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Understanding the association between neighbourhood green space quality and prosocial behaviour across childhood and adolescence

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Abstract

Background: While a legion of evidence indicates green spaces (e.g., parks) support health, there is a paucity of studies investigating their potential role in the development of prosocial behaviour (i.e., a range of behaviours that benefit others or promote positive relationships with others) across childhood and adolescence. The review of current evidence suggests that exposure to nearby green space may increase prosocial behaviour, but most of the evidence is cross-sectional, hindering causal inferences and understandings of temporality. Furthermore, most of this research has focused on the quantity of green space (i.e., the amount of green space available in the residential environment), neglecting the potentially critical importance of green space quality (i.e., aspects or attributes of green space that influence its utilisation) as a key determinant in its use and in the development of prosocial behaviour. Besides, candidate mediators and effect modifiers have not been comprehensively examined by previous studies, limiting understandings of plausible pathways and potential contingencies in who benefits. Therefore, research on green space quality and prosocial behaviour is important to improve the quality of current evidence and inform avenues on how to maximise the role of green space in shaping the development of prosocial behaviour. Enhancing the development of prosocial behaviour from a young age is important due to health, psychological, and social benefits.

Aims: This PhD thesis primarily aimed to examine the longitudinal association between green space quality and prosocial behaviour among children and adolescents. This thesis also investigated whether the accumulation of, or changes in, green space quality during childhood and adolescence were associated with the development of prosocial behaviour.

Potential effect modifiers of the association and plausible pathways in which green space quality may influence prosocial behaviour were also assessed. In addition, the potential role of prosocial behaviour as a missing link – a candidate mediating variable – on the causal chain from green space quality to child health-related outcomes was tested.

Methods: This thesis used 10-year longitudinal data retrieved from the K-cohort of the Longitudinal Study of Australian Children. Data pertaining to green space quality, child prosocial behaviour, health-related outcomes (mental health, physical activity, and health-related quality of life (HRQOL)), and socioeconomic measures were biennially recorded from 4,983 children for a 10-year period, from 2004 (children aged 4-5 years: Wave 1) to 2014 (14-15 years: Wave 6). Green space quality was measured using caregiver reports on the availability of good parks, playgrounds, and play spaces in the neighbourhood. Caregivers also evaluated their child's prosocial behaviour using the prosocial subscale from the Strengths and Difficulties Questionnaire (SDQ). Multilevel linear regression was applied to assess the association between green space quality and prosocial behaviour. Trajectories in green space quality experienced across childhood and adolescence were examined using latent class analysis. Causal mediation analysis was used to identify mechanistic pathways between green space quality and prosocial behaviour, as well as to test prosocial behaviour as a candidate mediator of the associations between green space quality and child health-related outcomes.

Results: The presence of quality neighbourhood green space was positively associated with child prosocial behaviour, irrespective of residential relocation. In addition, children whose caregiver perception of green space quality was 'very good' over time, trended from 'good' to 'very good' or from 'very good' to 'good' had higher prosocial behaviour than children of caregivers who consistently perceived nearby green space as low in quality. Evidence also indicated that the accumulation of very good quality green space over time may attenuate socioeconomic inequalities in prosocial behaviour. The association between green space quality and prosocial behaviour was found to be stronger among boys, children speaking only English at home, and children living in more affluent and/or remote areas. Moreover, physical activity enjoyment, social interaction, child and caregiver mental health, and HRQOL served as mechanistic pathways in which green space quality influenced prosocial behaviour. Prosocial behaviour was found as a mediator of the associations between green space quality and child health (mental health, HRQOL), and physical activity enjoyment.

Conclusions: The findings indicate that policies on provisioning and maintaining the quality of green space across childhood and adolescence in a targeted manner (e.g., prioritised in more disadvantaged and remote areas) can potentially buffer the negative impact of growing up in unfavourable socioeconomic circumstances and foster the development of prosocial behaviour. Improving the quality of neighbourhood green space that also encourages social interactions, physical activity enjoyment, and mental health might provide better support for the development of prosocial behaviour and vice versa. In addition, ensuring the neighbourhood to be safe and friendly for ethnic minorities is vital as it removes impediments to such populations gaining benefits from quality green space. Furthermore, identifying attributes of quality green space suitable for both boys and girls, and children from different age groups forms an important next step to maximise the benefits of quality green space for all.

Keywords: nature, child health, child behaviour, prosociality, physical activity, mental health, health-related quality of life, longitudinal study, multilevel model, latent class analysis, causal mediation analysis

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Thesis Certification

I, I Gusti Ngurah Edi Putra, declare that this thesis submitted in fulfilment of the requirements for the conferral of the Doctor of Philosophy degree, in the School of Health and Society, in the Faculty of the Arts, Social Sciences and Humanities, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualifications at any other academic institution.

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List of Publications

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List of Abbreviations

ABS	: Australian Bureau of Statistics
AIFS	: Australian Institute of Family Studies
ARIA	: Accessibility-Remoteness Index of Australia
ART	: Attention Restoration Theory
AUD	: Australian Dollar
BIC	: Bayesian Information Criterion
CAG	: Consortium Advisory Group
DIC	: Deviance Information Criterion
DSS	: Department of Social Services
GIS	: Geographical Information System
HREC	: Human Research Ethics Committee
HRQOL	: Health-related Quality of Life
K6	: Kessler 6 Psychological Distress Scale
LSAC	: Longitudinal Study of Australian Children
m	: Metres
MCMC	: Markov Chain Monte Carlo
NDE	: Natural Direct Effect
NDVI	: Normalised Difference Vegetation Index
NHMRC	: National Health and Medical Research Council
NIE	: Natural Indirect Effect
NSW	: New South Wales
OR	: Odds Ratio
PA	: Physical Activity

PedsQL	: Paediatric Quality of Life Scale
PET	: Psycho-evolutionary Theory
PM	: Particulate Matter
PRISMA	: Preferred Reporting Items for Systematic Reviews and Meta-Analysis
QOL	: Quality of Life
RRR	: Relative-Risk Ratios
SA2	: Statistical Area, Level 2
SD	: Standard Deviation
SDQ	: Strengths and Difficulties Questionnaire
SEIFA	: Socio-Economic Index for Areas
SOCARP	: System for Observing Children’s Activity and Relationship during Play
SOCC	: Social Orientation Choice Card
SRT	: Stress Reduction Theory
TDS	: Total Difficulties Score
TUD	: Time Use Diary
UK	: United Kingdom
US	: United States of America
WHO	: World Health Organization

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Chapter 1: Introduction and review of the literature

1.1 Preface

This chapter provides an overview of the thesis, general review of the literature, aims of the study, conceptual framework, research questions, and significance of the study. Some sub-chapters of the literature review presented in this chapter were published in the systematic review (Appendix C) with minor adjustments for tables, figures, referencing style, and overall thesis formatting requirements. At the end of this chapter, a brief description of each of the subsequent chapters is presented.

1.2 Prosocial behaviour

1.2.1 The definition and development of prosocial behaviour

Prosocial behaviour is increasingly recognised as an important part of child development (Dunfield, 2014). Prosocial behaviour is a term that covers a range of behaviours and typically refers to any action that "benefits others or at very least promotes harmonious relations with others" (Hay, 1994, p. 33). Prosocial behaviour among children is constituted by the presence of several positive behaviours. These include sharing, helping, cooperating, and comforting (Dunfield, 2014; Hammond et al., 2015; Hay, 1994; Piotrowski et al., 2015; Wittek & Bekkers, 2015).

Early childhood is an important period of human life when prosocial behaviour begins to develop (Brownell, 2013; Hay et al., 2004). In the first year of life or during infancy, prosocial behaviour emerges and can be seen in children's abilities to respond to others' stress; and they can show "global empathy" by understanding and feeling how others may feel (Roth-Hanania et al., 2011; Wittek & Bekkers, 2015). Between one and three years of age, prosocial behaviour progressively increases in frequency, variety, and complexity (Knafo et al., 2008; Roth-Hanania et al., 2011; Zahn-Waxler et al., 1992), and children also spontaneously communicate and have been shown to help, cooperate, and share with others (Brownell, 2013; Brownell et al., 2009). Moreover, by the age of four years, children experience increased competency in thinking about their own actions and those of others (Carlo, 2014; Carpendale & Lewis, 2004).

As children get older, they begin to regularly spend time with friends, and the complexity of their prosocial behaviour increases in these new social relations (Abrams et al., 2015; Hay & Cook, 2007). Children start understanding the emotions of others (e.g., friends, peers) and also the expectations of schools and teachers (Hammond & Brownell, 2015). Even though in some circumstances, children's prosocial behaviours become more selective with age, the growth of socio-cognitive abilities leads to more opportunities for older children to act prosocially. Children aged from 7 to 12 years have been found to exhibit greater prosocial behaviour compared to pre-schoolers (3 to 6 years) (Eisenberg et al., 2015). However, past work suggests that prosocial behaviour might fall in adolescence and then start to increase again in late adolescence or early adulthood (Carlo et al., 2007; Eisenberg et al., 2015; Luengo Kanacri et al., 2013).

1.2.2 Prosocial behaviour among children and adolescents in Australia

The second Australian Child and Adolescent Survey of Mental Health and Wellbeing conducted in 2013-2014 described children's and adolescents' parent-reported prosocial behaviour (n=6,310). Prosocial behaviour was measured using the prosocial domain from Goodman's Strengths and Difficulties Questionnaire (SDQ) that consists of five items with a total score ranging from 0 to 10 for each item (Lawrence et al., 2015). A higher score indicates more favourable prosocial behaviour and the total score can be classified as normal (6-10), borderline (5), and abnormal (0-4) (Goodman, 1997). The prevalence of prosocial behaviour in the "abnormal" range (or low scores of prosocial behaviour), which indicates a substantial risk for significant problems, was 2.9% and 1.9% among boys and girls aged 4-11 years, respectively. The abnormal range was consistently higher among adolescent males (12-17 years) (4.5%) than females (1.8%). This nationally representative survey also highlighted that higher proportions of children and adolescents in the abnormal range of prosocial behaviour were reported by low-income families, less educated, and unemployed parents or caregivers (Lawrence et al., 2015).

A regional representative survey, the 2015 Middle Childhood Survey (MCS), conducted among 27,808 children aged 11 years from 829 schools in New South Wales (NSW), Australia, found that average scores of self-reports on the prosocial subscale from the SDQ were relatively high (8.03 out of 10; n=27,474). The prevalence of children in the abnormal range of prosocial behaviour was 3.7%, with higher proportions observed among boys than girls (5.1% vs. 2.3%) (Laurens et al., 2017). In addition, self-reported prosocial behaviour was assessed among students aged 12–16 years (n=6,793) from 21 schools located in disadvantaged areas in NSW (Dray et al., 2016). Findings from this study showed that prosocial behaviour scores were 7.19, on average, and 8.9% of the students' scores were in the abnormal range. In line with other study findings, males scored lower for prosocial behaviour than females. Lower scores of prosocial behaviour were also reported among Indigenous (i.e., Aboriginal and/or Torres Strait Islanders) than non-Indigenous students.

