report use across multiple devices (122). A considerable body of research has shown that high levels of screen time are associated with poorer psychological outcomes for young people (151). Longitudinal research in the U.S. has shown that increases in digital technology use have been associated with increases in depressive symptoms and suicidal thoughts (311), and decreases in self-esteem, life satisfaction, and happiness (312), across successive cohorts of adolescents. In another notable study, European adolescents who were characterised as high tech-users were considered an "invisible" risk group for mental health concerns as they were comparable to high-risk adolescents who smoked and consumed drugs/alcohol for prevalence of depression, anxiety, and suicidal thoughts (638).

The majority of available evidence around screen time and psychological well-being focuses on the “displacement hypothesis”, with explanations that screen time displaces behaviours which are protective for mental health, including sleep (114, 115), physical activity (116, 117), and in-person social interactions (118). Beyond this, screen time also appears to fatigue important cognitive resources, such as attention capacity and inhibition control, through constant top-down processing of digital content in the brain (542-544). Experimental studies have shown that the mere presence of smartphones (532), receiving WhatsApp messages (538), watching 10-minutes of fast-paced television (539), or doing just 15-minutes of online shopping (542) can impair attention and inhibition. However, experimental evidence, particularly in adolescents, is still sparse (151).

While this depletion of cognitive resources may be acute or short-term, it is likely to occur at high frequencies given adolescents are a group of high-tech users (363, 490). This impairment is problematic because attention capacity and inhibition control are central processes in emotion regulation, a competency which is extended and refined in adolescence (505). Emotion regulation requires disengagement and redirection of attention away from threat stimuli and negative thoughts, which enables greater capacity to cognitively reappraise both thoughts and feelings and change the emotional significance of a situation (12, 364, 502, 503). Effective emotion regulation ultimately minimises vulnerability to anxiety and depression through reducing ruminative and catastrophising thinking patterns (364, 499). Repeated acute depletion of the cognitive resources involved in emotion regulation may impede adolescents’ ability to effectively practice regulating their emotions and thus cumulatively increase the risk of internalising problems.

Technology can be beneficial for young people for a variety of social and academic reasons (604-606, 611, 612, 615, 617), but there is arguably a need to determine how adolescent well-being may be balanced around screen time. While cognitive resources are replenished overnight through sleep (544), in a high-tech era it is valuable to explore more immediate restorative options which could be drawn upon throughout the day. We propose that nature immersion, or “green time”, may be used as an activity to balance adolescent well-being. Specifically, we suggest that green time may restore cognitive resources and boost affect (mood) more adeptly than other “down-time” activities. The rationale is that fatigued top-down cognitive processes can be restored in natural environments with activity being reduced in the prefrontal cortex as a legacy of our evolutionary biology (146, 186).

Prior to technological advancements, human evolution occurred slowly, and in the context of natural environments, for millions of years (147). Our new technological way of life represents a major deviation from the social and ecological environment in which we evolved to function best (153, 639). Research has consistently shown that high levels of green time are associated with favourable psychological outcomes for young people, including reduced symptoms of mental illness, alongside greater mental well-being, cognitive functioning, and academic achievement (151). Green time supports behaviours that protect mental health, including sleep, physical activity, and in-person social interactions (151). But beyond the role of these lifestyle factors, two theories within the environmental psychology literature, Attention Restoration Theory (ART) (146) and Stress Reduction Theory (SRT) (147), account for the psychological restorative potential of nature (132). Both draw on theory of evolution (132), however, the theories differ in their claims about the mechanisms behind the beneficial effects of nature, with ART focussing on cognitive processes and SRT concentrating on autonomic processes.

Kaplan’s (146) Attention Restoration Theory is a cognitive framework which suggests that nature has specific restorative effects, leading to improved cognitive functioning (192). Constant directed attention to tasks in our environment, such as multi-tasking with technologies, requires the engagement of top-down cognitive processes, which can lead to attention fatigue. ART postulates that when direct attention mechanisms are fatigued, they can be restored in natural environments because they are inherently fascinating to humans, and thus employ involuntary attention, which is not tiring or effortful. Involuntary attention allows direct attention mechanisms to rest and be restored with attention being captured in a bottom-up fashion by features of the environment itself (186, 640). From an evolutionary perspective, being interested in the natural environment has historically been vital for the survival of human beings and for this reason is argued to be intrinsically fascinating (146, 641). Therefore, according to ART, spending time in nature can improve cognitive functioning by restoring attention abilities, enabling individuals to consequently perform better on tasks that depend on attention (such as emotion regulation).

Ulrich's (147) Stress Reduction Theory suggests that nature induces positive affect through reduced stress. Like ART, SRT emerged from psycho-evolutionary theory, which contends that humans may be psychologically and physiologically adapted to natural, as opposed to urban environments, due to extensive human evolution in natural environments (26). SRT proposes that the brain may process natural content with relative ease due to the evolution of neurological and sensory systems in natural environments (147, 369). Given this evolutionary tuning is lacking for excessive exposure to modern technological environments, exposure to such surroundings may overload an individual, placing greater demands on processing resources and requiring greater coping efforts (147, 370). Modern humans may have a biologically prepared readiness to quickly and readily acquire restoration from stress in natural settings, but have limited preparedness for highly stimulating technological environments.

Few studies have considered the psychological impacts of screen time and green time together (151), but a study by Mutz and colleagues (353) showed that daily screen time was a moderator of adolescents' mental health changes following an outdoor adventure program.

Specifically, young people with typically high levels of screen time (>3 hours daily) reaped greater benefits from the outdoor adventure program than those with low-to-moderate (≤3 hours daily) screen use, as shown by greater increases on measures of life satisfaction post-program (353). Another study by Greenwood and Gatersleben (352) also considered the role of both screen time and green time for adolescents. Young people in the study completed a series of stressor tasks before being assigned to an outdoor or indoor environment for a period of rest, with either a friend or alone with a mobile phone. The study found that self-reported attentiveness decreased more rapidly when young people were playing on a mobile phone compared to being with a friend, but this only occurred for adolescents in the indoor environment. These findings suggest that being outdoors may *buffer* the psychological effects of playing on a mobile phone to some degree, but more research is needed to support this (352).

In this study, we test the proposition that green time may buffer the acute psychological impacts of screen time through a pre-post randomised pilot study. We hypothesised that (1) following a period of screen time, adolescents would experience acute decreases in mood, inhibition, and attention abilities, and (2) following a period of screen time, adolescents who participated in a period of green time would experience superior mood, inhibition, and attention restoration when compared to adolescents who participate in a rest period in an indoor environment.

6.2 Method

6.2.1 Participants and Design

The study was a randomised pre-post pilot study, which followed the Consolidated Standards of Reporting Trials Statement Social and Psychological Intervention trials (CONSORT-SPI) where relevant and appropriate (169). Eighty-seven adolescents (52% female) aged 14 to 18 years (M = 15.51 years, SD = 1.27), participated in the study. They were recruited from two Australian schools located in close proximity to one another. Participants were from Year 9 (typically 14 years old), or Year 11 and 12 classes (typically 16 and 17 years old, respectively), who participated in the research during their class time. The true meaning of the study was concealed to reduce the potential for selection and measurement bias. Instead, participants were informed that the aim of the research was to explore different activities and functions in the brain.

This study received ethical approval from the University of Adelaide Human Research Ethics Committee (approval number H-2020-262) (Appendix 14) and relevant school governance. Participants were provided with an information sheet about the study, were informed that participation was completely voluntary, and of their right to withdraw at any time. Signed consent to participate was provided by all students, and by parents where required by ethics, before the research commenced. Participants used pseudonyms during data collection to ensure complete anonymity. At the conclusion of the research, participants were debriefed and thanked for their time with a gift bag of snacks and stationary items (valued at approximately $10 AUD).

6.2.2 Measures

6.2.2.1 Baseline sociodemographic and lifestyle measures

Participants first completed a brief computer-based survey to gather information to enable characterisation of the groups in terms of factors relevant to adolescent well-being. They were asked to provide their gender, age, and residential postcode. Residential postcodes were used as a measure of area-level socioeconomic status and assigned into quintiles (1 = most disadvantaged, 5 = most advantaged) based on the Australian Bureau of Statistics (ABS) within state Socio-Economic Indexes for Areas Index of Relative Advantage and Disadvantage (427).

Participants were asked to indicate separately how much time they felt they spent on a phone, on social media, playing video games, watching TV, using streaming services (e.g., Netflix), or using a computer/laptop/iPad (not for schoolwork). Consistent with recent research (474), response options were *too little time, about the right amount of time, too much time*, or *I don't have or use this*. Using a set of brief instructions, participants were also asked to indicate their average daily screen time as reported by their smartphone.

To measure connectedness to nature, participants completed the 6-item Nature Connection Index (NCI) (642), a reliable and valid measure of connectedness to nature for young people (643). Respondents were asked to indicate the extent to which they agreed with 6 statements on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). Examples of statements include *"I always find beauty in nature"* or *"Spending time in nature is very important to me"*. Higher scores indicate a greater connection with nature. The measure had a Cronbach's alpha score of 0.89 in this study.

Participants were asked to indicate the number of different physical activities/sports they participated in from a provided list (available on request), as well as the number of days they typically participated in these activities during an average week. This approach to measuring physical activity was informed by the 7-day recall Physical Activity Questionnaire for Adolescents (644). Responses were summed to give each participant a total number of physical activities/sports and a total number of active days in an average week.

Participants' sleep quality was measured with the 10-item Adolescent Sleep-Wake Scale-revised (ASWS-R), a self-report measure of sleep quality for 12-to-18-year adolescents (645). Respondents were asked to indicate how often a range of sleep behaviours occurred during the past month on a 6-point Likert scale (1 = always, 6 = never) (646). Examples include *"In general, I try to "put off" or delay going to bed"* or *"In the morning, I wake up* *feeling rested and alert".* Final scores range from 1 to 6, with higher scores indicating better quality sleep. Items were reverse coded according to the methods used by Sommer and colleagues (647).The measure had a Cronbach's alpha score of 0.85 in this study.

To obtain an indication of baseline psychological distress, participants completed the Patient Health Questionnaire-4 (PHQ-4) (648). This 4-item measure yields a global measure of distress based on questions about anxiety and depression which the respondent has experienced over the past two weeks. Examples include "*Not being able to stop or control worrying*" or "*Feeling down, depressed, or hopeless*". Response options range from 0 (*Not at all*) to 3 (*Nearly every day*). Scores on the PHQ-4 range from 0 – 12 and categorise respondents as experiencing no (0 – 2), mild (3 – 5), moderate (6 – 8), or severe (9 – 12) psychological distress. The measure had a Cronbach's alpha score of 0.86 in this study.

6.2.2.2 Experimental measures

Experimental measures were administered at three time points during the research: at baseline (T0), after a screen time period (T1), and after a resting period (T2). The software *Psytoolkit* was used for data collection (649, 650).

6.2.2.3 Mood and Sleepiness

Participants' mood was assessed using a Visual Analogue Scale (VAS) in which they were asked to indicate their current mood at each of the time points on a scale from *1 (worst mood)* to *10 (best mood)*. Participants' level of sleepiness was also assessed using a VAS in which they were asked to indicate how sleepy they felt at each of the time points on a scale from *1 (Not sleepy at all)* to *10 (Extremely sleepy)*.

6.2.2.4 Sustained Attention Capacity

Sustained attention capacity was assessed with the Sustained Attention to Response Task (SART) (651, 652). The SART is a brief and conceptually simple task with no memory load or learning effects, but is very demanding (192). It is a continuous performance test which requires participants to monitor long sequences of stimuli and change their response when presented with infrequent targets (192). The SART has been found to correlate with outcomes on the Cognitive Failures Questionnaire, a measure of “slips” in daily life as a result of inattentiveness (192, 652, 653).

The SART took approximately five minutes to complete and was divided into two blocks, with performance feedback provided at the end of each block. The first was a practice block and the second was the real test block made up of 225 trials. Each trial involved the presentation of a white digit (ranging from 1 to 9) in the centre of the black screen for 250 milliseconds (ms), followed by a mask (a white circle with a cross inside) for 900ms. Participants are asked to press the spacebar on a standard keyboard every time a digit appeared, except for the digit “3”. The digit “3” is referred to as the target stimuli and appeared for 11% of the trials (25/225). Emphasis was placed on the importance of responding both quickly and accurately throughout the task. The task timing and stimulus sizes used followed the original Robertson study (651, 652); there were five different font sizes (48-point, 72-point, 94-point, 100-point, and 120-point) and the digits never repeated one another. In the training block, each digit was used two times, and in the real block each digit was used 25 times.

Six outcome measures were calculated from the SART. Each participant was given a Hit Rate (percentage of correct hits) and a Hit reaction time (RT) (average RT for correct hits). Participants were also given a Commission Error Rate (percentage of incorrect responses to the target stimuli) and a Commission Error RT (average RT for incorrect responses to the target stimuli). An Omission Error Rate (percentage of non-target trials in which the participant failed to respond) was calculated for each participant. Finally, a Total Error rate was calculated for each participant, combining both Commission and Omission errors, capturing overall sustained attention capacity.

6.2.2.5 Inhibitory Control

Inhibitory control was assessed with a form of a Go/No-Go Task called the Stop Signal Task (SST) (654, 655). The SST took approximately three minutes to complete and was divided into two blocks, with performance feedback provided at the end of each block. The first was a practice block and the second was the real test block including 40 trials. Each trial began with the presentation of a fixation cross inside a white circle in the centre of the screen. The fixation cross was then replaced with a green left- or right-pointing arrow. Participants were instructed to indicate whether the left- or right-pointing arrow appeared by pressing either the “b” or “n” keys on a standard keyboard, with an emphasis to respond to the arrows as quickly and accurately as possible. The arrow remained on the screen for 500ms or until the participant responded. If participants did not respond with the correct key within 500ms, an error message appeared.

For 25% of the trials (10/40), the white circle surrounding the arrow turned red after a variable delay (between 100ms and 450ms), following the arrow onset. This red circle is the “stop signal” and cued participants to inhibit their response; these trials are referred to as the no-go trials. In the no-go trials, participants who responded to the arrow after the red circle had appeared received an error message. Participants who responded to the arrow before the red circle appeared, but inhibited a response once the red circle had appeared, did not receive an error message.

Four outcome measures were calculated from the SST. Each participant was given a Correct Go Rate (percentage of hits on go trials) and a Go RT (average RT for hits on go trials). Participants were also given an Inhibition Rate (percentage of inhibited no-go trials) and a No-Go RT (average RT for incorrect responses on no-go trials).

6.2.3 Procedure

The research took place over five days between the 31st of May and the 30th of August 2021, with one school class group participating on each day (total of 5 school class groups). These school class groups are referred to as clusters from this point forward, and ranged in size from 7 to 23 students. The research was approximately 2 hours in duration (see Figure 6.1 for an overview of activities). Participants and their teachers met the researchers (TKO and SGEK) at the University of Adelaide to participate in the research and were escorted to a computer suite.

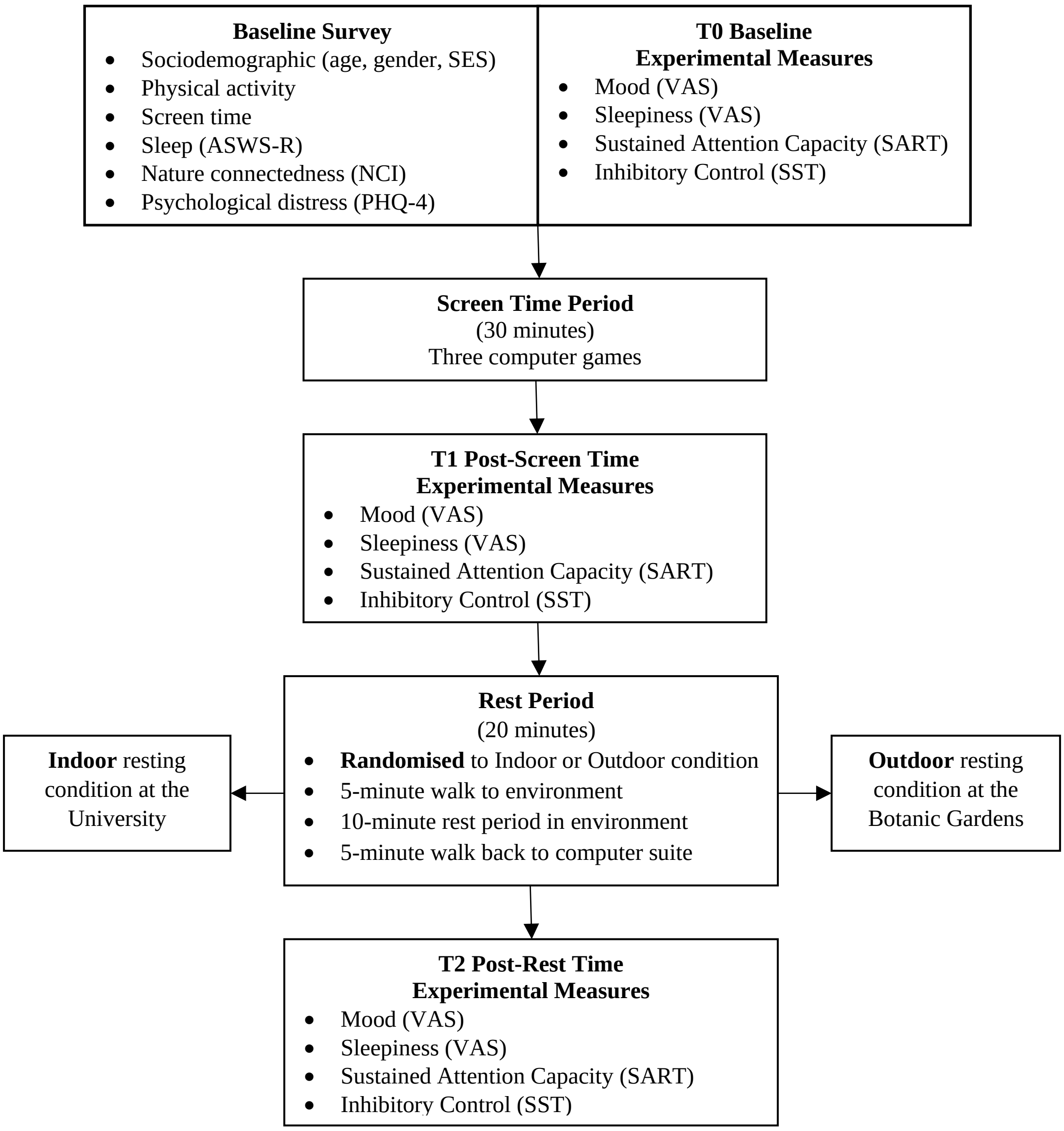

Figure 6.1 Overview of pilot study activities

Participants were asked to open the first web link on their computer to start the research. This involved completing the baseline survey (see section 6.2.2.1) and baseline experimental measures (T0) (see sections 6.2.2.2 – 6.2.2.5). This took 15 minutes to complete on average.

Next, participants were asked to open the first envelope on their desk; inside was a gaming score card. Participants were informed that they would be playing three computer games for 10 minutes each. The objective was to try and get the highest score possible in the 10-minute time limit and to record this on their gaming score cards. The first computer game required participants to continuously line up at least three candies of the same type in a row to create explosions and earn points. The second computer game involved using a sling shot to sling fish and knock over chickens in a series of obstacles. The third computer game involved rapidly slicing fruits as they appeared on the screen, while also avoiding random bombs. These three games were chosen because they do not require previous experience to be able to play and are popular among people of all ages and genders. Participants listened to the same playlist of music during this 30-minute screen time period, were permitted to use their smartphones, and typically spoke with one another.

Following the screen time period, participants were asked to open the second web link on the computer. This involved repeating the experimental measures (T1) (see sections 6.2.2.2 – 6.2.2.5). This took 10 minutes to complete on average.

A rest period then followed the T1 measures. Participants were asked to open the second envelope on their desk; inside was a piece of paper with either the letter “N” or “U”. The envelopes were prepared prior to the session using a computer-generated randomisation list that generated allocations for each of the five clusters. The envelopes were sealed and contents were not visible until they were opened. Half of the room in each cluster was randomised to an indoor resting environment (letter “U”), while the other half were randomised to an outdoor resting environment (letter “N”). Each cluster included students of the same sex and similar age, which assisted in overall stratification of the conditions by participant age and sex. Participants could not swap or alter the group they were allocated to.

Participants with the letter “N” were escorted to the Adelaide Botanic Gardens, while those with the letter “U” were escorted to an indoor teaching space in the University, for a 10-minute rest period. It took participants five minutes to walk from the computer suite to their respective randomised rest environments. The walk to the indoor resting environment was mostly built and urban, while the walk to the outdoor resting environment was mostly natural (see Figure 6.2). The indoor resting environment was a quiet teaching space at the University with unique, artistic design features (e.g. wall paper), minimal natural light, and limited view of nature (see Figure 6.2). The outdoor resting environment was at the Adelaide Botanic Gardens, adjacent to the university campus; the space was peaceful with grassed areas, a water fountain, as well as a high degree of biodiversity in terms of large trees, shrubs, ferns, plants, flowers, and some bird-life (see Figure 6.2). The weather was cool and mostly dry on the five study days, with intermittent sun and overcast skies. Participants were told not to use their smartphones during the rest period or to do any physical activity that could raise their heart rate, like running. They were encouraged to wander around and explore the space, chat with their friends, or sit down if they wanted. It then took five minutes to walk back along the same routes to the computer suite.

Once back in the computer suite, participants were asked to open the final web link on the computer. This involved repeating the experimental measures (T2) (see sections 6.2.2.2 – 6.2.2.5) and indicating which environment they were in for the rest period. This took 10 minutes to complete on average.

Figure 6.2 Environments in pilot study (A) Walking route to the indoor resting environment; (B) Indoor resting environment; (C) Walking route to the outdoor resting environment; (D) Outdoor resting environment

6.2.4 Statistical Analysis

Statistical analyses were performed using R version 3.6.3 (656) and STATA version 17.0. Assumptions of normality were assessed via visual inspection of histograms, boxplots and Q-Q plots. Values which exceeded the 3x interquartile rule based on John Tukey's method were classified as outliers (657); they were considered invalid attempts of the tasks and not included in analyses.

Linear mixed modelling (LMM) was used with residual maximum likelihood estimations to examine the effect of time (baseline (T0), post-screen time (T1), and post-rest period (T2)) and condition (Indoor vs Outdoor at T2) on the dependent variables: mood, sustained attention capacity, and inhibitory control. LMM was selected as the preferred approach for this repeated-measures research design because: (a) data is grouped by subject, and within and between subject variance is appropriately accounted for, (b) exploratory factors (fixed effects) can be categorical or continuous, and (c) the covariance structure (random effects) is modelled rather than assuming a predetermined structure (658). LMM prevents type-1 error inflation while retaining power of the model (658, 659).

Outcomes were analysed using the ‘lme4’ package for R (660) and Type II *F* tests (with Kenward-Rodger adjustment) were used to provide p-value estimates from the ‘car’ package (661). Effects were plotted using the package ‘effects’ (661) and ‘parameters’ (662). Fixed effects in the model included sex, age category, Time and Condition (at T2), with participant ID and cluster specified as random effects. The SART Total Error rate was used for the sustained attention capacity outcome; to statistically control for speed-accuracy trade-offs and enhance SART validity, SART Hit RT was also entered as a covariate (663). The SST Inhibition rate was used for the inhibitory control outcome and the mood VAS score was used for the mood outcome. Sleepiness was entered as a covariate in models for all three outcomes.

Each outcome was first modelled with an initial maximal Model A. Given the Condition (Indoors or Outdoors) did not exist at T0 or T1 it was assumed that there should be no observable difference by Condition at these Time points. Therefore, in Model A, Condition was only considered at T2 (expressed as Condition^{T2}). After Model A was interpreted for each outcome, the model was re-parameterised (Model B) to include the full interaction of Time x Condition (all six levels) to check the a priori assumption that there would be no Condition effect at T0 and T1. Where no statistically significant effect of Condition was found at T0 or T1, model reduction was consequently performed on Model A by successively dropping non-significant terms from the model, while respecting the principle of marginality. If a statistically significant Condition effect was identified at T0 or T1, model reduction was conducted by successively dropping non-significant terms from the re-parameterised model (Model B, with the full interaction of Time x Condition), while respecting the principle of marginality.

Between-group differences on relevant sociodemographic and lifestyle variables, and on outcome variables at baseline, were evaluated using t-tests or chi-square tests. All data are presented as means and standard deviations (SD), and p-values were 2-tailed with statistical significance defined as $p < 0.05$, except where indicated otherwise.

6.3 Results

6.3.1 Descriptive Statistics and Group Comparisons

Eighty-seven adolescents participated in the pilot study; 43 (49%) were randomised to the Indoor condition and 44 (51%) were randomised to the Outdoor condition. Participant recruitment, clusters, condition randomisation, and completeness of data are shown in Figure 6.3. Complete data were available for 99% of participants at T0 and T1; for one participant (in cluster 5), SART data were classified as outliers at both time-points and consequently removed. Complete data were available for 93% of participants at T2; the six participants for whom complete data were not available had either dropped out part-way through the tests ($n = 2$ (in cluster 2) on the SST) or did not complete the tests according to the protocol ($n = 4$ (in cluster 5) on the SART and SST; e.g., went to the toilet mid-test). One participant who dropped out of the SST at T2 (in cluster 2) was classified as an outlier on the SART and consequently removed.

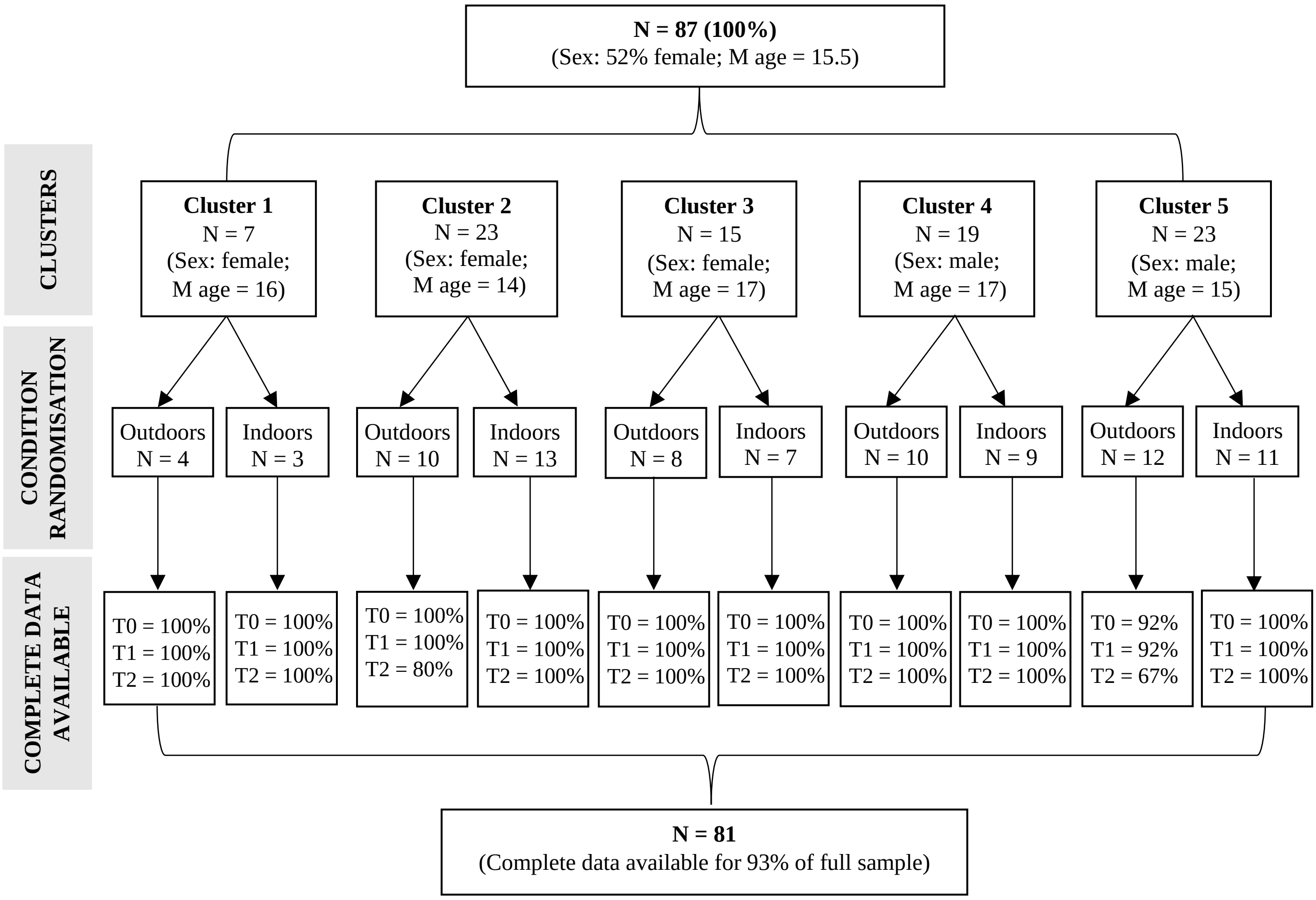

Figure 6.3 Participant recruitment, clusters, condition randomisation, and completeness of data
Note. M = mean

Relevant sociodemographic and lifestyle variables are shown in Table 6.1 (further screen time information is available in Appendix 15). Participants were mostly from middle-to-high socioeconomic residential areas. They reported spending an average of 4.5 hours daily on their smartphones, with almost 70% reporting that they feel like they spend too much time on their phones. Videogaming was more common among male participants, with almost 50% of females reporting that they did not use videogames. High levels of TV watching were not common among participants (approximately 10% reporting overuse), but use of streaming services like Netflix was (approximately 40% reporting overuse). On average, participants had moderate sleep quality and reported being involved in about 2 physical activities/sports, across approximately 3 days, a week. Connectedness to nature was relatively high and levels of psychological distress were mild on average. Participants in the Indoor and Outdoor resting conditions were comparable on all sociodemographic and lifestyle variables, with the exception of average daily hours spent on their smartphones (4.12 hours for Indoor group vs 4.93 hours for Outdoor group), although this difference was unlikely to be practically meaningful.

Table 6.1 Sociodemographic and lifestyle variables

	All (N = 87)	**Indoor Condition** (N = 43; 49%)	**Outdoor Condition** (N = 44; 51%)	
		Mean (SD)		*p-value*
Age	15.51 (1.27)	15.44 (1.31)	15.57 (1.23)	0.6446
Sex (female)	45 (52%)	23 (53%)	22 (50%)	0.745
Socioeconomic status (quintile)				0.143
1 (most disadvantaged)	10 (12%)	3 (7%)	7 (16%)	
2	8 (9%)	5 (12%)	3 (7%)	
3	16 (19%)	10 (24%)	6 (14%)	
4	29 (34%)	17 (41%)	12 (28%)	
5 (most advantaged)	22 (26%)	7 (17%)	15 (35%)	
Average daily hours on smartphone	4.53 (1.73)	4.12 (1.66)	4.93 (1.72)	**0.0325**
Connectedness to Nature Index	30.40 (6.56)	31.65 (6.52)	29.18 (6.44)	0.0791
Number of Physical Activities / Sports	1.89 (1.47)	1.60 (1.33)	2.16 (1.55)	0.0772
Average Number of Active Days	2.76 (1.95)	2.53 (2.07)	2.98 (1.81)	0.2928
Sleep Quality	3.62 (0.92)	3.61 (0.93)	3.62 (0.92)	0.9512
PHQ-4	4.59 (3.56)	4.84 (3.75)	4.34 (3.39)	0.5195

Notes. SD = standard deviation; PHQ-4 = Patient Health Questionnaire-4; statistically significant p-values are bolded.

There were differences on experimental measures at baseline by sex and age category (see Table 6.2). Female participants reported feeling sleepier than male participants at baseline, male participants had faster RTs, and younger students (<16 years) made more errors than older students (≥16 years). In unadjusted comparisons, participants in the Indoor and Outdoor conditions were comparable on all outcome measures at baseline (T0) (see Table 6.3).

Table 6.2 Comparison of participants by sex and age category on experimental measures at baseline (T0)

	All	Female	Male		Aged <16 years	Aged ≥16 years	
		Mean (SD)		*p-value*	*Mean (SD)*		*p-value*
Mood	6.36 (1.93)	6.20 (1.93)	6.33 (1.95)	0.7490	6.48 (2.08)	6.02 (1.72)	0.2750
Sleepiness	5.70 (2.24)	6.18 (2.14)	5.19 (2.25)	**0.0389**	5.57 (2.40)	5.85 (2.06)	0.5513
Sustained Attention Capacity (SART)							
Hit rate (%)	99.17 (1.00)	99.22 (0.81)	99.12 (1.18)	0.6439	98.99 (1.17)	99.38 (0.72)	0.0702
Hit RT	157.62 (57.02)	148.60 (60.27)	167.52 (52.16)	0.1250	160.81 (57.67)	154.11 (56.80)	0.5894
Commission Error rate (%)	44.70 (22.83)	42.13 (20.26)	47.51 (25.30)	0.2777	49.33 (21.83)	39.61 (23.08)	**0.0479**
Commission Error RT	122.49 (61.59)	109.05 (51.75)	137.24 (68.47)	**0.0332**	116.35 (43.18)	129.22 (76.94)	0.3360
Omission Error rate (%)	0.83 (1.00)	0.78 (0.81)	0.88 (1.18)	0.6439	1.01 (1.17)	0.62 (0.72)	0.0702
Total Error rate (%)	5.70 (2.96)	5.37 (2.44)	6.06 (3.44)	0.2853	6.38 (2.94)	4.95 (2.83)	**0.0248**
Inhibitory Control (SST)							
Correct Go rate (%)	84.29 (13.52)	85.41 (14.32)	83.10 (12.65)	0.4284	80.80 (16.57)	88.21 (7.34)	**0.0098**
Correct Go RT	373.74 (35.49)	389.60 (27.40)	356.74 (35.55)	**0.0000**	371.60 (43.09)	376.13 (24.64)	0.5550
Incorrect No-Go RT	146.77 (38.98)	149.34 (44.00)	144.03 (33.09)	0.5288	147.53 (36.32)	145.93 (42.21)	0.8500
Inhibition rate (%)	37.70 (17.50)	38.44 (19.06)	36.90 (15.85)	0.6843	38.04 (18.57)	37.32 (16.44)	0.8481

Notes. SD = standard deviation; SART = Sustained Attention to Response Task; SST = Stop Signal Task; ms = milliseconds; statistically significant p-values are bolded.