1.2.3 Factors associated with prosocial behaviour

The development of prosocial behaviour is jointly determined by factors that can be broadly described as personal and environmental characteristics (Piliavin, 2001). Genetic factors (Fortuna & Knafo, 2014; Israel et al., 2015; Knafo-Noam et al., 2015), gender (Abdi, 2010; Kok et al., 2018), personality traits or self-concepts (Cauley & Tyler, 1989; Gallitto & Leth-Steensen, 2019), and empathy (Garaigordobil, 2009; Williams et al., 2014) are the factors that contribute to individual differences in prosocial behaviour. In addition, published literature has also suggested that cultural background is a correlate of prosocial behaviour (Richman et al., 1988; Smith et al., 2019).

Socio-environmental factors such as parental influences (parental nurturing, parent-child relationship, parental warmth, parental socialisation) (Carlo et al., 2010; Ferreira et al., 2016; Pastorelli et al., 2016; Pettygrove et al., 2013) and peer influences (Fabes et al., 2012; Fujisawa et al., 2008; Lai et al., 2015; Lee et al., 2016; Oldfield et al., 2016; Silke et al., 2018) are important predictors for the development of prosocial skills among children and adolescents. Family socioeconomic status (e.g., caregiver income and/or education) was also found to be associated with prosocial behaviour among children (Silke et al., 2018). Moreover, exposure to prosocial content from media can positively influence prosocial acts, whereas exposure to violent media might have negative impacts (Bar-on, 2000; de Leeuw et al., 2015; Greitemeyer, 2011; Prot et al., 2014).

Previous literature also indicates the potential influence of neighbourhood environments, such as neighbourhood deprivation (Safra et al., 2016), attachment and cohesion (Kingsbury et al., 2015; Lenzi et al., 2012) on child prosocial behaviour. In addition, aspects of the physical environment, such as schools, may influence prosocial behaviour since schools enable social interactions among children and adolescents through organised cooperative learning activities in class, and through opportunities for play (Wentzel, 2015). The presence of other physical environments that facilitate social contacts and interactions, such as green space – that is, public areas with natural entities or characteristics where people commonly gather for recreation, relaxation, and other social activities (e.g., parks, gardens, etc.) (Dennis & James, 2016; Dinnie et al., 2013; Jennings & Bamkole, 2019) – potentially serve as an additional space for children to develop and practise prosocial acts. A synthesis of current evidence regarding the potential role of green space in shaping the development of prosocial behaviour is discussed in Chapter 2 of this thesis.

1.2.4 The importance of prosocial behaviour

A current body of literature highlights the importance of prosocial behaviour in positively contributing to aspects of youth development. Positive outcomes include greater academic success (Collie et al., 2018; Gerbino et al., 2018), social competence (Bar-Tal, 1982), and problem-solving skills (Carlo et al., 2012; Eisenberg et al., 2015). Prosocial behaviour is considered a psychosocial asset (Leventhal et al., 2015) that contributes to better quality peer relationships (Caputi et al., 2012) and lower reported aggression (Obsuth et al., 2015; Swit, 2012). Findings from a longitudinal study also suggest that prosocial skills during kindergarten are associated with future wellness, such as high school and college education completion, stable and full-time employment, financial independence (e.g., not receiving public assistance) in young adulthood, and a reduced likelihood of involvement in crime during adolescence and early adulthood (Jones et al., 2015).

Previous work also suggests that prosocial behaviour is associated with child health and wellbeing-related outcomes including fewer externalising and internalising behavioural problems (Flouri & Sarmadi, 2016; Flynn et al., 2015), greater happiness (Aknin et al., 2015; Aknin et al., 2012), better quality of life (Carona et al., 2020; Frontini et al., 2012; Larsen et al., 2020), and optimal cardiometabolic health (Qureshi et al., 2019). In addition, prosocial behaviour in childhood was found to be negatively associated with the number of days of binge drinking and marijuana use in young adulthood, and the number of years on medication for behavioural and emotional problems during high school (Jones et al., 2015). Given these positive health, psychological, and social benefits, promoting prosocial behaviour development beginning in early childhood is important. Furthermore, the potential bi-directional associations between prosocial behaviour and child health-related outcomes (i.e., child physical activity and mental health) are specifically discussed in the following sub-chapters. This understanding forms a basis for investigating the mechanistic pathways linking green space to prosocial behaviour and the examination of whether prosocial behaviour mediates the associations between green space and health-related outcomes.

1.2.5 Prosocial behaviour and child physical activity

There are two possible channels to explain how physical activity may lead to prosocial behaviour. It is posited that a primary channel is that physical activity performed in a group can affect prosocial skill development through encouraging social contacts or interactions and developing empathy, as well as promoting the learning process and practice of cooperating, offering help, and sharing with peers (Di Bartolomeo & Papa, 2017). Ongoing positive face-to-face interactions among members can increase trust, cooperation, and a sense of belonging, all of which contribute to greater quality of peer relationship. The evidence from a longitudinal observational study among Dutch children also found that membership in a sports club and a moderate-to-high level of sport participation was associated with higher prosocial behaviour (Moeijes et al., 2018). Findings from a scoping review by Clark et al. (2015) also support the association between sport participation and positive social behaviours, including prosocial behaviour. Meanwhile, another potential channel is through the positive effects of physical activity on neurotransmitters for developing positive emotions or reducing anxiety and stress (Di Bartolomeo & Papa, 2017). Someone with positive emotional states is more likely to engage in cooperative behaviours (Aknin et al., 2018).

A systematic review of the psychosocial outcomes of sport participation by Eime et al. (2013) has proposed a model suggesting that the relationship between psychosocial health and sport participation is bi-directional in nature. Psychosocial assets such as one's social network may increase the participation in organised sport and may further facilitate the development of psychosocial assets. On the other hand, those with low levels of psychosocial assets are less likely to participate in organised sport, and this may subsequently prevent them from developing and enhancing their psychosocial assets (Vella et al., 2017). This hypothesis of bi-directional associations might apply for the association between prosocial behaviour and physical activity. While the causal chain from physical activity to prosocial behaviour is clearly defined, an additional pathway from prosocial behaviour to physical activity might also emerge.

Current published literature on how peers influence physical activity may help explain the mechanism of a causal chain from prosocial behaviour to physical activity. Several studies argued that the presence of peers (Beets et al., 2006; Salvy et al., 2008), peer activity levels (Sawka et al., 2013), and positive interaction such as peer support (Garcia et al., 2016; Voorhees et al., 2005; Zhang et al., 2012) have been identified as important predictors of physical activity. In addition, positive peer interaction (e.g., cooperating, helping) as a marker of prosocial behaviour might be developed from initial physical activity and then can support the stability of physical activity among children. Positive social interaction may be an important component in creating a motivational climate that increases enjoyment and social supports for future physical activity. By contrast, lack of social support and increased social pressure during outdoor play are noticeable factors for dropping out of sports (Crane & Temple, 2015).

1.2.6 Prosocial behaviour and child mental health

One's social domain can act as either a risk or protective factor for mental health and includes parental-, school- or friend-, and community-induced factors (WHO, 2005). A theory of cognitive development put forward by Vygotsky posits that human interaction, for example children's contacts with peers, and/or parents and teachers, is important for psychological functioning. Positive social interaction can foster social and cognitive development and later be a protective factor of child mental health (García-Carrión et al., 2019). Interactions with prosocial characteristics can increase the expression of positive emotionality and reduce negative emotionality, decrease behavioural and emotional problems, and boost the quality of peer relationships (Clark & Ladd, 2000). Behaviours that result in positive emotions are more likely to be repeated and can sustain prosocial behaviour among children (Aknin et al., 2012). This is in accord with previous findings that a greater affiliation with prosocial peers was associated with higher rates of positive emotionality in later peer interaction that have important implications for child mental wellbeing (Fabes et al., 2012).

Previous evidence indicates that prosocial behaviour is associated with some indicators of child mental health. Past studies among toddlers found that altruistic prosocial behaviour (i.e., behaviour resulting in benefits for others with no expectation of return), such as giving treats to others without an expectation of reward, is associated with greater happiness than receiving treats due to positive emotions or the "warm glow" generated – i.e. the satisfaction or emotional reward of giving to others (Aknin et al., 2015; Aknin et al., 2012). A study that defined mental health problems as problem behaviours, as measured using the SDQ's total difficulties score (TDS), found that a higher prosocial behaviour score was associated with lower TDS, irrespective of neighbourhood socioeconomic status or school-level achievement (Flouri & Sarmadi, 2016). Similarly, rather than examining total problem behaviours using the TDS, another study examined associations separately for the two SDQ subscales that combine to form the TDS, namely, internalising problems – emotional responses to stressors that are directed inward (e.g., anxiety, worry, nervousness) and externalising problems – emotional responses to stressors that are directed away from the self (e.g., impulsiveness, aggressiveness) (Flynn et al., 2015). This study found that prosocial behaviour predicted lower scores on both subscales.

Previous studies among adult samples suggest that the association between social interaction and mental health is bi-directional (Almquist et al., 2016; Cai et al., 2017; Saeri et al., 2017). Those studies may support arguments for bi-directional associations between prosocial behaviour and child mental health since social interaction is concomitant with prosocial behaviour. In addition, bi-directional relationships between subjective wellbeing and prosocial behaviour were reported among elementary school children (Chen et al., 2019). While a causal chain is apparent from prosocial behaviour to child mental health, reverse causality might also occur. For instance, children with conduct problems often have difficulties in empathising and may misinterpret others' intentions as being mean-spirited, which, in turn, can manifest as aggressive behaviours against others (e.g., threatening, disobedience, fighting or bullying, etc.) (Campbell et al., 2000). In addition, children with emotional problems (e.g., anxiety disorders) tend to be worried about things before they happen, fear making mistakes, and have low self-confidence and self-esteem (American Academy of Child and Adolescent Psychiatry, 2012). Therefore, children with poor mental health may have insufficient social skills to develop and maintain friendships, therefore they might be less likely to engage in prosocial behaviour (Ogundele, 2018). Furthermore, this situation may continue to place those with these mental health problems at a disadvantage in regard to developing and maintaining prosocial behaviour that has positive health and social benefits for them.

1.3 Green space

1.3.1 Green space definition and measurement

Currently, there is no universally accepted definition of green space since it varies depending on the study context and disciplines, and with regard to its health impacts. Based on the World Health Organization (WHO) (2012), the definition of urban green space includes parks, sports fields, natural meadows, woods, wetlands or other ecosystems. Hartig et al. (2014) in a review of reviews on nature and health identified that "nature" refers to physical existence and processes that are not human made or created, such as features of vegetation, animal, or landscape that comprises these entities; and, practically, it also includes artificial or built environments that appear natural or bear natural elements, such as gardens, parks, street trees that are designed and maintained for human purposes. Until recently, for urban planning and public health policy-making purposes, green space that is universally accessible to all urban residents or open to the public (regardless of socioeconomic status) such as parks and gardens, was more likely to be studied in earlier work (WHO Regional Office for Europe, 2016).

Vargas-Hernández et al. (2018), operating under the assumption that green space is an important ecosystem in any community development, suggested that the ability of green space to meet the needs and aspirations of local users may also be important. Therefore, components of green space might also include some built facilities such as playgrounds, sport areas, and artistic features, as well as other amenities and resources that support its utilisation. In addition, findings from a review of 125 studies on green space conducted by Taylor and Hochuli (2017) suggested that green space definitions varied by study, and could include natural vegetation, woodland, forest, sparsely-landscaped streets, playfields, parks, outdoor sports fields, school playgrounds, etc. Moreover, the WHO Regional Office for Europe (2017) also suggested that parks, playgrounds, sport and play areas, and school grounds should be included as part of urban green space interventions. Therefore, the notion of green space might not solely focus on the vegetation aspect, but also other components that support the utilisation of green space.

The availability of green space can be quantitatively measured using the normalised difference vegetation index (NDVI). This is predominantly used in epidemiological and population-based studies as an indicator showing how much green vegetation exists in a particular area. It is a validated measure and practical metric to investigate greenness and health (Markevych et al., 2017). NDVI is based on remote sensing, estimating the proportion of green space area by light absorption characteristics, for example by chlorophyll in plants (WHO Regional Office for Europe, 2016). Its limitation lies in its inability to distinguish different types and quality of green space (Villeneuve et al., 2018). The results of using NDVI are also sensitive to (seasonal) changes present due to weather at the time of imagery. NDVI can, nevertheless, help calculate an indication of average so-called ‘greenness’ in a statistical or administrative area (WHO Regional Office for Europe, 2016). Geographic information system (GIS)-based land use and satellite-based indices are also other techniques increasingly being used to assess the percentage of green space within a certain set distance from residential locations (Gupta et al., 2012; Markevych et al., 2017).

In addition to objective measures (e.g., NDVI, land use data, etc.) to identify the presence of green space in the neighbourhood, previous studies have also used subjective-based assessment. For example, a study by Reuben et al. (2020) in the US assessed the presence of neighbourhood green space or park by asking caregivers the following question: *"In your neighbourhood, is there a park or playground?"*. Caregiver report on the availability of green space or public parks was also used in a study in Germany to investigate the association between green space and pre-schoolers' mental health (Zach et al., 2016). Moreover, Dzhambov et al. (2018) used self-reported neighbourhood greenness – supplied in answer to the question, *"To what extent is your neighbourhood "green" (e.g., parks, gardens, street trees)?"* – to evaluate the association between green space and general health among students in Bulgaria. Other studies also examined different subjective measures of green space exposure, such as subjective proximity to green space (Abbasi et al., 2020; Aggio et al., 2015), the frequency of using or visiting green space (McCracken et al., 2016), and the amount of time spent in green space (Andrusaityte et al., 2019; McEachan et al., 2018), in relation to child health-related outcomes.

A growing body of literature has begun to recognise the "quality" aspect of green space as an important measure as it might influence green space usage. A review of some qualitative evidence on green space confirmed that perceptions of social environment and physical attributes of green space, such as safety, aesthetic appearance, cosiness, attractiveness, and maintenance, are important factors in relation to green space quality (McCormack et al., 2010). Green space quality might be more important than green space quantity since one's decision to visit and spend time in green space could be influenced by preferences on particular aspects of green space (Fongar et al., 2019). Green space quality has been observed to be associated with physical activity (Björk et al., 2008; de Jong et al., 2012) and level of psychological distress (Pope et al., 2015). Green space quality is also more strongly associated with mental health than is green space quantity (de Vries et al., 2013; Francis et al., 2012). Therefore, taking into account the aspect of quality is important when examining the influence of green space on certain health outcomes.

To date, there is no gold standard by which to measure green space quality. Green space quality can be objectively assessed using the GIS-based measures, expert assessments through audits or checklist, or physical observations (Zhang et al., 2017). However, objective measures of green space quality often do not take into account the appraisals of residents who have the day-to-day experience of residing in the neighbourhood. Measuring people's perceptions about their surrounding environment is important in order to understand what particular aspects they view as being more valuable, and which may contribute to improving their health and quality of life. Their perception might therefore be relevant and consequential for urban planning (Hur et al., 2010). A study by Zhang et al. (2017) also highlighted the importance of perceived green space quality in mediating the association between objectively-determined green space quality and neighbourhood satisfaction. These findings might imply that a subjective measure of green space quality is a more proximate determinant to health and behavioural outcomes than the objective measure.

Green space quality can be considered an important measure related to, but still distinct from green space quantity, particularly among children. Children, particularly those in younger age groups, are more likely to be reliant on parents; thus, parental or caregiver subjective assessment of green space quality might be a more relevant measure for green space exposure among children. Past studies using datasets from the Longitudinal Study of Australian Children (LSAC) measured the quality of neighbourhood green space by asking caregivers to rate on a Likert-scale the extent to which they agreed with the following statement: "*There are good parks, playgrounds and play spaces in this neighbourhood*" (Feng & Astell-Burt, 2017a, 2017c, 2017d). Findings suggest that favourable perceptions of green space quality were associated with higher child wellbeing (Feng & Astell-Burt, 2017c, 2017d) and decreased odds of sub-optimal general health (Feng & Astell-Burt, 2017a) independent of green space quantity. Interestingly, green space quality was found to be more strongly associated with children's externalising problems than green space quantity (Feng & Astell-Burt, 2017c). Therefore, the indicator of caregiver-reported green space quality matters in evaluating the association between green space and child health and behavioural outcomes.

1.3.2 Potential mechanisms linking green space and prosocial behaviour

The availability of urban green space for children has been found to be associated with more physical activity and/or less screen time (Akpinar, 2017; Roemmich et al., 2006; Sanders et al., 2015), better mental health and wellbeing (Feng & Astell-Burt, 2017c, 2017d; Flouri et al., 2014; McCormick, 2017; Vanaken & Danckaerts, 2018), and lower odds of respiratory health problems among children (Eldeirawi et al., 2019; Feng & Astell-Burt, 2017b; Tischer et al., 2017). In addition, while children in urban environments are characterised by less time spent on outdoor activities and less social contact with other children (Singer et al., 2009), the presence of nearby green space might provide additional places to foster prosocial behaviour development.

Scholars in multidisciplinary fields have suggested a conceptual model to help understand the mechanisms by which urban green space might influence health outcomes. Three domain pathways are proposed and these comprise: (i) harm mitigation (e.g., reducing harmful environmental exposure – air pollution, noise, heat), (ii) restoring capacities (e.g., restorative effects, stress recovery), and (iii) building capacities (e.g., promoting physical activity, facilitating social cohesion) (Markevych et al., 2017). Under the frame of this theoretical model, potential mechanisms linking urban green space to prosocial behaviour have been theorised. In addition, the concept of life course epidemiology has also been combined into the proposed model to understand how each mechanistic pathway links green space to prosocial behaviour by considering the development of prosocial behaviour by age. This concept suggests that exposure to physical or social factors during the life course might have long term effects on later disease risk or health outcomes (Ben-Shlomo et al., 2014; Kuh et al., 2003). The theory of life course epidemiology can also help identify critical and sensitive periods for the influence of green space on the development of prosocial behaviour. The combined model is shown in Figure 1.1.

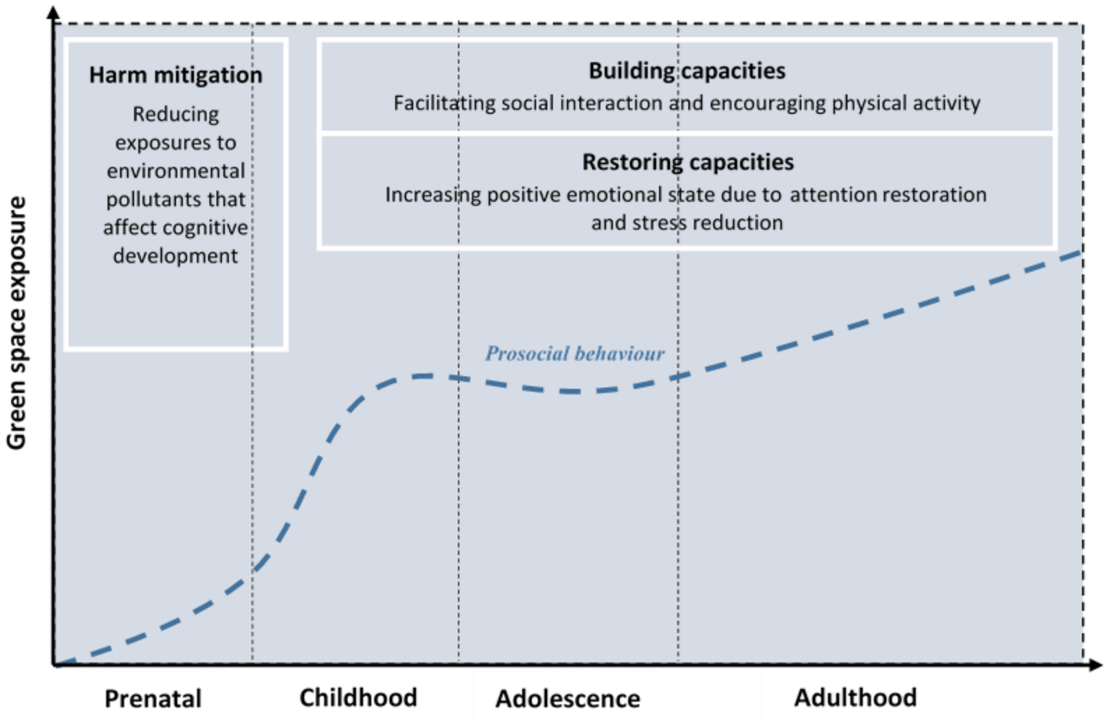


Figure 1.1 Potential pathways linking green space to prosocial behaviour. Adopted from Markevych et al. (2017) and Ben-Shlomo et al. (2014)

Harm mitigation may be the first pathway linking green space to child prosocial behaviour. Exposure to environmental pollutants during vulnerable temporal “windows”, such as the prenatal or early postnatal periods, might have adverse impacts on child cognitive development (Dadvand et al., 2015), which, in turn, influences prosocial behaviour. Ren et al. (2019) conducted a cross-sectional study to examine the associations of prenatal exposure to outdoor air pollution on prosocial behaviour among China's pre-schoolers. Exposure to PM_{10} (particulate matter <10 μm in diameter) and $PM_{2.5}$ (particulate matter <2.5 μm in diameter) during the full gestation period were reported to be associated with increased odds of a score in the abnormal range of prosocial behaviour after controlling for child-related factors, maternal factors, and socioeconomic status. Meanwhile, past work suggested that air-related pollution can be reduced by the presence of green space (Dadvand, Nazelle, et al., 2012; Dadvand, Sunyer, et al., 2012; Su et al., 2011). Previous studies also found the association between urban greenness and cognitive development among children was partly explained by reduction in air-related pollution (Dadvand et al., 2015; Liao et al., 2019). Therefore, early and frequent exposure to nearby greenness can positively affect later prosocial behaviour by mitigating harmful environmental stressors during windows of susceptibility such as during the prenatal period. Furthermore, negative effects of prenatal exposure to air pollution on prosocial behaviour can be attenuated by factors driving cognitive development, such as learning activities and social interactions that can occur in other settings (e.g., schools) (Durlak et al., 2011; Gustin et al., 2018; Weinstein & Bearison, 1985).