Table 6.3 Unadjusted comparison of groups (Indoor vs Outdoor) on experimental measures at baseline (T0), post-screen time (T1), and post-rest period (T2)

Measure	All (N = 87; 100%)			Indoor Condition (N = 43 randomised; 49%)			Outdoor Condition (N = 44 randomised; 51%)		
	T0 (n = 86; 99%)	T1 (n = 86; 99%)	T2 (n = 81; 93%)	T0 (n = 43; 100%)	T1 (n = 43; 100%)	T2 (n = 43; 100%)	T0 (n = 43; 98%)	T1 (n = 43; 98%)	T2 (n = 38; 86%)
Mood	6.36 (1.93)	6.54 (1.68)	6.67 (2.15)	6.09 (2.02)	6.44 (1.75)	6.88 (2.26)	6.43 (1.84)	6.64 (1.62)	6.45 (2.05)
Sleepiness	5.70 (2.24)	5.29 (2.31)	5.26 (2.26)	5.49 (2.16)	4.98 (2.36)	4.98 (2.41)	5.91 (2.31)	5.59 (2.24)	5.55 (2.10)
Sustained Attention Capacity (SART)									
Hit rate (%)	99.17 (1.00)	98.97 (2.03)	99.29 (1.23)	99.10 (0.90)	99.14 (1.19)	99.36 (1.00)	99.24 (1.09)	98.80 (2.61)	99.22 (1.46)
Hit RT (ms)	157.62 (57.02)	162.03 (74.76)	168.04 (75.16)	152.78 (60.15)	157.07 (54.91)	163.73 (70.16)	162.45 (53.98)	166.99 (90.81)	172.79 (80.98)
Commission Error rate (%)	44.70 (22.83)	47.63 (26.47)	48.93 (25.72)	47.16 (21.14)	52.19 (24.47)	51.26 (24.02)	42.23 (24.40)	43.07 (27.88)	46.36 (27.56)
Commission Error RT (ms)	122.49 (61.59)	122.34 (53.05)	129.77 (60.27)	118.91 (50.72)	124.04 (51.43)	130.42 (57.10)	126.07 (71.26)	120.52 (55.34)	128.98 (64.67)
Omission Error rate (%)	0.83 (1.00)	1.03 (2.03)	0.71 (1.23)	0.90 (0.90)	0.86 (1.19)	0.64 (1.00)	0.76 (1.09)	1.20 (2.61)	0.78 (1.46)
Total Error Rate (%)	5.70 (2.96)	6.21 (3.87)	6.07 (3.34)	6.04 (2.57)	6.56 (3.25)	6.26 (3.02)	5.36 (3.30)	5.85 (4.41)	5.85 (3.68)
Inhibitory Control (SST)									
Correct Go rate (%)	84.29 (13.52)	82.18 (12.18)	83.70 (11.27)	83.57 (14.90)	83.26 (10.27)	84.26 (10.40)	85.00 (12.15)	81.14 (13.83)	83.07 (12.29)
Correct Go RT (ms)	373.74 (35.49)	377.67 (39.10)	382.15 (29.06)	376.30 (39.63)	381.73 (32.92)	380.25 (31.87)	371.23 (31.17)	373.72 (44.35)	384.30 (25.76)
Incorrect No-Go RT (ms)	146.77 (38.98)	136.00 (39.45)	141.92 (40.97)	146.01 (37.35)	136.42 (44.33)	140.64 (41.20)	147.52 (40.94)	135.60 (34.54)	143.41 (41.22)
Inhibition Rate (%)	37.70 (17.50)	40.69 (16.12)	38.77 (16.38)	39.53 (17.18)	38.60 (16.12)	38.37 (12.90)	35.91 (17.83)	42.73 (16.05)	39.21 (19.78)

Notes. Data presented as mean (standard deviation); SART = Sustained Attention to Response Task; SST = Stop Signal Task; ms = milliseconds

Table 6.4 Sustained attention capacity, inhibitory control, and mood outcome inferential statistics for all fixed effects F-values (Type II with Kenward-Roger Adjustment) and statistical significance

SART Total Error Rate

Model 1A

	F	*df*	*p*
SART RT	22.1	1	**0.00**
Sleepiness	0.3	1	0.57
Sex	1.1	1	0.72
Age	16.9	1	0.52
Time	2.5	2	0.09
Sex x Age	0.47	1	0.77
Time x Condition^{T2}	0.64	1	0.42
Sex x Time	0.8	2	0.47
Age x Time	2.7	2	0.07
Sex x Time x Condition^{T2}	0.1	1	0.82
Age x Time x Condition^{T2}	0.2	1	0.65
Sex x Age x Time	2.6	2	0.08
Sex x Age x Time x Condition^{T2}	0.2	1	0.65

Model 1B

	F	*df*	*p*
SART RT	17.4	1	**0.00**
Condition	0.2	1	0.66
Age	18.9	1	0.04
Time	2.3	2	0.11
Condition x Age	7.1	1	0.01
Condition x Time	0.5	2	0.59
Age x Time	2.9	2	0.06
Condition x Age x Time	3.4	2	**0.04**

SST Inhibition Rate

Model 2A

	F	*df*	*p*
Sleepiness	0.33	1	0.56
Sex	0.99	1	0.72
Age	0.18	1	0.84
Time	0.80	2	0.45
Sex x Age	5.90	1	0.56
Time x Condition^{T2}	0.03	1	0.86
Sex x Time	0.33	2	0.72
Age x Time	0.02	2	0.98
Sex x Time x Condition^{T2}	0.44	1	0.51
Age x Time x Condition^{T2}	0.34	1	0.56
Sex x Age x Time	1.31	2	0.27
Sex x Age x Time x Condition^{T2}	3.37	1	**0.07†**

Mood

Model 3A

	F	*df*	*p*
Sleepiness	25.71	1	**0.00**
Sex	1.67	1	0.69
Age	0.00	1	0.99
Time	1.11	2	0.33
Sex x Age	0.18	1	0.84
Time x Condition^{T2}	3.68	1	0.06
Sex x Time	4.25	2	0.02
Age x Time	2.02	2	0.14
Sex x Time x Condition^{T2}	0.04	1	0.84
Age x Time x Condition^{T2}	0.06	1	0.80
Sex x Age x Time	3.74	2	0.03
Sex x Age x Time x Condition^{T2}	1.11	1	0.29

Model 3B

	F	*df*	*p*
Sleepiness	26.98	1	**0.00**
Sex	1.62	1	0.70
Age	0.00	1	0.99
Time	1.09	2	0.34
Sex x Age	0.22	1	0.83
Sex x Time	4.07	2	0.02
Age x Time	1.99	2	0.14
Sex x Age x Time	3.59	2	**0.03**

Notes. SART = Sustained Attention to Response Task; SST = Stop Signal Task; RT = reaction time; Sex = male, female; Age = <16 years, ≥16 years; Time = T0 (baseline), T1 (post-screen time period), T2 (post-rest period); Condition^{T2} = Condition (Indoors or Outdoors for rest period) was only considered at Time 2; Condition = Condition (Indoors or Outdoors for rest period) was considered at all three Time points; df = degrees of freedom; statistically significant p-values are bolded.

6.3.2 Main Analysis

Results of the linear mixed models for the outcomes sustained attention capacity, inhibitory control, and mood are presented in Table 6.4.

6.3.2.1 Sustained attention capacity

In Model 1A, which considered Condition at T2 only, the highest order interaction of Sex x Age x Time x Condition^{T2} was not statistically significant for sustained attention capacity (Table 6.4). This is shown in Figure 6.4 and the associated values are also presented in Appendix 16. As shown by the overlapping black error bars at T0 and T1 for most of the age category and sex combinations, a uniform deficit in sustained attention capacity was not observed following the screen time period. The overlapping blue (Indoors) and green (Outdoors) error bars also show that there were no differences in SART Total Error Rate by Condition at T2, for any of the age category and sex combinations. Only SART reaction time (RT) was a statistically significant predictor of SART Total Error Rate in Model 1A ($F(1) = 22.1$, $p = 0.00$; see Appendix 17 for figure).

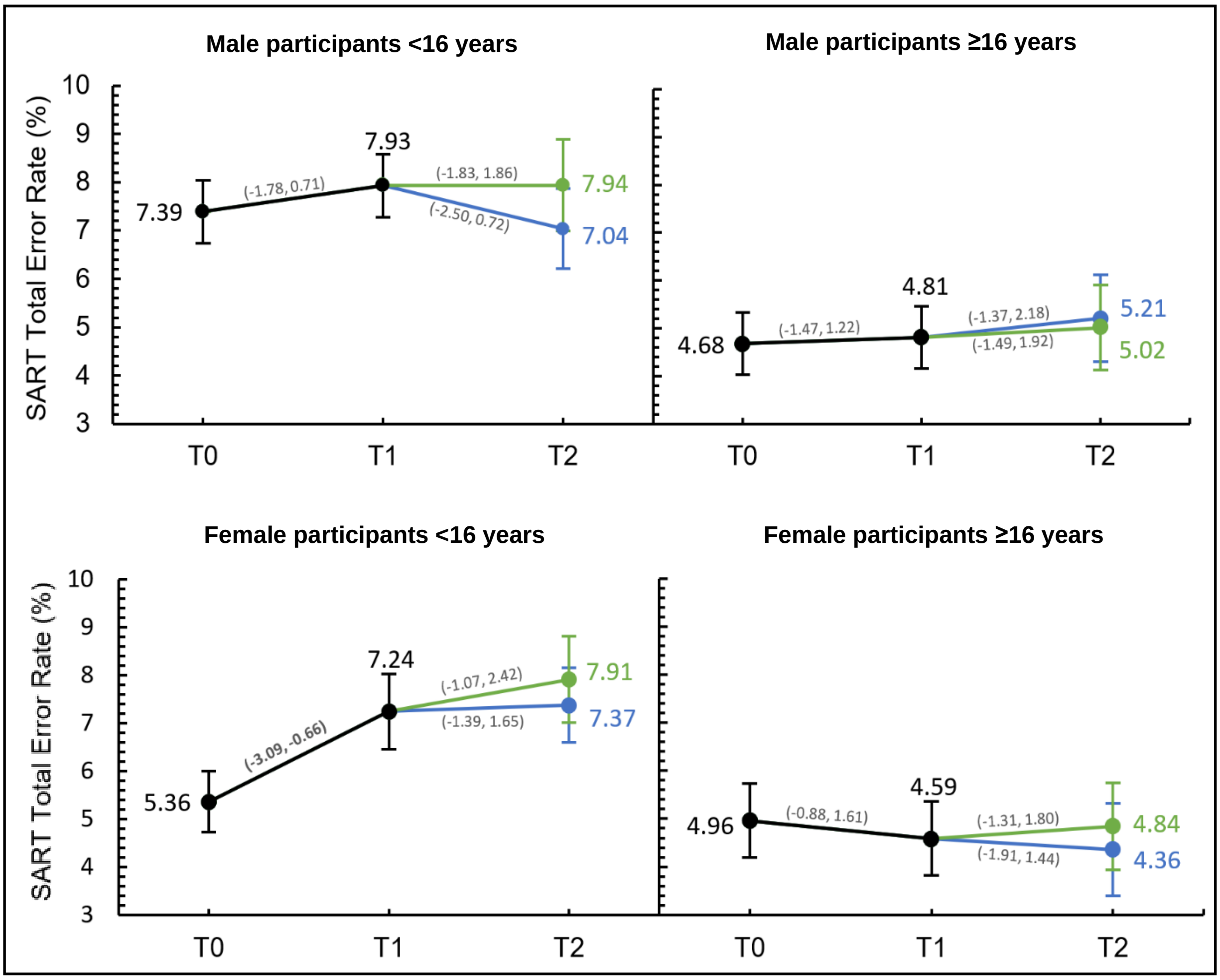

Figure 6.4. Plotted effects of highest order interaction of Sex x Age x Time x Condition^{T2} for SART Total Error Rate (%) (Model 1A; adjusted for SART Hit RT and sleepiness)

Notes. The circle points represent means and the error bars represent standard error of the mean. The outcome value is depicted on the y-axis, with the time point (T0 = baseline; T1 = post-screen time period; T2 = post-rest period) across the x-axis of each panel. Outcomes for all participants in each sex / age combination are shown in black at T0 and T1. Outcomes at T2 are further divided by resting condition, with the blue series representing participants who rested Indoors and the green series representing participants who rested Outdoors. Grey text in the brackets represents the 95% confidence interval for the mean change between time points; T1 was used as the reference category and bolded grey text indicates a statistically significant change from T1. SART = Sustained Attention to Response Task; RT = reaction time. Higher SART Total Error Rate indicates poorer sustained attention capacity.

Re-parameterisation of the model to include all six levels of Time and Condition showed that there was a statistically significant Age x Condition x Time effect ($F(2) = 6.56$, $p = 0.001$; model not shown). In the final Model 1B, sex was not included (no statistically significant effect), and the highest order interaction of Condition x Age x Time was statistically significant ($F(2) = 3.4$, $p = 0.04$; see Figure 6.5). Participants aged <16 years in the Indoors and Outdoors conditions followed a similar pattern across the three Time points, but participants aged ≥16 years showed opposite trends; those in the Indoors condition had higher SART Total Error Rates at T1, while those in the Outdoors condition had lower SART Total Error Rates at T1. SART RT was still a statistically significant predictor of SART Total Error Rate in Model 1B ($F(1) = 17.4$, $p = 0.00$).

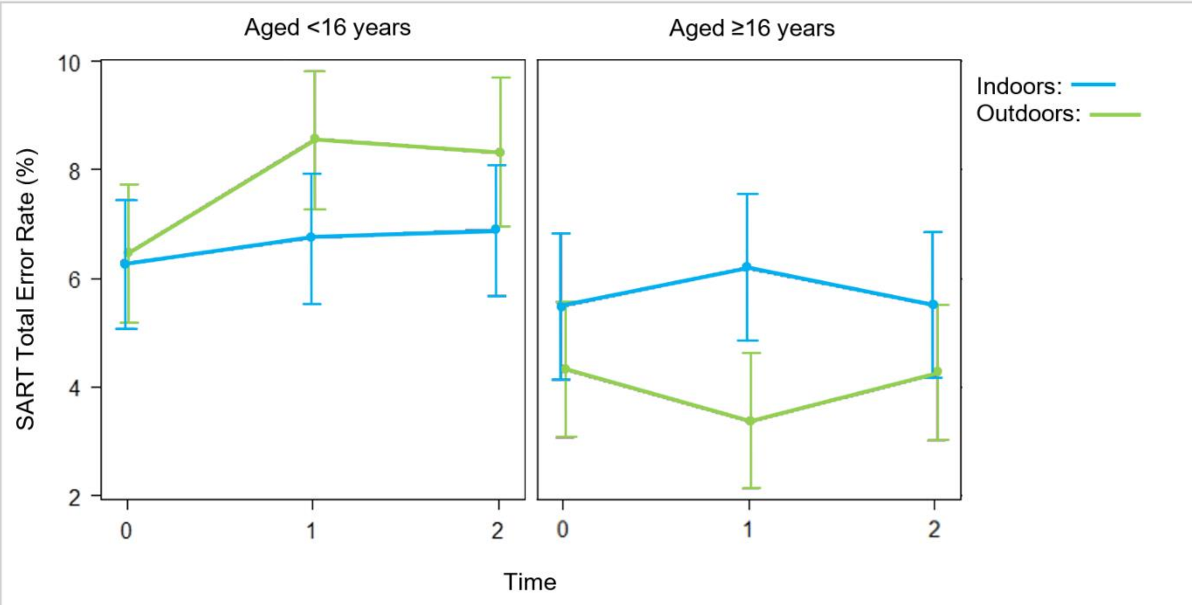

Figure 6.5 Condition x Age x Time interaction for SART Total Error Rate (%) from Model 1B. Bars represent 95% confidence intervals.

6.3.2.2 Inhibitory control

In Model 2A, which considered Condition at T2 only, the highest order interaction of Sex x Age x Time x Condition^{T2} was weakly statistically significant for SST Inhibition Rate ($F(1) = 3.37$, $p = 0.07$; Table 6.4). This is illustrated in Figure 6.6 and the associated values are also presented in Appendix 18. As shown by the overlapping black error bars at T0 and T1 for all of the age category and sex combinations, a deficit in inhibitory control was not observed following the screen time period. The overlapping blue (Indoors) and green (Outdoors) error bars also show that there were no differences in SST Inhibition Rate by Condition at T2, for three of the age category and sex combinations. Post hoc analysis revealed that for males aged <16 years there was a weak statistically significant difference by

Condition at T2 ($t(238) = 1.75$, $p = 0.08$). The mean change in SST Inhibition Rate from T1 to T2 was statistically significant for male participants aged <16 years in the Indoor condition only (mean change = -13.01, $t(195) = -2.14$, $p = 0.03$).

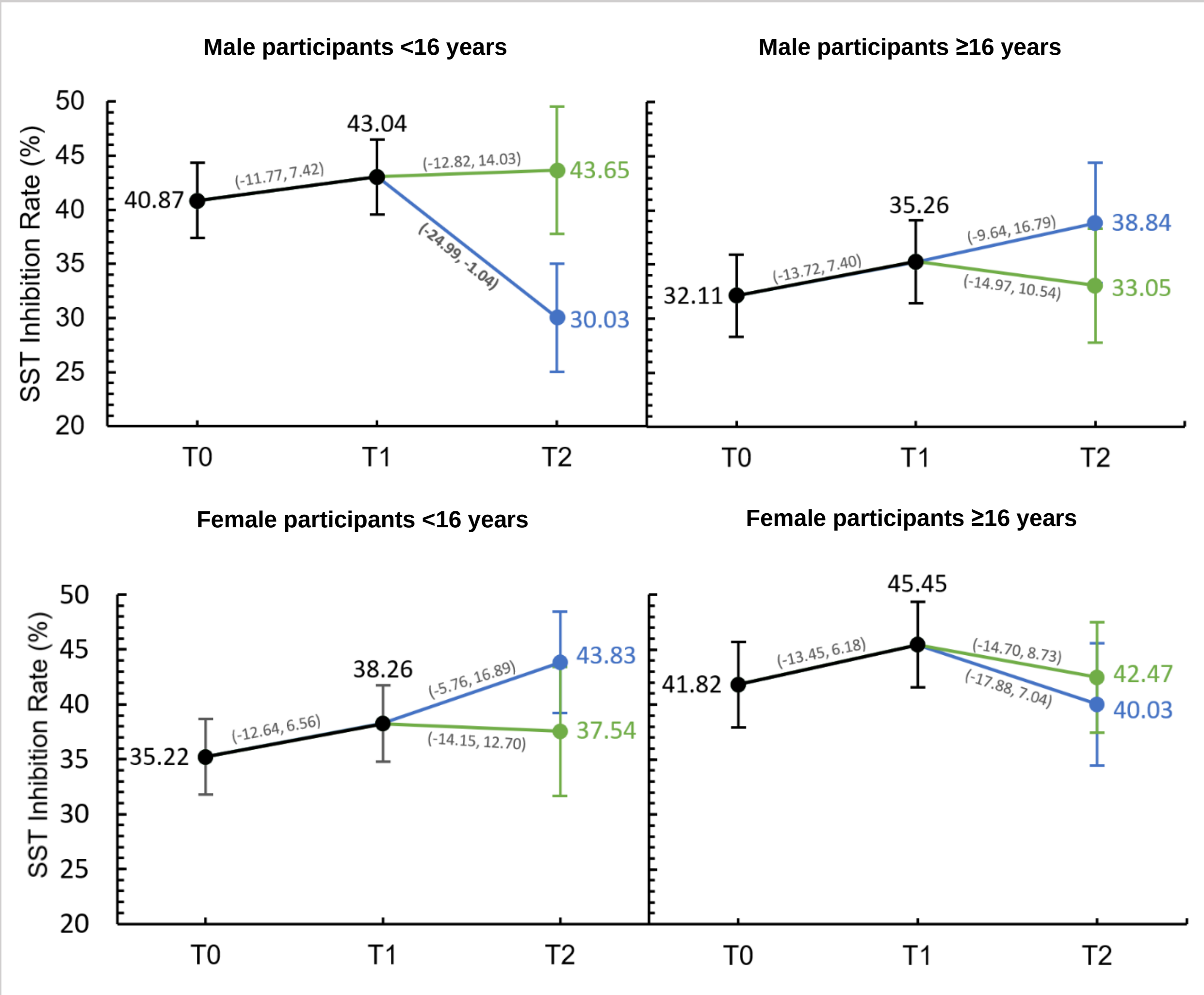

Figure 6.6. Plotted effects of highest order interaction of Sex x Age x Time x Condition^{T2} for SST Inhibition Rate (%) (Model 2A; adjusted for sleepiness)

Notes. See Figure 6.4 for detailed explanation. SST = Stop Signal Task. Higher SST Inhibition Rate indicates better inhibitory control.

Re-parameterisation of the model to include all six levels of Time and Condition showed no statistically significant effects relating to Condition differences at T0 or T1 (model not shown). All terms in the model were non-significant when the weakly significant highest order interaction of Sex x Age x Time x Condition^{T2} was dropped; therefore, Model 2A was retained as the final model for Inhibitory Control.

6.3.2.3 Mood

In Model 3A, which considered Condition at T2 only, the highest order interaction of Sex x Age x Time x Condition^{T2} was not statistically significant for the mood outcome (Table 6.4). This is shown in Figure 6.7 and the associated values are also presented in Appendix 19. As shown by the overlapping black error bars at T0 and T1 for all of the age category and sex combinations, a uniform decrease in mood was not observed following the screen time period. The overlapping blue (Indoors) and green (Outdoors) error bars also show that there were no differences in mood score by Condition at T2, for all of the age category and sex combinations. Sleepiness was a statistically significant predictor of Mood in Model 3A ($F(1) = 25.71$, $p = 0.00$; see Appendix 20 for figure).

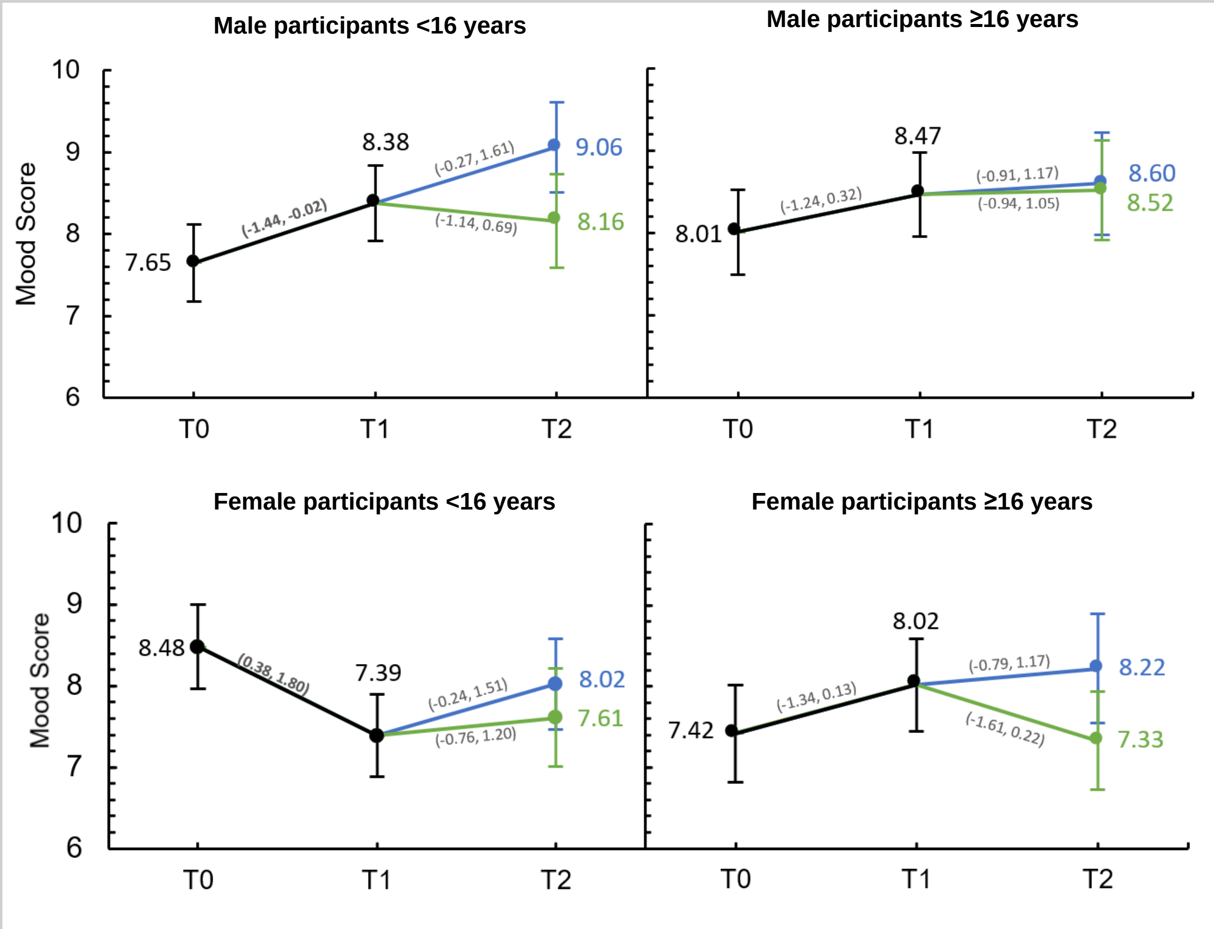

Figure 6.7. Plotted effects of highest order interaction of Sex x Age x Time x Condition^{T2} for Mood outcome (Model 3A; adjusted for sleepiness)

Notes. See Figure 6.4 for detailed explanation. Higher mood score indicates better mood.

Re-parameterisation of the model to include all six levels of Time and Condition showed no statistically significant effects relating to Condition differences at T0 or T1 (model not shown). In the final Model 3B, Condition^{T2} was not included (no statistically significant effect), and the highest order interaction of Sex x Age x Time was statistically significant ($F(2) = 3.59$, $p = 0.03$; see Table 6.4 and Figure 6.8). Mood scores for male participants followed a similar pattern across the three Time points, irrespective of age category. Contrastingly, female participants had opposite patterns depending on age category. Specifically, mood scores for female participants aged <16 years decreased from T0 to T1 and then increased from T1 to T2, while for female participants aged ≥16 years mood scores increased from T0 to T1 and decreased from T1 to T2. Sleepiness was still a statistically significant predictor of mood in the final Model 3B ($F(1) = 26.98$, $p = 0.00$).

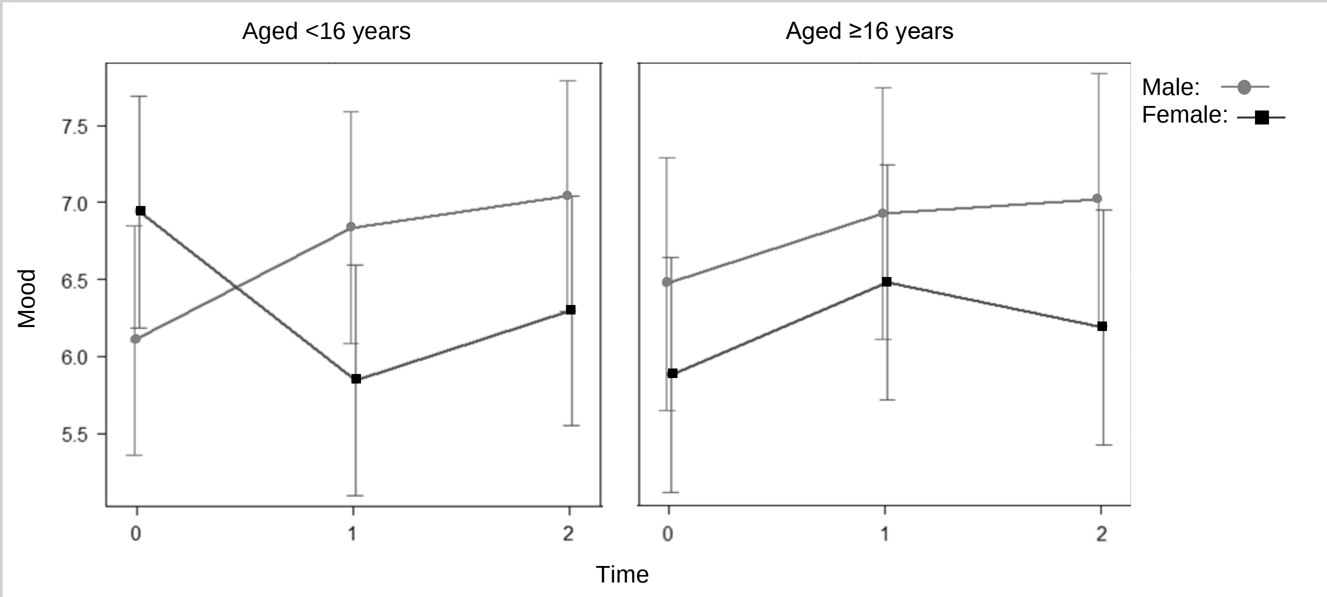

Figure 6.8 Sex x Age x Time interaction for Mood from Model 3B. Bars represent 95% confidence intervals.

6.4 Discussion

Using a randomised pre-post pilot design, this study explored the acute psychological impacts of screen time for adolescents, as well as the restorative potential of nature immersion. This novel study had several strengths which addressed limitations in the existing literature (151), including groups which were comparable at baseline on relevant sociodemographic, lifestyle, and outcome variables, randomisation of participants to conditions, the use of validated computerised psychological measures, and close adherence to a procedural protocol.

The results did not support the proposed hypothesis that adolescents would experience acute deficits in mood, inhibitory control, and sustained attention following a relatively brief period of screen time. However, consistent with previous research, developmental differences in cognitive performance were observed, with younger participants (<16 years) making more errors on the SART than older participants (≥16 years) (664). Performance on the SART was also predicted by participant reaction time, demonstrating speed-accuracy trade-offs (663), while mood scores were predicted by self-reported sleepiness with greater levels of sleepiness associated with lower mood.

The hypothesis that adolescents who experienced a period of green time would show superior restoration when compared to adolescents who participated in an indoor rest period could not be appropriately tested, because a uniform deficit in cognitive performance was not observed across participants after the screen time period, meaning there was no "room for improvement". Other studies investigating the restorative potential of nature have involved purposive stressor tasks, such as the Trier Stressor Task (302), which intentionally induce mental fatigue and therefore provide room for potential for psychological restoration from nature experiences.

Our study explored screen time as a mental fatigue or "stressor", however it was not possible to adequately determine beforehand what screen activity or exposure timeframe would be required to observe an acute deficit in cognitive performance, because this is not clearly articulated in the literature. The screen time literature is highly dominated by cross-sectional studies, while experimental evidence is sparse (151). The few existing experimental studies have little consistency in terms of the sample studied or the screen exposure considered, ranging from pre-school children watching 10-20-minutes of television (539), to samples of college students shopping online for 15-minutes (542), which were found to result in cognitive deficits. The screen time period in our study was 30-minutes in length and involved playing three games on a computer. A screen time period involving smart phones and streaming services (e.g., Netflix viewing) may have been more relevant, given participants in our study indicated that they engaged with these activities most commonly and games were reported as largely irrelevant to female participants.

Although there was a lack of measurable cognitive deficit, during the pilot study participants reported feeling most fatigued after the screen time period, exclaiming that it was difficult to complete the T1 measures. Despite this, they were still able to attend to the cognitive tasks and perform relatively consistently compared with baseline. According to Borbèly, this is a common phenomenon in which individuals can report feeling fatigued, but are still able to focus well on cognitive tasks for a *brief* period of time (665). In the screen time literature, some differences in self-reported versus objectively-measured cognitive performance have also been reported. For example, in a cross-sectional study of young adolescents, Baumgartner and colleagues found that media multi-tasking was not associated with inhibition or attention when measured by objective cognitive tests, but when participants *self-reported their daily difficulties* in these areas of cognitive functioning, higher levels of media multitasking were associated with poorer self-reports of inhibition and attention abilities (244). Similarly, in the experiment by Greenwood and Gatersleben (352) a three-way interaction was observed between *environment* (resting indoors), *context* (playing on a mobile phone), and *time* on adolescents' self-reported attentiveness, but there was no significant three-way interaction effect on attention when objectively measured by the Necker Cube Pattern Control Task.

While we did ask participants about their levels of sleepiness throughout the study, the addition of self-reported indicators of attention and inhibition would have provided an important perspective and should be employed in future experimental studies. Self-reported assessments of attention and inhibition are also likely to be more applicable in real-world situations where emotion regulation is ongoing and not confined to completing a brief computerised task. Furthermore, while cognitive *components* of emotion regulation were assessed in the current study, alternative tasks which more adeptly capture the *integration* of these components required for emotion regulation in real-world experiences, should also be considered in future research. The Ways of Responding (WOR) scale is one example of an emotion regulation task which may permit this (666). The scale requires participants to read six hypothetical stressful scenarios and to write any thoughts they would have in that scenario, as well as what behaviours they may engage in the situation (667). This task requires the respondent to integrate various aspects of cognition in order to achieve effective emotion regulation in possible real-world experiences, including (a) redirection of attention away from negative thoughts, (b) reappraisal of thoughts and feelings to change the emotional significance of the scenario, and (c) inhibition of maladaptive behavioural responses. Outcomes on emotion regulation tasks like the WOR scale may be supplemented with physiological indicators of emotion regulation, for greater convergent validity. For example, heart rate variability is the physiological measure most commonly proposed as an index of emotional regulation capacity (668).

The results of this study must be considered while appreciating some limitations. For example, there were certain limitations around working with high school students. Practical constraints meant that school students participated in the pilot study in class groups. This was likely to have affected their task results, with previous research demonstrating the impacts of peer influence on cognitive performance. For example, Breiner and colleagues (669) found that adolescents aged 13 – 17 years experienced diminished cognitive control on a Go/No-Go task in the presence of peers, relative to when they were alone. Similarly, a study by Block and Heyes reported that teenagers tend to “catch moods” from their friends (670), meaning emotion contagion between participants could have possibly occurred within research sessions. Despite task performance and mood being potentially affected in a group setting, this approach was more ecologically valid, reflecting adolescents’ real-world social settings and daily experiences with their peers. Furthermore, a previous study suggested that the benefits of nature immersion might depend on having peer interaction, meaning having students participate in the research activities together was preferred (352). The context in which the adolescents participated in the research – on a university campus – was a novelty however, and a level of excitement from the participants was evident. This may have impacted outcomes. McCambridge and colleagues emphasise that researchers should not overlook the extent to which research studies are unusual contexts in which individuals may react in unexpected ways, introducing a range of potential biases (671).

Furthermore, Verbruggen and colleagues (672) recommend 200 trials of the Stop Signal Task should be used when testing inhibitory control in adult samples, but due to both time constraints and the fact that participants were completing measures of sustained attention in the same sitting, 40 trials was a pragmatic approach in our study. Future research solely focussing on inhibitory control and screen time could address this limitation. While we took care to try to ensure participants in the indoor and outdoor conditions were comparable at baseline on a range of relevant measures, including psychological distress symptoms (e.g., PHQ-4), we did not consider whether participants had a previous diagnosis of ADHD/ADD, which should be addressed in future research.

Finally, it was not possible to a priori calculate a sample size required to detect changes in cognitive performance after a period of screen time; this was due to a lack of information in the available literature, meaning expected effect sizes could not be ascertained. In hindsight, the study likely lacked statistical power to adequately test the hypotheses. Studies of this kind are expensive because the sample size required to detect potentially small effects is significantly larger. While acute cognitive impacts of screen time on adolescents may potentially be modest and often short-term, investment in this research is still meaningful from a public health perspective because this is likely to occur at high frequencies with adolescents being a group of high-tech users (363, 490). Given the known role of attention and inhibition in emotion regulation, repeated acute depletion of these cognitive resources may impede adolescents' ability to effectively practice regulating their emotions, and cumulatively increase the risk of internalizing problems. Ongoing research exploring the restorative potential of green time is also worthwhile, as this may lead to support for investment in urban greenspaces and green infrastructure in schools, providing pro-mental health resources to support adolescent psychological well-being (152).

6.5 Conclusion

Research tells us that screen time and green time could influence psychological well-being in contrasting ways; while screen-based technologies may displace protective behaviours and exhaust cognitive resources, natural environments appear to promote a range of protective behaviours and encourage attention restoration and stress reduction. As such, the combination of high screen time and low green time may present a dual-burden on adolescent psychological well-being in the 21st century (151). This study demonstrated that adolescents did not experience a uniform deficit in cognitive performance after a screen time exposure, which meant that the hypothesis concerning the potential restorative effects of green time could not be adequately tested. Nevertheless, a range of conceptual and methodological lessons were learned from this study, which will help to inform and further strengthen future research investigating the psychological benefits of green time for young people growing up in a high-tech era.

CHAPTER SEVEN: GENERAL DISCUSSION & CONCLUSION

7.0 Preamble

The purpose of Chapter 7 is to provide a general discussion and conclusion for the thesis as a whole. The key findings of the four research studies are first reiterated. A discussion on the key learnings gained from this body of work as a whole, which go beyond the scope of the individual papers, is then presented. This includes current challenges and barriers in the field, as well as implications for policy, practice and research. Strengths and limitations of the work are then summarised.

As outlined in Chapter 1, most mental health problems emerge before the age of 25 years (24), with the onset peaking at 14.5 years of age (25). Mental disorders are the leading cause of disability for young people globally (19, 22), and there is some evidence to suggest that prevalence is increasing – especially internalising problems in adolescent girls (26, 34). Importantly, experiences of poor psychological well-being while young have broad impacts across the lifespan, with future vulnerability persisting into adulthood across a range of health and non-health-related outcomes (2, 9, 17, 32).

As such, there is an urgent need to identify and address determinants of youth psychological well-being. While a plethora of determinants exist, because mental health is shaped by the socio-ecological context, the current thesis focused on two contemporary determinants relevant to young people; increased screen time (engagement with screen-based technologies) and decreased green time (time spent in, or exposure to, natural environments). These determinants were selected because they are concurrent, had not been researched together, and are highly topical, meaning they are relevant to parents, educators, health professionals, and young people themselves. The overarching purpose of this thesis was to explore the psychological impacts of screen time and green time on young people, as well as to investigate the potential psychological benefits of green time in a high-tech era. Four studies, each underpinned by a public health psychology research approach, were conducted to address this overarching aim.

7.1 Key findings from the research studies

The first study (presented in Chapter 3) was a systematic scoping review, which aimed to critically review the international literature looking at the links between screen time, green time, and psychological outcomes in young people. Almost 200 studies were included in the systematic scoping review, which was published in *PLOS ONE* (see Appendix 4), and a number of key findings and research gaps were identified.