The harm mitigation pathway might also work by alleviating harmful environmental and psychosocial stressors of growing up in socioeconomically unfavourable familial and neighbourhood circumstances. Previous research findings suggest that children from households of low socioeconomic status (e.g., poorly educated parents and/or low family income) (Silke et al., 2018) and living in disadvantaged neighbourhoods (Safra et al., 2016) tend to have lower prosocial behaviour. The salutogenic (health improving) effects of exposure to green space, however, has been shown to potentially reduce socioeconomic-related health inequalities (Mitchell & Popham, 2008; Mitchell et al., 2015; Wang & Lan, 2019). These findings indicate the potential role of green space in influencing the development of prosocial behaviour by mitigating the adverse effects of living in deprived neighbourhoods and/or low-income households.

Childhood could be one of the critical periods for the green space – prosocial behaviour association. A “critical period” refers to a specific time window in which exposure has effects on the development and subsequent health or behavioural outcome (Kuh et al., 2003). While prosocial behaviour can progressively increase with age during childhood, exposure to green space might help elevate prosocial behaviour development through the mechanisms of building and restoring capacities. Moreover, “late childhood” can be considered as the sensitive period because exposure to green space might have a greater effect than it would be at other childhood periods. Older children widen their friendships and develop socio-cognitive skills (Abrams et al., 2015; Hay & Cook, 2007). They tend to have more social interactions and behave more prosocially than their younger counterparts (Eisenberg et al., 2015), and the presence of nearby green space might multiply these opportunities.

According to the building capacities pathway, green space provides attractive places for children to foster social interactions and then facilitate prosocial behaviour development. This is supported by the social network theory which posits that repeated and frequent interaction among individuals brings opportunities for cooperation and helps to build trustworthiness, which, in turn, stimulates individuals to engage in prosocial behaviour towards others (Wittek & Bekkers, 2015). In addition, the intergroup contact hypothesis contends that time spent interacting with people from different backgrounds can promote positive intergroup attitudes and decrease prejudice (Allport et al., 1954; Davies et al., 2011). A study conducted by Meleady and Seger (2016) showed that imagining social interactions with outgroup members can encourage prosocial behaviour and the association is mediated by increased trust. Furthermore, some previous studies have suggested that green space potentially facilitates social interactions among adults (Aram et al., 2019; Hong et al., 2018; Jennings & Bamkole, 2019; Kaźmierczak, 2013). These studies indicate that green space can possibly influence prosocial behaviour through increased social interactions that align with the nature of prosocial behaviour which is developed and practised through frequent interaction (Oerlemans et al., 2018). Neighbourhood green space can also attract children to engage in outdoor physical activity with peers (Sanders et al., 2015; Ward et al., 2016), which, in turn, brings opportunities to foster prosocial behaviour (Di Bartolomeo & Papa, 2017).

Other theoretical perspectives help explain the possible roles of green space for restoring capacities in relation to prosocial behaviour. According to psycho-evolutionary theory (PET), natural environments are best suited for humans as places where we initially evolved and humankind's survival was reliant on nature before the agricultural revolution. Emotional responses to natural environments are viewed as part of feeling connected to nature and as being "central to the psychological components of stress and restoration" (Ulrich et al., 1991) (p. 207). PET is more commonly known as stress reduction theory (SRT) which suggests that contact with natural environments can reduce the levels of stress (Ulrich, 1983). Another complementary theory, attention restoration theory (ART), contends that taking time in natural environments reduces attention-demanding tasks and allows individuals to restore attention thereby building more positive emotional and psychological states (Kaplan, 1995; Ohly et al., 2016). Zhang et al. (2014) reported that positive emotions mediate the association between exposure to greenery perceived as beautiful and prosocial behaviour among adults. Positive emotional states due to exposure to nature can lead to prosocial tendencies by changing a person's mental frame from an individual to a collective mental frame or "unselfing" process – (i.e., from self-interest to an interest outward towards other people, e.g., enhancing the willingness or intention to comfort and help others) (Schwartz et al., 2019; Zhang et al., 2014). In addition, Goldy and Piff (2020) argued that contact with the natural environment can increase attention to others and enhance prosocial behaviour through psychological processes whereby those environments generate positive effects that include the feeling of awe and a perception of beauty.

Building and restoring capacities might interact to link green space and prosocial behaviour among children and adolescents. For example, children who spend time in green space playing with friends and having positive interactions may also experience attention restoration due to viewing natural vegetation. Frequent exposure to green space may be required to enable repeated and increased social interactions, as well as to build positive emotionality. These, in turn, facilitate prosocial behaviour development. Early and longer accumulation of exposure to green space may generate greater levels of benefit for prosocial behaviour, particularly during the potentially critical period of childhood and the potentially sensitive period of late childhood. However, the increase in prosocial behaviour associated with accumulated green space exposure in adolescence might not be as high as in childhood since the natural decline of prosocial behaviour is reported in this period (Eisenberg et al., 2015). Another possible scenario is that the accumulated exposure is insufficient to lessen or moderate the intrinsic developmental decline in prosocial behaviour. Prosocial behaviour may start to rebound in early adulthood (Eisenberg et al., 2015) and the accumulation of exposure to green space may help to increase the levels of prosocial behaviour.

1.4 Understanding the association between green space quality and prosocial behaviour – the rationale

To date, limited studies examining the potential role of neighbourhood green space in facilitating prosocial behaviour development among children and adolescents have shown inconsistent findings (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; Bates et al., 2018; Carrus et al., 2015; Dopko et al., 2019; Mayfield et al., 2017; McEachan et al., 2018; Odgers et al., 2012; Park et al., 2016; Richardson et al., 2017; Sobko et al., 2018; Van Aart et al., 2018; van Dijk-Wesselius et al., 2018; Whitten et al., 2018). A critical review of these studies presented in Chapter 2 suggests that exposure to nearby green space may be positively associated with prosocial behaviour among children and adolescents (Putra et al., 2020); however, a lack of evidence based on longitudinal data limits causal inference. There was weak evidence in regard to the relationship between green space quantity and prosocial behaviour, while, there is a paucity of studies testing whether green space quality matters for the development of prosocial behaviour. Potential effect modifiers were also not comprehensively assessed by previous studies. Furthermore, potential mechanisms linking green space to prosocial behaviour have not so far been tested. Therefore, further investigation is warranted to fill these current knowledge gaps.

Exposure to quality green space may be important for the development of prosocial behaviour across childhood and adolescence. Weak evidence on green space quantity in relation to prosocial behaviour could indicate that green space quality might be a more relevant measure in evaluating whether children can derive maximum benefits from neighbourhood green space. This is because children's access to green space is more likely dependent on parents' or caregivers' decision to visit and their preferences on particular aspects of green space being viewed as good for children's outdoor activities

(Feng & Astell-Burt, 2017a, 2017d; Kalish et al., 2010). The association between green space quality and prosocial behaviour may occur through the hypothesised mechanisms of harm mitigation, and building and restoring capacities. This association may thus provide further benefits for child health and wellbeing. Hence, testing the association between green space quality and prosocial behaviour, identifying who tends to benefit more from the presence of quality green space, and investigating how quality green space may influence prosocial behaviour and whether prosocial behaviour might result in better child health-related outcomes are important to enrich the current literature and inform policies in a targeted manner.

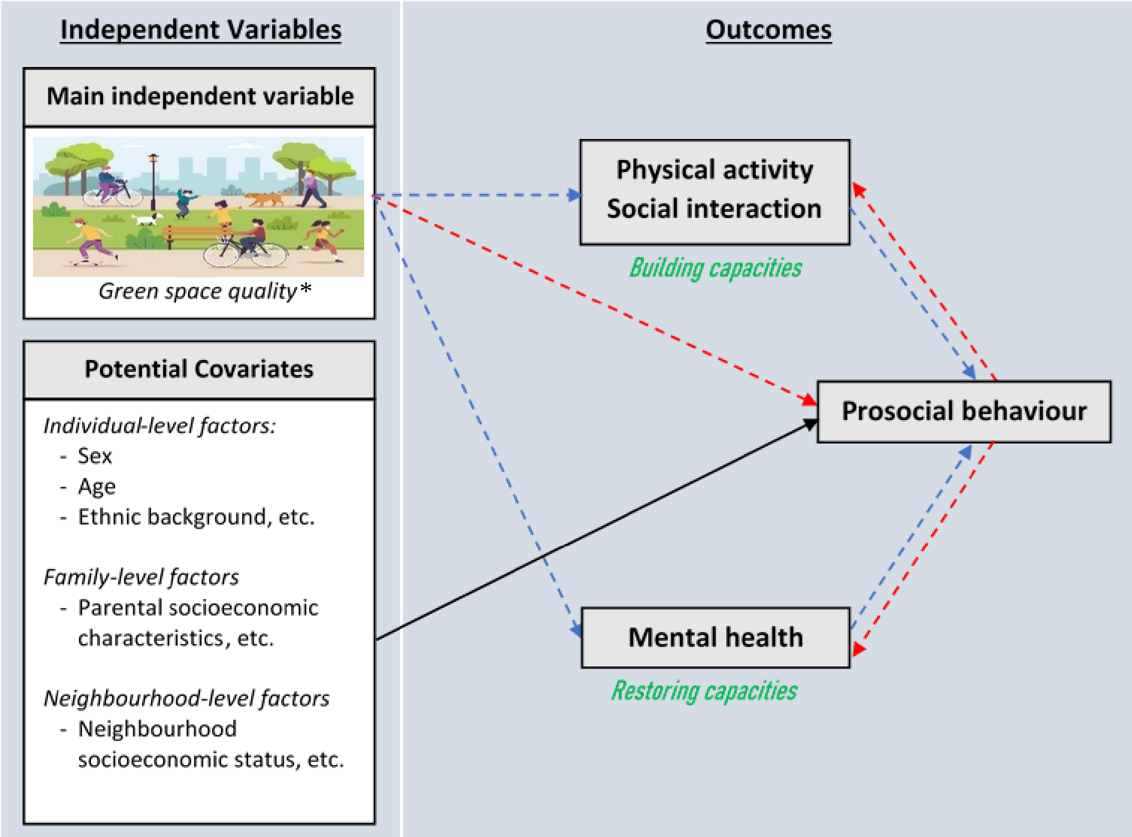
1.5 Aims and objectives of the study

The aims of this PhD research were to investigate the association between green space quality and the development of prosocial behaviour in children and adolescents, and to explore to what extent prosocial behaviour might be a candidate mediator, or outcome of, associations between quality green space and child health (physical activity, social interaction, and mental health). The objectives are to i) critically review current evidence on green space quality and child prosocial behaviour, ii) examine the longitudinal association between green space quality and prosocial behaviour, and identify the potential effect modifiers, iii) understand the role of physical activity, social interaction, and mental health in mediating the association between green space quality and child prosocial behaviour, and iv) investigate the role of prosocial behaviour as a mediator for the relationship between green space quality and child health-related outcomes.

1.6 Conceptual framework

The conceptual framework for this PhD research was developed by combining and modifying several existing frameworks. First, the Social-Ecological Model of Human Development proposed by Urie Bronfenbrenner (1979) highlighted that growth or change (e.g., in prosocial behaviour) results from the interaction between personal attributes and environmental influences. In addition, the framework conceptualised by the US National Research Council suggested that children's health is determined by four major factors, consisting of biology, behaviour, and the social and physical environment (National Research Council & Institute of Medicine, 2004). This framework might imply that child-health related outcomes (e.g., physical and/or mental health) can be influenced by personal-biological characteristics (e.g., age, sex), behaviour (e.g., prosocial behaviour), social environment (e.g., family, peers), and physical environment (e.g., green space quality). In addition, a conceptual model of three pathways linking green space to health proposed by multidisciplinary experts was also adopted (Markevych et al., 2017).

Figure 1.2 illustrates that green space quality as the main independent variable may influence child prosocial behaviour through linking pathways of building capacities (promoting physical activity, facilitating social interaction) and restoring capacities (increasing the expression of positive emotionality or improving mental health) as shown by the blue dash arrows. Given the possibility of bi-directional associations, green space quality may also lead to prosocial behaviour development, which in turn, may affect child health and behaviour (physical activity and mental health), as shown by the red dash arrows. In addition, other potential covariates including individual-, family-, and neighbourhood-level factors are also taken into account.



*The picture was designed by Freepik (https://www.freepik.com/free-vector/hand-drawn-people-doing-outdoor-activities_15498229.htm)

Figure 1.2 Diagram illustrating the conceptual framework of the research. Adopted from various frameworks (Bronfenbrenner, 1979; Markevych et al., 2017; National Research Council & Institute of Medicine, 2004)

1.7 Research questions

This PhD research aimed to answer the following research questions to fill some of the current knowledge gaps.

1. What evidence is there on the association between green space quality and child prosocial behaviour?
2. Within the Australian context, to what extent is the accumulation of, and change in, the availability of quality green space associated with the development of prosocial behaviour across childhood?

To what extent is the association moderated by:

a) Child characteristics,

b) Family characteristics, and

c) Neighbourhood socioeconomic circumstances?

3. To what extent do physical activity, social interaction, and mental health mediate the association between green space quality and child prosocial behaviour?
4. To what extent does prosocial behaviour mediate the association between green space quality and child health-related outcomes?

To address these research questions, one systematic review and four empirical studies are presented. A systematic review was conducted to answer the first research question. Additionally, four empirical studies using nationally representative longitudinal data of Australian children were undertaken to address research questions 2 to 4. The first and second empirical studies were dedicated to address research question 2, while, the third and fourth empirical studies addressed research questions 3 and 4, respectively.

1.8 Significance of the study

This PhD research adds to the current knowledge on the association between green space quality and prosocial behaviour among children which is limited due to a paucity of studies with robust evidence available. This research improves the quality of current evidence by taking into account limitations of past research (i.e., weak study design, a lack of measure for green space quality, untested potential effect modifiers and mediators). In addition, this study is among the first to investigate whether physical activity, social interaction, and mental health mediate the association between green space quality and child prosocial behaviour and whether prosocial behaviour is a potential mediator of the causal pathway from green space quality to child health.

Understanding the roles of neighbourhood green space quality in shaping prosocial behaviour among children and adolescents is important due to the positive impacts of prosocial behaviour on health, psychological and social outcomes. Better health outcomes may be achieved for populations by the provision and maintenance of favourable green space quality across the life course, beginning in childhood. Therefore, findings from this research do not only fill the knowledge gap, but also potentially inform the urban planning and public health policies and practices in Australia so that they enhance the quality of neighbourhood green space aiming to promote better health and behavioural outcomes among children in their present and future lives.

1.9 Outline of the thesis

This thesis is presented as a thesis by compilation. It includes five publications (i.e., published articles) in high-impact-factor peer-reviewed journals. Each published article is presented in separate subsequent chapters (Chapters 2, and 4 to 7). Chapter 3 is dedicated to the methodological aspects of this thesis. The discussion and conclusion of research findings are presented in Chapter 8 as the final chapter. All references from each chapter are presented together at the end of this thesis. A brief description of the subsequent chapters constituting this thesis is as follows.

Chapter 2 describes the systematic review of relevant studies on the association between green space and prosocial behaviour among children and adolescents. Eligible studies were critically reviewed and assessed to identify the current research gap. Findings from the systematic review highlighted the knowledge gaps and identified the need for subsequent studies presented within this thesis that included conducting studies on investigating the role of green space "quality" in shaping the development of prosocial behaviour and testing effect modifiers and mechanistic pathways linking green space quality to prosocial behaviour.

Chapter 3 provides an overview of the research methodology for four empirical studies conducted within this thesis. This chapter consists of the following sections: (i) preface; (ii) study design, data, and sample, detailing the use of LSAC dataset; (iii) variables, including explanations of the exposure, the outcome, candidate mediators, and other independent variables; (iv) statistical analysis; and (v) ethical considerations.

Chapter 4 presents findings from an empirical study on the longitudinal association between the availability of neighbourhood green space quality and prosocial behaviour. Sensitivity analyses by child's sex and history of changing neighbourhood were undertaken. Furthermore, multilevel growth curve models were also developed to identify at which ages the effect of quality green space was stronger for prosocial behaviour.

Chapter 5 describes findings from an investigation on the longitudinal association between trajectory classes of caregiver-reported green space quality and the development of prosocial behaviour. This study adopted the concept of life course epidemiology to examine whether the accumulation of, and changes in, the availability of quality green space across childhood matter for the development of prosocial behaviour. In addition, the theory of differential exposure became a basis for investigating the potential role of quality green space in reducing socioeconomic-related prosocial behaviour inequalities. Based on the differential effect theory, potential effect modifiers were also assessed in this chapter.

Chapter 6 describes an investigation of potential pathways linking green space quality to child prosocial behaviour. This was based on the understanding of mechanistic pathways proposed by multidisciplinary experts and included building capacities and restoring capacities. A range of candidate mediators across physical activity, social interaction, mental health, and health-related quality of life (HRQOL) were tested.

Chapter 7 presents findings from the testing of prosocial behaviour as a candidate mediator of the associations between green space quality and child health-related outcomes (physical activity, mental health, HRQOL). This is based on the synthesis of current literature suggesting bi-directional associations between prosocial behaviour and participation in physical activity, as well as between prosocial behaviour and mental health. Therefore, prosocial behaviour might lie on the causal pathway between green space quality and child-related outcomes.

Finally, Chapter 8 presents an overall discussion by summarising and integrating the major findings presented in previous chapters. This chapter then provides the strengths and limitations of the thesis. Furthermore, the implications of findings for future research and policy are discussed. This chapter ends by providing a conclusion for the study findings and guidance for future research.

Chapter 2: Systematic review

2.1 Preface

Previous studies suggest the plausible role of green space in shaping the development of child prosocial behaviour. However, no studies appear to critically assess and synthesise the current evidence on the potential influence of green space on child prosocial behaviour. This chapter addressed the first research question, i.e., "*What evidence is there on the association between green space quality and child prosocial behaviour?*", by presenting a systematic review that critically synthesised the available data on associations between green space and prosocial behaviour among children and adolescents. The systematic review in this chapter is presented as it was published (Appendix C) with minor adjustments for tables, figures, referencing style, and overall thesis formatting requirements.

Citation

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Author contributions

I Gusti Ngurah Edi Putra, Thomas Astell-Burt, and Xiaoqi Feng conceptualised the review. I Gusti Ngurah Edi Putra conducted the systematic search, study quality assessment, summarised the findings, wrote, and revised the manuscript. Eme Eseme John peer-reviewed the systematic search, performed full-paper assessment of the eligible articles and reviewed the draft manuscript. Thomas Astell-Burt, Dylan P. Cliff, Stewart Vella, and Xiaoqi Feng provided critical inputs throughout the process and edited the manuscript. All authors approved the final version of the manuscript.

The findings from this chapter were presented at the following conferences:

1. Powerful Ideas Symposium, Population Wellbeing and Environment Research Lab (PowerLab), School of Health and Society, Faculty of the Arts, Social Sciences and Humanities, University of Wollongong on 13 December 2019 (Appendix H),
2. School of Health and Society Research Seminar, Faculty of the Arts, Social Sciences and Humanities, University of Wollongong on 22 April 2020 (a virtual seminar) (Appendix I),
3. The 14th Biennial Conference of the Asian Association of Social Psychology (AASP) 2021 on 31 July 2021 (a virtual conference) (Appendix K).

2.2 The published article: “The relationship between green space and prosocial behaviour among children and adolescents: A systematic review”

2.2.1 Abstract

The plausible role of nearby green space in influencing prosocial behaviour among children and adolescents has been studied recently. However, no review has been conducted of the evidence testing the association between green space and prosocial behaviour. This systematic review addresses this gap among children and adolescents. Within this review, the direction, magnitude, effect modifiers, and mediators of the association are discussed, followed by a narrative synthesis of future study directions. Out of 63 extracted associations from 15 studies, 44 were in the positive or expected direction, of which 18 were reported to be statistically significant ($p<0.05$). Overall, the current evidence shows that exposure to green space may potentially increase prosocial behaviour among children and adolescents, with some contingencies (e.g., child’s sex, ethnic background). However, the volume and quality of this evidence is not yet sufficient to draw conclusions on causality. Further, heterogeneity in the indicators of green space exposure could lead to mixed findings. In addition, none of the included studies investigated potential mediators. Nevertheless, this review provides preliminary evidence and a basis for further investigation with rigorous study methodology capable of drawing causal inferences and testing potential effect modifiers, linking pathways, and relevant green space measures.

2.2.2 Introduction

Health benefits due to neighbourhood green space exposure in urban environments have been well-documented among children that include better mental health and wellbeing (Feng & Astell-Burt, 2017c, 2017d; Flouri et al., 2014; McCormick, 2017; Vanaken &

Danckaerts, 2018), more physically active and/or less screen time (Akpinar, 2017; Roemmich et al., 2006; Sanders et al., 2015), and reduced odds of respiratory health problems (Eldeirawi et al., 2019; Feng & Astell-Burt, 2017b; Tischer et al., 2017). Moreover, favourable health outcomes due to green space exposure across the lifespan have been reported in some recent systematic reviews (Kondo et al., 2018; Lee & Maheswaran, 2011; Twohig-Bennett & Jones, 2018; van den Berg et al., 2015). However, the potential association between green space and prosocial behaviour and its underlying mechanisms have not been widely reported.

While children in urban areas tend to spend less time in outdoor activities and have less social contact with other children (Singer et al., 2009), the presence of nearby green space might promote positive social interactions that lead to prosocial behaviour development. The plausible influence of urban green space on child prosocial behaviour is increasingly being studied in recent years (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; McEachan et al., 2018; Richardson et al., 2017; Whitten et al., 2018). However, no systematic review of these studies is available so far.

This systematic review aimed to evaluate the available literature on the association between green space and prosocial behaviour among children (0-12 years) and adolescents (13-18 years). These age ranges were selected based on a previous systematic review on prosocial behaviour among adolescents (Silke et al., 2018). A narrative synthesis of the existing published literature on green space and prosocial behaviour nexus is presented. The subsequent sections discuss the findings and future study directions.