The first key finding was that screen time and green time have contrasting relationships with psychological outcomes across the literature; higher screen time tended to be associated with unfavourable psychological outcomes while greater green time was associated with favourable psychological outcomes. However, overall, the body of evidence lacked studies with a longitudinal or rigorous experimental component. Furthermore, appropriate analysis of competing explanations, such as potential confounding or mediating sociodemographic and lifestyle factors, was also lacking. Underlying mechanisms between screen time and psychological outcomes were poorly articulated across the literature. The review also highlighted the importance of considering the way in which specific types of screen time and green time may affect young people of different ages, depending on the social and biological factors unique to their developmental stage of life. The importance of teasing out the psychological impacts of passive (e.g., television) versus interactive/stimulating (e.g., smartphones) screen activities, and incidental (e.g., green neighbourhood) versus purposive (e.g., nature walk) green time exposure, was also highlighted.

From a social justice and health equity perspective, the review emphasised that young people from disadvantaged backgrounds may be disproportionately affected by high screen time and low green time, meaning future research in this area should prioritise youth experiencing disadvantage. Finally, the review concluded with the suggestion that exploration of green time as a potential ameliorator (or "buffer") to the psychological consequences of extensive screen time is warranted. The ensuing research contributing to this thesis was informed by these key findings and attempted to address some identified research gaps.

In response to the identified research gaps, the original intention for the second study was to perform a longitudinal analysis of the psychological impacts of screen time and green time on South Australian school students, considering the possible role of confounding and mediating sociodemographic and lifestyle factors. Unfortunately, the COVID-19 pandemic disrupted the availability of the routinely collected data required for this investigation. Furthermore, the meaning and role of screen time and green time changed in the context of the pandemic, with lockdowns and restrictions in Australia affecting daily routines and activities for young people. Therefore, this study was abandoned.

The second study (presented in Chapter 4) was consequently re-oriented to reflect the current global situation and context relevant to young people's mental health at that point in time. A national cross-sectional study was conducted, which aimed to explore associations between potential risk and protective factors relevant to young Australians mental health in the context of the COVID-19 pandemic. Just over 1,000 young Australians participated in the study, which was published in the *International Journal of Environmental Research and Public Health* (see Appendix 9). The Complete State Model of Mental Health (162) was used in this study, which assesses mental health comprehensively by including indicators of mental well-being alongside symptoms of mental illness. This study was the first to use the Complete State Model of Mental Health when researching mental health in the context of the

COVID-19 pandemic, and provides important new evidence about the state of mental health of young Australians.

While the research design could not provide reliable prevalence estimates as it used an online convenience sample, it could be used to investigate associations, with a sizeable number of diverse participants recruited through quota sampling. In the study, 14% of participants were classified as Flourishing (best mental health), 25.5% as Languishing (not mentally ill, but experiencing low levels of mental well-being), 47.5% as Struggling (experiencing symptoms of mental illness, but also high levels of mental well-being), and 13% as Floundering (worst mental health).

Protective factors associated with Flourishing mental health (after taking into account gender and socioeconomic status) included being in secure employment, using screen time to connect with others, and reporting high levels of hope. Both incidental and purposive contact with nature were associated with Flourishing mental health, while a lack of green or bluespace within walking distance was associated with Languishing, absence of outdoor residential space was associated with Floundering, and lower neighbourhood greenness was associated with all three suboptimal mental health states. Precarious employment, financial stress, living alone, reporting decreased screen time during lockdowns, lower levels of hope, and high disruption of core beliefs were also associated with Struggling and Floundering mental health.

The study highlighted that a substantial proportion of young Australians may require dedicated mental health services to deal with current mental illness burden (allowing for lack of reliability in prevalence). Importantly, they should also be supported through a range of mental illness preventive strategies which target mental health risk factors (like precarious employment), as well as mental health promotion initiatives which enhance protective factors (like urban green infrastructure). Another key point was the importance of assessing indicators of mental well-being, in addition to symptoms of mental illness, in mental health research. The findings support the need for more widespread use of this approach to conceptualising mental health in ongoing research following the pandemic. One quarter of the study sample were classified as Languishing, meaning they reported no-to-mild levels of psychological distress, but they also reported low levels of mental well-being. Given low mental well-being is predictive of future mental illness, this finding was concerning. Conceptualisations of mental health which fail to consider indicators of mental well-being overlook this substantial group who may require intervention to promote mental well-being (and movement up to the Flourishing category) and prevent future mental illness (movement across to the Floundering category).

The third study (presented in Chapter 5) also aimed to address research gaps identified in the systematic scoping review. Specifically, a theoretical paper and accompanying conceptual model were developed to explore mechanisms and pathways underpinning associations between screen time and psychological outcomes, considering a range of social and biological factors relevant to adolescence as a specific developmental period. The theoretical paper drew together important segments of literature across a range of disciplines, including developmental psychology, clinical psychology, cognitive psychology, neuroscience, public health, and others. The conceptual model, which comprised of four main dimensions, was used to integrate findings and highlight relevant synergies.

Self-regulation was central to the conceptual model and theoretical paper, and was highlighted as an important potential link between excessive screen time and youth mental health problems. Adolescence is a critical period for the development of cognitive abilities and related neuroanatomical maturational changes which contribute to self-regulation. Importantly, self-regulation enables cognitive control of emotions to protect against internalising problems, such as through reappraisal of threats and reducing rumination. These self-regulation capabilities must be refined and strengthened across adolescence through a variety of experiences and interactions with the external world. As such, excessive screen time may displace opportunities for experience-dependent maturation of these capabilities and thus may increase a young person's vulnerability to the internalising problems seen in depression and anxiety. This conceptualisation, linking cognition and emotion in the screen time literature, has not been considered in-depth before. While the habit-forming or addictive properties of some technologies are recognised in other literature, few links are made around how this contributes to internalising symptoms.

An in-depth discussion was included in the theoretical paper around how the development, refinement, and strengthening of self-regulation may be affected by (1) the addictive properties of digital technologies, (2) media multi-tasking, and (3) pervasive exposure to social and emotional content online. These factors were considered within the context of contemporary patterns of adolescent socialisation, and developmental and evolutionary neurobiology. The well-being benefits that digital technologies can offer adolescents socially and academically were also acknowledged and some suggestions to help develop and strengthen self-regulation, as well as support youth mental health in a high-tech era, were provided.

The fourth study (presented in Chapter 6) was a randomised pre-post pilot study, which aimed to investigate the acute psychological impacts of screen time on adolescents, and to explore the proposition that green time may be restorative, or "buffering", of psychological consequences associated with screen time. Eighty-seven adolescents were recruited to participate in this study. Based on theories in cognitive and environmental psychology, it was hypothesised that (1) adolescents would experience acute decreases in mood, inhibitory control, and sustained attention following a period of screen time, and (2) following the screen time period, adolescents who participated in a period of green time would experience superior mood, inhibition, and attention restoration when compared to adolescents who participated in a rest period in an indoor setting. Designing this study was difficult due to a lack of published data to guide crucial aspects, such as required sample size and length of exposure to screen time.

While the results did not support the hypotheses, this study is one of a very few experimental studies in the screen time field, making it an important contribution. Being the first study to test the buffering potential of green time in the context of high screen time, it provides a novel contribution to the wider evidence base. A number of key lessons were learned which will be useful for planning and strengthening future research in this space. In particular, recommendations were made around possible improvements in selection of screen time activity, the importance of including self-reported assessments of cognitive difficulties, and the possible benefits offered by measures which capture the integration of cognitive components of emotion regulation in real-world scenarios.

7.2 Key learnings from the body of work: challenges, barriers, and implications for policy, practice, and research

Youth mental health problems are a public health problem, requiring public health approaches which address socio-ecological determinants of youth mental health. Screen time and green time are an important part of this response and illustrate where this change is invited. While screen time and green time play a partial role in the psychological well-being of contemporary youth overall, researching these determinants gave rise to a number of learnings around potential explanations as to why public mental health solutions are lacking in societies more broadly. These learnings are discussed below in section 7.2.1 and implications for policy and practice are highlighted. Similarly, exploring the role of screen time and green time in youth psychological well-being revealed a number of barriers to moving the research field forward, particularly around disciplinary discrepancies in standards of evidence. These barriers in research and consequent implications are outlined in section 7.2.2.

7.2.1 Challenges in moving upstream: youth public mental health as a wicked problem requiring systems thinking

During my PhD candidature, discussions around public mental health have been amplified in the context of the COVID-19 pandemic. Described as "collective emotion during collective trauma" (673), mental health difficulties have been experienced somewhat mutually across populations globally, rather than being viewed as an experience unique to particular individuals. The important role of public health in the mental health sector has also been appreciated, as clinical/psychological services have been stretched to capacity (49), and inequities in pandemic-related psychological distress appear to have largely been driven by social determinants of health, such as socioeconomic status, employment disruptions, living conditions, and geographic location (383, 391).

While discussions of public mental health have made their way into political and public discourse, there is a long way to go in ensuring that funding is used to plan and execute necessary public mental health solutions. For example, in response to the mental health crisis in the pandemic, the Australian Government increased the number of psychology appointments individuals were entitled to claim through the universal health insurance *Better Access Scheme* in 2020, from 10 to 20 per annum (674). In addition to this, the Australian Government invested a further $74 million (AUD) into the expansion of tele-mental health services during the pandemic (675). While this acute clinical support was important for those experiencing distress, it ultimately represented a treatment-orientation to the crisis and did not alleviate the underlying circumstances which exacerbate the pathology, such as ongoing precarious employment arrangements and subsequent work loss experienced by young people during lockdowns and restrictions.

The “Cliff of Good Health” analogy describes the need to address upstream determinants of health to prevent illness, promote well-being, and ultimately avoid the situation in which individuals fall over the cliff into a state of pathology requiring clinical or medical person-based care (676). Scott and colleagues (43) similarly argue that mental illness incidence (and consequent persisting disability) can only be reduced by targeting upstream determinants of mental health, with an emphasis on reducing risk factors and strengthening protective factors; but there is currently a paucity of existing initiatives oriented to this (2, 9, 43). Historically, and during the pandemic, mental health problems have been addressed downstream at the bottom of the cliff (e.g., increasing Better Access funding), while little investment is made in upstream public mental health solutions (see Figure 7.1).

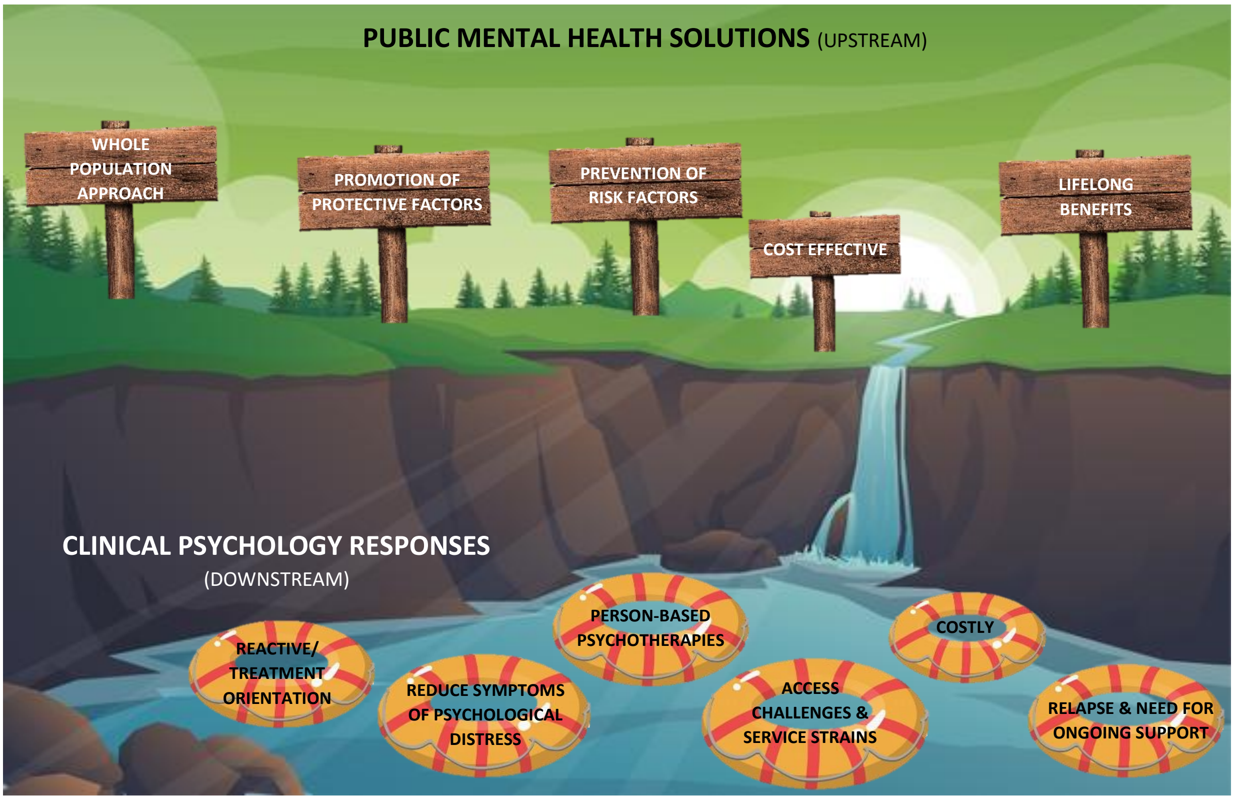

Figure 7.1 The Cliff of Good Health applied to youth mental health, illustrating upstream public mental health solutions and downstream clinical psychology responses

In 2020, an Australian Mental Health Productivity Commission report was published, recommending that the mental health system needed to be *refocussed* towards prevention and early intervention (677). This recommendation was further reiterated in the recent Australian National Preventive Health Strategy (2021 – 2030) (678). In response, the Australian Government released the National Mental Health and Suicide Prevention Plan (2021 – 2022), which would provide $2.3 billion (AUD) in funding across five pillars (679). While investment in a national Prevention Plan was promising, 62.8% of the funds were subsequently dedicated to the "Treatment" pillar of the plan, and only 10.8% of the budget was assigned to the "Prevention and Early Intervention" pillar (679).

There are a number of barriers which appear to contribute to the difficulty in being able to transition away from a clinical treatment-approach to mental health problems, to a focus on mental illness prevention, mental well-being promotion, and tangible public mental health solutions for youth psychological well-being. For example, Rittel and Webber argue that the roles and responsibilities of public health professionals and policy-makers historically entailed addressing problems which were easily defined and largely uncontested (680). Examples of these problems include the eradication of infectious disease, improving the provision of clean drinking water, and ensuring hygienic living conditions (681). These are known as "tame problems", meaning they are (1) easily defined, (2) the causes are primarily determined through scientific data, (3) the task is complete once the problem has been solved, and (4) scientific protocols can be used to help guide a choice of action or solutions (471). A classic example of a tame problem is London's cholera outbreak and the Broad Street Pump (471). Through John Snow's work, the problem was defined (cholera outbreak), proximate causes were determined through scientific data (epidemiologic mapping of disease and water sources), the task was complete once the source of the problem had been addressed (removal of pump handle), and this approach pioneered the development of protocols to deal with infectious diseases outbreaks into the future.

Hunter (682) highlights that traditional problem-solving approaches to tame problems are hierarchical and presume that relationships between potential exposures and health outcomes are unproblematic and linear (681). Similarly, according to Hannigan and Coffey, approaches to solving tame problems are based on “assumptions of order, cause-and-effect and the uncritical use of ‘best practice’ examples” (681). However, as argued by Snowden (683), best practices are often contestable when a problem is more complex; rather, solutions tend to be “emergent” in these situations (684).

In modern societies, and particularly following the epidemiologic transition, the public health problems we face are more difficult to define and are often open to dispute (681). As evidenced by Bronfenbrenner’s socio-ecological model in Chapter 1 of the thesis, youth mental health is driven by a complex system of interdependent factors spanning across various levels of influence (62, 685). Issues around youth psychological well-being are clearly not simple and linear; rather, they may be classified as “wicked problems”. As shown in Box 7.1, Rittel and Webber define wicked problems by 10 central properties (680). Overall, wicked problems may be viewed as resistant; definitions of the problem and potential solutions are often contestable, actions which were successful in one setting may not be appropriate in another, evidence to guide change is often open to challenge, and the interrelatedness of these problems means that the range of solutions which might be actioned in any given case is large (681). Kreuter and colleagues also emphasise that wicked problems, like complex environmental health problems, involve stakeholders with conflicting interpretations of the problem and the relevant science, given each have diverse values, goals, and experiences (471). Those with a vested interest will view the wicked problem uniquely, depending on a range of social and political factors, as well as the perspectives and biases they bring (471).

Box 7.1 Ten properties of wicked problems (Rittel and Webber 1973, pp161 – 166)

1. There is no definitive formulation of a wicked problem: *problems and solutions are inextricably linked.*
2. Wicked problems have no stopping rule: *work terminates based upon outcomes such as running out of time or money, or upon subjective criteria such as 'that's good enough'.*
3. Solutions to wicked problems are not 'true-or-false', but 'good-or-bad': *there are no criteria to judge whether an outcome is 'correct', and outcomes will often be ambiguous and contingent upon group or personal interests.*
4. There is no immediate and no ultimate test of a solution to a wicked problem: *solutions will generate 'waves of consequences' which may outweigh the benefits of the solution, and which may not be fully appreciated until the repercussions cease.*
5. Every solution to a wicked problem is a 'one-shot operation': *because there is no opportunity to learn by trial and error, every attempt counts.*
6. Wicked problems do not have an exhaustively describable set of potential solutions: *there are no criteria to prove that all solutions have been identified and considered.*
7. Every wicked problem is essentially unique: *despite similarities between previous problems and current ones each has a 'one-of-a-kind' quality.*
8. Every wicked problem can be considered to be a symptom of another problem: *the higher the level of problem formulation the broader and more general it becomes*.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways: *there is no rule to determine the 'correct' explanation of a problem.*
10. The planner has no right to be wrong: *the consequences of actions matter, and responsibility has to be taken.*

Exploring the role of screen time as a determinant of youth psychological well-being provided some insights into the complexity of dealing with wicked problems. While screen time is just one contemporary piece in the puzzle, it is non-linear and complex, demonstrating why it can be difficult to address youth mental health problems with public mental health solutions. For example, the research undertaken as a part of this thesis suggests that different types of screen activities (e.g., television, social media, videogames) are associated with different psychological outcomes for young people at different developmental stages of life (e.g., young children, schoolchildren, adolescents), and preliminary evidence suggests that young people from low socioeconomic backgrounds may be disproportionately affected by negative impacts of screen time. These points are further complicated by the contexts in which screen-based activities are used; whether they are used in educational settings, recreationally with friends, alone at night-time, or with the guidance of parents, will potentially result in different psychological consequences. In the global context of the pandemic, screen time served an important role for social connection, information sharing, education, and employment continuation in some cases. Whether screen time is accompanied by adequate sleep, physical activity, in-person social connections, and a diversity of activities, experiences, and interactions which support appropriate development, or whether excessive screen time displaces these factors, is also important to consider.

The *rapidly changing* landscape of contemporary digital technologies further complicates how psychological consequences for young people may be addressed. By the time policy-makers and practitioners come up with guidelines and recommendations for healthy screen time, new technologies have emerged and *the problem has once again changed*. For example, at the beginning of this thesis the social media platform *Tik Tok* was in its infancy, but by April 2020 it had been downloaded more than 2 billion times (686). Importantly, almost half of the users on Tik Tok are aged 16 – 24 years, with popularity increasing among 10 – 12-year-olds (687).

Screen time guidelines were originally informed by research mostly concerning television watching and were developed to reduce sedentary leisure time, an important determinant of childhood obesity (366). However, with the availability of portable technologies which permit Internet access, contemporary youth now report watching less television than previous cohorts (688) and the number of people using social media platforms has increased considerably over the past two decades (as shown in Figure 7.2). As discussed in Chapter 3, screen time guidelines informed by older screen modalities may not be relevant to contemporary youth or their psychological well-being. There is a need to constantly update this work and consider screen type and content in addition to screen time duration when developing guidelines for psychological well-being.

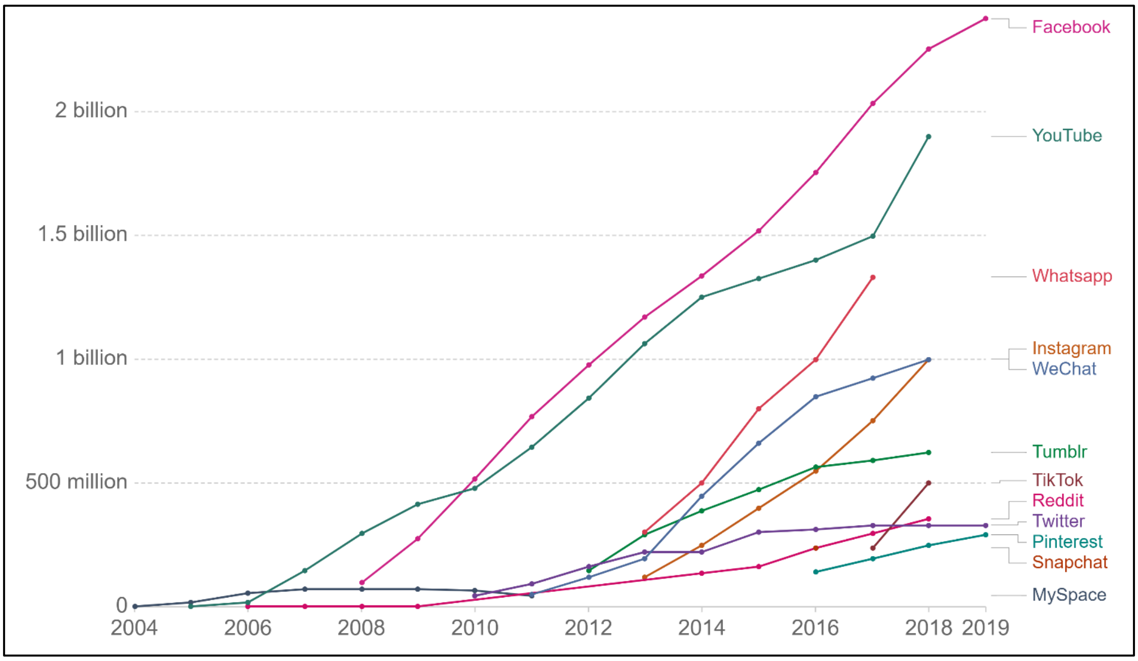

Figure 7.2. Number of people using social media platforms, 2004 to 2019 (presented by Ortiz-Ospina, 2019) (689)

The role of stakeholders and those with vested interests is also important to consider when thinking about screen time and youth psychological well-being. A discussion of the breadth of stakeholders across multitudes of digital technologies is beyond the scope of this thesis, however, social media may be used as a brief example. Social media is now an integral tool to many businesses for product marketing and customer engagement (690). Research shows that the use of social media platforms can enhance communication between potential customers and businesses, build trust, and ultimately increase purchase intensity (691). The use of "influencers" on social media is also common in product marketing (692). An influencer is a famous or popular person who is sponsored to endorse and promote products on Instagram (or similar platforms). Influencers are commonly used to influence adolescent purchasing intentions and have shown to be effective (692, 693). As discussed in Chapter 5, these influencers often promote unattainable lifestyles and ideals of physical beauty. In 2021, documents of internal research by Facebook (owner of Instagram, now known as Meta) were leaked. These documents revealed that the company is aware that the platform is a powerful engine for social comparison, which contributes to poor body image among teenage girls (694).

Politicians and the public sector also heavily rely on social media to communicate their messages (695). A clear example of this was the most recent U.S. election campaign and presidency, in which Donald Trump utilised Twitter as part of his "brand" and political strategy (696). An Internet search of the phrase "Trump tweets", by Ouyang and colleagues in 2019, returned more than 1.4 billion results, including over 53 million news articles (696). Social media has been referred to as "consumer-generated media", meaning without users' participation it ultimately has no content or value (690, 697). This emphasises the need to keep consumers engaged and participating. This outline shows the significant stake or vested interest that the founders, their companies, other businesses, and politicians have in social media use. Proliferation of social media use (despite some known negative impacts) may serve them well in terms of potential profit and audience reach, while reduced use would have implications for their success.

Many education systems around the world now rely on digital technologies to deliver their curriculum (176) and the mental health sector arguably has a stake in the issue as well. Many mental health services, particularly youth organisations, rely on online format options (e.g., chat rooms) to support patients at either end of the spectrum of distress – from those requiring low intensity intervention, to those in imminent crisis. The reliance of the mental health sector on the benefits offered by technology was advantageous during the pandemic, when access to in-person services was compromised.

The great complexity of wicked problems – like the issue of screen time and youth psychological well-being as demonstrated above – in conjunction with problem-solving approaches historically used for tame problems in public health, means that these issues are at risk of being "chucked into the 'too difficult to solve' category", as described by Hunter (681, 682). This sentiment may be central to the challenge in moving upstream to public mental health solutions for youth mental health problems. It may also explain why funding is typically channelled into treatment of mental illnesses – we know that mental illnesses *can be defined* based on criteria in the DSM-IV, the *causes can often be determined* through clinical assessment, and a number of *evidence-based* psychotherapies (or medications) can be *used to guide* possible treatments with an individual. Essentially, the dominant treatment-approach to youth mental health problems may reflect the preference and ability of policy-makers and practitioners to tackle problems that are tame. However, it is critical to note that where youth mental illness is not a tame problem, and cannot be addressed by this treatment-approach, is that *the task is not complete once the problem has been solved*, because maintaining good mental health is an ongoing accomplishment. A diagnosis and treatment of a mental disorder does not signal the closure of this problem. As discussed in Chapter 1, experiences of poor mental health in childhood and adolescence are associated with poor mental health across the lifespan and relapse is common, meaning individuals and societies experience ongoing social, health, and economic burden.

When it comes to wicked problems, Chapman (698) argues that governments need to think differently to deal with the complexity and interrelated parts of these issues (681).

Problem-solving approaches to wicked problems, including youth mental health issues and public mental health solutions, require what is called “systems thinking”. According to work by Haynes and colleagues in the Australian Prevention Partnership Centre (699), systems thinking is defined as “a way to make sense of complex systems that gives attention to exploring the relationships, boundaries and perspectives in a system” (684). Systems thinking embodies a “worldview” which considers the whole, the parts, and their interplay, keeping the interdependencies of components of the problem in the forefront (471). As emphasised by Langellier and colleagues (685), systems thinking is a useful approach for demonstrating social and ecological determinants of individual- and population-level mental health outcomes, and subsequent implications for policies and interventions. Systems thinking is also especially useful for highlighting feedback loops and bi-directional relationships which tend to be prominent in the pathogenesis of youth mental health disorders (685).

Importantly, systems thinking goes beyond just health systems and does not largely rely on expert driven solutions (471). Given wicked problems are inherently complex, comprising of multiple factors, forces, and potential solutions, it is necessary to seek transdisciplinary involvement and incorporate stakeholder engagement in the problem-solving process (471). This speaks to the *Health in All Policies* collaborative approach, which recognises that most public health challenges exist and can be addressed outside of the health sector, and thus aims to consider the health implications of policies and decisions made across all relevant sectors (700, 701). In problem-solving related to screen time and youth psychological well-being, intersectoral collaboration between policy/decision-makers, practitioners, and researchers across public health, clinical psychology, medicine, education, and relevant media bodies such as the Australian Press Council, would be particularly useful. There also needs to be some accountability from media companies, and there seems to be growing recognition of this (e.g., recent pressures on Facebook in the U.S.). In the case of green time and youth psychological well-being, it would be important to collaborate across public health, clinical psychology, medicine, urban design and planning, and environmental agencies, for example. Kreuter et al. state that “this process allows wicked problems to be broken down into more manageable components, many of which are likely to be amenable to tame problem-solving strategies” (471).

Notably, Conklin (472) further emphasises that wicked problems are best solved when *scientific uncertainty* or conflict is tempered by perspectives of community stakeholders (471). This is especially relevant in the case of screen time and youth psychological well-being, where there is contention about the psychological impacts of screen time in the scientific literature. As highlighted throughout the course of this thesis, there are notable conflicts about whether it is the *quantity or quality* of screen time which is most important to consider, whether associations between screen time and psychological outcomes are *causal (and directions of causation)*, and debates about whether screen time should be referred to as *addictive or simply a habit*.

Young people themselves (as well as parents and educators) should have the opportunity to *identify specific issues* related to screen time and psychological well-being which are relevant to them, and have the opportunity to engage in generating solutions. According to the Royal Commission into Victoria’s Mental Health System (702), co-design methods should be used to meaningfully involve young people in the planning and execution of mental health solutions (which could extend to issues pertaining to screen time, green time, and psychological well-being). Co-design is an approach which is being used increasingly – it brings together those with professional expertise (e.g., mental health clinicians and researchers), and those who have “lived experience” of the issue (e.g., young people, parents, and educators), on equal ground, to design solutions (700, 702, 703).

To give an example specific to screen time and psychological well-being, as discussed in Chapter 5, qualitative research seeking the perspectives of young people has highlighted that adolescents view social media as a kind of “addiction” and a threat to their mental well-being (476). Similarly, in the randomised pre-post pilot study (Chapter 6), almost 70% of high school participants reported feeling as though they spent too much time on their smartphones. Yet, many researchers (536, 558) are cautious about using the term “addiction” and prefer to conceptualise excessive technology use as a “media habit”. Allowing the perspectives and lived experiences of young people to be heard where there is scientific conflict, is an important part of dealing with wicked problems through systems thinking. A failure to do this may hinder progress towards systems change and young people may not receive the support *they feel they need* because of the barriers instilled by scientific language, uncertainty and debate.

Despite increasing use of complex systems approaches in other areas of public health and health promotion, few applications have extended to mental health (685). One key barrier is the siloed nature of government departments and research institutes, making it difficult to foster intersectoral collaboration and facilitate the transdisciplinary stakeholder engagement which is central to systems thinking (700). Furthermore, the use of community perspectives to move forward, despite scientific uncertainty, may be uncomfortable terrain for those whose fields rely on evidence-based practice. However, as argued by Tawa, some evidence-based approaches may lack relevance to certain groups and contexts, thus lived experience should be seen as evidence itself to ensure solutions are considered appropriate by those the issue affects (704).

Lamont (705) also reminds us that in real-world settings policy-makers are embedded in a culture which emphasises accountability and impact (684). This culture can cause tension for policy-makers who are grappling with wicked problems as it perpetuates a desire for “best practices" which will lead to measurable impact (684, 705). However, we know that wicked problems are more resistant than tame problems, and problem-solving through systems thinking requires considerable time and ongoing iterations to ensure *emergent practices* are relevant, appropriate, and *address problems arising*. Although necessary for tackling wicked problems, this kind of approach does not translate to the demonstrable impacts required in short-term political election cycles. Properly engaging in a systems thinking process with input from multiple sources takes time and requires patience to observe measurable impacts, but the long-term social and economic benefits of this will exceed the efforts and costs involved in the process (471). There is a need for governments to invest in and commit to continuity of planning and managing complex problems which will have long-term benefits for population health, beyond their short-term political cycles.

7.2.2 Disciplinary discrepancies in standards of evidence: from empirical perfectionism and causation criteria to the precautionary principle

Researching *psychological problems* of major *public health importance* also presents a number of challenges. A public health psychology research approach can be useful for this kind of research, in which strengths of psychology and epidemiology are married, alongside considerations of social justice and health equity. However, differing standards of evidence across disciplines can still make it difficult to move research fields forward, and ultimately further perpetuate the lack of real-world change seen in arenas of policy and practice. These barriers were particularly salient when researching screen time and green time as determinants of youth psychological well-being, across a variety of study designs; from a systematic scoping review (Chapter 3) to a national cross-sectional study (Chapter 4), a theoretical study (Chapter 5), and a randomised pre-post pilot study (Chapter 6).

As outlined in Chapter 2, in the pursuit of positioning psychology as a discipline firmly rooted in the scientific method, experimentation historically became the foundation of much psychological research (155). True experimental research designs, which capitalised on variable manipulation and random assignment to conditions, were touted as the only way to confidently assert causation between an exposure and outcome variable (155). Outside of psychological research, alternative criteria for establishing causation also exists in epidemiology research, developed to reflect the use of observational data in circumstances in which experiments with humans could not be undertaken. In 1965, Sir Austin Bradford Hill published nine "aspects of association" which he claimed could be used to help determine whether associations between exposures and outcomes were causal (706, 707). While the Bradford Hill Criteria were never intended to be viewed as rigid criteria for causation, they are still upheld as the most valid conceptual framework for deducing causal inference in contemporary epidemiology research (outside of clinical epidemiology) (706). Consistent with views in psychological research, clinical epidemiologists position the Bradford Hill criteria *experimental manipulation* as providing the strongest support for causal inference (706).

While experimentation permits the minimisation of confounding factors and solves the issue of individual differences, this precision of information about causation is also at risk of being generalisable only to a narrow range of (often unrealistic) situations and specific groups of people (such as high SES participants). Furthermore, the standard principles of experimental design, including experimental manipulation, random assignment, and control of confounding factors, may result in the exclusion of the very conditions and factors that make the problem what it is in real-world settings (471). This potential lack of realism, leading to poor external validity, is the main critique experimental designs attract (156).

The randomised pre-post pilot study conducted as a part of this thesis met these criteria around what makes gold standard evidence for determining causation: experimental manipulation (screen time exposure) and random assignment to condition (indoor or outdoor rest setting) were both conducted, while a procedural protocol was followed to ensure all other factors were held constant. While this study design permitted the control of confounding factors and individual differences, the extent to which the findings provided an accurate reflection of what typically occurs in a real-world setting may be questioned. For example, adolescents are more likely to play on their smartphones and watch Netflix at home during their leisure time, rather than play a burst of games on a University computer during their school hours with their classmates and teacher present. This approach to research is largely based on positivistic assumptions, dividing and categorising participants, activities, and outcomes into measurable units, which diminishes the relative importance of the real-world contexts in which these activities take place and relationships exist (708).

Beyond issues surrounding external validity, the pursuit of empirical perfectionism may not always be practical when researching psychological problems of major public health importance. As discussed in Chapter 2, these experimental or intervention-based study designs are typically used in psychological research when trying to measure medium-to-large effect sizes (154). For example, intervention approaches were previously used to establish the efficacy of behavioural therapies for phobias, using less than 25 patients per experimental group (154). However, when researching determinants of youth psychological well-being, like screen time and green time, effect sizes may be considerably smaller, requiring large samples and a commensurate increase in costs and logistics to achieve adequate statistical power (154). The randomised pre-post pilot study conducted as a part of this thesis was time-consuming and costly, yet statistical power was not reached. In light of the absence of evidence to inform the design, the purpose of the randomised pre-post pilot study was ultimately to generate preliminary evidence that would inform a larger, appropriately powered trial. While this kind of research is resource intensive, it is important to understand that it is worthwhile, as factors which contribute a small amount of variance in a psychological outcome may still have a significant impact on the psychological well-being of populations as a whole and effect sizes may be larger in certain sub-groups (like groups from low SES backgrounds) (154). These kinds of pilot studies are critical to advance the field and provide evidence to inform policy and provide a basis for more substantial funding.

In the medical world, pharmaceutical companies will invest billions of dollars in these gold standard trials to determine the efficacy of different treatments, and ultimately reap benefits from sales down the line (709). But the question remains around who would invest in these kinds of studies for public health matters. While it is the populations that would gain longer-term benefits from investment in our social and environmental settings, like funding urban greenspaces for example, it is harder to directly measure these benefits, thus it is not prioritised on research agendas. Biomedical formulations of disease processes and a lack of emphasis on social determinants of health leads to favouring investment in basic and applied science, with the aim of improving potential treatment options (681), rather than investment in preventive public health research which aims to improve the underlying circumstances which can determine psychological well-being in societies. In Australia, public research funding tends to favour basic or clinical science, while funding for preventive health research is limited. For example, in 2020, less than 20% of the overall *Investigator Grants* from the *National Health and Medical Research Council* were allocated to the broad research area "public health", while the rest went to basic science (30%), clinical medicine (42.2%), and health services (8.4%) (710).

When thinking about these costly gold standard trials or experiments, in many circumstances it is also not possible or ethical to manipulate environmental variables or randomise individuals to certain conditions, especially when working with young or vulnerable populations. Thus, researchers in epidemiology must rely on other research designs outside of experimentation. For example, well-conducted population surveys, which capitalise on random sampling and use validated measures, can help to identify a sample of individuals who are representative of a population of interest and provide meaningful insights into determinants of psychological well-being. However, population surveys are typically cross-sectional and rarely allow researchers to make causal statements about associations between variables of interest. Nevertheless, these kinds of studies can still be useful for gaining an understanding about associations in a population at a specific point in time and identify areas where more research (such as longitudinal studies which address temporality) is warranted. Importantly, the direction of causation for some variables could also be judged or interpreted in light of existing research as well. The national cross-sectional study conducted as part of this thesis was able to achieve this; a range of determinants associated with various mental health states in the context of the pandemic were identified in a timely fashion, highlighting where ongoing research and focus is required to ensure good psychological well-being for young Australians as we shift into the "living with COVID-19" phase of the pandemic. In this study, it was far more likely that precarious employment led to poorer mental health, rather than the other way around, so some tentative judgements about causation could be drawn in this circumstance.

These non-experimental studies may also be critiqued because they typically use self-reported measures, which, as seen through poorer study quality ratings in systematic reviews (127, 128), are seen to be inferior to objectively measured exposure and outcome variables. However, evidence obtained from these types of self-report measures should not be discounted. For example, in the case of the randomised pre-post pilot study conducted as a part of this thesis, it is likely that self-reported measures of cognitive difficulties would have been more relevant to real-world emotion regulation capabilities than the objective computer-based cognitive batteries that participants completed (244, 352). Currently, there is a need to keep working towards determining gold standard approaches for conceptualising and measuring screen time duration and content exposure; therefore, self-reports are still an important way to gauge typical screen time (151). Ecological momentary assessment (EMA) offers a novel and promising approach to measuring young peoples' daily screen time, and is being used increasingly in research. EMA involves repeated sampling of a participants' current behaviours and experiences in real-time and in their natural environments, using written diaries, phone prompts, electronic reminders, or physiological sensors (711). EMA assists in minimising recall bias, maximising ecological validity, and allows for the study of behaviours in real-world contexts, rather than under unrealistic experimental conditions (711).

Discrepancies in the benefits and drawbacks offered by experimental and non-experimental study designs may be overcome by undertaking a *multi-method research program* which maximises the desirable research qualities each can offer (156). Specifically, as was done in this thesis, diverse study designs which address the same research aim, but operationalise the exposure and outcome variables of interest in different ways, can provide important understanding and insight into an issue. While some studies may be able to provide superior information about causality (e.g., the randomised pre-post pilot study), others will give insights into sub-groups that require further attention (e.g., youth from low SES backgrounds in the systematic scoping review), broader trends that could be addressed (e.g., national cross-sectional study), and possible mechanisms underpinning observed findings (e.g., theoretical study).

In addition to multi-method research programs, Fedak and colleagues (706) argue that the criteria for determining causal inference must change as the world of epidemiologic research has evolved and expanded. Specifically, when Bradford Hill created his famous criteria for causation, diseases were understood on a more elementary level than they are in modern science. We now have a greater understanding of the complexity behind disease onset and progression (706), and, in modern psychological and public health research, researchers face complex health issues that involve a multitude of social determinants, meaning Bradford Hill's criteria cannot always be applied to determine causation. Like historic problem-solving approaches suited to tame problems, this historic approach to assessing causation may need to become more nuanced in research around contemporary determinants of youth mental health.

To demonstrate with examples, three of Hill's criteria for causation are (1) Strength of the association, (2) Consistency of the association, and (3) Temporality. Each of these criteria present issues for causal inference in research pertaining to screen time, green time, and youth psychological well-being. The *strength of the association* criteria states that the larger an association between an exposure and health outcome, the more likely it is to be causal. However, health states are often multi-factorial, and in the case of screen time and youth psychological well-being, several factors must be considered when assessing the relationship, including the type of screen activity being engaged with (e.g., passive vs. interactive) and the context in which use occurs (e.g., alone at bedtime vs. under parental guidance). Furthermore, the confidence interval, which provides a range of possible magnitudes of effects, is now the accepted benchmark for judging an association in modern epidemiology. Importantly, risk factors that are small in magnitude can still be convincingly linked (and meaningful from a population-level perspective). It is also important to note that statistically significant results are not always biologically or clinically meaningful, and a failure to mathematically demonstrate statistical significance in one study does not prohibit the possibility of a true causal relationship in reality.

Consistency of the association suggests that the association should be repeatedly observed in different study populations, in different places, circumstances and time-points. While this criterion is very useful for identifying causal relationships between screen time, green time, and psychological well-being, Bradford Hill's original concept of consistency involved repetitive *epidemiologic findings*. Repetitive epidemiologic studies may fail to take important psychological processes into account and could limit our understanding of relationships. Rather, repeated findings across different disciplines and methodologies would provide more valuable insight.

Temporality means that for a relationship to be causal, exposure must precede the onset of the health outcome. This criterion works well for disease states that are binary, but is problematic for measures of health that are on a continuum, or in cases where both the exposure and outcome are ongoing aspects of daily life. Specifically, it is not possible (or ethical) to guarantee that screen time and green time will not precede the onset of any psychological state – young people cannot be raised without these exposures in contemporary society. Low-level exposure to different screen-based technologies and natural environments will occur over childhood and adolescence, even where purposive use or engagement is limited. This can make designing a traditional longitudinal epidemiologic study, in which temporality is clearly established, a costly, time consuming, and possibly unfeasible task. Panel studies are one way to address this.

To overcome these issues, a shift towards a *data integration approach* is necessary for causal inference in 21st century public mental health research (706). Data integration involves the amalgamation of data, knowledge, and evidence from a *variety of scientific disciplines* when evaluating causation, with the aim of creating a level of understanding that no discipline could achieve alone (706, 712, 713). For example, assessing strength of association in causal inference would require examination of underlying methods, comparison of the weight of evidence in the literature, and consideration of other contextual factors relevant to the relationship under investigation. Data integration approaches also view consistency in a much broader way; consistency is thought to be achieved when similar understandings of a relationship between an exposure and health outcome are seen across multiple disciplines or practices. This integration of results across studies from different scientific disciplines can highlight various mechanistic points along the causal pathway. For example, environmental and cognitive psychology studies may illuminate the mechanisms in the brain through which nature can encourage stress reduction, while cohort studies may show that young people living in (or moving out of) green neighbourhoods experience changing levels of stress.

These multi-method and data integration approaches were seen in the systematic scoping review conducted as part of this thesis. The review included *diverse study designs from a variety of disciplines*, each conceptualising and measuring screen time, green time, and psychological outcomes in different ways. Despite the challenges this presented in terms of synthesising the evidence, this study allowed different study designs and sources of evidence to be compared and contrasted, and this triangulation of evidence was useful for overcoming the limitations associated with interpreting evidence from experimental or non-experimental study designs in isolation. As discussed in Chapter 3, it also provided some grounds for accepting that the associations between screen time, green time, and psychological outcomes were not artefacts; the abundance of findings and their relative consistency in terms of mostly favourable associations between green time and psychological outcomes and mostly unfavourable associations between screen time and psychological outcomes, suggest that the associations were not chance findings and were possibly causal.

In addition to these approaches, the theoretical paper included in the thesis (Chapter 5) also discussed the *precautionary principle* in relation to screen time and youth psychological well-being. Uncertainty about health risks pertaining to different exposures in environmental health and epidemiology research gave rise to the concept of the "precautionary principle", which argues that scientific certainty should not postpone preventive measures (471). It involves the creation of policies and preventive action in the face of scientific uncertainty, to protect population health, and encourages public participation in decision-making (471). Essentially, the precautionary principle is useful for protecting population health against a backdrop of scientific uncertainty. The importance of youth mental well-being, in terms of health and opportunities across the lifespan, as well as the ubiquitous presence of screen time in contemporary life, necessitates a precautionary principle approach to public policy concerning screen time.

7.3 Strengths and limitations

A number of strengths and limitations pertaining to the research conducted as part of this thesis should be considered. The specific strengths and limitations of the four studies were discussed in the preceding study chapters (3, 4, 5, and 6), and are also summarised in Table 7.1.

When considering the thesis as a whole, one of the main strengths is that the research topic studied was highly topical and relevant for young people and a range of other stakeholders in contemporary society. Interest in this topic across a variety of disciplines and professions was reflected in the number of presentation invitations I received during my candidature, from a breadth of diverse organisations (see beginning of thesis for list). As discussed in Chapter 5 and section 7.2.1 of the thesis, young people have also discussed their concerns around screen time and psychological well-being. Therefore, addressing an issue which young people have identified as relevant themselves is an important strength of the thesis. Public interest in this research topic was also demonstrated following the publication of my systematic scoping review. The publication was covered by approximately 135 media sources worldwide and currently has an *Altmetric* attention score of 432, placing it in the top 5% of all research outputs worldwide in terms of media and public interest.

Another strength of the thesis was the public health psychology approach underpinning the research, which incorporated a diversity of study designs, as well as an emphasis on theory and coherence with existing psychological research. This approach capitalised on the methodological and empirical strengths offered by epidemiology and psychology, and also ensured issues of social justice, health equity, and public mental health solutions were addressed. This approach is especially appropriate for researching psychological issues of major public health importance and highlights the benefits of cross-disciplinary and multi-methods research, no matter the determinants under investigation. It allowed for in-depth thought and discussion around the barriers and challenges to enacting public mental health solutions, particularly the importance of systems thinking with wicked problems. A critical discussion on disciplinary discrepancies and practical challenges in standards of evidence also illuminated why research agendas may continue to favour investment in basic and applied science that aims to develop (measurable) treatment options, over investment in preventive public health research which would provide longer-term (hard to measure) benefits for populations, through improvements in the social and environmental settings which can determine psychological states.

The overarching limitation of the work contributing to the thesis was the disruption caused by the COVID-19 pandemic. My overall research plans were significantly impacted in the context of the pandemic. As discussed previously, competing priorities meant that the South Australian Department for Education could not provide the required data to schedule for the planned longitudinal study in my thesis. Restrictions around contact with human participants also meant that recruitment of adolescents to participate in the randomised pre-post pilot study was delayed. This ultimately reduced the number of schools I could engage, and subsequent study sample I could recruit, in the remaining timeframe. The nature of my research topic was also impacted by the pandemic more broadly. For example, lockdowns, restrictions, and immeasurable loss (in a number of ways) during critical life stages, meant that many young people's psychological well-being was impacted during my PhD in ways that could not be comprehended in a pre-pandemic world. The role of screen time and green time in young people's daily lives and routines inevitably changed as well.

Despite the challenges caused, these limitations may also be viewed as strengths. For example, the pandemic significantly changed the way we view and discuss mental health across societies more broadly. It highlighted the critical need for public mental health solutions which address social and ecological determinants of mental health, in addition to the clinical person-based responses the Australian health system currently emphasises. This made my thesis increasingly relevant as the years progressed. The challenges brought about by the pandemic also helped me to become a more adaptive researcher over time. For example, I learnt the importance of being flexible as evidenced through reconfiguring my second study within a very short timeframe, and I also was able to learn in real-time about the need to ensure that my research was relevant, and thus translational, to real-world contexts.

Table 7.1 Main strengths and limitations of the studies conducted as part of the thesis

Main strengths	Main limitations
Study 1: Systematic scoping review	
• This was the first review to collate evidence about the effects of both screen time and green time on child and adolescent psychological outcomes (including poor mental health, positive mental health, cognitive functioning, and academic achievement) • Findings were presented by age group, carefully considering the social and biological nuances of different developmental stages • Study designs and analysis plans in the existing literature were critiqued, to investigate the basis for causal links and potential underpinning mechanisms/pathways • The role of socioeconomic status (SES) was closely considered, as the extent to which associations between screen time, green time, and youth psychological outcomes hold across the spectrum of SES was explored • The review attempted to delineate reciprocal effects of screen time and green time on youth psychological outcomes • The review included a discussion of the possible psychological impacts of different types of screen time (interactive versus passive) and green time (purposive versus incidental)	• Inability to fully synthesise and systematically appraise included studies, due to substantial heterogeneity across included studies • It was beyond the scope of the review to discuss the magnitude of the effects of screen time and green time on psychological outcomes; the disparate ways exposure variables were measured in the included studies made it difficult to make these comparisons • The review focused upon screen time duration rather than content; therefore, it was not possible to comment on the differential effects of specific content, such as violent videogames and educational TV programs • The review was limited to articles published in English • I may not have identified all relevant studies, despite attempts to be as comprehensive as possible; this may be due to the inconsistent terminology used in describing and indexing screen time and green time

Study 2: National online cross-sectional study	
• This study was highly relevant to the global context and focussed on young Australians; a group that was underrepresented in the literature and disproportionately psychologically affected by the COVID-19 pandemic • Unlike other COVID-related studies which focused on the presence or absence of psychological distress only, mental health was conceptualised holistically in the study; indicators of mental well-being and mental illness were included through the Complete State Model of Mental Health • Quota sampling was used in an attempt to capture a sample which covered a spectrum of parameters balanced by gender, state/territory, and SES, meaning the final sample had strengths in terms of size and participant diversity • Recommendations were made for a range of preventive strategies which target mental health risk factors and enhance protective factors for young Australians in the context of the COVID-19 pandemic	• It was not possible to generate a random sample of young adults for an online survey directly from electronic contact details, due to the lack of a sampling frame, thus a convenience sample was used • Due to the cross-sectional nature of the data, the direction of associations remains uncertain • Likewise, causation could not be claimed and there was likely bi-directionality • The changing context of the COVID-19 pandemic (including cluster outbreaks and snap-lockdowns) may have affected participants' mental health at the time of response • Some of the relative risk ratio estimates should be interpreted with caution, where wide confidence intervals were present as a result of sparse data
Study 3: Theoretical paper and conceptual model	
• A new conceptual model was developed • Various bodies of literature were addressed, including: biopsychology, clinical, cognitive, developmental, educational, health, evolutionary, and social psychology, neuroscience, and public health	• Some of the writing was necessarily speculative • It was difficult to do justice to the material in the word limit

• A number of key connections around links between digital technology use, self-regulation, and mental health in adolescence were examined and justified • These examinations involved looking at the addictive properties of digital technologies, the impact of media multi-tasking, and consequences of pervasive exposure to social and emotional content online • Each of these examinations were considered within the context of contemporary patterns of adolescent socialisation, and developmental and evolutionary neurobiology • Suggestions to help develop and strengthen self-regulation, as well as support youth mental health in a high-tech era, were provided	
Study 4: Randomised pre-post pilot study	
• This study was the first to test the proposition that green time may buffer the acute psychological impacts of screen time, making a novel contribution to the existing literature • The study added to the sparse experimental evidence base pertaining to screen time and psychological outcomes • The study was a randomised pre-post pilot study, following the CONSORT-SPI checklist to ensure rigor and reduce bias • Participants were randomised to resting conditions (indoors or outdoors) • The indoor and outdoor groups were comparable at baseline on relevant sociodemographic, lifestyle, and outcome variables • Validated, computerised measures of sustained attention and inhibitory control were used	• It was not possible to adequately determine beforehand what screen activity or exposure timeframe would be required to potentially observe an acute deficit in cognitive performance, because this is not clearly articulated in the literature • The addition of self-reported indicators of attention and inhibition would have provided an important perspective • The use of alternative tasks which more adeptly capture the integration of the cognitive components required for emotion regulation in real-world experiences would have provided more meaningful outcomes • The outcome measures could have been supplemented with physiological indicators of emotion regulation (e.g., heart rate variability) for greater convergent validity

• A procedural protocol was closely adhered to • A number of conceptual and methodological lessons were learned to inform future research in this field	• Participation in the study in a novel and exciting environment may have affected participant performance/outcomes, and limited external validity • A greater number of trials on the Stop Signal Task may have provided a more reliable measure of inhibitory control • Whether participants had a previous diagnosis of ADHD/ADD should have been considered • It was not possible to a priori calculate a sample size required to detect changes in cognitive performance after a period of screen time; this was due to a lack of information in the available literature, meaning expected effect sizes could not be ascertained

7.4 Conclusion

Mental health problems are the leading cause of reduced quality of life among young people globally, and prevalence is increasing. From a public health perspective, it is important to prevent mental illness and promote mental well-being in young people, given this is a developmental period which can determine an individuals’ mental health trajectory across the lifespan. Identifying and addressing risk and protective factors for youth mental health is central in achieving this. This thesis has shown how screen time and green time are an important part of this response and illustrate where this change is invited. In line with the precautionary principle, it was argued in this thesis that we cannot wait for scientific certainty and the availability of perfect data to take actions which protect youth psychological well-being. Rather, we need to listen to the needs of young people and invest in the underlying social and ecological factors which can determine young peoples’ psychological states. Overall, we require a shift away from solely relying on clinical responses to youth mental health problems as they arise. Further rigorous research into the potential psychological benefits of green time for young people living in a high-tech era is warranted.

CHAPTER EIGHT: REFERENCES

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CHAPTER NINE: APPENDICES

Table 9.1 Appendices for the thesis

Appendix Number	Description	Chapter Number
1	Aim 2 – Approval letter from the South Australian Department for Education	2
2	Pilot Study - Protocol	2
3	Relevant items from the CONSORT-SPI checklist used in the pilot study	2
4	Preview of publication in *PLOS ONE* – Psychological impacts of “screen time” and “green time” for children and adolescents: A systematic scoping review	3
5	Systematic Scoping Review S1 File – PRISMA-ScR Checklist	3
6	Systematic Scoping Review S2 File – Search strategies for review	3
7	Systematic Scoping Review S3 File – Descriptive characteristics of studies included in the systematic scoping review	3
8	Systematic Scoping Review S4 File – Results from studies including mixed age groups	3
9	Preview of publication in the *International Journal of Environmental Research and Public Health* - Mental Health of Young Australians during the COVID-19 Pandemic: Exploring the Roles of Employment Precarity, Screen Time, and Contact with Nature	4

APPENDIX 1

Government of South Australia
Department for Education

System Performance
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Education.ResearchUnit@sa.gov.au
www.education.sa.gov.au

Reference No: 2018-0071

Ms Tassia Oswald
Health and Medical Sciences
University of Adelaide
Level 2 Helen Mayo North Building
Frome Road
ADELAIDE SA 5000

Dear Ms Oswald

Your research project *"Examining the relationships between screen time, mental health, and academic achievement in primary and secondary students in South Australia"* has been reviewed by a senior officer within our department.

You application requests access to wellbeing and academic achievement data for 2016 and 2017 which has previously been supplied to Dr Zohra Lassi of the University of Adelaide.

I am pleased to advise you that your application to access the de-identified dataset provided to Dr Lassi has been approved, subject to the following conditions:

- That a copy of any final reports, presentations or manuscripts accepted for publication be submitted to the Education.ResearchUnit@sa.gov.au mailbox 30 days prior to their publication.
- That the Department for Education is notified when findings are to be released to other government or nongovernment agencies or to participating sites.
- Data access to be restricted to those researchers listed on the application form and data to be managed as detailed in the application form.

Please contact Betty Curzons in the Business Intelligence Unit for any other matters you may wish to discuss regarding your application (Tel. (08) 8226 0809 or email: Education.ResearchUnit@sa.gov.au).

I wish you well with your research.

Ben Temperly
EXECUTIVE DIRECTOR, SYSTEM PERFORMANCE

25 July 2018

APPENDIX 2

Pilot Study – Protocol Script

FIRST THINGS

- Meet out front
- Go upstairs to L1
- Show where toilets are
- Go in computer room – instruct participants to sit where there are drink bottles
    - Need even split across conditions

INTRODUCTION

- Introduce self and other RA.
- This is a research study which will be a part of my PhD.
- It is called Screen Time and Chill Time, and we are looking at different brain functions in high school students.
- Participation in the project is completely voluntary – if you want to stop at any point, feel free to close the computer browser. No questions will be asked.
- If you decide to participate in the whole study, know that the school and yourselves individually will be completely anonymous in my PhD thesis and publication.
- We can assure that all data collected will be kept completely confidential.
- This research study has been approved by the University of Adelaide Human Research Ethics Committee and Catholic Education SA, so you can be assured that we are following ethical guidelines while we conduct this research.
- We will be using this script and some signs today as we give instructions, to make sure we are consistent across all of the school groups that come in to do the study.
- If you have any questions today, feel free to raise your hand and we are happy to help.
- I just want to flag with you all that the computers we are working on are not the most flash, so we may run into technical difficulties along the way. Please be patient and we will help troubleshoot any issues which may pop up.
- You will see on your desk that there is a pen, piece of paper, and 2 envelopes.
- Please do not open the envelopes until you are instructed to do so.
- You will see on the paper that there is a username (brainstudy2021) and password to log-in to the computers.
- We logged these in when we arrived, but if they have since signed out could you please sign back in now.
- On the piece of paper, you will see three URLs.
- Today's study is made up of 3 parts.

PART 1 – SURVEY

- I'll ask everyone to please open Google Chrome now and type in the URL for Part 1. Alternatively, you will see a Word document on the desktop of the computer called **Part URLs**– you can copy the URL from there and paste it into the Google Chrome browser.
- Once you have done this, the web page should look like this up the top (show Part 1 place card). Please just wait while I give some more instructions.
- The first thing you will need to do is enter a Nickname in the textbox provided. We are using these nicknames in place of your real names, so that all data collected is anonymous. This nickname should be unique to you. Please write it down on the paper with the URLs as well. You will be using the nickname for parts 1, 2, and 3 today, so this will help you remember it.
- Once you have entered your nickname, the first part of the survey will ask you some questions about your life, as shown here. This will take you between 5 – 10 minutes to complete.
- Once you get to this Please Wait symbol, please wait! Don't close your browser. Don't continue. Just wait for further instructions.
- RA and I will be walking around. We won't be looking at what you doing, we are just keeping an eye out for when everyone has the Please Wait sign on their screen, so we can move onto the next set of instructions.
- If you have your smartphone here with you, you will need it during this survey. If you don't have one with you, that's okay too.
- Okay, now you can go on with this Part 1 survey. If you have any technical difficulties or questions, please just let us know. Please take your time and answer the questions honestly.

PART 1 – TESTING

- Has everyone got the Please Wait sign up on their screen now? Great.
- This next section will take about 10 minutes to complete (show place card).
- First, we will ask you a question about your mood and how sleepy you feel right now.
- You will then do 2 computer tasks.
- Each computer task will begin with a set of instructions and will let you do a practice run before the real task.
- The first computer task is called the SART. The SART goes for 5 minutes – but it can feel like longer.
- In this task you need to press the spacebar on your keyboard for every number that pops up, except the number 3. The instructions will remind you of this again, so no need to worry about remembering right now.
- The second computer task is called the Stop Signal Task. The Stop Signal Task goes for about 3 minutes.
- In this task you use the letter keys B and N on your keyboard to respond to arrows that come up on the screen. Again, there will be instructions and a practice round before the real task.

- The tests will give you some feedback on how you went – you don't need to worry about what this means. Just press the space bar to continue on when it instructs you to do so.
- We ask that you concentrate and do your best in these tasks. Keeping quiet will help with this. It is important to respond as quickly as you can to the prompts on the screen, but it is also important to be accurate in your responding.
- If you have any questions or tech problems, please let us know.
- Again, when you see the Please Wait sign, please wait.
- We will check back in with you all in about 10 minutes.

SCREEN TIME

- Has everyone got the Please Wait sign up on their screen now? Great.
- Could everyone please now open the envelope which is labelled "Do Not Open – ST".
- The ST stands for Screen Time (show place card).
- We will now have a period where we are going to play three games for 10 minutes each.
- The first game is a version of Candy Crush, where you have to line up 3 of the same coloured candies to make them explode. You use your mouse to do this.
- The second game is a version of Angry Birds, except the characters are fish. You use a sling shot to launch the fish at the chickens which you are aiming to hit. You use your mouse to do this.
- The third game is Fruit Break, which is like Fruit Ninja. You use your mouse to slice as many fruits as you can to get points.
- During each 10-minute period you want to get the best score, or to the highest level, that you can. Once the 10 minutes is up, I will ask you to write down your score on the paper and we will move on to the next game block. Please make sure the same nickname from Part 1 is written on the game paper as well.
- Because these games are hosted on free websites you will get ads come up. Please close them or skip them as you can. At no point do you have to sign up to play or enter your email address, so please ignore that too. You don't need to make any purchases to play, so close any pop-ups of that nature or get us to help you if you need.
- When you press next on the browser, it will show a link that takes you out of the survey. Please click this and it will take you to game 1 - Candy Crush.
- Once everyone has it up on their screen, I will start the 10-minute timer, please just wait until everyone has got it. If you could also please turn off the volume that would be great.
- Up on everyone's screen? Great. I'll start the timer. Just have fun with this and feel free to chat with one another.
- **START 10 MINUTE TIMER. PLAY MUSIC.**
- Once timer goes off – stop music. Everyone write down your score on the paper please.
- We will now go on to game 2 – a fish version of Angry Birds.

- You can either type the URL in from the paper you have, or you can open the Word document on the desktop which is titled **Copy and Paste** to find the URL. Please just make sure you use Google Chrome.
- Once everyone has the game up, we will start the 10 minutes, so please just wait a moment. Remember you want to get to the highest level you can.
- If you have any tech problems, pop your hand up and we will come and help you.
- Up on everyone's screen? Great. I'll start the timer. Just have fun with this and feel free to chat with one another.
- **START 10 MINUTE TIMER. PLAY MUSIC.**
- Once timer goes off – stop music. Everyone write down your score on the paper please.
- We will now go on to game 3 – called Fruit Break.
- You can either type the URL in from the paper you have, or you can open the Word document on the desktop which is titled Copy and Paste. Please just make sure you use Google Chrome.
- Once everyone has the game up, we will start the 10 minutes, so please just wait a moment. Remember you want to get to the highest score you can.
- If you have any tech problems, pop your hand up and we will come and help you.
- Up on everyone's screen? Great. I'll start the timer. Just have fun with this and feel free to chat with one another.
- To start the game, slice the watermelon in half.
- **START 10 MINUTE TIMER. PLAY MUSIC.**
- Once timer goes off – stop music. Everyone write down your score on the paper please.

PART 2 – TESTING

- We will now be going on to do Part 2 of the research (show place card).
- Please open the Part 2 URL – either by typing it in from the first piece of paper, or by using the Word document called **Part URLs** on the desktop. Please make sure you use Google Chrome.
- While you are doing this, RA will come around and grab your game score cards.
- Once you've opened the URL, it should look like this with Part 2 written in this font at the top.
- Again, please enter the same nickname you used in Part 1 and for your game score card.
- In Part 2, we will be asking you the same question about your mood and how sleepy you are right now.
- You will then be repeating the SART and Stop Signal Task.
- This should take you 10 minutes total.
- We ask that you concentrate and do your best in these tasks. Keeping quiet will help with this. It is important to respond as quickly as you can to the prompts on the screen, but it is also important to be accurate in your responding.
- When you reach the Please Wait sign, please wait for further instructions.

CHILL TIME

- Thank you for completing the Part 2 tasks!
- Could everyone please now open the envelope which is labelled "Do Not Open – CT".
- The CT stands for Chill Time (show place card).
- Inside the envelope is a piece of paper with a letter on it.
- Please keep this letter, it is yours.
- Now, press continue on your browser and tell us which letter you received.
- You can then continue and click on the link which will take you out of the Part 2 web page.
- Everyone who has the letter N will be going for a walk with RA.
- Everyone who has the letter U will be going for a walk with me.
- From this point forth, until the end of Part 3, we ask that you do not use or look at your phone at any point.
- This is important for the study.
- So, everyone with a U follow me and everyone with an N follow RA. We will head downstairs now.
- **TAKE 5 MINUTES TO WALK TO LOCATIONS.**
- **When arrive at TEACHING SPACE or BOTANIC GARDEN FOUNTAIN:**
  - **We will now spend 10 minutes resting here.**
  - **You can wander around this space, chat amongst yourselves, and sit down if you like.**
  - **We just ask that you don't look at or use your phones and that you're not doing anything too physical like running.**
  - **For Gardens, please don't go further than the wider boundary around the fountain area.**
  - **For Teaching space, please don't go in other rooms, stay in this open walk way space.**
  - **Once the 10 minutes is up, we will meet back here and walk back to the computer labs.**
- **TAKE 5 MINUTES TO WALK BACK TO COMPUTER ROOM.**

PART 3 – TESTING

- Please return back to the computer you were sitting on before.
- We hope you enjoyed the rest time.
- Just a reminder not to use your phones still.
- If your computer has signed out, please log back in using the username and password on the paper.
- Is everyone logged in? We will wait until everyone is.
- Please open up Google Chrome and type in the URL for Part 3 of the study. Or copy the URL from the Word document **Part URLs** on the desktop, just make sure you use Google Chrome.
- Once you've opened the URL, it should look like this with Part 3 written in this font at the top.
- Again, please enter the same nickname you used in Part 1, Part 2, and for your game score card.
- In Part 3, we will be asking you the same question about your mood and how sleepy you are right now.
- You will then be repeating the SART and Stop Signal Task for one last time – I promise!

- This should take you 10 minutes total.
- Again, we ask that you concentrate and do your best in these tasks. Keeping quiet will help with this. It is important to respond as quickly as you can to the prompts on the screen, but it is also important to be accurate in your responding.
- At the end we will ask you one last question about your experience today and then you can finish up Part 3.

WRAP-UP

- It looks like everyone has finished part 3 now.
- Thank you so much for all of your effort today.
- We can’t wait to share the results of this study with you as soon as possible.
- In the meantime, feel free to ask me any questions on your way out today or to email me as well.
- Please don’t forget to take a thank you bag with you as well.

APPENDIX 3

Pilot Study – Relevant items from the CONSORT-SPI checklist used in the pilot study

Study section	Item	Requirement
Title and abstract	1b	Structured summary of trial design, methods, results, and conclusions
Introduction		
Background and objectives	2a	Scientific background and explanation of rationale
	2b	Specific objectives or hypotheses
Methods		
Participants	4a	Eligibility criteria for participants
	4b	Settings and locations where the data were collected
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered
Outcomes	6a	Completely defined pre-specified outcomes, including how and when they were assessed
Sample size	7a	How sample size was determined
Randomisation		
Sequence generation	8a	Method used to generate the random allocation sequence
	8b	Type of randomisation (such as blocking and block size)
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence
Implementation	10	Who generated the random allocation sequence, enrolled participants, and assigned participants to interventions
Awareness of assignment	11a	Who was aware of intervention assignment after allocation, and how any masking was done
	11b	If relevant, description of the similarity of interventions
Analytical methods	12a	Statistical methods used to compare group outcomes
	12b	Methods for additional analyses, such as subgroup analyses, adjusted analyses, and process evaluations

Results		
Participant flow	13a 13b	For each group, the numbers randomly assigned, receiving the intended intervention, and analysed for the outcomes (a diagram is strongly recommended)
Recruitment	14a	Dates defining the periods of recruitment and follow-up
Baseline data	15	A table showing baseline characteristics for each group; include socioeconomic variables where applicable
Numbers analysed	16	For each group, number included in each analysis and whether the analysis was by original assigned groups
Outcomes and estimation	17a	For each outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses, adjusted analyses, and process evaluations, distinguishing pre-specified from exploratory
Discussion		
Limitations	20	Trial limitations, addressing sources of potential bias
Generalisability	21	Generalisability (external validity, applicability) of the trial findings
Interpretation	22	Interpretation consistent with results, balancing benefits and hams, and considering other relevant evidence
Important information		
Declaration of interests	25	Sources of funding and other support Declaration of any other potential interests
	26c	Incentives offered as part of the trial

APPENDIX 4

RESEARCH ARTICLE

Psychological impacts of "screen time" and "green time" for children and adolescents: A systematic scoping review

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Abstract

Technological developments in recent decades have increased young people's engagement with screen-based technologies (screen time), and a reduction in young people's contact with nature (green time) has been observed concurrently. This combination of high screen time and low green time may affect mental health and well-being. The aim of this systematic scoping review was to collate evidence assessing associations between screen time, green time, and psychological outcomes (including mental health, cognitive functioning, and academic achievement) for young children (<5 years), schoolchildren (5–11 years), early adolescents (12–14 years), and older adolescents (15–18 years). Original quantitative studies were identified in four databases (PubMed, PsycInfo, Scopus, Embase), resulting in 186 eligible studies. A third of included studies were undertaken in Europe and almost as many in the United States. The majority of studies were cross-sectional (62%). In general, high levels of screen time appeared to be associated with unfavourable psychological outcomes while green time appeared to be associated with favourable psychological outcomes. The ways screen time and green time were conceptualised and measured were highly heterogeneous, limiting the ability to synthesise the literature. The preponderance of cross-sectional studies with broadly similar findings, despite heterogeneous exposure measures, suggested results were not artefacts. However, additional high-quality longitudinal studies and randomised controlled trials are needed to make a compelling case for causal relationships. Different developmental stages appeared to shape which exposures and outcomes were salient. Young people from low socioeconomic backgrounds may be disproportionately affected by high screen time and low green time. Future research should distinguish between passive and interactive screen activities, and incidental versus purposive exposure to nature. Few studies considered screen time and green time together, and possible reciprocal psychological effects. However, there is preliminary evidence that green time could buffer consequences of high screen time, therefore nature may be an under-utilised public health resource for youth psychological well-being in a high-tech era.