2.2.3. Methods

2.2.3.1 Search strategy and selection criteria

This review was conducted following the guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Moher et al., 2009). The literature search was carried out in 5-6 October 2019 using nine frequently used databases, including PubMED (US National Library of Medicine, Maryland, U.S.), Scopus, ScienceDirect (Elsevier, Amsterdam, Netherlands), Web of Science (Clarivate Analytics, Philadelphia, U.S.), PsycINFO, PsyschARTICLES (American Psychologist Association, Washington D.C., U.S.), CINAHL (EBSCO Publishing, Massachusetts, U.S.), Cochrane Library (John Wiley & Sons, New Jersey, U.S.), and ProQuest (ProQuest LLC, Michigan, U.S.). Guidance on the search terms selected was obtained from recently published systematic reviews on green space (Houlden et al., 2018; Vanaken & Danckaerts, 2018) and prosocial behaviour (Martí-Vilar et al., 2019; Oviedo, 2016; Silke et al., 2018). The terms as presented in Table 2.1 were searched in the titles, abstracts, and/or keywords of the articles. In addition, references from eligible articles were also searched.

Table 2.1 Search terms and strategy used to search relevant literature

Main Keywords	Search Terms
Green space	"green space" OR greenspace OR greenness OR greenery OR green OR "green area" OR landscape OR wilderness OR wild OR natur* OR park OR garden OR playground OR playspace OR "play space" OR "open space" OR recreation OR vegetation OR wood OR woodland OR tree OR plant OR grass OR forest OR shinrin-yoku
Prosocial behaviour	prosocial* OR pro-social* OR altruis*

*truncation symbol used to enable search all possible variations of the word

2.2.3.2 Eligibility criteria

The inclusion criteria consisted of studies that; 1) were peer-reviewed research articles, 2) had quantitative observational or experimental design; 3) investigated association between green space as an exposure that includes objective and/or subjective measures (quantity, quality, or both) and prosocial behaviour as either an outcome or as a mediator of a health outcome; 4) were published in English; and 5) included participants ≤ 18 years of age. No restriction on publication date was applied. Published articles that only contained an abstract (e.g., conference proceedings) were excluded.

Prosocial behaviour among children and adolescents was the outcome of interest. In this review, prosocial behaviour was defined as a range of positive behaviours that include offering help, sharing, cooperating, and comforting. The outcome focuses on the behavioural aspect rather than cognitive or affective responses (e.g., kindness, love, etc.). Meanwhile, green space refers to naturally-created areas or built environments that bear natural vegetation. Green space exposure in this review considered all characteristics of green space in accordance with the keywords provided (presented in Table 2.1). Green space characteristics measured using land cover maps, remote sensing data, physical observation, and audits were categorised as objective measures, whilst green space exposure data collected through interviews and questionnaires were assigned as subjective measures (Houlden et al., 2018; Vanaken & Danckaerts, 2018). Green space measures can also be classified as assessing quantity which refers to amount of green space available locally within a particular administrative area (e.g., average greenness, percentage of green space), while quality of green space is evaluated by some aspects that influence the usability (e.g., cosiness, safety, amenities, facilities, attractiveness, etc.) (Feng & Astell-Burt, 2017d, 2018; Marselle et al., 2014; McCormack et al., 2010). In addition, studies examining subjective connectedness to nature were also taken into account following a previous systematic review on green space (Houlden et al., 2018).

2.2.3.3 Selection strategy and data collection

All articles retrieved using the search terms in the selected databases were downloaded into EndNote. Duplicate articles were removed either using the EndNote function or manually. Two reviewers independently assessed the title and abstract of the published articles using the same inclusion criteria, followed by the full-text assessment. Further, any discrepancies between the two reviewers were discussed and consulted with a third reviewer. Information about publication details, study design, sample size, participant characteristics, exposure concept and measurement, measure instrument of prosocial behaviour, and the results were extracted into Table 2.2.

2.2.3.4 Data analysis

Quality and risk of bias of the articles were assessed using the quality assessment tools developed by the National Institutes of Health (2019) for observational and experimental studies. Similar to the process of article screening and data extraction, two reviewers independently performed the quality assessment and any discrepancies were discussed with the third reviewer. The extracted data from all eligible articles were summarised along with study quality assessment outcomes, followed by the narrative synthesis of the evidence on direction, magnitude, effect modifiers, and mediators of the association. The findings were then discussed and future study directions were proposed.

2.2.4 Results

2.2.4.1 Literature search results

Figure 2.1 presents the search results based on the PRISMA guidelines. Out of 15,267 articles retrieved from nine databases, 5,686 duplicates were removed. Screening based on title and abstract resulted in the selection of 35 articles for the full review. After the full-text assessment, 14 studies met the eligibility criteria. During this process, one paper (Carrus et al., 2015) was identified through references, resulting in a total of 15 papers for review.

2.2.4.2 Study characteristics and methods

Table 2.2 presents a summary for studies included in this review. All studies were from high-income countries. The majority were carried out in European countries (9; 60%), and followed by the US (3; 20%). Even though there was no restriction for publication date applied, all eligible studies were published between 2012-2019 and more than half (66.7%) were published in the last 3 years (2017-2019). There was an equal number (six studies) of cross-sectional (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; Odgers et al., 2012; Sobko et al., 2018; Whitten et al., 2018) and experimental studies (Bates et al., 2018; Carrus et al., 2015; Dopko et al., 2019; Mayfield et al., 2017; Park et al., 2016; van Dijk-Wesselius et al., 2018). The remaining studies were of a longitudinal design (McEachan et al., 2018; Richardson et al., 2017; Van Aart et al., 2018). The design of experimental studies varied with regards to the inclusion of a control group and measurement of the outcome before the intervention (pre-test). Out of two single group experimental studies, one study was a single group post-test only experiment (Bates et al., 2018), whereas another used a single group pre-post design (Park et al., 2016). The other four experimental studies reported using a control group, including two studies with- (Mayfield et al., 2017; van Dijk-Wesselius et al., 2018) and two without pre-test (Carrus et al., 2015; Dopko et al., 2019), respectively. Moreover, two (McEachan et al., 2018; Richardson et al., 2017), eight (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; Mayfield et al., 2017; Park et al., 2016; Van Aart et al., 2018; van Dijk-Wesselius et al., 2018; Whitten et al., 2018), and five (Bates et al., 2018; Carrus et al., 2015; Dopko et al., 2019; Odgers et al., 2012; Sobko et al., 2018) studies included in this review were judged to be of good, fair, and poor quality, respectively.

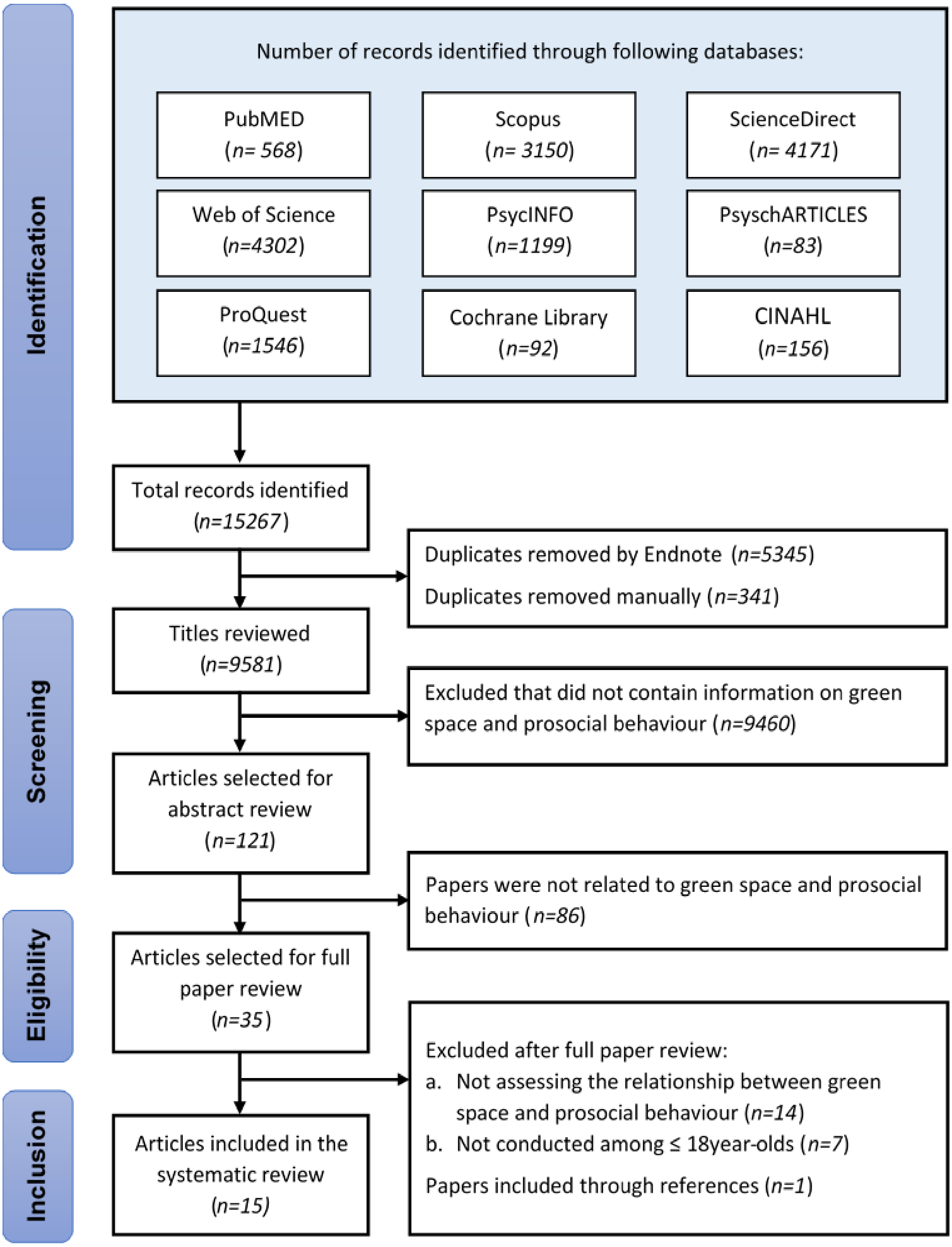

Figure 2.1 Study selection process based on PRISMA guidelines

Table 2.2 Summary of study characteristics and results

Authors, year, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Amoly et al. (2014), Spain	Cross-sectional study	2,111 (7-10 years)	a. Time spent playing in green spaces *(a total number of hours during the last school period and summer holidays)*; b. Residential surrounding greenness in buffers of 100 m, 250 m, and 500 m; c. School greenness in a buffer of 100 m; d. Home-school greenness *(average residential and school surrounding greenness in a buffer of 100 m, weighted by daily time spent at home and school)*; e. Residential proximity to a major green space *(a binary variable indicating whether the child's home within 300 m of a major green space)*	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ (*a continuous variable)*	Child's sex, school level, ethnicity, preterm birth, breastfeeding, exposure to environmental tobacco smoke, maternal smoking during pregnancy, responding person, parental educational achievement, parental employment status, and neighbourhood socioeconomic status	Quasi-Poisson mixed-effects models	No statistically significant association was found between all green space indicators and pro social behaviour ***(non-significant in expected direction)***.	Fair