APPENDIX 5

S1. Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

(Page numbers correspond to *PLOS ONE* publication page numbers, not the thesis page numbers)

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE(S)#:
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3-5, 8
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	5-7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	N/A Prospero does not currently accept scoping review protocols.
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	8-9
Information sources	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	8
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	8 (+ Supporting file 2)
Selection of sources of evidence	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	8-12 (Fig 1)
Data charting process	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	9-11

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE(S)#:
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	9-11
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	N/A
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	9-11
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	12 (+ Fig 1)
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	13-15 (+ Supporting file 3)
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	13-57
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	13-57
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	57-65
Limitations	20	Discuss the limitations of the scoping review process.	66-67
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	68
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Funding section

Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. (2018). PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med.;169:467–473. doi: 10.7326/M18-0850

APPENDIX 6

S2. Search strategies for review

PubMed Logic Grid

(#1 AND #4 AND #5 AND #6) – Both exposures

(#1 AND #2 AND #3 AND #5 AND #6) - Green AND Screen exposures

#1 Population	#2 Exposure: Green	#3 Exposure: Screen	#4 Exposure: Both	#5 Outcome	#6 Study Type
child[mh] OR child*[tiab] OR adolescen*[tiab] OR teen*[tiab] OR adolescent[mh] OR youth*[tiab] OR “young people”[tiab] OR “young person”[tiab] OR parents[mh] OR parent*[tiab]	ecosystem[mh] OR ecosystem[tiab] OR biodiversity[mh] OR biodiversity[tiab] OR gardens[mh] OR garden*[tiab] OR Urbanization[mh] OR urbanization[tiab] OR urbanisation[tiab] OR “green space”[tiab] OR greenspace[tiab] OR “nature exposure”[tiab] OR “nature experience*”[tiab] OR Trees[mh] OR Tree*[tiab] OR greenness[tiab] OR NDVI[tiab] OR “normalized difference vegetation index”[tiab] OR “normalised difference vegetation index”[tiab] OR “public open space*”[tiab]	“internet use”[tiab] OR “computer use”[tiab] OR Computers[mh:noexp] OR Computers, Handheld[mh] OR Cell Phone Use[mh] OR “cell phone*”[tiab] OR “mobile phone*”[tiab] OR “smart phone*”[tiab] OR Video Games[mh] OR “video game*”[tiab] OR Television[mh:noexp] OR television[tiab] OR TV[tiab] OR “screen time”[tiab] OR “screen use”[tiab] OR Social Media[mh] OR “social media”[tiab] OR “digital media”[tiab]	ecosystem[mh] OR ecosystem[tiab] OR biodiversity[mh] OR biodiversity[tiab] OR gardens[mh] OR garden*[tiab] OR Urbanization[mh] OR urbanization[tiab] OR urbanisation[tiab] OR “green space”[tiab] OR greenspace[tiab] OR “nature exposure”[tiab] OR “nature experience*”[tiab] OR Trees[mh] OR Tree*[tiab] OR greenness[tiab] OR NDVI[tiab] OR “normalized difference vegetation index”[tiab] OR “normalised difference vegetation index”[tiab] OR “public open space*”[tiab] OR “urban green space*”[tiab] OR “green area*”[tiab] OR	Mental Health [mh] OR “mental health”[tiab] OR Mental Processes[mh] OR resilien*[tiab] OR Stress, Psychological[mh:noexp] OR Psychological Tests[mh] OR Depression[mh] OR depression[tiab] OR Anxiety[mh:noexp] OR anxiety[tiab] OR Happiness[mh] OR happiness[tiab] OR optimism[mh] OR optimism[tiab] OR Affect[mh] OR “positive affect”[tiab] OR “negative affect”[tiab] OR Cognition[mh] OR cogniti*[tiab] OR Educational status[mh] OR Achievement[mh] OR Underachievement[mh] OR Wechsler Scales[mh] OR Intelligence[mh] OR Attention[mh] OR attention[tiab] OR Executive	cross-sectional studies[mh] OR cross-sectional[tiab] OR Cohort Studies[mh] OR cohort[tiab] OR Case-Control Studies[mh] OR case-control[tiab] OR Longitudinal Studies[mh] OR longitudinal[tiab] OR GIS[tiab] OR “geographic information system*”[tiab] OR “geographical information system*”[tiab] OR epidemiologic studies[mh] OR systematic review[tiab]

	OR “urban green space*”[tiab] OR “green area*”[tiab] OR “natural environment*” [tiab] OR forests[mh] OR forest*[tiab] OR wilderness[mh] OR wilderness[tiab] OR “connectedness to nature”[tiab] OR “nature immersion”[tiab] OR outdoor*[tiab] OR “nature relatedness”[tiab] OR ecotherapy[tiab] OR “attention restoration theory”[tiab] OR “stress reduction theory”[tiab]		“natural environment*”[tiab] OR forests[mh] OR forest*[tiab] OR wilderness[mh] OR wilderness[tiab] OR “connectedness to nature”[tiab] OR “nature immersion”[tiab] OR outdoor*[tiab] OR “nature relatedness”[tiab] OR ecotherapy[tiab] OR “attention restoration theory”[tiab] OR “stress reduction theory”[tiab] OR “internet use”[tiab] OR “computer use”[tiab] OR Computers[mh:noexp] OR Computers, Handheld[mh] OR Cell Phone Use[mh] OR “cell phone*”[tiab] OR “mobile phone*”[tiab] OR “smart phone*”[tiab] OR Video Games[mh] OR “video game*”[tiab] OR Television[mh:noexp] OR television[tiab] OR TV[tiab] OR “screen time”[tiab] OR “screen use”[tiab] OR	Function[mh] OR “executive function*”[tiab] OR Mental fatigue[mh:noexp]	

			Social Media[mh] OR “social media”[tiab] OR “digital media”[tiab]		

PsycInfo Logic Grid

(#1 AND #4 AND #5 AND #6) AND peer-reviewed journal.pt - Both

(#1 AND #2 AND #3 AND #5 AND #6) AND peer-reviewed journal.pt - Green AND Screen Exposures

#1	#2	#3	#4	#5	#6
Population	**Exposure: Green**	**Exposure: Screen**	**Exposure: Both**	**Outcome**	**Study Type**
(child* OR adolesen* OR parent* OR youth* OR "young people" OR "young person" OR teen*).ti,ab.	neighborhood.sh. OR neighbo?rhood*.ti, ab. OR Recreation areas.sh. OR exp "Nature (Environment)"/ OR exp Horticulture Therapy/ OR "horticulture therapy".ti,ab. OR ecology.sh. OR exp Urbanization/ OR urbani?ation.ti,ab. OR tree*.ti,ab. OR "green?space".ti,ab. OR greenness.ti,ab. OR NDVI.ti,ab. OR "normali?ed difference vegetation index".ti,ab. OR "public open space*".ti,ab. OR "urban green space*".ti,ab. OR biodiversity.ti,ab. OR forest*.ti,ab. OR "connectedness to nature".ti,ab. OR "nature immersion".ti,ab. OR outdoor*.ti,ab. OR "nature relatedness".ti,ab. OR ecotherapy.ti,ab. OR wilderness.ti,ab. OR restorati*.ti,ab. OR "attention restoration	Computers.sh. OR exp Computer Games/ OR Computer Usage.sh. OR "computer use".ti,ab. OR Internet Usage.sh. OR "internet use".ti,ab. OR exp Mobile Devices/ OR Screen Time.sh. OR Social Media.sh. OR "screen time".ti,ab. OR "social media".ti,ab. OR TV.ti,ab. OR television.ti,ab. OR "smart?phone*".ti, ab. OR "cell phone*".ti,ab. OR "mobile phone*".ti,ab.	neighborhood.sh. OR neighbo?rhood*.ti, ab. OR Recreation areas.sh. OR exp "Nature (Environment)"/ OR exp Horticulture Therapy/ OR "horticulture therapy".ti,ab. OR ecology.sh. OR exp Urbanization/ OR urbani?ation.ti,ab. OR tree*.ti,ab. OR "green?space".ti,ab. OR greenness.ti,ab. OR NDVI.ti,ab. OR "normali?ed difference vegetation index".ti,ab. OR "public open space*".ti,ab. OR "urban green space*".ti,ab. OR biodiversity.ti,ab. OR forest*.ti,ab. OR "connectedness to nature".ti,ab. OR "nature immersion".ti,ab. OR outdoor*.ti,ab. OR "nature relatedness".ti,ab. OR ecotherapy.ti,ab. OR wilderness.ti,ab. OR restorati*.ti,ab. OR "attention restoration	Mental Health.sh. OR "mental health".ti,ab. OR exp Cognitive Processes/ OR exp Attention/ OR attention.ti,ab. OR "Depression (Emotion)".ti,ab. OR depression,ti.ab. OR Major Depression.sh. OR anxiety.sh,ti,ab. OR Generalized Anxiety Disorder.sh. OR Distress.sh,ti,ab. OR Well Being.sh. OR "well?being".ti,ab . OR Happiness.sh,ti,ab. OR Optimism.sh,ti,ab . OR "Resilience (Psychological)". sh. OR resilien*.ti,ab. OR exp Academic Achievement/ OR "academic achievement".ti,ab. OR "academic success".ti,ab. OR Intelligence.sh,ti, ab. OR exp Intelligence Measures/ OR exp Cognitive Ability/ OR	exp Cohort Analysis/ or cohort.ti,ab. or exp Longitudinal Studies/ or longitudinal.ti,ab. or intervention.sh,ti,ab . or "cross?sectional".ti, ab. or "case?control".ti,ab . or GIS.ti,ab. or "geographic information system*".ti,ab. or "geographical information system*".ti,ab. or RCT.ti,ab. or "randomi?ed controlled trial".ti,ab. or “systematic review”.ti,ab

	theory".ti,ab. OR "stress reduction theory".ti,ab. OR garden*.ti,ab. OR "green area*".ti,ab. OR "nature exposure".ti,ab. OR "nature experience*".ti,ab. OR ecosystem.ti,ab.		theory".ti,ab. OR "stress reduction theory".ti,ab. OR garden*.ti,ab. OR "green area*".ti,ab. OR "nature exposure".ti,ab. OR "nature experience*".ti,ab. OR ecosystem.ti,ab. OR Computers.sh. OR exp Computer Games/ OR Computer Usage.sh. OR "computer use".ti,ab. OR Internet Usage.sh. OR "internet use".ti,ab. OR exp Mobile Devices/ OR Screen Time.sh. OR Social Media.sh. OR "screen time".ti,ab. OR "social media".ti,ab. OR TV.ti,ab. OR television.ti,ab. OR "smart?phone*".ti, ab. OR "cell phone*".ti,ab. OR "mobile phone*".ti,ab.	cogniti*.ti,ab. OR Life Satisfaction.sh. OR (satisfaction adj3 life).ti,ab. OR Positive Emotions.sh. OR Negative Emotions.sh. OR "positive affect".ti,ab. OR "negative affect".ti,ab.	

Scopus Logic Grid

(#1 AND #4 AND #5 AND #6) AND (Limit-to (SRCTYPE, “j”)) – Both exposures

(#1 AND #2 AND #3 AND #5 AND #6) (Limit-to (SRCTYPE, “j”)) - Green AND Screen exposures

#1	#2	#3	#4	#5	#6
Population	**Exposure: green**	**Exposure: screen**	**Exposure: both**	**Outcome**	**Study Type**
TITLE-ABS (child* OR adolescen* OR youth* OR parent* OR teen* OR {young person} OR {young people})	TITLE-ABS (*{green space}* OR *{green spaces}* OR *greenspace** OR *{nature exposure}* OR *{nature experience}* OR *{nature experiences}* OR *tree** OR *garden** OR *greenness* OR *ndvi* OR *{normalized difference vegetation index}* OR *{normalised difference vegetation index}* OR *{public open*	TITLE-ABS (*{computer use}* OR *{internet use}* OR *{video game}* OR *{video games}* OR *videogame** OR *television* OR *tv* OR *{screen time}* OR *{screen use}* OR *{social media}* OR *{digital media}* OR *{electronic device}* OR *{electronic*	TITLE-ABS (*{green space}* OR *{green spaces}* OR *green space** OR *{nature exposure}* OR *{nature experience}* OR *{nature experiences}* OR *tree** OR *garden** OR *greenness* OR *ndvi* OR *{normalized difference vegetation*	TITLE-ABS (*{mental health}* OR *depression* OR *anxiety* OR *well-being* OR wellbeing OR {well being} OR *happiness* OR *optimism* OR *{life W/3 satisfaction}* OR *resilien** OR *{positive affect}* OR *{negative affect}* OR *cogniti** OR *{cognitive function}* OR *{cogni*	TITLE-ABS ({systematic review} OR *cross-sectional* OR *rct OR {randomised controlled trial} OR {randomized controlled trial}* OR *cohort* OR *pre-post* OR *case-control* OR *{ca*

	space} OR {public open spaces} OR {urban green space} OR {urban green spaces} OR ecosystem OR biodiversity OR {green area} OR {green areas} OR {natural environment} OR {natural environments} OR forest* OR {connectedness to nature} OR {nature immersion} OR outdoor* OR {nature relatedness} OR ecotherapy OR wilderness OR urbanisation OR urbanization OR restorati* OR {attention restoration theory} OR {stress reduction theory})	devices} OR {cell phone} OR {cell phones} OR {mobile phone} OR {mobile phones} OR {smart phone} OR {smart phones} OR smartphone*)	index} OR {normalised difference vegetation index} OR {public open space} OR {public open spaces} OR {urban green space} OR {urban green spaces} OR ecosystem OR biodiversity OR {green area} OR {green areas} OR {natural environment} OR {natural environments} OR forest* OR {connectedness to nature} OR {nature immersion} OR outdoor* OR {nature relatedness} OR ecotherapy OR wilderness OR urbanisation OR urbanization OR restorati* OR {attention restoration theory} OR {stress reduction theory} OR {computer use} OR {internet use} OR {video game} OR {video games} OR video game* OR television OR tv OR {screen time} OR {screen use} OR {social media} OR {digital media} OR {electronic device} OR {electronic devices} OR {cell phone} OR {cell phones} OR {mobile phone} OR {mobile phones} OR {smart phone} OR {smart	tive functioning} OR attention OR {executive function} OR {executive functioning} OR {academic achievement} OR {academic success} OR intelligence)	se control} OR longitudinal OR gis OR {geographic information system} OR {geographic information systems} OR {geographical information system} OR {geographical information systems} OR intervention)

			phones} OR *smart phone*)*		

Embase Logic Grid

(#1 AND #4 AND #5 AND #6) AND ‘article’/it - Both

(#1 AND #2 AND #3 AND #5 AND #6) AND ‘article’/it - Green AND Screen exposures

#1	#2	#3	#4	#5	#6
Population	**Exposure: Green**	**Exposure: Screen**	**Exposure: Both**	**Outcome**	**Study Type**
Child/de OR “preschool child”/de OR “school child”/de OR toddler/de OR child*:ti,ab OR adolescen*:ti,ab OR teen*:ti,ab OR adolescent/de OR youth*:ti,ab OR “young people”:ti,ab OR “young person”:ti,ab OR parent/de OR parent*:ti,ab OR “school child*”:ti,ab OR “preschool child*”:ti,ab	Ecosystem/de OR ecosystem:ti,ab OR biodiversity/exp OR biodiversity:ti,ab OR garden*:ti,ab OR Urbanization/de OR urbanization:ti,ab OR urbanisation:ti,ab OR “green space”:ti,ab OR greenspace:ti,ab OR “nature exposure”:ti,ab OR “nature experience*”:ti,ab OR Tree/de OR Tree*:ti,ab OR greenness:ti,ab OR NDVI:ti,ab OR “normalized difference vegetation index”:ti,ab OR “normalised difference vegetation index”:ti,ab OR “public open space*”:ti,ab OR “urban green space*”:ti,ab OR “green area*”:ti,ab OR “urban area”/de OR “residential	Internet/de OR “internet use”:ti,ab OR “computer use”:ti,ab OR Computer/de OR “Cell Phone Use”/de OR “cell phone”:ti,ab OR “mobile phone”:ti,ab OR smartphone/de OR “smart phone”:ti,ab OR “Video Game”/de OR “video game*”:ti,ab OR Television/de OR television:ti,ab OR TV:ti,ab OR “screen time”:ti,ab OR “screen use”:ti,ab OR “social media”/de OR “social media”:ti,ab OR “digital media”:ti,ab	Ecosystem/de OR ecosystem:ti,ab OR biodiversity/exp OR biodiversity:ti,ab OR garden*:ti,ab OR Urbanization/de OR urbanization:ti,ab OR urbanisation:ti,ab OR “green space”:ti,ab OR greenspace:ti,ab OR “nature exposure”:ti,ab OR “nature experience*”:ti,ab OR Tree/de OR Tree*:ti,ab OR greenness:ti,ab OR NDVI:ti,ab OR “normalized difference vegetation index”:ti,ab OR “normalised difference vegetation index”:ti,ab OR “public open space*”:ti,ab OR “urban green space*”:ti,ab OR “green area*”:ti,ab OR “natural environment*”:ti	“Mental Health”/de OR “mental health”:ti,ab OR “psychological well-being”/de OR resilien*:ti,ab OR Stress/de OR “mental stress”/de OR Psychologic Test/exp OR Depression/de OR depression:ti,ab OR Anxiety/de OR anxiety:ti,ab OR Happiness/de OR happiness:ti,ab OR optimism/de OR optimism:ti,ab OR Affect/de OR “negative affect”:ti,ab OR “positive affect”:ti,ab OR Cognition/exp OR cogniti*:ti,ab OR “Educational status”/exp OR “academic achievement”/exp OR	“cross-sectional study”/de OR cross-sectional:ti,ab OR “Cohort Analysis”/de OR cohort:ti,ab OR “Case Control Study”/de OR “case control”:ti,ab OR “Longitudinal Study”/de OR longitudinal:ti,ab OR “geographic information system”/de OR GIS:ti,ab OR “geographic information system*”:ti,ab OR “geographical information system*”:ti,ab OR “systematic review”/de OR “systematic review”:ti,ab OR RCT:ti,ab OR “randomized controlled

	area"/de OR "suburban area"/de OR "natural environment*":ti,ab OR forest/de OR forest*:ti,ab OR wilderness/de OR wilderness:ti,ab OR "connectedness to nature":ti,ab OR "nature immersion":ti,ab OR outdoor*:ti,ab OR "nature relatedness":ti,ab OR ecotherapy:ti,ab OR "attention restoration theory":ti,ab OR "stress reduction theory":ti,ab		,ab OR forest/de OR forest*:ti,ab OR wilderness/de OR wilderness:ti,ab OR "connectedness to nature":ti,ab OR "nature immersion":ti,ab OR outdoor*:ti,ab OR "nature relatedness":ti,ab OR ecotherapy:ti,ab OR "attention restoration theory":ti,ab OR "stress reduction theory":ti,ab OR Internet/de OR "internet use":ti,ab OR "computer use":ti,ab OR Computer/de OR "Cell Phone Use"/de OR "cell phone":ti,ab OR "mobile phone":ti,ab OR smartphone/de OR "smart phone":ti,ab OR "Video Game"/de OR "video game*":ti,ab OR Television/de OR television:ti,ab OR TV:ti,ab OR "screen time":ti,ab OR "screen use":ti,ab OR "social media"/de OR "social media":ti,ab OR	"Wechsler intelligence scale for children"/de OR "Wechsler preschool and primary scale of intelligence"/de OR Intelligence/de OR Attention/exp OR attention:ti,ab OR "Executive Function"/de OR "executive function*":ti,ab	trial"/de OR "randomised controlled trial":ti,ab OR "randomized controlled trial":ti,ab

			“digital media”:ti,ab		

APPENDIX 7

S3. Descriptive characteristics of studies included in the systematic scoping review

(Reference numbers correspond to *PLOS ONE* publication reference list, not the thesis reference list)

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
Aggio (2016)	United Kingdom	2001 – 2013	Longitudinal	8,462	Mixed (YC & SC)	ST; parent-reported TV, videos, DVDs, computer, or video games time.	CF; British Ability Scales & Verbal Similarities Test.	• 42% of mothers had high academic qualification. • 76% of families had income above the poverty level.	201
Aggio (2017)	United Kingdom	2008 – 2009	Cross-sectional	13,169	SC	Both; parent-reported TV time; parent-reported independent outdoor play.	PR & PS; parent-completed SDQ.	• 71% of families had income above the poverty level.	248
Agostini (2018)	Italy	2014 – 2015	Longitudinal with comparison group	93	YC	GT; outdoor education at kindergarten.	CF & PS; teacher-report on Kuno Beller Developmental Tables.	• Unclear	61
Aguilar (2015)	Chile	2014	Cross-sectional	395	EA	ST; self-report on typical daily television, computer, and video games time.	AA; grades in mathematics and language.	• 82% classed as middle or high SES.	112
Allen (2015)	Australia	2010 – 2014	Longitudinal & Cross-sectional	7,818	Mixed (SC & EA)	ST; parent-reported TV and electronic gaming time.	PR & PS; parent-completed SDQ.	• Non-English speaking families were underrepresented. • Those with incomplete data had a lower household income and neighbourhood socioeconomic position.	215
Amoly (2015)	Spain	2012 – 2013	Cross-sectional	2,111	SC	GT; parent-reported play in greenspaces; residential and school surrounding greenness (NDVI); residential proximity to greenspaces; parent-reported annual beach attendance.	CF & PR; teacher-reported inattention (ADHD symptom criteria of DSM); parent-completed SDQ.	• 55% of mothers and 49% of fathers had university qualifications. • Neighbourhood SES mentioned but not reported.	74
Anderson (2017)	England, Wales, Scotland, Northern Ireland	2001 – 2013	Cross-sectional	10,995	Mixed (YC & SC)	ST; parent-reported daily TV and video time.	PR; parent-completed Child Social Behaviour Questionnaire to measure self-regulation.	• 41.6% of original cohort not in analysis and were more likely to be from ethnic-minorities and households with less socioeconomic advantage.	202
Arora (2018)	England	2011 – 2014	Longitudinal	853	Mixed (EA & OA)	ST; self-reported use of TV, video games, mobile phones, computers, laptops, social networking before bedtime.	AA; score based off of English, Mathematics & Science records.	• Schools were selected to ensure different school types within different areas were included, which served as a proxy of socio-economic status.	177

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
Babic (2017)	Australia	2014	Longitudinal	322	EA	ST; self-report on the Adolescent Sedentary Activity Questionnaire; daily recreational and non-recreational TV, DVD, computer, tablet, mobile phone time.	PR & PS; self-completed Flourishing Scale & SDQ.	• Majority of participants (58%) were from middle socioeconomic backgrounds (5^{th} & 6^{th} decile).	113
Bagot (2015)	Australia	?	Pre-PSt design	550	SC	GT; self-report on the Perceived Restorative Components Scale for Children to measure perceived restorativeness of school playground.	PR & PS; self-report on the Positive and Negative Affect Scale for Children.	• Schools across a broad range of socioeconomic groups.	75
Balseviciene (2014)	Lithuania	2013	Cross-sectional	1,468 mother-child dyads	Mixed (YC & SC)	GT; residential proximity to parks; residential greenness (NDVI).	PR; mother-reported SDQ.	• 80% of children's mothers had a university/college degree.	203
Barton (2016)	England	2006 - 2012	Pre-Post design	130	Mixed (SC, EA & OA)	GT; wilderness expedition.	PS & Other; self-report on Rosenberg's Self-Esteem Scale; self-report on State Connectedness to Nature Scale.	• Unclear.	222
Barton (2015)	England	2009	Pre-Post intervention	52	SC	GT; nature orienteering intervention.	PS; self-report on Rosenberg's Self-Esteem Scale.	• Participants were amongst the 20% most socio-economically deprived in England for one or a combination of factors, such as housing, income and health, crime and living environment.	76
Baumgartner (2014)	The Netherland s	?	Cross-sectional	523	EA	ST; self-reported daily time and simultaneous use of TV, sending messages, social networking, using the computer, and playing video games, to measure media multitasking.	CF; the Dutch version of the Behaviour Rating Inventory of Executive Function measured executive function; The Digit Span measured working memory; the Eriksen Flankers task measured inhibition; the Dots-Triangles task measured shifting ability.	• Participants came from different levels of schools in both urban and rural areas.	114
Baumgartner (2017)	The Netherland s	?	Longitudinal	1,441 & 439	EA	ST; self-reported daily time and simultaneous use of TV, sending messages, social networking, using the computer, and playing	CF; self-report on 9 symptoms for inattentiveness, adapted from the DSM-5 criteria for ADHD.	• Unclear.	115

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
						video games, to measure media multitasking.			
Beere (2017)	New Zealand	2003 – 2012	Cross-sectional	230,929	SC	GT; greenspace exposure measured by percentage of public and private greenspace within school parcel boundaries and zone buffers.	AA; New Zealand National Standards in mathematics, reading, and writing.	• Urban schools across all deciles of SES.	77
Benson (2013)	United States	2007 – 2008	Cross-sectional chart review design	117	EA	ST; child/caregiver-report of total daily hours watching TV and/or using a computer/video game.	PR; self-completed Children's Depression Index.	• SES not included in analysis.	116
Bezold (2018)	United States	1989 – 2013	Prospective cohort	11,346	Mixed (YC, SC, EA & OA)	GT; surrounding residential greenness (NDVI) during childhood and adolescence.	PR; McKnight Risk Factor Survey and Center for Epidemiologic Studies depression scale.	• 63% of participants had a household income equal to or above $75,000. • 65% of participant's fathers had college level education.	209
Bickham (2015)	United States	2009 – 2010	Longitudinal	126	Mixed (EA & OA)	ST; daily TV, video game, computer, and mobile phone use measured through survey questions, time use diaries, and ecological momentary assessment.	PR; self-administered Beck Depression Inventory for Primary Care.	• 45% of participants were not White. • 52% of participant's parents had college level education.	178
Bolling (2019)	Denmark	?	Quasi-experiment	631	SC	GT; education outside the classroom.	PR & PS; student-completed SDQ.	• 75% from high SES backgrounds.	78
Booker (2014)	United Kingdom	2009	Cross-sectional	4,899	Mixed (SC, EA & OA)	ST; self-report of hours spent chatting on social networking sites, game console use, computer game use, and TV, video & DVD watching on a normal school day.	PR & PS; self-reported SDQ; self-report on 6 questions about happiness.	• More than 20% (weighted percentage) of the sample had parents with degree qualifications.	223
Borzekowski (2005)	United States	1999 – 2000	Cross-sectional	348	SC	ST; parent- and self-report on average time spent watching TV, videos, and playing video games.	AA; mathematics, reading, and language arts sections of the Stanford Achievement Test.	• The sample was ethnically diverse. • 44% of students came from households where no parent had completed more than high school. • 28% lived in households where English was not the main language spoken.	79

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
Brodersen (2005)	England	1999	Cross-sectional	4,319	SC	ST; self-report time spent watching TV or videos, playing video games or on the computer.	PR & PS; self-report on the Perceived Stress Scale, SDQ, and single self-rated health question.	• Schools varied by ethnicity and SES (independent (fee-paying) schools, schools from affluent outer London boroughs, and schools from more deprived inner-city areas). • The average deprivation score of the sample was more deprived than the U.K. population in general.	80
Brussoni (2017)	Canada	2014	Pre-post design	45	YC	GT; Seven C scores to measure the quality of outdoor play spaces in childcare centres.	PR & PS; teacher-completed SDQ; teacher-completed Preschool Social Behaviour Scale-Teacher Form.	• The centres' outdoor play spaces scored lowest quality among 16 centres participating in previous research.	62
Busch (2013)	The Netherlands	?	Cross-Sectional	2,425	EA	ST; daily TV, computer, Internet, and video games time.	PR & PS; self-reported SDQ; self-report on Rosenberg's Self-Esteem Scale; self-report on Schwarzer's Generalised Self-Efficacy Scale.	• Students' SES was reported to be higher than that of their peers in the Netherlands.	117
Cao (2011)	China	2010	Cross-sectional	5,003	EA	ST; self-reported TV and computer time on usual weekday and weekend day.	PR & PS; self-report on Depression Self-Rating Scale for Children; self-report on Screen for Child Anxiety Related Emotional Disorders; self-report on School Life Satisfaction Rating Questionnaire for Adolescents.	• Low, medium, and high perceived SES. Proportions of sample not clear.	118
Carson (2012)	United States	2006 – 2007	Cross-sectional	6,700	EA	ST; self-reported daily internet use, video game playing, computer game playing for weekdays and weekends.	AA & PR; self-report on the Social Skills Rating System; parent-reported SDQ; reading and mathematics achievement assessed in a one-on-one assessment.	• Majority White sample. • Poverty level and parental education level differed by ethnicity/race (White, Black, Asian American, Latino).	119
Casey (2016)	Australia	?	Cross-sectional	494	EA (100% female)	ST; TV viewing, video game and computer activity.	PS; self-report on the Pediatric Quality of Life 4.0 Generic Core Scales for Teens aged 13-18.	• Sample from rural communities. • Majority of participants lived with both parents.	120

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
								• Most parents were employed and had more than 12 years education.	
Casiano (2012)	Canada	2000 – 2001	Cross-sectional	9,137	Mixed (EA & OA)	ST; self-reported weekly TV/video watching, video game playing, and computer/Internet use over the past 3 months.	PR; symptoms of depression were measured with the Composite International Diagnostic Interview-Short Form.	• Majority of participants were White. • Majority of participants had middle-to-high household income.	179
Chen (2014)	Australia	2011 – 2012	Cross-sectional	3,353	Mixed (SC & OA)	ST; number of days students experienced 2 or more hours of ST (TV, computers, video games) per day outside of school hours over the past week; average screen hours across school and non-school days.	PS; the Child Health Utility 9D measured health-related quality of life.	• SES was close to average Australian levels as measured by the Index of Community Socio-Educational Advantage.	213
Corder (2015)	United Kingdom	2005 – 2007	Prospective cohort	845	EA	ST; self-reported daily TV, video, DVD, internet, and video game time.	AA & PR; General Certificate of Secondary Education results at the end of Year 11; self-report on the Mood & Feelings Questionnaire.	• The sample had middle-to-high levels of socioeconomic advantage overall.	121
Corraliza (2012)	Spain	?	Cross-sectional	172	SC	GT; nearby nature in school and home areas measured by the Nearby Nature Observational Scale; child-report on the Perceived Nature Questionnaire to measure perception that the child has about the nearby nature in his/her surroundings.	PR; child-report on the Perceived Stress Scale; child-report on the Stressful Events Questionnaire.	• Unclear.	81
Dadvand (2017)	Spain	2003 – 2013	Longitudinal	888 - 978	Mixed (YC & SC)	Both; residential surrounding greenness (NDVI); residential surrounding tree cover; time spent watching TV.	CF; Connors' Kiddie Continuous Performance Test; Attentional Network Task.	• Participants in follow-up analyses had mothers with higher education than those who were lost to follow-up.	234
Dadvand (2015)	Spain	2012 – 2013	Longitudinal	2,593	SC	GT; greenness surrounding home, commuting route between home and school, within and around school boundaries, and total surrounding greenness (NDVI).	CF; n-back test assessed working memory and superior working memory; Attentional Network Test assessed attention.	• The 36 schools were reflective of the general SES of schools across Barcelona.	82

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Dalton (2011)	United States	2007	Cross-sectional	152	Mixed (SC & EA)	ST; self-reported TV, video game, and recreational computer time on school days.	PS; self-report on the Pediatric Quality of Life Inventory.	• The sample was quite disadvantaged socioeconomically and health-wise.	216
de Haan (2004)	The Netherlands	2001 – 2002	Cross-sectional	9,782	Mixed (EA & OA)	ST; watching TV and using the computer.	AA & PR; self-reported school results in Dutch, English and arithmetic; internalising and externalising problem behaviour.	• Unclear.	180
Dennison-Farris (2017)	United States	2015	Cross-sectional	121	SC	ST; self-reported time spent watching TV, using a computer, playing sedentary electronic games, and playing non-sedentary electronic games on weekdays and weekend days.	PR; self-report on the Child Depression Inventory.	• Sample of American Indian youth. • Potentially more disadvantaged, but not explicitly reported.	83
Dettweiler (2017)	Germany	?	Longitudinal with comparison group	48	SC	GT; outdoor learning in a forest setting.	PR; salivary cortisol analyses, with samples taken at 8:30am, 10:20am, 12:30pm over the school year, to measure stress levels.	• Similar SES across both groups. • Unclear how advantaged the participants were.	28
Duch (2013)	United States	?	Longitudinal & cross-sectional	119 (CS) & 73 (L)	YC	ST; parent- and child-reported 24-hour recall of screen media use on weekday, including TV, cell phones, DVDs, or computers.	CF; Ages and Stages Questionnaire: a Parent-Completed Child Monitoring System, Third Edition.	• All families had incomes below the poverty line. • Majority Hispanic.	63
Dumais (2008)	United States	2002 – 2004	Longitudinal	11,642	Mixed (EA & OA)	ST; self-reported weekday TV and video game time.	AA; 11th grade GPA; 12th grade maths scores.	• On average, participants were from SES quartile 2.6 (SD = 1.1).	181
Dumith (2010)	Brazil	1993 – 2005	Cross-sectional	4,431	SC	ST; self-reported TV, video games, and computer time on weekdays and weekends.	PS; happiness faces scale.	• Adolescents across whole socio-economic spectrum were represented. • Numbers/proportions unclear.	84
Dunton (2011)	United States	Across 4 days (Friday – Monday)	Ecological Momentary Assessment Study	121	Mixed (SC & EA)	GT; time spent outdoors measured through ecological momentary assessment with mobile phones.	PR & PS; self-reported negative affect measured through 4 items; self-reported positive affect measured through 2 items.	• Low-to-middle income, ethnically diverse children in Southern California.	217
Dzhambov (2018)	Bulgaria	2016	Cross-sectional	399	OA	GT; availability, access, quality, and usage of greenspaces was investigated; residential greenspace measured by NDVI, SAVI, and tree cover density;	PR; self-report on the General Health Questionnaire-12.	• A range of − 3.29 to 4.19 was observed on an individual level socioeconomic index.	42

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						distance to nearest urban greenspace; self-reported perceived neighbourhood greenness, visible greenery from home, walking time to nearest greenspace, time spent in neighbourhood greenspace per week, and perceived neighbourhood greenspace quality.			
Espinosa (2006)	United States	1998 – 2002	Longitudinal	Unclear: ~17,008 based on baseline 21,260 and attrition of 20%	Mixed (YC & SC)	ST; parent-reported Internet use at home (yes/no) and TV time at home (between 3pm and dinner); teacher-rated computer proficiency.	AA; reading and mathematics achievement.	• Children are represented across the spectrum of SES. • Numbers/proportions unclear.	204
Esteban-Cornejo (2015)	Spain	2011 – 2012	Cross-sectional	1,146	EA	ST; self-completed Youth Sedentary Behavior Questionnaire; average daily time watching TV/videos, playing computer/video games, internet surfing, doing homework/study with computer.	AA; math score, language score, and GPA from school records.	• 30% of participant's mothers had a university level qualification.	122
Fagerstam (2014)	Sweden	?	Quasi-experiment	86	EA	GT; outdoor learning.	AA & PS; mathematics skills were assessed via a test; self-regulation skills were assessed with a Programme for International Student Assessment questionnaire.	• Unclear.	123
Feda (2015)	United States	?	Cross-sectional (GIS)	68	EA	GT; park access, park area, and housing density in adolescents' neighbourhood.	PR; self-report on the Perceives Stress Scale.	• Overall, SES was approximately middle-class in the sample.	124
Feng (2017)	Australia	2012	Cross-sectional (GIS)	3,083	EA	GT; greenspace quantity assessed by percentage of land-use within each 'statistical area 2' of residence classified as "parkland" by the Australian	PR; parent-, teacher-, and self-completed SDQ.	• Appears children across the spectrum of SES were included.	125

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						Bureau of Statistics; parent-reported greenspace quality in the neighbourhood.		• Unclear on numbers/proportions of children in each SES tertile.	
Feng (2017)	Australia	2004 – 2012	Longitudinal	4,968 – 3,798	Mixed (YC, SC & EA)	GT; greenspace quantity assessed by percentage of land-use within each 'statistical area 2' of residence classified as "parkland" by the Australian Bureau of Statistics; parent-reported greenspace quality in the neighbourhood.	PR & PS; parent-reported SDQ.	• Over 60% of children were from average-to-affluent socioeconomic backgrounds.	210
Ferguson (2011)	United States	?	Cross-sectional	603	EA	ST; self-report on Media use questionnaire, average weekly TV and video game time.	AA & CF; parent-report of adolescent's GPA; child- and parent-completed Child Behavior Checklist to assess attention problems.	• Majority Hispanic sample. • Low average household income (compared to national average). • Reflective of the community.	126
Ferguson (2014)	United States	6-month follow-up	Cross-sectional & Longitudinal	237 (CS) & 101 (L)	EA	ST; self-reported TV and social media time.	PR & PS; self-completed Zung Depression Inventory; self-completed Beck Anxiety Inventory; self-completed Satisfaction with Life Scale (5-item).	• Majority Hispanic sample. • Reflective of the community.	127
Finne (2013)	Germany	2003 - 2006	Cross-sectional	6,813	EA	ST; self-reported average daily TV/videos, computer/Internet, and gaming console use time.	PS; self-completed age specific versions of the revised German KINDL-R questionnaire, assessing health-related quality of life.	• Participants excluded due to missing data were more likely to be from low SES or immigrant backgrounds.	128
Flouri (2014)	England	2000 – 2007	Longitudinal	6,348	SC	GT; neighbourhood greenspace assessed using the 2001 Generalised Land Use Database.	PR; parent-reported SDQ.	• The non-analytic sample were more advantaged than the analytic sample (because people in rural areas of England tend to be more affluent). • Maternal education and two-parent family structure were more common in those who dropped out.	85
Garcia-Hermoso (2017)	Chile	2014	Cross-sectional	395	EA	ST; self-report of the number of hours per typical day in the past seven days spent watching TV,	AA; grades in mathematics and language core subjects	• 72% of participants were from a middle SES background.	129

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						playing computer or video games, and other computer use.			
Gentile (2014)	United States	7-month time period	Prospective study	1,323	SC	ST; self-reported TV, video game, and computer use time during different times of the day, separately for weekdays and weekends.	AA; teacher-reported average grade for each child.	• The average education of participants' parents was some college level.	86
Barlett (2012)	United States	13-month time period	Prospective study	1,323	SC	ST; self-reported TV, video game, and computer use time during different times of the day, separately for weekdays and weekends.	CF; teacher-report on 3-items that measured attention problems.	• Unclear.	87
Godinho (2014)	Portugal	2003 – 2004	Cross-sectional	1,680	EA	ST; self-reported TV and computer time on week and weekend days.	PR; self-report on the Second Edition of the Beck Depression Inventory.	• Those not included in analyses were more likely to attend public schools, have younger, less educated parents, and clinical scores indicative of depression.	130
Goldfield (2016)	Canada	2005 – 2010	Cross-sectional	358	OA	ST; self-reported daily TV, sedentary video game, and recreational computer use hours.	PR; self-report on the Children's Depression Inventory.	• 71% of sample was Caucasian. • Parental education mentioned but not reported.	162
Goldfield (2015)	Canada	2005 – 2010	Cross-sectional	358	OA	ST; self-reported daily TV, sedentary video game, and recreational computer use hours.	PS; self-report on the Adolescent Core version of the Pediatric Quality of Life scale.	• 71% of sample was Caucasian.	163
Gopinath (2012)	Australia	2004 – 2011	Cross-sectional & Longitudinal	2,353 – 1,691	Mixed (EA & OA)	Both; self-reported daily hours watching TV, playing video games, and using a computer for fun; self-reported number of weekly hours in non-sporting outdoor activities.	PS; self-report on the Pediatric Quality of Life Inventory.	• Participants lost at follow-up were more likely to be East & South-East Asian. • Mix of public, private, or religious high schools. • Over 50% of parents had tertiary qualifications.	235
Greenwood (2016)	England	?	Randomised Experiment	120	OA	Both; flowing baseline measures, stressor tasks, and pre-treatment measures, participants were sent into either an outdoor or indoor environment for 20 minutes; in addition to the 2 environmental	CF & PS; attention was measured using the Necker Cube Pattern Control Task; mood and attentiveness were assessed using Zuckerman's (1977) Inventory of Personal Reactions.	• College in South-West London.	243

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						conditions, participants were randomised into 3 social contexts (alone, with a friend, of playing a game on a mobile phone).			
Griffiths (2010)	England, Wales, Scotland, Northern Ireland	2005 – 2007	Cross-sectional	13,470	SC	ST; mother-reported hours per day their child spent watching TV/videos/DVDs, used a computer, or played electronic games.	PR & PS; parent-completed SDQ.	• 89% of sample was White. • 59% of mothers employed. • ~30% of mothers had a diploma or degree. • 81% of households were non-lone mother. • Purposive overrepresentation of children living in disadvantaged areas and from ethnic minority groups, from Wales, Scotland, and Northern Ireland.	88
Gubbels (2016)	The Netherlands	2010 – 2012	Longitudinal	401	EA	GT; perceived greenery, perceptions of greenery improvement, and greenery use following greenery interventions in districts.	PR; self-report on the Center for Epidemiologic Studies Depression Scale.	• 20 severely deprived districts in The Netherlands.	131
Gunnell (2016)	Canada	2006 – 2010	Longitudinal & cross-sectional	1,160 - 236	Mixed (EA & OA)	ST; self-reported hours per day typically engaged in TV viewing, video game playing, and computer use for weekdays and weekend days.	PR; self-report on the Children's Depression Inventory; self-report on the Multidimensional Anxiety Scale for Children-10.	• 74% Caucasian. • 75% of parents (either one or both) had college-level education.	182
Gustafsson (2012)	Sweden	12-month timeframe	Quasi-experimental non-equivalent groups design	230	SC	GT; outdoor education in a green context.	PR & PS; parent-report on the SDQ.	• 83% of children came from middle-to-high SES backgrounds and none were from immigrant parents in the Intervention school. • 32% of children came from middle-to-high SES backgrounds and 65% were from immigrant parents in the Reference school.	89

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Hamer (2009)	Scotland	2003	Cross-sectional	1,486	SC	ST; parent-reported weekly TV and screen entertainment time for their child.	PR; parent-report on the SDQ.	• Sample spanned spectrum of SES, but numbers/proportions not reported.	90
Han (2009)	Taiwan	2005 – 2006	Quasi-experimental control-series design	76	EA	GT; limitedly visible indoor plants were placed in classrooms.	AA & PR & PS; average term examination grades in Mandarin, English, mathematics, civil ethics, history, geography, chemistry, and physical education; self-report on the State Anxiety Inventory; self-report on Well-Being Measures by Kaplan (2001).	• Unclear.	132
Hartson (2018)	United States	2015 – 2016	Cross-sectional	40	SC	ST; self-reported weekly hours watching TV, DVDs, videos, or playing on the computer or with video games.	PS; self-report on Rosenberg's Self-Esteem Scale.	• 74% of children were from lower income households. • 80% of parents had high school level education, or lower.	91
Hayward (2016)	Australia	2014	Cross-sectional	3,295	OA	ST; self-report on an item from the Core Indicators and Measures of Youth Health Survey; adolescents reported their ST for the previous seven days.	PR; self-report on the Moods and Feelings Questionnaire-Short Form.	• Sample had mid-range SES.	164
Herman (2015)	Canada	2011 – 2012	Cross-sectional	7,725	Mixed (EA & OA)	ST; adolescents reported how much time they spent on a computer playing computer games and using the Internet (outside of school/work), playing video games, and watching TV or videos, in a typical week over the past 3 months.	PS; self-rated health and mental health.	• 73% of sample was White. • 84% of households had < post-secondary / post-secondary graduate education level.	183
Hignett (2018)	England	2011	Pre-post design	40	EA	GT; surfing program, fostering connectedness to the natural and marine environment.	PR, PS & Other; an adapted version of the Parent-Child Interaction System was used to monitor negative and positive affect in an interview; teacher-report on the Social and Emotional Aspects of Learning questionnaire; self-reported well-being on a relevant section	• Students had either been excluded from mainstream school or were at risk of exclusion.	133

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							of the Youth version of the British Panel Household Survey; self-report on an adapted and extended version of the Inclusion of Nature in the Self scale.		
Hinkley (2014)	Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, & Sweden	2007 – 2010	Prospective cohort	3,604	Mixed (YC & SC)	ST; parent-report on adapted questions from the Generation M-study; reported child's TV viewing and e-game/computer use for weekdays and weekends separately.	PR & PS; parent-report on the SDQ; parent-report on the KINDL.	• Over 57% of children were from middle-to-high SES families. • 9% of children were from low SES families.	205
Hinkley (2017)	Australia	2008 – 2012	Prospective cohort	108	Mixed (YC & SC)	ST; parent-report of child's week and weekend time spent watching TV, DVDs, videos, playing sedentary electronic games, playing active electronic games, and computer/internet use, over the past month.	PS; self-report on the Bar-On Emotional Quotient Inventory – Youth Version (short version).	• Childcare centres in low-, mid-, and high-SES areas were included. • 76% of participants were from a high SES family with a university-educated mother.	206
Hinkley (2018)	Australia	2013 – 2014	Cross-sectional	575	YC	Both; mother-report of child's TV, DVD, video, computer/electronic game/handheld device time for week and weekend days; mother-report of child's outdoor play for week and weekend days.	PS; mother-report on the Adaptive Social Behavior Inventory.	• Selection of socioeconomically diverse local government areas in Melbourne. • 75% of the sample were from high SES and 22% were from mid-SES.	247
Hoare (2014)	Australia	2012	Cross-sectional	800	EA	ST; self-report on the Adolescent Behaviours, Attitudes, and Knowledge Questionnaire; reported TV, video, DVD, videogame, and recreational computer use time on a single school day and weekend days.	PR; self-completed Short Moods and Feelings Questionnaire.	• 67% of sample were of European-Australian decent. • 56% of parents had completed tertiary education.	134
Hodson (2017)	United States	2010 – 2011	Cross-sectional	222 primary schools	SC	GT; urban environmental variables; **level of greenness, grass cover, shrub cover** based on the U.S. Geological Survey National Land Cover Dataset (NLCD) for 2011; the NLCD 2011	AA; school-level academic performance using third-grade reading and mathematics test scale scores, and the proportion of third grade students	• A socioeconomically and demographically diverse population. • Approximately 10% living below the poverty line.	92

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						U.S. Forest Service **Tree Canopy** cartographic product; NLCD 2011 Percent Developed Imperviousness dataset to calculate mean **impervious surface** percent; the percentage of **waterbodies** using the USGS National Hydrography Dataset.	exceeding basic standards in reading and mathematics ability.	• Numerous ethnic and racial groups are represented in school populations and vary greatly in their proportions from school to school.	
Hofferth (2010)	United States	1997 – 2003	Longitudinal	~3,558	Mixed (SC, EA & OA)	ST; Time Use Diaries completed by parent or parent and child, asking about the child's activities over a randomly designated 24-hour period; watching TV, playing video games (Game boy and other hand-held video game devices), playing on the computer, studying using the computer, computer communications (internet searching, accessing web sites, emailing, and instant messaging).	CF & PR; parent-report on the Behavior Problems Index; child-completed Woodcock-Johnson Revised Test of Basic Achievement (letter-word identification, passage comprehension, applied problems).	• 75% of children lived with 2 parents. • 44% of mothers had completed some college. • Two thirds of mothers were employed. • 72% of students were White.	224
Hofferth (2012)	United States	2003 – 2008	Longitudinal	1,221	Mixed (SC, EA & OA)	ST; child- and/or parent-completed time diaries measuring weekday and weekend computer game play, web site visits, email or instant messaging, study using the computer, video game play on hand-held devices or consoles, and television viewing.	CF; child-completed Woodcock-Johnson Revised Test (letter-word identification, passage comprehension, applied problems).	• Children from diverse ethnic/racial backgrounds are represented. • Numbers/proportions unclear.	225
Hrafnkelsdottir (2018)	Iceland	2015	Cross-sectional	244	OA	ST; self-reported TV/DVD, Internet, and computer hours per day on average, separately for weekdays and weekends.	PR & PS; self-completed 22-item version of the Subscales of the Symptom Checklist 90; self-completed Rosenberg Self-Esteem Scale; self-completed Diener's Satisfaction with Life Scale.	• 60% of mothers had university level education.	165

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Hunter (2018)	Canada	2012 – 2015	Longitudinal	4,408	Mixed (EA & OA)	ST; self-reported average daily time watching/streaming TV shows or movies, playing video/computer games, surfing the internet, and texting, messaging, emailing.	AA; self-reported grades in Math and English.	• Students lost at follow-up were more likely to be from ethnic minorities. • 82% of sample was White.	184
Huynh (2013)	Canada	2009 – 2010	Cross-sectional	17,249	Mixed (SC, EA & OA)	GT; features of public natural space (total, green, blue) in 5km buffers around schools were obtained from the CanMap Route Logistics and Enhanced Points of Interests geographic information systems, including local parks and sport fields, provincial/territorial parks, national parks, other parks, wooded areas, campgrounds, picnic areas, golf courses, driving ranges, national wildlife and migratory areas, botanical gardens, and water bodies (oceans lakes, rivers, streams).	PS; self-completed Cantril ladder (a direct and global indicator of subjective wellbeing over time).	• 71% of the sample was Caucasian. • Over 92% of the sample had mid-to-high family affluence. • 71% of participants living in neighbourhoods with medium-to-high SES.	226
Iannotti (2009)	United States & Canada	2001 – 2002	Cross-sectional	22,053	EA	ST; self-reported hours per weekday and weekend day using a computer (excluding homework), watching TV/videos.	PR & PS; self-reported somatic symptoms; self-rated Perceived Health Status; self-rated Life Satisfaction.	• Samples were representative of the United States and Canadian populations. • No further SES information provided.	135
Iannotti (2009)	United States, Canada, Switzerland, the Netherlands, Czech Republic, Poland, Finland, Norway, Italy & Spain	2005 – 2006	Cross-sectional	49,124	Mixed (EA & OA)	ST; self-reported hours per weekday and weekend day using a computer (excluding homework), watching TV/videos.	PR & PS; self-reported somatic symptoms; self-rated Perceived Health Status; self-rated Life Satisfaction.	• In the majority of countries, national representative samples were drawn and samples were stratified to ensure representation of relevant subgroups. • No further SES information provided.	185

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Jackson (2010)	United States	?	Cross-sectional	500	EA	ST; self-reported typical number of days of Internet, videogame, and cell phone use for more than 3 hours; self-reported email and instant messaging frequency.	PS; self-completed Rosenberg's Self-Esteem Scale.	• 67% of the sample were Caucasian Americans. • Children from high and low income households were represented, but numbers/proportions are not reported.	136
Jackson (2011)	United States	?	Cross-sectional	482	EA	ST; self-reported typical number of days of Internet, videogame, and cell phone use for more than 3 hours.	AA, CF & PS; self-reported school grades and GPA; reading and mathematics skills assessed using the Wide Range Achievement Test Revision 3; visual spatial skills assessed using the Wide Range Assessment of Visual Motor Abilities Section 2, Matching; self-completed Rosenberg's Self-Esteem Scale.	• 67% of the sample were Caucasian Americans. • Parents of males were more likely to be in the lowest income level (32.9%) than were parents of females (21.2%). • African American parents (43.1%) were more likely to be in the lowest income level than were Caucasian American parents (18.7%). • Only 5.2% of African American parents were in the three highest income levels compared to 13.9% of Caucasian American parents.	137
Jackson (2011)	United States	3-year time period	Longitudinal	482	EA	ST; self-reported typical number of days of Internet and videogame use for more than 3 hours.	AA & CF; self-reported school grades and GPA; reading and mathematics skills assessed using the Wide Range Achievement Test Revision 3; visual spatial skills assessed using the Wide Range Assessment of Visual Motor Abilities Section 2, Matching.	• 67% of the sample were Caucasian Americans. • Parents of males were more likely to be in the two lowest income levels (30%, 37.5%) than were parents of females (19.3%, 29.3%). • Parents of African Americans were more likely to be in the two lowest income levels (38.6%, 48.6%) than were parents of Caucasian Americans (19%, 27.5%). • Parents of Caucasian Americans were more likely to be in the three highest income	138

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								levels (10%, 2%, 1.5%) than were parents of African Americans (1.4%, 0%, 0%).	
Jalali-Farahani (2016)	Iran	?	Cross-sectional	465	OA	ST; self-report on the Quantification de l'Activite Physique en Altitude Chez les Enfants questionnaire; total screen time, TV, and videogames/Internet hours per week, reported separately for during school period and vacation period.	PS; self- and parent-report on the Pediatric Quality of Life Inventory.	• Students were recruited from 3 different socio-economic zones in Tehran. • No further SES information provided.	166
Janssen (2016)	Canada	2014	Cross-sectional	20,122	EA	Both; self-reported daily time spent playing active video games and sedentary video games; self-reported time spent playing outdoors outside of school hours.	PS; emotional problems measured via 9 questions designed for the study; self-rated life satisfaction using the Cantril Ladder; prosocial behaviour measured via 5 questions designed for the study.	• 77% of the sample was white. • 81% were Canadian born. • 80% of children lived in dual parent household. • 57% had high-perceived family wealth. • Excluded participants were more likely to be from ethnic minorities.	236
Kantomaa (2016)	Finland	1985 – 2002	Cross-sectional	8,061	OA	ST; self-reported average daily TV viewing, working on a computer, and playing video games in hours.	AA; GPA calculated from grades in languages, mathematics, biology, geography, physics, chemistry, religion or ethics, history, music, visual arts, physical education, crafts, and home economics.	• 13% of mothers had higher education.	167
Katon (2010)	United States	2007 – 2008	Cross-sectional	2,291	OA	ST; two questions about the hours and minutes spent on a computer and watching TV, that were adapted from a questionnaire used in a large survey of high school students.	PR; self-completed Patient-Health Questionnaire two-item depression scale.	• Household income mentioned but not reported for total sample. • 7% of sample was classified as a low-income household.	168
Kelz (2015)	Austria	2009	Pre-post quasi-experimental field research	133	EA	GT; schoolyard greening intervention.	CF, PR & PS; executive functioning was assessed with the Attention Network Test (alerting score, orienting score, and conflict score); blood pressure was measured as an	• Rural Austria. • Unclear.	139

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							indicator of physiological stress; the Basler Well-Being Questionnaire was used to assess current well-being (intra-psychic balance); the Recovery-Stress Questionnaire was used to determine recovery from stress.		
Khan (2018)	Bangladesh	?	Cross-sectional	671	EA	ST; self-report on the Adolescent Sedentary Activity Questionnaire, reporting time spent watching TV or DVDs, using a computer, and social media during each typical school day and weekend day.	PR; parent-report on the SDQ.	• 52% of mothers and 71% of fathers had tertiary level education. • Family income was split relatively evenly across quartiles. • Those with missing data were more likely to report low education or income.	140
Khouja (2019)	England	1991 – 2010	Longitudinal	1,869	OA	Both; self-report on six questions relating to average hours watching television, computer use, and texting for weekdays and weekend days; self-reported playing outdoors in Summer and Winter.	PR; self- and parent-report on the Pediatric Quality of Life Inventory.	• Participants lost at follow-up were more likely to have a mother with lower educational level. • 81-91% of children came from a “non-manual” family occupational social class.	238
Kim (2016)	United States	?	Cross-sectional	92	SC	Both; half-mile and quarter mile buffers were generated surrounding participant's homes, and various landscape indices were analysed; Percentage of Landscape, Number of Patches, Mean Patch Size, Mean Shape Index, Mean Nearest Neighbour Distance, and Patch Cohesion Index; total TV watching hours during the weekend, captured via the Physical Activity Questionnaire for Older Children.	PS; child- and parent-completed Pediatric Quality of Life Inventory, deriving psychosocial health summary score and total HRQOL score.	• The sample was composed of mostly Hispanic (83%), low-SES individuals. • 76% of children lived with both parents. • 49% of mothers were employed. • 22% of mothers had a college, vocational, or technical degree beyond secondary school.	237
Koivusilta (2007)	Finland	2001	Cross-sectional	7,292	Mixed (EA & OA)	ST; self-report of daily time spent on the computer for email, writing and surfing, playing	AA, PR & PS; student's subjective assessment of his/her relative position in class based on	• 60% of participants were from middle-to-high SES backgrounds.	186

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						digital games, and on mobile phone for texting, gaming.	preceding end-of-term school report; school status and type of school (not in school, vocational school, upper secondary school); 'educational career' was formed describing hypothesised educational prospects in adulthood; self-rated Health Status; self-reported Daily Health; self-report on 2 questions about Depression.		
Kremer (2014)	Australia	2006	Cross-sectional	8,029	SC	ST; self-report time spent watching television, on a computer, or playing video games for leisure, separately for week and weekend days in hours.	PR; self-report on the Short Mood and Feelings Questionnaire.	• Stratification by SES and rurality was conducted and communities were randomly selected from each stratum. • Within each community, a random sample of schools from the Catholic, independent and government sectors were represented across each state.	93
Kuo (2018)	United States	2009 – 2010	Cross-sectional	318 schools	SC	GT; greenness was measured in the School, the Catchment area (attendance boundaries for the school), and the Neighbourhood (the area inside the school catchment but outside the school zone); tree canopy cover and grass cover were captured for each area; Greenness variables were assessed by green cover data from the Chicago Urban Tree Canopy Assessment.	AA; School-level academic achievement; percentage of third graders at a school meeting or exceeding expectations in reading and math.	• Highly disadvantaged public elementary schools in Chicago. • 87% of third graders were eligible for free lunch • 45% were African-American, 43% Hispanic, and 3% Asian/Pacific Islander. • 26% spoke a language other than English at home.	94
Kweon (2017)	United States	2010 – 2011	Cross-sectional	219 schools	Mixed (SC, EA & OA)	GT; Green Space was measured in schools, including trees, grass and shrubs, bare soil, paved surfaces, and buildings; schools were geocoded for analysis and the 2011 land-use/land-cover map of D.C.	AA; Percentage of students who received Proficient or Advanced academic performance scores in mathematics; Percentage of students who received Proficient or Advanced academic performance scores in reading.	• 66% of students were enrolled in the free lunch program. • 80% of students were African American, followed by Hispanic (12.04%), and white (6.18%).	229

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Lacy (2012)	Australia	2005 – 2006	Cross-sectional	3,040	EA	ST; assessed via questions adapted from the 2002 National Children's Nutrition Survey conducted in New Zealand, which related to hours spent television viewing (including videos and DVDs), playing video games, and using the computer (other than for homework) over the last 5 school days and previous weekend.	PS; self-report on the adolescent module of the Pediatric Quality of Life Inventory 4.0 Generic Core Scales.	• 19% of participants were from areas with high SES. • 55% of participants were from middle SES areas.	141
Largo-Wright (2018)	United States	6-week period	Experimental cross-over	37	YC	GT; outdoor vs indoor classrooms.	PS; children completed a brief, self-reported 'Face Scale' survey after every writing lesson, to measure happiness; teachers completed an online survey at the conclusion of the study to measure perspectives on children's happiness and wellbeing in the nature and control conditions.	• 85-88% of the students identified as White, non-Hispanic.	64
Lemola (2015)	Switzerland	2012 - 2013	Cross-sectional	362	OA	ST; student-report on media consumption in bed before going to sleep on a regular school night; watching TV or movies, playing video games, talking or texting on the phone, and spending time online on Facebook or in chat rooms, or surfing the Internet.	PR; self-report on 6-items from the short version of the German version of the Centre of Epidemiological Studies Depression Scale.	• Unclear.	169
Li (2016)	United States	?	Randomised Controlled Experiment	94	Mixed (EA & OA)	GT; one classroom had no windows, one classroom had windows which opened onto a built space, and the third classroom had windows which opened onto a greenspace.	CF & PR; subjective attentional functioning was assessed using a Visual Analogue Scale questionnaire; objective attentional functioning was assessed with the Digit Span Forward and the Digit Span Backward tests; subjective stress was assessed using a Visual	• Diverse ethnicities included in sample, but numbers/proportions are not reported. • Schools were suburban, urban, and rural. • No SES information provided.	187

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							Analogue Scale questionnaire; objective stress was measured via physiological measures.		
Liu (2016)	China	?	Cross-sectional	13,659	OA	ST; 2 items from the Youth Risk Behavior Survey were used as measures of ST; self- reported hours watching TV or playing videogames/computer use on a typical school day.	PR; self-report on the Center for Epidemiologic Studies-Depression Scale; self-report on the Multidimensional Anxiety Scale for Children; Youth Self-Report scale.	• The sample's mean subjective social and economic status score (SD) was 6.1 (1.6; range, 1-the lowest to 10-the highest).	170
Maras (2015)	Canada	2006 – 2010	Cross-sectional	2,482	EA	ST; Leisure-Time Sedentary Activities 6-item questionnaire was designed by the investigators; self-report hours per day in TV viewing, video game playing, and computer use on weekdays and weekends.	PR; self-completed Children's Depression Inventory; self-completed Multidimensional Anxiety Scale for Children-10.	• At least one parent completed college for 87% of participants. • 72% of sample was Caucasian.	142
Markevych (2014)	Germany	2006 – 2009	Cross-sectional	1,932	SC	Both; access to urban green spaces measured by the shortest distance between each child's place of residence and the nearest urban green space, with data obtained from the local Bavarian land use dataset; time spent outdoors during Summer and Winter; time spent in front of a screen during Summer and Winter.	PR; parent-report on the German SDQ.	• 77% of parents had high educational level. • 89% of children lived with 2 parents.	249
Markevych (2019)	Germany	1995 – ~2014	Cross-sectional	2,429	Mixed (SC & OA)	GT; residential and school greenspace measured by NDVI, tree cover density, proportions of agricultural land, forest, and urban green space in buffers around addresses using a variety of GIS datasets; a combined home-school greenspace exposure was also created.	AA; parent-report of German and Maths grades at 10-years follow-up; self-report of German and Maths grades at 15-years follow-up.	• In the Munich sample, 73% of parents had high educational level & 83% of children lived with both parents. • In the Wesel sample, 42% of parents had high educational level, 50% had medium educational level, & 86% of children lived with both parents. • Participants with low SES and from immigrant families were	212

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								underrepresented in analytical samples.	
Mårtensson (2009)	Sweden	2004	Cross-sectional with comparison	198	SC	GT; Outdoor Play Environment at Preschools measured with the OPEC instrument; the fraction of free sky above the play structures (i.e. sky view factor) was also assessed.	CF; teacher-rated on the Early Childhood Attention Deficit Disorders Evaluation Scales.	• 29% of mothers had high educational level. • 54% came from high SES background.	95
Martinez-Lopez (2015)	Spain	2011	Cross-sectional	2,293	EA	ST; self-report on number of hours a day they watch TV and use the PC, for weekdays and weekends.	PS; Self-perceived health measured with a single item from the Health Behaviour in School-Aged Children Questionnaire; Well-being measured with a single item from the Health Behaviour in School-Aged Children Questionnaire.	• Unclear.	143
Mathers (2009)	Australia	2005	Cross-sectional	925	OA	ST; use-of-time data were collected by a computerised activity recall diary, the Multimedia Activity Recall for Children and Adolescents (MARCA); adolescents completed 4 MARCA diaries (2 full school days and 2 full weekend days); the MARCA's was used to determine minutes (per recall) devoted to television viewing, using a computer, playing video games, and telephone use (talking/texting).	PR & PS; Global Health assessed by self-report on a single item from the Child Health Questionnaire; Health Status assessed by self-report on the Pediatric Quality of Life Inventory 4.0; Health-related Quality of Life assessed by self-report on the KIDSCREEN; self-report on the Kessler-10; self-report on the SDQ.	• Baseline sample came from areas of greater advantage than the analysis sample. • 31% of participants were in the most advantaged socioeconomic quartile. • 60% of participants were from middle SES areas.	171
Matin (2017)	Iran	2011 – 2012	Cross-sectional	13,486	EA	ST; prolonged screen time was defined as watching TV, computer work and sedentary behavior (screen time in general) for more than 2 hours a day.	PS; Self-Rated Health was measured via a single question; participants indicated their degree of life satisfaction by using a ten-point scale.	• 66% of participants were from middle-to-high SES.	144
Matsuoka (2010)	United States	2004 – 2005	Cross-sectional	101 public schools	Mixed (EA & OA)	GT; student exposure to nature at each school involved three groups of measures; the views of nature that students had from	AA; academic achievement was measured via the percentage of Michigan merit award winners, based on performance on the	• Participant ethnicity and eligibility for free lunch program was considered, but	188

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						the school buildings were rated; vegetation levels on the campuses were measured; student potential access to this vegetation was determined.	Michigan Educational Assessment Program test; graduation rates as reported to the state; the percentage of seniors stating that they planned to attend a four-year college upon graduation.	numbers/proportions not reported.	
McAnally (2018)	New Zealand	?	Pre-post with comparison	104	EA (100% male)	GT; Outdoor Education Programme.	PS, AA & PS; self-completed Satisfaction with Life Scale; self-completed Rosenberg Self-Esteem Scale, self-completed SDQ; Students' National Certificate in Educational Achievement marks for English, Maths, Science, and Social Studies; Creative Thinking & Problem Solving assessed with the Remote Associates Test (Mednick, 1962).	• Private boarding school. • 86% identified as New Zealand European. • Students from mostly high socio-economic communities (school decile rating of 9, where 10 represents schools with the lowest proportion of students from low socio-economic communities).	145
McCracken (2016)	Scotland	2014	Cross-sectional	276	SC	GT; use of greenspace over the previous week assessed by self-report of type of green space used, frequency of use for each, and how often they had exercised outside in the previous week; Residential Greenspace data obtained from the Central Scotland Green Network and analysed with GIS.	PS; self-report on the Kid-KINDL questionnaire.	• On average, participants were from decile 6 (SD = 2.9) on the Scottish Index for Multiple Deprivation.	96
McCree (2018)	England	2013 – 2016	Longitudinal mixed methods	11	SC	GT; Forest Schooling.	AA, PS & Other; Wellbeing, involvement, and engagement measured by session leader and researcher using Leuven scale measures; academic attainment measured by comparing students on national standards in reading, writing, and mathematics; Nature Connection measured with the Connection to Nature Index.	• Included a social mix of families, with 26% eligible for Free School Meals (national average = 26%). • Children who were 'struggling to thrive', were seen as likely to underachieve, and were economically and emotionally disadvantaged with special education needs, were chosen for the Forest School.	97

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McDonald (2018)	Canada	2008 – 2010	Cross-sectional	1,596	YC	ST; parent-report of child's time per day on any type of media (television, movies, computer/tablet).	PR; parent-report on the Brief Infant-Toddler Social and Emotional Assessment.	• Mothers who joined and completed participation were more likely to have tertiary education, greater household incomes, & be Caucasian. • 78% of mothers had post-secondary qualifications. • 71% came from households earning ≥$80,000. • 82% of the sample was White/Caucasian.	65
McEachan (2018)	England	2012 – 2015	Cross-sectional	2,594	YC	GT; residential greenspace calculated with the NDVI around participants' geocoded home; subsample of respondents rated satisfaction with, and use of, local green spaces (public parks, sports playing fields, or other natural habitats; parents reported how many days their child played outside in green spaces per week in summer and winter, and how long on average (minutes per day); parents reported which greenspace they used most frequently in summer and were satisfied they were with its quality.	PR & PS; parent-report on SDQ.	• The study area, Bradford, is characterised by high levels of ethnic diversity and deprivation. • 58% of participants were of South Asian origin.	66
McHale (2001)	United States	2-year time period	Longitudinal	198	Mixed (SC & EA)	Both; each year seven evening telephone interviews were conducted; children and parents reported daily activities outside of school and work hours, including outdoor play and watching TV.	AA & PR; school grades were obtained from most recent report cards, and grade point averages were calculated from grades in math, science, social studies, and language arts; self-report on the Children's Depression Inventory; mothers rated children's conduct using the 5-item conduct problems subscale from the	• Almost all families were White. • 90% of parents were employed. • Maternal education level was reported as a mean of 14.57 (SD = 2.17), with 12 representing high school graduate and 16 representing college graduate. • Paternal education was a mean of 14.67 (SD = 2.40).	242

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							Strengths and Vulnerabilities Questionnaire.	• Family background characteristics were variable, ranging from working to upper-middle class.	
Mendelsohn (2010)	United States	2005 – 2008	Longitudinal	253	YC	ST; 24-hour recall diary based on an interview with the mother; information about all electronic media (television, videos/DVDs, movies, and games) on the most recent typical day.	CF; language development assessed using the Preschool Language Scale-4.	• Bellevue Hospital Center, New York City, is an urban public hospital serving low SES families. • 94% of mothers were Latina. • Average maternal education level was completion of Grade 10.	67
Mireku (2019)	England	2014 – 2016	Cross-sectional	6,616	EA	ST; adolescent-report of screen time 1 hour before sleep (mobile phone, tablet, eBook reader, laptop, portable media player, portable video game console, desktop computer, television or video game console) with the light on or in darkness.	PS; self-report of health-related quality of life on the KIDSCREEN-10.	• Majority of participants were White and had parents in a 'higher' occupation. • Majority of parents did not have higher education.	146
Mundy (2017)	Australia	?	Cross-sectional	876	SC	ST; parent-report how many hours their child spends watching TV or DVDs, playing video games (on computer or console (eg, Xbox)), and using the computer (e-mail/ schoolwork/internet access/chat), on school days and weekend days.	PR; parent report on SDQ.	• The sample was skewed to higher SES.	99
Mutz (2019)	Germany	2016	Pre-test post-test	76	OA	Both; Outdoor Adventure Program - the campsite as well as the surrounding area has neither access to the internet and television nor service for mobile phones; self-reported daily leisure time screen time, in front of television, computer and game console in their on an average weekday and weekend day.	PR & PS; self-report on the Perceived Stress Questionnaire (subscales 'worry', 'tension', 'joy', 'demand'); life aatisfaction assessed with single self-report item; hedonic balance measured according to Bradburn (2015).	• Participants predominantly represent the German middle-class.	146

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Mutz (2016)	Germany	2015	Longitudinal pre-test post-test pilot study	12	EA	GT; 9-day hike.	PR & PS; self-report on the Perceived Stress Questionnaire ("worry" & "demand" subscales); self-report on the General Self-efficacy Scale; self-report on the Mindful Attention and Awareness Scale; happiness and long-term life satisfaction measured with 2 self-report questions.	• Unclear.	244
Mößle (2010)	Germany	2005	Cross-sectional & longitudinal	5,529	SC	ST; self-report of average daily time watching television or playing computer games for regular school day and regular weekend day; participants also completed a timetable for the day before the interview where they could mark on a 30 min basis to what extent they performed various activities (e.g., watching TV or DVD, playing computer games, etc).	AA; marks in German, Mathematics, Science, and physical activity were obtained via a teacher questionnaire.	• Majority of parents had high educational background. • Majority of participants were native to Germany.	98
Nakamura (2012)	Japan	2009	Cross-sectional	3,464	SC	ST; questions pertaining to time spent using media (game, TV, and PC).	PR; subjective health complaints; measured by 9 items pertaining to depression, sleeplessness, ill at ease, dizziness, poor appetite, headache, abdominal pain, short-tempered, and negative thinking.	• Unclear.	100
Nathanson (2018)	United States	?	Cross-sectional	402	YC	ST; mother-reported how many hours the child uses a tablet or hand-held game player on a typical weekday and on a typical weekend day during the morning, the afternoon, and the evening.	CF; mother-report on questions from the short form of the Early Childhood Behaviour Questionnaire to assess temperamental EC.	• 80% of mothers were Caucasian. • 43% of mothers were employed. • On average, mothers had received some college education.	68
Nelson (2006)	United States	1994 – 1996	Longitudinal	11,957	Mixed (EA & OA)	ST; adolescents reported hours per week watching TV/videos, and playing video or computer games.	AA & PS; academic grades self-reported; self-report to 6 items modified from or similar to the	• 70% of the sample was White. • 55% of parents had some college level education.	189

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							Rosenberg Self-Esteem inventory.	• Mean household income was $45,000/year.	
Nihill (2013)	Australia	2010	Cross-sectional	357	EA (100% female)	ST; self-report on the Adolescent Sedentary Activity Questionnaire (ASAQ); participants report time outside school, during week days and weekends, they spent watching TV/videos/DVDs, using computers for school and non-school purposes (e-games and e-communication).	PS; participants completed the physical self-concept and global self-esteem subscales from Marsh's Physical Self-Description Questionnaire.	• Girls from low-income communities. • Mean SES score of 4.3 (SD = 1.8), where 1 is more disadvantaged and 10 is most advantaged. • 85% of participants were Australian.	148
Norton (2014)	United States	2010	Pre-test post-test	159	OA	GT; Wilderness Expedition.	PS; self-completed 40 Developmental Asset Profile, encompassing positive identity and self-esteem.	• Under-resourced urban teens. • 38% Hispanic, 25% African American and 9% Caucasian. • 37% of parents had a high school diploma and 20% had some college level education.	172
Ohannessian (2009)	United States	2006 – 2007	Longitudinal & cross-sectional	328	Mixed (EA & OA)	ST; adolescents indicated how much time they spent watching television, text messaging, e-mailing/IMing, playing video games (PlayStation, Nintendo, Game Boy, Xbox, etc.) or computer games, and “surfing the Web” on an average day.	PR; self-report on the Center for Epidemiological Studies Depression Scale for Children; self-report on the Child Anxiety Related Disorders scale.	• 41% were Caucasian, 22% were African-American and 24% were Hispanic. • 96% of mothers and 95% of fathers completed high school; 26% of mothers and 24% of fathers had completed college. • 52% of adolescents lived with both biological parents.	190
Otte (2019)	Denmark	2014 - 2015	Quasi-experiment	619	Mixed (SC & EA)	GT; education outside the classroom.	AA; mathematics skills were assessed using Hogrefe’s MG/FG test.	• 53% from high SES backgrounds. • 41% from middle SES backgrounds.	221
Page (2010)	England	2006 – 2008	Cross-sectional	1,013	SC	ST; children reported how many hours they watched TV and played on the computer (not for homework) per day.	PR & PS; self-report on the SDQ.	• Participants who completed all data collection had lower deprivation scores compared to those who were excluded.	101
Parkes (2013)	England, Wales, Scotland, Northern Ireland	2005 – 2009	Longitudinal	11,014	SC	ST; mother-report of child’s television/video/DVD viewing and computer or electronic game playing, outside school on weekdays.	PR & PS; mother-report on the SDQ.	• 90% of mothers were White. • 41% of mothers working. • Approximately 38% of mothers had higher education qualifications.	102

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								• Those who dropped out were more likely to be from disadvantaged families.	
Peiró-Velert (2014)	Spain	2010	Cross-sectional	3,006	Mixed (EA & OA)	ST; self-report on sedentary screen media use variables from the Adolescent Sedentary Activity Questionnaire; including TV/video/DVD viewing, computer for playing, computer for communicating, computer for doing homework, overall computer use, passive videogames, active videogames, mobile for communicating, mobile for playing.	AA; academic achievement or performance in the previous academic year.	• Spectrum of SES appears to be represented, but no numbers/proportions are reported.	191
Perry (2012)	United States	2000	Cross-sectional	371	SC	ST; children reported how many hours they sat and watched television or videos, played video games, or used the computer yesterday.	PS; self-report on the Pediatric Quality of Life Inventory version 4.0.	• High concentration of minority residents and families with children living in poverty. • 57% of participants were Black and 40% were White. • 24% of participants experienced food insecurity. • 57% had annual income <$30,000.	103
Piccininni (2018)	Canada	2013 / 2014	Cross-sectional	20,697	Mixed (SC, EA & OA)	GT; students reported how many hours a day they usually spend time playing outdoors outside school hours and on weekends.	PR; self-report on an eight-item scale which asked about psychological (feeling low or depressed, irritability or bad temper, feeling nervous, and difficulties in getting to sleep) and somatic (headache, stomach ache, backache, and feeling dizzy) symptoms.	• There were no notable differences between those included and excluded with regards to ethnicity and perceived family wealth. • Of those included, 57% perceived their family wealth to be above average. • 80% of participants were from Canadian dominant culture. • 70% of participants came from neighbourhoods with medium-to-high capital.	227
Plitponkarnpim (2018)	Thailand	2014 - 2015	Cross-sectional	483 families	YC	ST; Information & Communication Technology exposure; daily screen time (TV,	CF; Capute Scales used to determine the presence of atypical development in	• 61% of parents had a bachelor's degree.	69