Andrusaityte et al. (2019), Lithuania	Cross-sectional study	1,489 (4-6 years)	a. Time spent in a city park (*hours per week)*; b. Residential surrounding greenness in buffers of 100 m.	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ (*a binary outcome: borderline/ abnormal vs. normal)*	Child's sex, birth weight, wheeze, asthma, allergy, BMI, breastfeeding, siblings, paracetamol and antibiotic usage during the first year of life, maternal education, tobacco smoke, age at childbirth	Logistic regression	Increased time spent in city parks per 1 hour per week was associated with decreased odds of borderline/ abnormal prosocial behaviour: aOR= 0.98 (0.96, 0.99) ***(significant in expected direction)***. Non-significant association was found for residential surrounding greenness **(*non-significant in expected direction)***.	Fair
Balseviciene et al. (2014), Lithuania	Cross-sectional study	1,468 (4-6 years)	a. Residential surrounding greenness in a buffer of 300 m; b. Proximity to the nearest city parks *(transformed using the square root function in meters).*	NDVI	Parent-reported prosocial scale from SDQ (*a continuous variable)*	Child's age, sex, and parenting stress	Linear regression	Analysis was stratified by mother's educational level. Increased distance to city parks was negatively associated with prosocial behaviour among lower education group: β=-0.029 (p<0.05) ***(significant in expected direction)***. Residential greenness was negatively associated with prosocial behaviour among higher education group: β=-1.104 (p<0.05) ***(significant in unexpected direction)***.	Fair

Bates et al. (2018), USA	Experimental study (one-group posttest-only design)	3,345 and 3,710 observations at the first (T1) and second (T2) time, respectively (age ranges from pre-kindergarten to 8th grade)	Schoolyard renovation by increasing the presence of natural components (e.g., grass, trees) and also the quality (e.g., aesthetics; facilities).	In-person observation	Positive social interaction, measured by behavioural mapping using System for Observing Children's Activity and Relationship during Play (SOCARP). It was measured two times (T1, T2) after schoolyard renovation.	No confounders adjusted in the analysis	Chi-square test	The percentage of observed positive social interaction or prosocial behaviour increased from T1 (27.10%) to T2 (35.20%) ($p<0.001$) ***(significant in expected direction)*.**	Poor (no pretest, no randomisa tion)
Carrus et al. (2015), Italy	Experimental study (two-group posttest-only design)	39 (1.5-3 years)	Children's spending time in school green space vs. in internal space of school	In-person observation	Positive social interaction, measured by a behavioural checklist to record frequency of positive relational behaviours	No confounders adjusted in the analysis	ANOVA	After children were exposed to green space, more frequent positive relational behaviours were observed on days when children spent time in school green space compared to days when they did not: $p=0.038$) ***(significant in expected direction)*.**	Poor (no pretest, no randomisa tion)
Dopko et al. (2019), Canada	Experimental study (two-group posttest-only design)	80 (mean age = 10.49 years)	Children' spending time outdoors at the nature school vs. indoors at the museum	In-person observation	Using two tasks: a. A windfall task by asking children to imagine that they received money and what they decided on four available options (buy things they want, give to charity, spend on gifts for other	No confounders adjusted in the analysis	Paired sample t-test	Windfall task: Mean score for spending money on charity was statistically higher among children visiting nature school than museum: $\beta=3.66$ (0.06, 7.26) ***(significant in expected direction)***. Mean score for spending money on gift	Poor (no pretest, no randomisa tion)

					people, and save for the future). Children who decided for charity and spending on gifts for other people represent higher prosocial behaviour. b. A tangram task by asking children to imagine that they assigned 11 tangrams from three categories: easy, medium, and hard to someone else in their class. Children who assigned more tangrams in easy and medium categories, and few in hard category represent higher prosocial behaviour.			was lower among children visiting nature school than museum: β=-4.15 (-8.32, 0.03) ***(non-significant in unexpected direction)***. Tangram task: Mean score for assigning easy tangram was statistically higher among children visiting nature school than museum: β=0.74 (0.01, 1.46) ***(significant in expected direction)***. Mean score for assigning hard tangram was statistically lower among children visiting nature school than museum: β= -1.29 (-2.15, -0.42) ***(significant in expected direction)***.	
Mayfield et al. (2017), USA	Experimental study (two-group pretest-posttest design)	Two elementary schools for each intervention and control groups. This study included	The intervention was carried out by improving the quality of playground through adding playground marking with colourful interactive games. In addition, intervention	In-person observation	Positive social interaction, measured by behavioural mapping using System for Observing Children's Activity and Relationship	Scans nested within days nested with schools	Mixed-effects regression analysis	There was a non-significant decrease in prosocial behaviour in the verbal or physical manner before and after the intervention (***non-significant in unexpected direction***).	Fair

		3,588 SOCARP scans representing 1,196 child recess days with 3 rotations conducted.	schools received equipment to use with the game and training sessions for teachers.		during Play (SOCARP).				
McEachan et al. (2018), UK	Longitudinal study	2,594 (aged 0 at baseline, 4 years at follow up)	a. Satisfaction with green space *(asked among a sub-sample of 832 (32%) only)* b. Time spent playing outside *(minutes per week calculated for winter and summer months - asked among a sub-sample of 832 (32%) only)* c. Residential surrounding greenness in buffers of 100 m, 300 m, and 500 m.	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ (*a continuous variable)*	Child's age, sex, maternal age, cohabitation status, maternal education, subjective poverty, household size, neighbourhood deprivation index, mother's smoking behaviour, and mother's treatment record of mental disorder	Linear regression	Analysis was stratified by ethnicity (white British vs. south Asian). Satisfaction with green space was significantly associated prosocial behaviour among south Asian children only: β=0.20 (0.02, 0.38) ***(significant in expected direction)***. Time spent playing outside was not associated with prosocial behaviour among both ethnicities ***(non-significant in expected direction*** *for south Asian children and* ***non-significant in non-reported direction*** *for white British children****)***. Residential greenness in all buffer distances were not associated with	Good

								prosocial behaviour among both ethnicities ***(non-significant in expected direction)***.	
Odgers et al. (2012), UK	Cross-sectional study	2,024 (12 years)	Percentage of green space in a buffer of 0.5 mile (*measured only among a sub-sample of 200 neighbourhoods*).	A systematic social observation using Google Street view	A combined parent and teacher's reports of Revised Rutter Parent Scale for School-Age Children (*a continuous variable)*	No confounders adjusted in the analysis	Linear regression	No association was observed between percentage of green space and pro social behaviour (***non-significant in unexpected direction***).	Poor (no control for confounders)
Park et al. (2016), South Korea	Experimental study (one-group pretest-posttest design)	336 (5-7 years)	Participation in 24-session horticultural activity program that included indoor and outdoor activities, such as transplanting, planting seeds, making and applying eco-friendly fertilizer, observing vegetable plants, harvesting, etc.).	In-person observation	Teacher-reported of prosocial behaviour using the revised questionnaire with four subscales (helping, sharing, cooperation, kindness) (*a continuous variable)*	No confounders adjusted in the analysis	Paired sample t-test	All prosocial behaviour scales (helping, sharing, cooperation, kindness) increased from pretest to posttest ***(significant in expected direction)***.	Fair
Richardson et al. (2017), UK	Longitudinal study	2,909 (aged 4 years at baseline, 6 years at follow-up)	a. Percentage of park space in a buffer of 500 m b. Percentage of total natural space in a buffer of 500 m c. Garden access (*indicating whether the child had access to a private garden*).	Land cover map; Questionnaire	Parent-reported prosocial scale from SDQ (*a continuous variable)*	Child's age, sex, screen time, household income, educational attainment, carer's mental health, and neighbourhood socio-economic status	Linear regression	Analysis was stratified by the child's sex and household educational level. Percentage of total natural space was significantly associated with prosocial behaviour among girls: β=0.14 ($p<0.01$) and among high education households: β=0.12	Good

								(p<0.05) ***(significant in expected direction)***. Percentage of parks was not significantly associated with prosocial behaviour among all sub-sample groups ***(non-significant in expected direction)***. Access to private garden was not significantly associated with prosocial behaviour among all sub-sample groups ***(non-significant in unexpected direction)***.	
Sobko et al. (2018), Hong Kong	Cross-sectional study	299 (2-5 years)	Connectedness to nature (enjoyment of, empathy for, responsibility toward, and awareness of nature)	Questionnaire	Parent-reported prosocial scale from SDQ (*a continuous variable)*	No confounders adjusted in the analysis	Structural equation modelling	Greater responsibility toward nature was significantly associated with improved prosocial behaviour: β=0.77 ***(significant in expected direction)***.	Poor (no control for confounders)
Van Aart et al. (2018), Belgium	Longitudinal study	172 (6-12 years at baseline, 9-15 years at follow-up)	a. Percentage of semi-natural and forested area in a buffer of 2000 m; b. Percentage of agricultural area in a buffer of 300 m.	Land cover map	Parent-reported prosocial scale from SDQ (*a continuous variable)*	Child's age, sex, and parental socio-economic status	Linear regression	Percentage semi-natural and forested area was not associated with prosocial behaviour ***(non-significant in unexpected direction)***. Percentage of agricultural area was not associated with prosocial behaviour	Fair

								(non-significant in expected direction).	
van Dijk-Wesselius et al. (2018), Netherlands	Experimental study (two-group pretest-posttest design)	About 700 (7-11 years)	The intervention was carried out by increasing the presence of natural components (e.g., grass, trees) and also the quality of schoolyards (e.g., aesthetics; facilities).	In-person observation	a. Prosocial orientation assessed by self-administrated Social Orientation Choice Card (SOCC) (*a binary variable)* b. Self-reported prosocial scale from SDQ (*a continuous variable)*	Child's sex, grade level	Multi-level analysis	Analysis was stratified by grade levels (4,5, and 6). Proportion of prosocial orientation in grades 4 and 5 in intervention compared to control group increased from baseline to the follow-up, but there was a significant decrease in grade 6. ***(significant in expected and unexpected directions)***. There was no significant increase of self-reported prosocial behaviour ***(non-significant in non-reported direction)***.	Fair
Whitten et al. (2018), Australia	Cross-sectional study	26,848 (mean age = 11.92 years)	Connectedness to nature	Questionnaire (self-report)	Self-reported prosocial scale from SDQ (*a continuous variable)*	Child's sex, social supports, empathy, attention, and neighbourhood socio-economic status	Linear regression	Increased connection to the nature was associated with higher prosocial behaviour: β= 0.12 (p<0.001) ***(significant in expected direction)***.	Fair

Sample size and age of participants differed by included study. Small sample sizes (<100) were reported in two experimental studies (Carrus et al., 2015; Dopko et al., 2019), whilst the largest sample size was observed in a cross-sectional study of 26,848 Australian children aged 11.9 years on average (Whitten et al., 2018). Two experimental studies recorded the number of person-observations as the unit of analysis instead of number of participants (Bates et al., 2018; Mayfield et al., 2017). Furthermore, age of participants differed across studies. One of the longitudinal studies collected the baseline data of exposure during pregnancy and then did the follow-up measurement of prosocial behaviour when children were aged 4 years old (McEachan et al., 2018). In cross-sectional studies, the age of participants ranged from 2 to 12 years-old (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; Odgers et al., 2012; Sobko et al., 2018; Whitten et al., 2018). Two experimental studies did not explicitly mention the age of participants (Bates et al., 2018; Mayfield et al., 2017). The youngest participants in experimental studies were aged 1.5 years, while 8th-grade students (aged 13-14 years depending on the country) were the oldest participant.