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						computer, tablet, smart phone, handheld game consoles) was parent-reported; 6-hour diary record blocks-recall input questionnaire at the clinic; prospective 1-hour blocks diary home recording.	cognitive development (visual-motor functioning) and expressive-receptive language.	• Over 60% of mothers worked.	
Poulain (2018)	Germany	2011 – 2017	Cross-sectional & longitudinal	850 & 512	EA	ST; self-report about the duration (hours) of the daily time spent with different screen-based media (TV/video, game console, PC/ internet, mobile phone).	AA; school grades were assessed for German, Mathematics, and Physical Education.	• 62% of participants belonged to the middle-class, while 22% to high-class.	149
Poulain (2019)	Germany	2011 – 2017	Longitudinal	814	Mixed (EA & OA)	ST; self-report of electronic media time per day using television/video, computers/Internet, and mobile phones.	PR & PS; behavioral difficulties assessed by the SDQ; quality of life derived from the KIDSCREEN-27.	• 62% of participants were from middle SES backgrounds, while 25% were from high SES backgrounds. • Compared to drop-outs, adolescents in analyses had higher SES.	192
Primack (2011)	United States	2003 – 2008	Cross-sectional	106	EA	ST; media exposure data were collected using a cellular telephone-based EMA protocol; calls from a trained staff member during 5 extended weekends (Friday through Monday) in an 8-week period; participants were asked at every telephone call to identify any media they were using; they were specifically asked about (1) television or movies, (2) music, (3) video games, (4) Internet, (5) print media (magazines, newspapers, books).	PR; adolescent and parent interviews using the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version; a child psychiatrist provided a final diagnosis based on DSM-III-R or DSM-IV criteria.	• 89% of participants were white.	150
Przybylski (2017)	England	?	Cross-sectional	120,115	OA	ST; self-reported time watching films and other media (e.g., TV programs), playing games (e.g., on computers and consoles), using computers (e.g., Internet,	PS; self-report on the Warwick-Edinburgh Mental Well-Being Scale.	• Nationally representative sample. • No specific numbers/proportions	22

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						e-mail), and using smartphones (e.g., social networking, chatting online) during free time.		reported on levels of deprivation or ethnicity.	
Radesky (2014)	United States	2001 – ~ 2004	Retrospective cohort study	7,450	YC	ST; parent-report how many hours their child spent watching TV and videos on a typical weekday and weekend day.	PR; caregivers completed the modified Infant Toddler Symptom Checklist.	• 46% of children were White, 16% were Black, 21% were Hispanic and 17% were Asian/Pacific Islander/Alaska Native. • 50% of mothers had at least some college level education. • 61% of mothers employed.	70
Reshadat (2013)	Islamic Republic of Iran	2012	Cross-sectional	573	EA	ST; students reported daily time spent playing computer or video games.	PR & PS; student-report on the General Health Questionnaire.	• 58% of fathers had a diploma or higher diploma. • 47% of mothers had a diploma or higher diploma.	151
Richardson (2017)	Scotland	2005 – 2010	Longitudinal	2,909	Mixed (YC & SC)	Both; quantified the area of public parks and total natural space around each child's home; surveyed whether the child had access (sole or shared) to a private garden; hours of screen time per day.	PR & PS; parent/caregiver-report on the SDQ.	• In 38% of households, at least one person had achieved a degree qualification. • In 38% of households, at least one person had achieved a vocational qualification. • 23% of participants were from the most deprived neighbourhood areas.	245
Robinson (2011)	Australia	1989 – ~ 2006	Cross-sectional	1,275	EA	ST; adolescent reported their daily television/video viewing habits and computer use.	PR; parent report on the Child Behaviour Checklist for Ages 4 – 18.	• 91% of adolescents were Caucasian. • Other measures of SES, such as family income, were considered but numbers/proportions were not clearly presented.	152
Roe (2011)	Scotland	2007	Pre-test post-test with comparison	36	SC	GT; Forest School.	PR & PS; a shortened 14-item version of the University of Wales Institute of Science and Technology Mood Adjective Checklist was used to measure participants' mood, hedonic tone, energy, stress, and anger levels.	• Deprived urban areas of Central Scotland.	104

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
Rose (2018)	Australia	2014 – 2015	Multisite pre-post design	160	OA	GT; Outdoor Programs.	PR & PS; students completed the Generalized Self-Efficacy Scale; the short form of the Ryff Well-Being Scales; 3 subscales (aggression, depression, and fear) from the Early Adolescent Temperament Questionnaire-Revised; the Nature Relatedness Scale.	• The sample was homogenous in terms of SES, which was considered high.	173
Rosen (2014)	United States	?	Cross-sectional	1,030	Mixed (YC, SC, EA & OA)	Both; parent-report of child's daily media and technology usage (going online, using a computer for other than being online, sending and receiving e-mail, IMing/chatting, talking on the telephone, texting, playing video games, listening to music, and playing with technological toys); parent-report of child's daily outdoor play and exercise.	CF & PR; parent-report on the 18-item Attention Deficit Hyperactivity Disorder Rating Scale–IV–school version; parent and child attention symptomology checklist; Yale Single Item Depression Scale; parent-report on behavior problems in three items from the 11-item symptomology checklist.	• 39% of children were Latino/a, 22% were Caucasian, and 18% were Black/African-American. • 60% of parents were employed full time or part time (14%). • 41% of parents had a college degree and an additional 31% had some college.	246
Rosenqvist (2016)	United States	2005 – 2006	Cross-sectional	381	SC	ST; parent-report of how many hours per day the child watches TV, or uses the computer for homework, playing games, Internet, or other).	CF; psychologist administered the NEPSY-11, measuring Attention and Executive Functioning, Language, Memory and Learning, Social Perception, and Visuospatial Processing.	• Those who did not participate were more likely to have parents with lower educational level. • 64% of mothers had college-level education.	105
Ruiz (2010)	Spain	2000 – 2002	Cross-sectional	1,820	Mixed (EA & OA)	ST; self-report of daily hours viewing television and playing video games.	CF; Spanish version of the "SRA Test of Educational Ability" to assess cognitive performance; verbal, numeric, and reasoning ability.	• SES considered in analyses, but numbers/proportions are not reported.	193
Rusby (2014)	United States	2009 – 2011	Ecological Momentary Assessment (EMA) Study	82	EA	ST; participants completed four EMA assessment periods; students were prompted during non-school hours only; participants were asked about activities or behaviours they were doing, including small screen activities (being on the	PR & PS; using a 1-to-9 scale, participants reported on their current mood states.	• 59% of participants were Caucasian, 16% Hispanic/ Latino, 5% American Indian, 2% Asian, 1% African American, 1% Hawaiian/Pacific Islander, 9% mixed race/ethnicity, and 7% unknown.	153

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
						computer, watching television, or playing video games).			
Russ (2009)	United States	2003 – 2004	Cross-sectional	54,863	Mixed (SC, EA & OA)	ST; parent-report of hours child spends watching TV, watching videos, playing video games, using the computer (not for schoolwork) on an average day.	PR & PS; parent-report of child's general health status on the National Survey of Children's Health; parent-report on one question about child social/emotional problems; parent-report on child's self-esteem.	• Excluded participants were more likely to be from low-income families, to be of black or Hispanic race/ethnicity, and to come from households where the highest reported educational level was less than college. • 66% of the sample was White. • 70% of parents had educational attainment beyond high school. • 75% of children lived in 2-parent households.	228
Sanders (2018)	United States	2011 – 2012	Longitudinal	374	Mixed (EA & OA)	ST; youth- reported how many hours they spend in a typical day watching TV programs and playing video games.	PR; internalizing behavior problems were measured using depression and anxiety-related items representative of core symptoms in each domain.	• 65% of participants identified as white, 13% as African-American, and 22% as other or mixed race. • 70% of children were from dual-parent households. • Average income was $66,000 yearly.	194
Schutte (2017)	United States	?	Experimental crossover	67	YC & SC (stratified)	GT; children were randomised to walk in either an urban environment or a natural environment.	CF; Spatial Working Memory Task; Go-No Go Task (Wiebe et al., 2011); Continuous Performance Task (Wiebe et al., 2011); Digit Span Back Task (school-aged children only).	• A majority of the families were middle class. • 69% of participants were reported as Anglo-American, 7% were African American, and 24% did not report race/ethnicity.	73
Sharif (2010)	United States	2003 – 2005	Longitudinal	4,533	EA	ST; self-report on how many hours adolescents watch TV, movies, videos, play videogames, on school days.	AA; self- and parent-reported school performance and grades.	• Participants who dropped out were more likely to be of non-white race and lower socioeconomic status. • 62% of participants were white, 18% Hispanic, 11% black, and 9% were other race.	154

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
								• 31% had a parent with a college degree. • Household income ranged from $10,000 or less (8%) to over $75,000 (30%).	
Sharif (2006)	United States	1999	Cross-sectional	4,508	EA	ST; self-reported hours adolescents watch TV and play videogames on weekdays and weekends.	AA; self-reported school performance.	• Those with missing data were more likely to have lower levels of parental education and come from lower SES schools. • For 78% of participants, both parents had completed high school. • 56% of schools were middle-to-high SES (based on free lunch programs).	155
Shiue (2015)	Scotland	2012 / 2013	Cross-sectional	1,997	Mixed (YC, SC & EA)	ST; parents reported children's daily TV and/or screen watching time in household interviews.	PR & PS; parent-report on the SDQ; self-rated health as either "good" or "fair to poor."	• Nationally representative sample. • No other SES information provided.	211
Soderstrom (2013)	Sweden	2009	Cross-sectional with comparisons	169	Mixed (YC & SC)	GT; outdoor environment quality at day care centres assessed by three persons using the Outdoor Play Environment Categories scoring tool; time spent outside was also measured for children.	PR; mid-morning and mid-afternoon saliva sampling to measure cortisol as an indicator of stress.	• Day-care centres with very low-quality environment and low SES were underrepresented. • Day-care centres were from 2 socio-economic regions – one being high/medium and the other being medium/low SES. • In high socio-economic areas, more mothers had post-graduate education.	207
Straker (2013)	Australia	2003 – 2006	Cross-sectional	643	EA	ST; self-report Multimedia Activity Recall for Children and Adults; adolescents recorded their activities in a self-report recall electronic diary/questionnaire for a minimum of seven days (weekdays and weekends); including TV viewing, playing	PR & PS; self-report on Cowan's Perceived Self-Efficacy Scale; self-report on Beck's Depression Inventory for Youth; self-report on the Child behaviour Checklist.	• 95% of participants had at least one Caucasian parent and SES comparable with the general Australian population.	156

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						electronic games at a video game centre, using handheld electronic game devices such as Gameboy, using console devices such as PlayStation, different computer uses such as graphics, word processing, email, internet, gaming, and general.			
Strong (2018)	Taiwan	2001 – 2006	Longitudinal	3,795	Mixed (EA & OA)	ST; self-reported hours spent online gaming and online chatting/communicating per week.	PR; participants completed the Center for Epidemiologic Studies Depression Scale (modified for mental health-related studies of adolescents in Taiwan).	• Study used a multistage cluster sampling design to provide a nationwide representative sample in Taiwan. • On average, parents had completed high school level education.	195
Suchert (2015)	Germany	2014	Cross-sectional	1,296	EA	ST; students reported how much time they spent on the most recent school day and the most recent Sunday with watching TV/DVDs, playing video/computer games (except active electronic gaming), other leisure-time pursuits on the computer/mobile phone.	PR & PS; self-report on the subscale “depressed affect” of the German version of the Center for Epidemiological Studies Depression Scale for Children; self-report on three items of the KINDL-R to measure self-esteem.	• 58% of participants attended a “Gemeinschaftsschule” or “Regionalschule” school, which tend to recruit students from low- to middle-class families. • 42% of participants attended a “Gymnasium” school, which serves mainly students from middle- and upper-class families.	157
Swing (2010)	United States	13-month period	Longitudinal & cross-sectional	1,323	SC	ST; parent and child reported average time spent watching TV and playing video games during 4 time periods (6AM - 12PM, 12PM = 6PM, 6PM - 12AM, 12AM - 6AM) on weekdays and weekends.	CF; teacher-report on 3 items that measure attention problems in the classroom.	• Unclear.	106
Syvaoja (2013)	Finland	2011	Cross-sectional	277	EA	ST; screen time was evaluated with questions used in the WHO Health Behavior in School-Aged Children study; self-reported weekday and weekend hours watching TV and videos, playing	AA; GPA was calculated and from subjects including native language, first foreign language, mathematics, physics/chemistry, biology, history, geography,	• In 79% of families, the highest level of parental education was tertiary level education.	158

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
						computer or video games, or using a computer (for purposes other than playing games, for example, e-mailing, chatting, or surfing the Internet or doing homework).	religion or ethics, visual arts, music, and physical education.		
Syvaoja (2014)	Finland	2011	Cross-sectional	224	EA	ST; self-reported daily hours on weekdays and weekends watching television/videos, playing computer or video games, using a computer (for purposes other than playing games, for example, emailing, chatting, or surfing the Internet or doing homework).	CF; cognitive functioning assessed using the Neuropsychological Test Automated Battery; visual memory assessed with a Pattern Recognition Memory test; executive functions assessed with Spatial Span and Intra-Extra Dimensional Set Shift tests; tests assessing attention were Reaction Time and Rapid Visual Information Processing.	• 71% of mothers and 56% of fathers had tertiary level education.	159
Tallis (2018)	United States	2012	Cross-sectional	495 schools	SC	GT; school surrounding greenness measured by the NDVI; agricultural lands in school surroundings; percentage of trees and shrubs around schools.	AA; California Standardized Testing and Reporting data on student achievement from 2012; standardized tests in science, mathematics and English language.	• Ethnicity and proportion of students eligible for a free lunch program were used as proxies for SES. • Numbers/proportions were not reported though.	107
Tillman (2018)	Canada	2011 – 2013 & 2016	Cross-sectional	851	Mixed (SC & EA)	GT; accessibility to nature (parks and water) was defined using Euclidean buffers at 500M around each child's home; NDVI was used to measure grass and shrubbery and dense vegetation in the buffers.	PS; child-report on the Pediatric Quality of Life Inventory 4.0.	• Almost 70% of participants living with 2 parents. • 62% of mothers and 52% of fathers had post-secondary education. • 62% of mothers and 68% of fathers were employed. • 67% of participants were from medium-to-high income households.	218
Tomopoulos (2010)	United States	2005 – 2008	Longitudinal	259	YC	ST; 24-hour recall diary based on an interview with child's mother; provided information about all electronic media (television, videos, DVDs, movies, games)	CF; cognitive development assessed using the Bayley Scales of Infant and Toddler Development-III; language development assessed using the Preschool Language Scale-4	• Urban public hospitals serving at-risk families. • 41% of mothers were high school graduates. • Spanish was the primary language spoken for 86%.	71

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						the child had been exposed on the most recent typical day.	(auditory comprehension and expressive communication subscales).		
Trinh (2015)	Canada	2009	Cross-sectional	2,660	OA	ST; self-reported daily hours watching TV/movies, playing video/computer games, on a computer chatting, emailing, or surfing the internet, over the past 7 days.	AA, PR & PS; psychological distress was measured with the General Health Questionnaire; self-report on the Center for Epidemiologic Studies Depression scale; self-report on six items adapted from the Rosenberg Self-Esteem Scale; self-reported academic grades.	• The study sample was a highly dispersed distribution of over 100 schools including students from urban and rural schools and at all levels of socio-economic status. • On average, highest parental education was 14.6 years (SD = 1.71).	174
Twenge (2018a)	United States	2009 – 2015	Surveillance: time-lag design	388,275 ; 118,545	Mixed (EA & OA)	ST; in 2009, 2011, 2013 & 2015 self-report of average daily hours spent playing video or computer games or using a computer for something that is not school work (including activities such as Nintendo, Game Boy, PlayStation, Xbox, computer games, the Internet, Nintendo DS, iPod touch, Facebook, an iPad or other tablet, a smartphone, YouTube, or other social networking tools); self-reported social media use (visiting social networking websites); self-reported frequency of reading news on the internet; self-reported TV watching on average weekdays and weekends.	PR; self-report on 6-items from the Bentler Medical and Psychological Functioning Inventory depression scale.	• A nationally representative survey of 8th, 10th, and 12th graders. • 62% of adolescents were from higher SES.	196
Twenge (2018b)	United States	2006 – 2016	Surveillance: time-lag design	41,773	Mixed (EA& OA)	ST; Internet hours per week (not for school or work - e-mailing, instant messaging, gaming, shopping, searching, downloading music, etc); gaming hours per week (playing electronic games on a computer, TV, phone, or other device);	PS; self-report on the Rosenberg Self-Esteem Scale; self-report on a single item about life satisfaction; self-reported happiness.	• Race/ethnicity, SES, mother's education considered in analyses, but numbers/proportions not reported.	197

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
						texting hours per week; social media hours per week (visiting social networking sites like Facebook); video chat hours per week (video chatting (Skype, etc.); reading news online; TV viewing.			
Ulset (2017)	Norway	2006 – 2009, 2011	Longitudinal	562	Mixed (YC & SC)	GT; daycare managers reported daily hours children spent outdoors at daycare centres; daycare centers were also categorised as "nature-based" or "conventional."	CF; teacher-report on the SDQ; children were tested with the Digit Span test, a subset of the Weschler Intelligence Scale for Children.	• 45% of mothers had some form of tertiary education, compared to 28% in Norway. • 84% of mothers and 96% of fathers were employed. • The median household income was approximately NOK 623 000. This was slightly lower than the national Norwegian average for households with children aged 0-5, but higher than the regional average for where the families lived.	208
Ussher (2007)	England & Wales	?	Cross-sectional	2,623	Mixed (EA & OA)	ST; children reported daily hours they watched TV, videos, and played computer games.	PR; self-report on the SDQ.	• Majority of participants lived with both parents. • Parents typically worked in middle-to-high class occupations.	198
van Dijk-Wesselius (2018)	The Netherlands	2014 – 2016	Quasi-experimental / prospective intervention study	2,031	SC	GT; schoolyard greening intervention.	CF & PR; Digit Letter Substitution Test to measure information processing speed (Natu & Agarwal, 1995); Sky Search task (a subscale from the Test of Everyday Attention for Children) to measure selective attention (Manly et al., 2001); emotional functioning assessed on the subscale emotional functioning of the Pediatric Quality of Life Scale.	• Intervention and control schools were carefully matched on socio-economic status. • No other SES information reported.	108
van Lier (2017)	New Zealand	2012	Cross-sectional	8,063	Mixed (EA & OA)	GT; gardening activity assessed with one item, "Do you or your	PR & PS; student-report on the World Health Organization Well-being Index; measures positive	• Diverse ethnicities.	199

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
						family grow any of your own vegetables?"	mood, vitality, and general interests; student-report on the Reynolds Adolescents Depression Scale-Short Form.	• Approximately 68% of the sample lived in areas which were middle-to-high SES. • 81% of participants lived in households with no individual-level poverty.	
Verburgh (2016)	The Netherlands	?	Cross-sectional	163	SC (100% male)	Both; participants indicated how many days per week and how many minutes per day they participated in outdoor play, TV-watching, computer use, and active gaming.	CF; motor inhibition measured with the Stop Signal Task; short term memory (verbal and visuo-spatial) assessed with the Digit Span Forwards task; working memory examined using the Digit Span Backwards task; modified version of the Attention Network Test used to measure alerting and orienting attention; modified version of the Flanker task to assess executive attention.	• Unclear.	250
Wang (2019)	United States	2009, 2011, 2013, 2015, 2017	Surveillance study	75,807	Mixed (EA & OA)	ST; self-report of daily hours playing video or computer games or using a computer for something that is not school work (Xbox, PlayStation, an iPod, an iPad or other tablets, a smartphone, YouTube, Facebook or other social networking tools, and Internet) on an average school day.	PR; self-reported psychological distress on three questions; poor mental health status was recorded if students answered yes to any of the three questions.	• Majority of the sample was White (>50% across each measurement year). • No other SES information reported.	200
Ward (2016)	New Zealand	2014	Observational Study	72	EA	GT; greenspace exposure measured by GPS monitors worn by students for a 7-day period; access to publicly accessible parks, sports fields, and reserves was measured, but vacant land, school playgrounds, or backyards were not measured.	CF & PS; self-report on the Life Satisfaction Scale, 5 items derived from Hubener's Student Life Satisfaction Scale, the Ten Domain Index of Wellbeing, and a single item measure of happiness with life; 7 computerised neurocognitive tests were used to calculate performance in visual memory, verbal memory, processing	• Participating schools were all middle-to-high SES.	160

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
							speed, psychomotor speed, reaction time, cognitive flexibility, and executive function.		
Wells (2000)	United States	?	Longitudinal (pre-move post-move design)	17	Mixed (SC & EA)	GT; a naturalness subscale completed by a trained researcher, of a detailed objective Housing Quality Scale (Evans, Wells, Chan, & Saltzman, 2000); amount of nature in the window views as well as the material of the yard; completed for participants' home at phase 1, and for their new home in phase 2.	CF; mother-report on the Attention Deficit Disorders Evaluation Scale.	• Low-income urban children. • 64% of children were African American.	219
Wells (2003)	United States	?	Cross-sectional	337	SC	GT; naturalness scale of the residential environment was developed as part of a detailed housing scale instrument (Evans, Wells, Chan, & Saltzman, 2000); the amount of nature in the window view, the number of live plants indoors, and the material of the outdoor yard.	PR & PS; mother-report on the Rutter Child Behavior Questionnaire; child-report on the Global Self-Worth subscale of the Harter Competency Scale (Harter, 1982).	• 44% of children's parents were single, divorced, or widowed. • 95% of participants were White. • 63% of mothers had completed some college. • Mean income-to-needs ratio for the families was 1.79 (SD = 1.66), where a ratio of 1.0 or below represents poverty.	109
Williams (2018)	Australia	2015 – 2016	Quasi-experimental cross-over trial	335	OA	GT; outdoor adventure program.	PS & PR; self-report on the Generalised Self-Efficacy Scale, the Short Warwick Edinburgh Mental Well-being Scale, and the Basic Psychological Needs Scale-General.; self-report on the short-form of the State-Trait Anxiety Inventory, the 10-item Center for Epidemiologic Studies Depression scale, and the SDQ; Nature Relatedness measured with a 6-item shortened version of the Nature Relatedness Scale.	• The sample was relatively homogeneous in terms of SES (mean = 5.98, SD = 1.22), which was considered high (range 4–10, where lower scores equate to higher SES).	175
Wood (2013)	England	2009	Randomised Controlled Trial	25	EA	GT; while completing a 10-minute cycling exercise,	PR & PS; self-report on the Rosenberg Self-Esteem Scale;	• Unclear.	161

First author (publication year)	Country of sample	Study time-frame	Study design	Sample total N	Age group (YC, SC, EA, OA)	Exposure (ST, GT, or Both)	Psychological outcome (AA, CF, PR, PS)	Indicator of socioeconomic status (SES)	Ref #
						participants either viewed natural or built scenes on a projector screen.	self-report on the Adolescent Profile of Mood States Questionnaire.		
Wu (2018)	Canada	2003 – 2011	Longitudinal	4,861	Mixed (SC & OA)	ST; students reported the daily number of hours they spent playing computers or video games and watching TV.	PR; primary diagnosis of an internalizing or externalizing disorder obtained from health administrative data.	• 70% of parents had college or university level education. • Approximately 88% of participants came from middle-to-high income households.	214
Wu (2014)	United States	2006 – 2012	Cross-sectional	905 public schools	SC	GT; amount of trees and vegetation (greenness) in the vicinity of schools, measured by the NDVI.	AA; data from the Massachusetts Comprehensive Assessment System provided the school-based measure of student performance in English and Math.	• Approximately 65% of students were middle-high income. • 67% of participants were White.	110
Yan (2017)	China	2016	Cross-sectional	2,625	OA	ST; students reported how many hours a day they usually spent watching television, playing e-games, receiving news or study materials from electronic devices, using social media sites or apps, and watching videos both on school days and on non-school days.	AA, PR & PS; self-reported scores on the last cumulative examination in their grade; self-report on the Middle School Student Mental Health Scale (developed by Wang) to assess anxiety; self-report on the Satisfaction with Life Scale; self-report on the Rosenberg Self-Esteem Scale.	• Unclear.	176
Yang (2013)	Iceland	2007	Cross-sectional	10,467	Mixed (SC & EA)	ST; students reported the average time they usually spent each day watching TV/DVD/VCR, playing Internet computer games, playing computer games not on the internet, using internet communication or 'chatting' channels, and 'other' computer use.	PR; self-report on the Symptom Check List 90 (little interest in doing things, little appetite, loneliness, that they cried easily or wanted to cry, had difficulties falling asleep or staying asleep, feeling sad or blue, or felt the future seemed hopeless).	• Population-based data, but SES not reported.	220
Zach (2016)	Germany	2005 – 2006	Cross-sectional	6,206	SC	GT; parents reported accessibility of green space (availability of public parks or green spaces).	PR; parent-report on the SDQ.	• Approximately 90% of parents were working. • Approximately 69% of households had medium-to-high income.	111

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								• Approximately 89% of children were raised by both parents.	
Zhao (2018)	China	2016	Cross-sectional	20,324	YC	ST; time spent on video programs, electronic games, and browsing the web via screen (including television, computer, cellphone, iPad, etc) on weekdays and weekends in the latest month was reported by parents.	PR & PS; parent-report on the SDQ.	• Approximately 50% of mothers had university level education. • 97% of children's parents were still married. • Approximately 73% of children lived in middle-to-high income households.	72

AA = academic achievement; ADHD = attention deficit hyperactivity disorder; CF = cognitive functioning; DSM = Diagnostic & Statistical Manual; DVD = digital video disc; EA = early adolescents (12 – 14 years old); GIS = geographic information systems; GPA = grade point average; GPS = Global Positioning System; GT = green time; HRQOL = health-related quality of life; NDVI – Normalized Difference Vegetation Index; OA = older adolescents (15 – 18 years old); PC = personal computer; PR = indicators of poor mental health; PS = indicators of positive mental health; SAVI = Soil Adjusted Vegetation Index; SES = socioeconomic status; SC = schoolchildren (5 - 11 years old); SD = standard deviation; SDQ = Strengths & Difficulties Questionnaire; ST = screen time; TV = television; VCR = videocassette recorder; WHO = World Health Organization; YC = young children (<5 years old).

S4. Results from studies including mixed age groups (ST = 36 studies; GT = 17 studies)

(Reference numbers correspond to *PLOS ONE* publication reference list, not thesis reference list)

Screen Time Exposures

Indicators of Poor Mental Health	**Psychological Outcomes Measured**	1 Active Electronic Games	2 Communication-Based Screen Time	3 Computer Use	4 Electronic Device Use - Leisure Time	5 Emailing/IMing/Texting	6 Gaming	7 Internet Use	8 Mobile Phone Use	9 Screen-Based Media Use/Screen Time	10 Sedentary/Passive Electronic Games	11 Social Media Use/Social Networking	12 TV Watching	13 TV/VCR/DVD Watching Time
	Anxiety					**190CS**; 190L	**190CS[V,B]**; **190L[V,B]**; **190CS[V,G]**; **190L[V,G]**	**190L**; **190CS[Alc]**					**190CS[B]**; **190CS[G]**; 190L	
	Anxiety Symptoms									**182CS**; 182L				
	Conduct Problems (SDQ)			192L[I]					192L	**215CS**; **215L[Kc]**; **211CS**				192L
	Cortisol Levels (morning)													
	Crying easily or wanting to cry			**220CS**			**220CS[I]**; **220CS**	**220CS[Ch]**						**220CS**
	Daily Health Complaints			**186CS**			**186CS[D]**		**186CS**					
	Daytime Tiredness			**186CS**			**186CS[D]**		**186CS**					
	Depression			178L; 179CS[I]; **186CS**		190CS; 190L	178L[V]; **179CS[V]**; **186CS[D]**; 190CS[V]; 190L[V]	190CS; 190L	**178L**; **186CS**				**178L**; 190CS; **190L[B]**; **190L[G]**	179CS
	Depressive Symptoms							**195L**; **196STLD[N]**		**182CS**; 182L		**196STLD[G]**; 196STLD[B]	**196STLD**	
	Emotion Self-Regulation													**202CS**
	Emotional Problems (SDQ)			**192L[I]**; **205PC[WD,G]**; 205PC[WD,B]; 205PC[WE]					192L	**215CS[Kc]**; **215L[Bc]**; **211CS**			205PC	192L
	Externalising Problems			180CS; 224L			**214L[V,C,B]**; 214L[V,C,G]; **224L[B,V]**; 224L[G,V]						**180CS**; 214L[B]; **214L[G]**; **224L[G†]**; 224L[B]; 224L[G‡]	
	Feeling Lonely			**220CS**			**220CS[I]**; **220CS**	**220CS[Ch]**						**220CS**

Green Time Exposures

Indicators of Poor Mental Health	**Psychological Outcomes Measured**	14 Agricultural Land	15 Blue Space / Water	16 Classroom Features	17 Connection to Nature	18 Distance to City Parks from Residence	19 Education Outside the Classroom	20 Forest Area	21 Gardening Activity	22 Green Features in Environment	23 Greenspace / Parks	24 Views	25 Greenness (NDVI)	26 High Quality Outdoor Environment	27 Naturalness in the Home	28 Nature-Based Daycare Centres	29 Outdoors	30 Total Natural Space	31 Trees	32 Vegetation on Campus	33 Wilderness Expedition
	Anxiety																				
	Anxiety Symptoms																				
	Conduct Problems (SDQ)					**203CS[LME]**; 203CS[HME]							203CS[R,LME]; **203CS[R,HME]**								
	Cortisol Levels (morning)													**207CSC**							
	Crying easily or wanting to cry																				
	Daily Health Complaints																				
	Daytime Tiredness																				
	Depression																				
	Depressive Symptoms								**199CS**				**209PC[CA]**								
	Emotion Self-Regulation																				
	Emotional Problems (SDQ)					203CS							203CS[R]								
	Externalising Problems																				
	Feeling Lonely																				

		Screen Time Exposures													Green Time Exposures																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Feeling Sad or Blue			**220CS**			**220CS**[I]; **220CS**	**220CS**[Ch]						**220CS**																				
	Feeling that the future is hopeless			**220CS**			**220CS**[I]; **220CS**	**220CS**[Ch]						**220CS**																				
	Having difficulties falling asleep or staying asleep			**220CS**			**220CS**[I]; **220CS**	**220CS**[Ch]						**220CS**																				
	Having little appetite			**220CS**			**220CS**[I]; **220CS**	**220CS**[Ch]						**220CS**																				
	Health Complaints									**185CS**[NA]; **185CS**[NE]; **185CS**[SE]; 185CS[WE]; **185CS**[EE]																								
	Hyperactivity/ Inattention (SDQ)			192L[I]					192L	**215CS**; **215L**[Kc]; 211CS				192L					**203CS**[LME]; 203CS[HME]							203CS[R]								
	Internalising Problems			180CS; 224L[B‡]; 224L[†]; **224L**[P,G‡]; **224L**[St,G‡]			**214L**[C,V]; 224L[V]			**194L**			**180CS**; 214L; 224L																					
	Little interest in doing things			**220CS**			**220CS**[I]; **220CS**	**220CS**[Ch]						**220CS**																				
	Peer Problems (SDQ)			**192L**[I]; 205PC					192L	**215CS**; **215L**[Kc]; **211CS**			205PC	192L					**203CS**[LME]; 203CS[HME]							203CS[R]								
	Psychological Distress				**200S**																													
	Psychosomatic Symptoms																	**227CS**[P]												227CS[P,B]; **227CS**[P,G]				
	Socioemotional Difficulties/ Problems			228CS			**223CS**[Con]; 223CS[C]	**223CS**[Ch]		**223CS**; **228CS**			223CS; **228CS**																					
	Stress Recovery																								**187RCE**[*]									
	Total Difficulties (SDQ)			**192L**[I]					192L	**211CS**; **198CS**				192L					**203CS**[LME]; 203CS[HME]							203CS[R]								
Indicators of Positive Mental Health	Adaptability	206PC		206PC[I]							206PC			206PC																				
	Emotional Functioning (HRQoL)									**216CS**						**218CSGIS**[SA]; 218CSGIS[RA]							218CSGIS	218CSGIS[SA]; 218CSGIS[RA]										
	Emotional Quotient	206PC		206PC[I]							**206PC**			206PC																				
	Emotional Wellbeing (KINDL)			205PC									205PC																					
	General Health Status			228CS						228CS			228CS																					
	Happiness		**197STLD**[VCh,◊]			**197STLD**[T,◊]	223CS[Con]; **223CS**[C]; **197STLD**	**223CS**[Ch]; **197STLD**; 197STLD[N]		**223CS**		**197STLD**	**223CS**; **197STLD**[◊]																					
	Health Status									**185CS**[NA]; **185CS**[NE]; 185CS[SE]; **185CS**[WE]; 185CS[EE]																								
	Health-related Quality of Life									**213CS**; **216CS**						**218CSGIS**[SA]; 218CSGIS[RA]							**218CSGIS**[SA°]; 218CSGIS[SA°]; 218CSGIS[RA]	**218CSGIS**[SA]; 218CSGIS[RA]										
	Interpersonal Scores	206PC		206PC[I]							206PC			206PC																				
	Intrapersonal Scores	206PC		206PC[I]							**206PC**			206PC																				

		Screen Time Exposures													Green Time Exposures																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Life Satisfaction									**185CS**[NA]; **185CS**[NE]; **185CS**[SE]; **185CS**[WE]; 185CS[EE]		**197STLD**[◦]																						
	Mental Well-being																					**199CS**												
	Positive Affect																													**217EMAS**[PA]				
	Positive Emotional Wellbeing															**226CS**[SC]; **226CS**[MA]; 226CS[RA]								226CS							**226CS**[SC]; 226CS[MA]; 226CS[RA]			
	Prosocial Behaviour (SDQ)									**215CS**; 215L; **211CS**									**203CS**[LME]; 203CS[HME]							203CS[R,LME]; **203CS**[R,HME]								
	Psychological Wellbeing			**192L**[I]		**197STLD**[T]	**197STLD**	**197STLD**	**192L**			**197STLD**		192L																				
	Psychosocial Score (HRQoL)									**216CS**						**218CSGIS**[SA]; 218CSGIS[RA]							**218CSGIS**[SA◦]; 218CSGIS[SA✡]; 218CSGIS[RA]	218CSGIS[SA]; 218CSGIS[RA]										
	Quality of Life			**192L**[I]					192L					192L																				
	School Functioning (HRQoL)									**216CS**						218CSGIS[SA]; 218CSGIS[RA]							**218CSGIS**[SA◦]; 218CSGIS[SA✡]; 218CSGIS[RA]	218CSGIS[SA]; 218CSGIS[RA]										
	Self-Esteem			228CS; 205PC				197STLD[N]		**228CS**		**197STLD**[◦]	**228CS**; 205PC; 197STLD																					**222PP**
	Self-rated Health			186CS			**186CS**[D]		**186CS**	**183CS**; **211CS**																								
	Self-rated Mental Health									**183CS**																								
	Social Functioning (HRQoL)									**216CS**						**218CSGIS**[SA]; 218CSGIS[RA]							**218CSGIS**[SA◦]; 218CSGIS[SA✡]; **218CSGIS**[RA]	**218CSGIS**[SA]; 218CSGIS[RA]										
	Social Functioning (KINDL)			205PC									205PC																					
	Stress Management Score	206PC		**206PC**[I]							**206PC**			206PC																				
	Wellbeing																							**210L**[QN]; **210L**[QL]										
Cognitive Functioning	Applied Problems Score			224L[†]; **224L**[Ch,B‡]; **224L**[P,G‡]; **224L**[St,G‡]; 225L			224L[V,B]; 224L[V,G‡]; **224L**[V,G†]; 225L[V]; 225L[C,G†,‖]; **225L**[C,G‡]; **225L**[C,B†]						224L; 225L																					
	Attention (hyperactivity/ inattention)																												**208L**	**208L**				
	Attention Restoration																								**187RCE**[*]									
	Cognitive Performance/ Functioning						193CS[V]; 201L						201L; 193CS																					
	Digit Span Scores																												208L	**208L**				
	Directed Attention Capacity																											**219L**						
	Letter-Word Score			224L; **225L**[E,B‡]; 225L			224L[V,B]; 224L[V,G†]; **224L**[V,G‡];						224L[G]; 224L[B†]; **224L**[B‡];																					

		Screen Time Exposures													Green Time Exposures																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
							225L[V,C]						225L																					
	Passage Comprehension Score			224L[G†]; **224L[Ch,B‡]**; **<u>224L[Ch,B†]</u>**; **<u>224L[St,B†]</u>**; **<u>224L[P,G‡]</u>**; 225L			224L[V,B]; 224L[V,G‡]; **224L[V,G†]**; **225L[V,†]**; 225L[V,‡,‖]; 225L[C,B]; 225L[C,G†‖]; **<u>225L[C,G‡]</u>**						224L[B]; 224L[G‡]; **224L[G†]**; 225L																					
Academic Achievement	Academic/ School Achievement/ Performance	191CS		180CS; 186CS; **191CS**; **191CS[Ch]**; **191CS[St]**;			**186CS[D]**; **191CS[C]**; 181L[V]		**186CS**; **191CS[Ch]**; **191CS[P]**	**191CS**	**191CS**		180CS; 181L	**191CS**			188CS[Nat]																	
Academic Achievement	English Grades/ Achievement		184L			184L	**177L[V]**; 184L	**184L[❖]**	**177L**	184L		**177L**	177L; **184L**										229CS[S]									**<u>229CS[S]</u>**		
Academic Achievement	German Grades												177L		212CSGIS[H,S,HS]						212CSGIS[H]; **212CSGIS[S]**; **212CSGIS[HS]**					212CSGIS[H,S,HS]						212CSGIS[H,S,HS]		
Academic Achievement	Graduation Rates																188CS[WIN]								**<u>188CS[*]</u>**								188CS	
Academic Achievement	Maths Grades/ Achievement/ Score		**184L**			184L	181L; 177L[V]; 184L	184L; **<u>204L</u>**	**177L**	184L		177L	**181L[•]**; **204L**; **<u>184L</u>**		212CSGIS[H,S,HS]					221QE	212CSGIS[H,S,HS]		229CS[S]			212CSGIS[H,S,HS]						**<u>229CS[S]</u>**; 212CSGIS[HS,S]; **212CSGIS[H,Mun]**		
Academic Achievement	Maths Growth							204L					**204L**																					
Academic Achievement	Michigan Merit Award Recipients																188CS[WIN]								**<u>188CS[*]</u>**								**188CS[¤]**	
Academic Achievement	Reading Growth							204L					204L																					
Academic Achievement	Reading Performance/ Score							204L					204L																					
Academic Achievement	Science Grades						177L[V]		177L			**177L**	177L																					
Academic Achievement	Students planning to go to college																**<u>188CS[WIN]</u>**								**<u>188CS[*]</u>**								**<u>188CS</u>**	
Other	Connectedness to Nature																																	**<u>222PP</u>**

Notes. Study reference number and study design in brackets. Studies reporting an **unfavourable** association between the exposure and outcome are bolded. Studies reporting a **<u>favourable</u>** association between the exposure and outcome are bolded and underscored. Studies reporting no statistically significant association are not bolded. *Study Designs*: CS = cross-sectional; CSGIS = cross-sectional geographic information systems study; EMAS = ecological momentary assessment study; L = longitudinal; PC = prospective cohort; PP = pretest-posttest design; QE = quasi-experiment; RCE = randomised controlled experiment; S = surveillance; STLD = surveillance time lag design. *When results differ for subgroups*: B = boys; EE = Eastern Europe; G = girls; HME = children with mothers who have high education level; LME = children with mothers who have low education level; MA = in metropolitan areas; Mun = in Munich; NA = North America; NE = Northern Europe; Alc = in the presence of parental alcoholism; RA = in rural areas; SA= suburban/urban areas; SC = in small cities; SE = Southern Europe; WE = Western Europe; ‡ = White children; † = Black children; • = for those in the second SES quartile only; ◊ = association significant for 8th & 10th graders only; Kc = association was only significant for the 'K Cohort'; Bc = association was only significant for the 'B Cohort'; ▫ = for 12th graders only; ‖ = Latino/a children. *Green Time Exposure details:* CA = in childhood/adolescence; H = home; HS = home and school combined; Nat = nature; P = play; PA = physical activity; QL = quality; QN = quantity; R = residential; S = school; WIN = window area; * = green views; ¤ = when considering lawn landscaped areas; ◦ = grass/shrubs; ☼ = dense vegetation. *Screen Time Exposure details:* C = computer; Ch = chatting/communication; Con = game console; D = digital; E = for email use; I = and internet; IMing = instant messaging; N = to read/access the news; P = play; St = studying; T = texting; V = video; Vch = video chatting; W = for website use; WD = weekday ST; WE = weekend ST; ❖ = association was significant for 1.5 – 3 hours/day only. *Psychological Outcomes:* SDQ = Strengths & Difficulties Questionnaire; HRQOL = Health-related quality of life. *Study Notes*: Study 189L is not included in table as it compared cluster types; Studies 224L & 225L report many different associations (e.g., by screen activity, gender, and ethnicity); the majority (especially those highlighted as important by study authors) are presented.

APPENDIX 9

International Journal of *Environmental Research and Public Health*

MDPI

Article

Mental Health of Young Australians during the COVID-19 Pandemic: Exploring the Roles of Employment Precarity, Screen Time, and Contact with Nature

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Abstract: The coronavirus disease 2019 (COVID-19) pandemic is widely understood to have contributed to mental health problems. In Australia, young people (18–24 years) have been disproportionately affected. To date, research has predominantly focused on the presence or absence of mental illness symptoms, while aspects of mental well-being have been overlooked. We aimed to explore associations between potential risk and protective factors and mental health more comprehensively, using the Complete State Model of Mental Health. An online survey of 1004 young Australians (55% female; M age = 21.23) was undertaken. Assessment of both mental illness and mental well-being enabled participants to be cross-classified into four mental health states. Those with 'Floundering' (13%) or 'Struggling' (47.5%) mental health reported symptoms of mental illness; a 'Languishing' group (25.5%) did not report symptoms of mental illness but mental well-being was compromised relative to those who were 'Flourishing' (14%) with high mental well-being. Multinomial logistic regressions were used to examine associations, adjusting for socio-demographic confounders. Protective factors associated with Flourishing mental health included being in secure employment, using screen time to connect with others, and reporting high levels of hope. Both incidental and purposive contact with nature were also associated with Flourishing, while a lack of green/bluespace within walking distance was associated with Languishing, absence of outdoor residential space was associated with Floundering, and lower neighbourhood greenness was associated with all three suboptimal mental health states. Precarious employment, financial stress, living alone, reporting decreased screen time during lockdowns, lower levels of hope, and high disruption of core beliefs were also associated with Struggling and Floundering mental health. Those who were Languishing reported somewhat less hardship and little disruption to core beliefs, but lower levels of hope compared to young people who were Flourishing. This study highlights that young adults require dedicated mental health services to deal with current burden, but should also be supported through a range of preventive strategies which target mental health risk factors, like precarious employment, and enhance protective factors, such as urban green infrastructure.

Keywords: young people; emerging adulthood; mental health; COVID-19 pandemic; screen time; nature; employment; precarity; hope; core beliefs

APPENDIX 10

Ethics approval

School of Psychology

Human Research Ethics Subcommittee

Principal Investigator: Dr. Mark Kohler

Co-investigator: Vivienne Moore/ Tassia Oswald

Application title: Young Australians' mental wellbeing and outlook on the future during COVID-19: The role of screen time and nature

Approval number: 20/85

Approval date: 3/11/2020

Signed

Professor Paul Delfabbro

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Acting Chair

APPENDIX 11

Supplementary File 1 –

Descriptive statistics of all study variables

Study Variables	Total n = 1,004 (100%)	Flourishing n = 142 (14%)	Languishing n = 257 (26%)	Struggling n = 477 (48%)	Floundering N = 128 (13%)	p-value
Employment & Financial Variables						
Employment Precarity						<.001
Permanent	288 (29%)	57 (40%)	69 (27%)	139 (29%)	23 (18%)	
Fixed-Term	89 (9%)	6 (4%)	24 (9%)	52 (11%)	7 (6%)	
Regular Casual Hours	200 (20%)	28 (20%)	47 (19%)	106 (22%)	19 (15%)	
Irregular Hours	98 (10%)	12 (9%)	21 (8%)	45 (9%)	20 (16%)	
JobKeeper	54 (5%)	3 (2%)	10 (4%)	31 (7%)	10 (8%)	
Not Employed	266 (27%)	35 (25%)	83 (33%)	102 (21%)	46 (37%)	
Working from home was stressful						.001
Disagree	77 (24%)	18 (39%)	25 (36%)	31 (17%)	3 (13%)	
Neutral	60 (19%)	10 (22%)	16 (23%)	29 (16%)	5 (22%)	
Agree	181 (57%)	18 (39%)	29 (41%)	119 (67%)	15 (65%)	
Hours change						<.001
Decreased	373 (50%)	45 (41%)	70 (40%)	211 (56%)	47 (59%)	
Stayed the same	238 (32%)	50 (46%)	82 (47%)	89 (24%)	17 (21%)	
Increased	131 (18%)	14 (13%)	23 (13%)	78 (21%)	16 (20%)	
Income change						<.001
Decreased	317 (43%)	35 (32%)	62 (35%)	177 (47%)	43 (53%)	
Stayed the same	260 (35%)	53 (48%)	76 (43%)	105 (28%)	26 (32%)	
Increased	168 (23%)	22 (20%)	37 (21%)	97 (26%)	12 (15%)	
Financial stress						<.001
No – low	218 (22%)	60 (42%)	80 (31%)	69 (14%)	9 (7%)	
Moderate	308 (31%)	48 (34%)	103 (40%)	118 (25%)	39 (30%)	
High – overwhelming	478 (48%)	34 (24%)	74 (29%)	290 (61%)	80 (63%)	
Screen Time Variables						
Overall screen time						<.001
Decreased	91 (9%)	2 (1%)	12 (5%)	72 (15%)	5 (4%)	
Stayed the same	144 (14%)	32 (23%)	42 (16%)	46 (10%)	24 (19%)	
Increased	769 (77%)	108 (76%)	203 (79%)	359 (75%)	99 (77%)	
Social Media Use						<.001
Decreased	105 (11%)	5 (4%)	9 (4%)	78 (17%)	13 (10%)	
Stayed the same	323 (33%)	44 (32%)	92 (36%)	146 (31%)	41 (33%)	
Increased	554 (56%)	88 (64%)	153 (60%)	242 (52%)	71 (57%)	
Videochatting						<.001
Decreased	114 (13%)	5 (4%)	10 (4%)	86 (19%)	13 (13%)	
Stayed the same	302 (34%)	36 (28%)	82 (36%)	150 (34%)	34 (33%)	
Increased	486 (54%)	87 (68%)	138 (60%)	206 (47%)	55 (54%)	
Streaming services						<.001
Decreased	109 (12%)	6 (4%)	13 (5%)	82 (18%)	8 (7%)	
Stayed the same	320 (34%)	42 (31%)	87 (36%)	155 (34%)	36 (31%)	
Increased	512 (54%)	87 (64%)	140 (58%)	214 (47%)	71 (62%)	
Videogaming						<.001
Decreased	148 (19%)	10 (9%)	25 (13%)	102 (26%)	11 (12%)	
Stayed the same	303 (38%)	45 (41%)	78 (40%)	147 (37%)	33 (36%)	

Increased	346 (43%)	56 (50%)	93 (47%)	150 (38%)	47 (52%)	
Phone Use						<.001
Decreased	110 (11%)	1 (<1%)	11 (4%)	92 (20%)	6 (5%)	
Stayed the same	294 (30%)	42 (30%)	85 (33%)	128 (28%)	39 (31%)	
Increased	570 (59%)	96 (69%)	158 (62%)	235 (52%)	81 (64%)	
Laptop / Computer Use						<.001
Decreased	106 (11%)	1 (<1%)	11 (4%)	85 (19%)	9 (7%)	
Stayed the same	303 (32%)	43 (31%)	89 (36%)	133 (30%)	38 (32%)	
Increased	545 (57%)	94 (68%)	148 (60%)	230 (51%)	73 (61%)	
ST helped stay connected to family & friends						<.001
Disagree	119 (12%)	12 (9%)	23 (9%)	66 (14%)	18 (14%)	
Neutral	143 (15%)	7 (5%)	26 (10%)	87 (19%)	23 (18%)	
Agree	722 (73%)	119 (86%)	205 (81%)	312 (67%)	86 (68%)	
I found myself disengaging from technology						<.001
Disagree	237 (24%)	47 (35%)	83 (33%)	91 (20%)	16 (13%)	
Neutral	327 (34%)	47 (35%)	89 (35%)	146 (32%)	45 (36%)	
Agree	412 (42%)	42 (31%)	83 (33%)	223 (48%)	64 (51%)	
ST was fatiguing						<.001
Disagree	177 (18%)	43 (31%)	49 (19%)	66 (14%)	19 (15%)	
Neutral	255 (26%)	33 (24%)	72 (28%)	114 (24%)	36 (28%)	
Agree	558 (56%)	61 (45%)	135 (53%)	289 (62%)	73 (57%)	
Technology helped me cope						0.06
Disagree	142 (14%)	14 (10%)	38 (15%)	64 (14%)	26 (20%)	
Neutral	290 (29%)	37 (27%)	87 (34%)	128 (28%)	38 (30%)	
Agree	553 (56%)	88 (63%)	129 (51%)	272 (59%)	64 (50%)	
Felt the need to restrict news viewing						<.001
Disagree	221 (23%)	47 (34%)	70 (27%)	80 (17%)	24 (19%)	
Neutral	285 (29%)	37 (27%)	71 (28%)	133 (29%)	44 (35%)	
Agree	476 (48%)	54 (39%)	114 (45%)	249 (54%)	59 (46%)	
Nature Access Variables						
Perceived neighbourhood naturalness						<.001
Highly built	54 (5%)	5 (4%)	14 (5%)	21 (4%)	14 (11%)	
Moderately built	140 (14%)	19 (13%)	44 (17%)	56 (12%)	21 (16%)	
Even mix of built and natural	331 (33%)	54 (38%)	91 (35%)	139 (29%)	47 (37%)	
Moderately natural	391 (39%)	48 (34%)	99 (39%)	202 (42%)	42 (33%)	
Highly natural	88 (9%)	16 (11%)	9 (4%)	59 (12%)	4 (3%)	
Greenspace and/or bluespace in walking distance						0.11
No	226 (23%)	21 (15%)	64 (25%)	109 (23%)	32 (25%)	
Yes	777 (77%)	120 (85%)	193 (75%)	368 (77%)	96 (75%)	
Access to residential outdoor space						.004
No	51 (5%)	3 (2%)	6 (2%)	30 (6%)	12 (10%)	
Yes	951 (95%)	139 (98%)	251 (98%)	447 (94%)	114 (90%)	

Nature Experience Variables						
Overall contact with nature						.01
Decreased	288 (31%)	29 (21%)	75 (31%)	136 (30%)	48 (41%)	
Stayed the same	407 (43%)	62 (45%)	98 (40%)	196 (44%)	51 (43%)	
Increased	249 (26%)	46 (34%)	70 (29%)	114 (26%)	19 (16%)	
Went out in neighbourhood						.001
Decreased	272 (29%)	33 (24%)	57 (24%)	134 (30%)	48 (44%)	
Stayed the same	366 (39%)	50 (37%)	94 (39%)	183 (41%)	39 (35%)	
Increased	298 (32%)	52 (39%)	91 (38%)	132 (29%)	23 (21%)	
Spent time in local park						.03
Decreased	284 (32%)	37 (28%)	60 (27%)	148 (34%)	39 (39%)	
Stayed the same	371 (42%)	49 (37%)	99 (44%)	179 (41%)	44 (44%)	
Increased	235 (26%)	46 (35%)	66 (29%)	106 (24%)	17 (17%)	
Planned activities in nature						.007
Decreased	305 (34%)	36 (28%)	72 (32%)	149 (34%)	48 (46%)	
Stayed the same	375 (42%)	49 (38%)	103 (45%)	182 (42%)	41 (39%)	
Increased	217 (24%)	45 (35%)	52 (23%)	105 (24%)	15 (14%)	
Time in nature felt like "getting away"						.002
Disagree	109 (11%)	5 (4%)	25 (10%)	62 (14%)	17 (15%)	
Neutral	232 (24%)	23 (17%)	62 (25%)	114 (25%)	33 (28%)	
Agree	613 (64%)	108 (79%)	161 (65%)	278 (61%)	66 (57%)	
Time in nature felt uncomfortable						<.001
Disagree	516 (54%)	103 (75%)	161 (66%)	189 (42%)	63 (55%)	
Neutral	207 (22%)	19 (14%)	51 (21%)	107 (24%)	30 (26%)	
Agree	226 (24%)	15 (11%)	33 (13%)	157 (35%)	21 (18%)	
Other Psychological Factors						
Level of Hope (AHS)						<.001
	M = 42.50 (SD 9.40)	M = 49.83 (SD 7.42)	M = 43.64 (SD 7.97)	M = 41.99 (SD 8.24)	M = 33.82 (SD 10.66)	
Disruption to Core Beliefs (CBI)						<.001
	M = 2.83 (SD 0.95)	M = 2.80 (SD 1.08)	M = 2.58 (SD 0.96)	M = 2.94 (SD 0.83)	M = 2.92 (SD 1.11)	

M = mean; SD = standard deviation; VET = vocational and educational training; PD = professional development; AHS = Adult Hope Scale; ABI = Core Beliefs Inventory.

APPENDIX 12

Supplementary File 2 –

Associations Between Different Types of Screen Activity and Mental Health State during COVID-19

Variables	Languishing vs. Flourishing RRR[a] (95% CI)	Struggling vs. Flourishing RRR[a] (95% CI)	Floundering vs. Flourishing RRR[a] (95% CI)
Social Media Use			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	0.86 (0.27 – 2.71)	**4.95 (1.88 – 13.02)**	2.89 (0.94 – 8.83)
Increased	0.82 (0.53 – 1.29)	0.84 (0.55 – 1.28)	0.85 (0.50 – 1.45)
Video-chatting			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	0.88 (0.28 – 2.77)	**4.04 (1.53 – 10.72)**	2.65 (0.85 – 8.25)
Increased	0.67 (0.42 – 1.08)	**0.56 (0.36 – 0.88)**	0.63 (0.35 – 1.14)
Streaming services			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	1.05 (0.37 – 2.95)	**3.65 (1.49 – 8.99)**	1.58 (0.50 – 5.01)
Increased	0.78 (0.50 – 1.24)	0.67 (0.44 – 1.03)	0.92 (0.53 – 1.59)
Video-gaming			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	1.45 (0.64 – 3.31)	**3.00 (1.44 – 6.25)**	1.48 (0.56 – 3.91)
Increased	0.92 (0.56 – 1.52)	0.76 (0.48 – 1.20)	1.13 (0.62 – 2.06)
Phone Use			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	5.46 (0.68 – 43.70)	**30.71 (4.15 – 227.43)**	6.51 (0.75 – 56.54)
Increased	0.81 (0.52 – 1.27)	0.79 (0.52 – 1.21)	0.88 (0.52 – 1.49)
Laptop / Computer Use			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	5.37 (0.67 – 43.00)	**27.63 (3.73 – 204.67)**	**10.17 (1.23 – 84.12)**
Increased	0.74 (0.47 – 1.16)	0.75 (0.49 – 1.15)	0.87 (0.51 – 1.48)

ST = screen time; RRR[a] = Relative Risk Ratio adjusted for gender, studying (yes/no) and SES; statistically significant associations bolded.

APPENDIX 13

Supplementary File 3 –

Associations Between Different Types of Nature Activities and Mental Health State during COVID-19

Variables	Languishing vs. Flourishing RRR[a] (95% CI)	Struggling vs. Flourishing RRR[a] (95% CI)	Floundering vs. Flourishing RRR[a] (95% CI)
Out in neighbourhood			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	0.93 (0.53 – 1.60)	1.11 (0.68 – 1.82)	**1.85 (1.00 – 3.41)**
Increased	0.93 (0.57 – 1.51)	0.70 (0.45 – 1.10)	0.56 (0.30 – 1.08)
Time in local park			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	0.82 (0.48 – 1.40)	1.08 (0.67 – 1.75)	0.17 (0.64 – 2.14)
Increased	0.73 (0.44 – 1.21)	0.64 (0.40 – 1.02)	**0.41 (0.20 – 0.81)**
Planned activities in nature			
Stayed the same	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Decreased	0.95 (0.56 – 1.61)	1.11 (0.68 – 1.79)	1.59 (0.88 – 2.90)
Increased	**0.54 (0.32 – 0.91)**	0.64 (0.40 – 1.03)	**0.40 (0.20 – 0.82)**

RRR[a] = Relative Risk Ratio adjusted for gender and SES; statistically significant associations bolded.

APPENDIX 14

RESEARCH SERVICES
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY
THE UNIVERSITY OF ADELAIDE

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CRICOS Provider Number 00123M

Our reference 34870

14 December 2020

Professor Vivienne Moore
Public Health

Dear Professor Moore

ETHICS APPROVAL No:	H-2020-262
PROJECT TITLE:	Buffering “screen time” with “green time” in adolescence: A pilot study demonstrating acute psychological effects of screen time and the restorative potential of nature immersion

The ethics application for the above project has been reviewed by the Human Research Ethics Committee and is deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research 2007 (Updated 2018)*.

You are authorised to commence your research on: 14/12/2020
The ethics expiry date for this project is: 31/12/2023

NAMED INVESTIGATORS:

Chief Investigator:	Professor Vivienne Moore
Student - Postgraduate Doctorate by Research (PhD):	Ms Tassia Kate Oswald
Associate Investigator:	Associate Professor Alice Rumbold
Associate Investigator:	Dr Mark Kohler
Associate Investigator:	Ms Sophie Kedzior

CONDITIONS OF APPROVAL: Thank you for addressing the feedback. Your revised application submitted on the 9th of December 2020 has been approved.

Ethics approval is granted for three years and is subject to satisfactory annual reporting. The form titled Annual Report on Project Status is to be used when reporting annual progress and project completion and can be downloaded at http://www.adelaide.edu.au/research-services/oreci/human/reporting/. Prior to expiry, ethics approval may be extended for a further period.

Participants in the study are to be given a copy of the information sheet and the signed consent form to retain. It is also a condition of approval that you immediately report anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants,

- previously unforeseen events which might affect continued ethical acceptability of the project,
- proposed changes to the protocol or project investigators; and
- the project is discontinued before the expected date of completion.

Yours sincerely,

Professor Paul Delfabbro
Convenor

The University of Adelaide

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Ms Tassia Oswald
BPsych (Hons) | PhD Candidate
School of Public Health, Faculty of Health and Medical Sciences
The University of Adelaide

Email: tassia.oswald@adelaide.edu.au

Dear Tassia

Research Request Reference 202105 – Buffering "Screen Time" with "Green Time" in Adolescence: A Pilot Study Demonstrating Acute Psychological Effects of Screen Time and the Restorative Potential of Nature Immersion

Thank you for your email dated 10 February 2021, requesting permission to conduct research in South Australian Catholic schools.

I am pleased to advise your research proposal has been approved, subject to the following conditions:

- copies of any questionnaires or surveys have been provided to the Principal
- the active consent of parents and teachers/school staff, if applicable, has been obtained
- the research complies with the ethics proposal approved by the university, or the research organisation's generally accepted ethics requirements
- the research complies with any provisions under the Privacy Act, that may require adherence by researchers in gathering and reporting data
- no comparison between schooling sectors is made
- the researcher will be carrying out the research within view of the class teacher, or authorised school observer, where students are involved
- sector requirements relating to child protection and police checks are met by researchers:
    - where researchers obtain information in relation to a student which suggests or indicates abuse, this information must be immediately conveyed to the Director of Catholic Education SA
    - all researchers and assistants, who in the course of the research interact in any way with students or student data, are required to provide evidence of an acceptable police clearance directly to the school.

At the conclusion of the study, a copy of the research findings should be forwarded to:

The Director
Catholic Education Office
PO Box 179
Torrensville Plaza SA 5031 **or** director@cesa.catholic.edu.au

Best wishes for the research process.

Yours sincerely

Teresa Cimmino
Senior Education Advisor, Learning and Curriculum

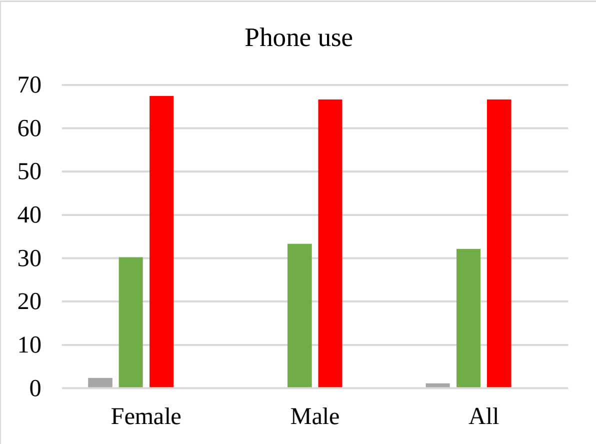
18 March 2021

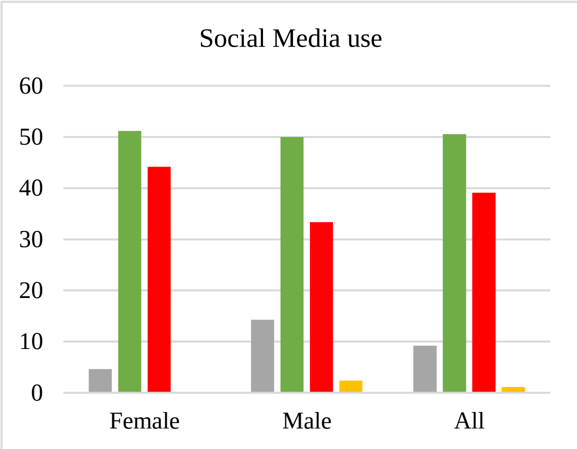
APPENDIX 15

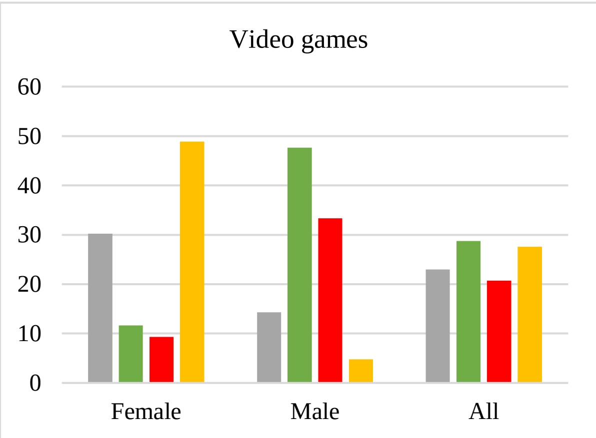
Pilot Study – Adolescent self-reported use of screen activities

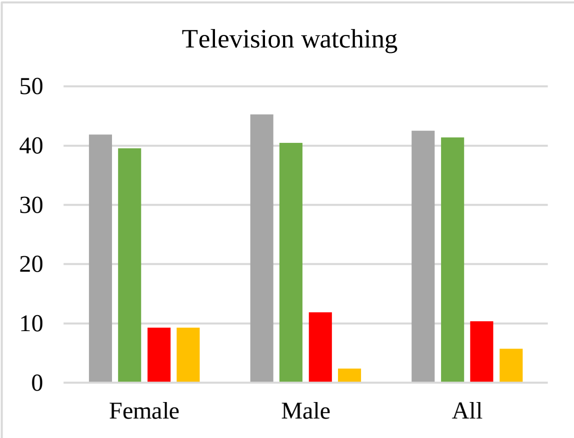
"How much time *do you feel* you spend on the following screen activities?"

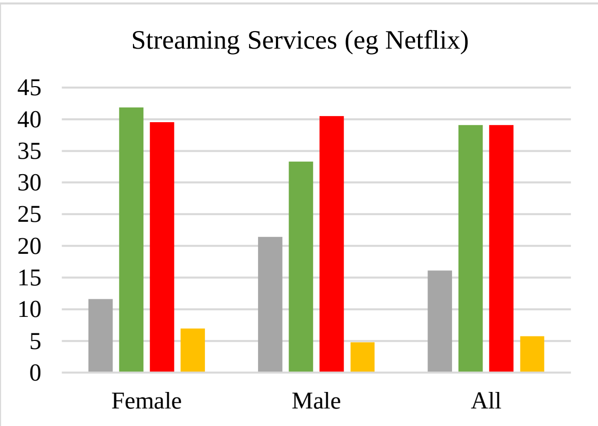
Too little time | About the right amount of time | Too much time | I don't have or use this

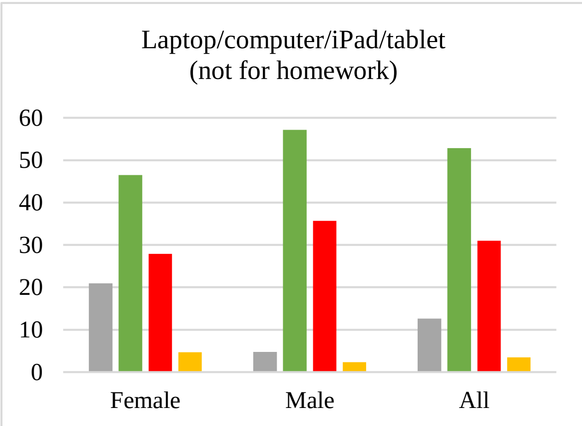












APPENDIX 16

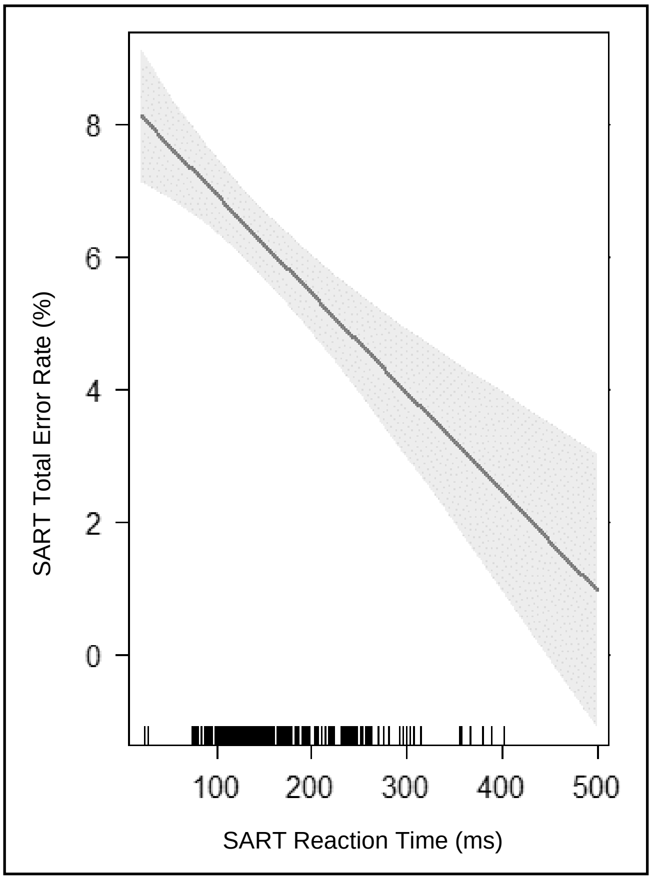
Pilot Study – Sex x Age x Time x Condition^{T2} for SART Total Error Rate (Model 1A)

Sex, age category, and time point	Mean	SE	Mean change	SE	95% CI	*t*	*df*	*p*
Time 0 (baseline)								
Male <16 years	7.39	0.65	-0.53	0.63	-1.78, 0.71	-0.85	155	0.40
Male ≥16 years	4.68	0.70	-0.13	0.68	-1.47, 1.22	-0.19	156	0.85
Female <16 years	5.36	0.63	-1.88	0.62	-3.09, -0.66	-3.04	155	0.00
Female ≥16 years	4.96	0.77	0.36	0.63	-0.88, 1.61	0.58	155	0.56
Time 1 (post-screen time period)								
Male <16 years	7.93	0.65	Ref.	-	-	-	-	-
Male ≥16 years	4.81	0.70						
Female <16 years	7.24	0.63						
Female ≥16 years	4.59	0.77						
Time 2 (post-rest period; Indoors condition)								
Male <16 years	7.04	0.83	-0.89	0.82	-2.50, 0.72	-1.09	169	0.28
Male ≥16 years	5.21	0.91	0.41	0.90	-1.37, 2.18	0.45	169	0.65
Female <16 years	7.37	0.78	0.13	0.77	-1.39, 1.65	0.17	168	0.87
Female ≥16 years	4.36	0.96	-0.24	0.85	-1.91, 1.44	-0.28	170	0.78
Time 2 (post-rest period; Outdoors condition)								
Male <16 years	7.94	0.95	0.02	0.94	-1.83, 1.86	0.02	174	0.99
Male ≥16 years	5.02	0.89	0.22	0.86	-1.49, 1.92	0.25	167	0.80
Female <16 years	7.91	0.90	0.67	0.89	-1.07, 2.42	0.76	172	0.45
Female ≥16 years	4.84	0.90	0.25	0.79	-1.31, 1.80	0.31	167	0.76

Notes. Effects are calculated at the mean value of the covariate SART HIT RT. Adjusted for sleepiness.

APPENDIX 17

Pilot Study – SART Total Error Rate (%) by SART Reaction Time (milliseconds). Shading represents 95% confidence intervals



APPENDIX 18

Pilot Study – Sex x Age x Time x Condition^{T2} for SST Inhibition Rate (Model 2A)

Sex, age category, and time point	Mean	SE	Mean change	SE	95% CI	*t*	*df*	*p*
Time 0 (baseline)								
Male <16 years	40.87	3.45	-2.17	4.86	-11.77, 7.42	-0.45	157	0.66
Male ≥16 years	32.11	3.80	-3.16	5.35	-13.72, 7.40	-0.59	157	0.56
Female <16 years	35.22	3.45	-3.04	4.86	-12.64, 6.56	-0.63	157	0.53
Female ≥16 years	41.82	3.89	-3.64	4.97	-13.45, 6.18	-0.73	157	0.47
Time 1 (post-screen time period)								
Male <16 years	43.04	3.45	Ref.	-	-	-	-	-
Male ≥16 years	35.26	3.80						
Female <16 years	38.26	3.45						
Female ≥16 years	45.45	3.89						
Time 2 (post-rest period; Indoors condition)								
Male <16 years	30.03	5.02	-13.01	6.07	-24.99, -1.04	-2.14	195	**0.03***
Male ≥16 years	38.84	5.55	3.57	6.70	-9.64, 16.79	0.53	195	0.59
Female <16 years	43.83	4.61	5.57	5.74	-5.76, 16.89	0.97	187	0.33
Female ≥16 years	40.03	5.56	-5.42	6.32	-17.88, 7.04	-0.86	198	0.39
Time 2 (post-rest period; Outdoors condition)								
Male <16 years	43.65	5.89	0.60	6.81	-12.82, 14.03	0.09	209	0.93
Male ≥16 years	33.05	5.26	-2.22	6.47	-14.97, 10.54	-0.34	191	0.73
Female <16 years	37.54	5.89	-0.72	6.81	-14.15, 12.70	-0.11	209	0.92
Female ≥16 years	42.47	5.03	-2.98	5.94	-14.70, 8.73	-0.50	189	0.62

Notes. Adjusted for sleepiness.

APPENDIX 19

Pilot Study – Sex x Age x Time x Condition^{T2} for Mood (Model 3A)

Sex, age category, and time point	Mean	SE	95% CI	Mean change	SE	95% CI	*t*	*df*	*p*
Time 0 (baseline)									
Male <16 years	7.65	0.47	-5.07, 20.37	-0.73	0.36	-1.44, -0.02	-2.04	161	0.04
Male ≥16 years	8.01	0.52	3.35, 12.68	-0.46	0.40	-1.24, 0.32	-1.16	162	0.25
Female <16 years	8.48	0.52	3.41, 13.55	1.09	0.36	0.38, 1.80	3.04	161	0.00
Female ≥16 years	7.42	0.60	5.57, 9.26	-0.60	0.37	-1.34, 0.13	-1.63	164	0.11
Time 1 (post-screen time period)									
Male <16 years	8.38	0.46	-6.34, 23.10	Ref.	-	-	-	-	-
Male ≥16 years	8.47	0.51	2.86, 14.08						
Female <16 years	7.39	0.51	1.83, 12.94						
Female ≥16 years	8.02	0.57	6.01, 10.04						
Time 2 (post-rest period; Indoors condition)									
Male <16 years	9.06	0.55	5.44, 12.67	0.67	0.48	-0.27, 1.61	1.42	174	0.16
Male ≥16 years	8.60	0.62	6.25, 10.96	0.13	0.53	-0.91, 1.17	0.25	175	0.80
Female <16 years	8.02	0.56	4.86, 11.18	0.63	0.44	-0.24, 1.51	1.43	172	0.16
Female ≥16 years	8.22	0.67	6.54, 9.89	0.19	0.50	-0.79, 1.17	0.39	176	0.70
Time 2 (post-rest period; Outdoors condition)									
Male <16 years	8.16	0.57	5.17, 11.14	-0.23	0.46	-1.14, 0.69	-0.49	174	0.63
Male ≥16 years	8.52	0.61	6.11, 10.94	0.05	0.50	-0.94, 1.05	0.11	173	0.92
Female <16 years	7.61	0.60	5.06, 10.15	0.22	0.50	-0.76, 1.20	0.44	176	0.66
Female ≥16 years	7.33	0.61	5.63, 9.03	-0.70	0.46	-1.61, 0.22	-1.50	174	0.13

Notes. Adjusted for sleepiness.

APPENDIX 20

Pilot Study – Mood score by Sleepiness score. Shading represents 95% confidence intervals.