2.2.4.3 Green space measures

Green space measurements varied by study. Secondary data linked with objective measurements of area-level green space were used in seven observational studies mostly reported from European countries (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; McEachan et al., 2018; Odgers et al., 2012; Richardson et al., 2017; Van Aart et al., 2018). Green space quantity, such as residential nearby greenness, as well as the percentage of green space or other related characteristics (e.g., park space, semi-natural and forested, agricultural area) within specified distances from participants' homes were commonly used objective measurements of green space exposure. Only one study reported measuring school and combined home-school greenness in relation to prosocial behaviour (Amoly et al., 2014). In addition, residential proximity (e.g., distance to major or nearby green space) was assessed by two studies (Amoly et al., 2014; Balseviciene et al., 2014). Normalised Difference Vegetation Index (NDVI) was predominantly utilised (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; McEachan et al., 2018), followed by land cover map (Richardson et al., 2017; Van Aart et al., 2018) and Google Street View (Odgers et al., 2012).

Some studies (Amoly et al., 2014; Andrusaityte et al., 2019; McEachan et al., 2018; Richardson et al., 2017; Sobko et al., 2018; Whitten et al., 2018) also introduced subjective measures of green space and mostly relied on questionnaire-based parental-led approach. The indicator of children's time spent in green space was reported by three studies in Europe (Amoly et al., 2014; Andrusaityte et al., 2019; McEachan et al., 2018). Other studies from the UK also measured access to private gardens (Richardson et al., 2017) and satisfaction with green space (McEachan et al., 2018). Only two studies measured the contacts of green space as a perception of connectedness to nature, of which one measured connection to nature in general (Whitten et al., 2018) and the other (Sobko et al., 2018) employed multiple indicators (enjoyment of, empathy for, responsibility of, and awareness of nature).

For six experimental studies, exposure to green space was observed directly among participants. There were two main concepts of intervention model for green space exposure exhibited that included: 1) improving the appearance of frequently accessed green space by children and adolescents (e.g., schoolyards; playground markings) and 2) spending time in green space or participating in activities involving contacts with natural vegetation (e.g., horticultural programs). Improvements in the quality of schoolyards by increasing the presence of natural components and other facilities was evaluated in studies in the US (Bates et al., 2018) and the Netherlands (van Dijk-Wesselius et al., 2018), while another study in the US measured the change of prosocial behaviour due to improved playgrounds in schools (Mayfield et al., 2017). Moreover, studies in Italy (Carrus et al., 2015) and Canada (Dopko et al., 2019) compared differences in prosocial behaviour between children spending time outdoors in school green space compared to indoors within or outside a school setting. A study in South Korea observed change in prosocial behaviour after children participated in a horticultural program that facilitated contact with natural vegetation (Park et al., 2016).

2.2.4.4 Prosocial behaviour measures

Even though tools for assessing prosocial behaviour varied by study, the data were mostly documented based on parental report (7; 47%). However, measurements based on teacher-reports (1; 7%), combined parent- and teacher-report (1; 7%), and self-report (2; 13%) were also observed. In addition, prosocial behaviour was assessed through in-person observations in four experimental studies (27%). The Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997), which is a common tool for assessing prosocial behaviour, was employed in the majority of studies (9; 60%). This prosocial scale consists of five Likert-scale questions with a higher total score indicating more favourable prosocial behaviour. Only one study categorised a prosocial behaviour score into a binary variable using a validated cut-off point (normal with score >5; abnormal/borderline with score ≤5) (Andrusaityte et al., 2019). Meanwhile, experimental studies used different measures, such as the System for Observing Children's Activity and Relationship during Play (SOCARP) (Bates et al., 2018; Mayfield et al., 2017), a behavioural checklist (Crust et al., 2014), assigned tasks (Dopko et al., 2019), the Social Orientation Choice Card (SOCC) (van Dijk-Wesselius et al., 2018), and a questionnaire developed by previous researchers (Park et al., 2016). Three experimental studies used multiple measures of prosocial behaviour to disentangle which measure or component of prosocial behaviour is more relevant for green space exposure (Dopko et al., 2019; Park et al., 2016; van Dijk-Wesselius et al., 2018).

2.2.4.5 Association between green space and prosocial behaviour among children and adolescents

A total of 63 associations between green space and prosocial behaviour were observed from 15 articles, including all indicators of green space and prosocial behaviour analysed within individual studies, as well as multiple analyses disaggregated by effect modifiers (see Table 2.3). Exposure to green space was objectively (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; Bates et al., 2018; Carrus et al., 2015; Dopko et al., 2019; Mayfield et al., 2017; McEachan et al., 2018; Odgers et al., 2012; Park et al., 2016; Richardson et al., 2017; Van Aart et al., 2018; van Dijk-Wesselius et al., 2018) or subjectively (Amoly et al., 2014; Andrusaityte et al., 2019; McEachan et al., 2018; Richardson et al., 2017; Sobko et al., 2018; Whitten et al., 2018) measured. Overall, 44 (69.9%) out of 63 associations were in the expected direction. However, only 18 associations were reported to be statistically significant in the expected direction (Andrusaityte et al., 2019; Balseviciene et al., 2014; Bates et al., 2018; Carrus et al., 2015; Dopko et al., 2019; McEachan et al., 2018; Park et al., 2016; Richardson et al., 2017; Sobko et al., 2018; van Dijk-Wesselius et al., 2018; Whitten et al., 2018).

Two studies reported statistically significant associations between objective area-level measures of green space and prosocial behaviour after socio-demographic characteristics were counted as effect modifiers (Balseviciene et al., 2014; Richardson et al., 2017). A longitudinal study in the UK reported statistically significant confounder-adjusted associations between percentage of green space in a buffer of 500 m and prosocial behaviour among 2,909 children (Richardson et al., 2017). Analyses stratified by the child' sex (males vs. females= 51% vs. 49%) and household educational level (high vs. low = 38% vs. 62%) showed that positive associations were only found among samples of girls and participants in highly educated households (Richardson et al., 2017). By contrast, a cross-sectional study in Lithuania found that increased residential greenness within a distance of 300 m from home was associated with lower levels of prosocial behaviour among children from high-educated mothers (Balseviciene et al., 2014). This study also reported an expected direction association that lower distance to city parks increased prosocial behaviour among children from low-educated mothers.

In-person observations used to measure green space exposure in experimental studies tended to report statistically significant findings. Children and adolescents who had used the quality-improved schoolyards (Bates et al., 2018; van Dijk-Wesselius et al., 2018) or participated in activities involving contact with nature (Carrus et al., 2015; Dopko et al., 2019; Park et al., 2016) had higher prosocial behaviour. One study in the Netherlands suggested that grade levels as a proxy of children's age modified the effects of intervention (van Dijk-Wesselius et al., 2018). The effects of a schoolyard renovation on child prosocial orientation varied by grade level. Among younger students (grade 4 and 5), the proportion of prosocial orientation increased from baseline to the follow-up, but a negative association was observed among older students (grade 6).

Nine out of 15 associations between subjective measures of green space and prosocial behaviour were reported in positive direction, of which only four were statistically significant. One study reported that increased time spent in city parks by one hour per week was associated with decreased odds of borderline or abnormal prosocial behaviour after controlling for covariates (Andrusaityte et al., 2019). By contrast, studies that measured either spending time in green space as annual total hours during the last school period and holidays (Amoly et al., 2014), or time spent playing outside (minutes per week during summer and winter months) (McEachan et al., 2018) did not report statistically significant associations. Only one study from Bradford, UK assessed the green space quality by asking parents about their satisfaction with frequently visited green space (McEachan et al., 2018). Analysis was disaggregated by the child's ethnicity (white British vs. south Asian), which was defined by parental report of which ethnicity they belonged to. This study found a statistically significant positive association for south Asian children, but the direction of the non-significant association was not reported among white British children. In addition, analyses of the access to private green space stratified by child's sex (male vs. female) and household educational level (low vs. high) consistently found non-significant negative associations for all sub-group analyses (Richardson et al., 2017). Furthermore, studies in Australia (Whitten et al., 2018) and Hong Kong (Sobko et al., 2018) reported that increased feelings of connection to nature and responsibility for nature were statistically significant associated with greater prosocial behaviour, respectively.

Table 2.3. Summary of the associations extracted from 15 articles

Green space measurements	n[i]	Association				
		Significant		Non-significant		
		E[ii]	UE[iii]	E[ii]	UE[iii]	NR[iv]
Objective						
Residential surrounding greenness in buffers of:						
- 100 m	**4**			4		
- 250 m	**1**			1		
- 300 m	**4**		1	2	1	
- 500 m	**3**			3		
School greenness in a buffer of 100 m	**1**			1		
Home-school greenness in a buffer of 100 m	**1**			1		
Percentage of green or natural space in a buffer of:						
- 500 m	**4**	2		2		
- 0.5 mile (≈804.672 m)	**1**				1	
Percentage of park space in a buffer of 500 m	**4**			3	1	
Percentage of semi-natural and forested area in a buffer 2000 m	**1**				1	
Percentage of agricultural area in a buffer 300 m	**1**			1		
Residential proximity to green space	**3**	1		2		
Schoolyard renovation[v]	**7**	3	1			3
Spending time in school green space[v]	**5**	4			1	
Playground marking[v]	**4**			1	3	
Participation in horticultural program[v]	**4**	4				
Sub-total	**48**	14	2	21	8	3
Subjective						
Time spent in green space	**4**	1		2		1
Access to private garden	**4**				4	
Satisfaction with green space	**2**	1				1
Connectedness to nature	**1**	1				
- Enjoyment of nature	**1**			1		
- Empathy for nature	**1**			1		
- Awareness of nature	**1**			1		
- Responsibility of nature	**1**	1				
Sub-total	**15**	4	0	5	4	2
Total: n (%)	**63**	**18 (28.6)**	**2 (3.2)**	**26 (41.3)**	**12 (19.0)**	**5 (7.9)**

[i]number of the associations examined between green space and prosocial behaviour that count multiple indicators of green space or prosocial behaviour, as well as, multiple analyses (e.g., analysis stratified by effect modifiers); [ii]association in expected direction; [iii]association in unexpected direction; [iv]association in non-reported direction; [v]green space exposure assessed by in-person observation in experimental studies

2.2.5 Discussion

This review aimed to provide an overview of existing evidence assessing potential links between green space and prosocial behaviour among children and adolescents. The balance of evidence suggests that the development of prosocial behaviour may be associated with exposure to higher levels of nearby green space. However, the quality of this evidence is not yet sufficient to draw firm conclusions around causality or to offer specific guidance around well-defined interventions. Moreover, potential effect modifiers of the relationship between green space and prosocial behaviour were evident in some study contexts. Plausible mechanisms linking green space to prosocial behaviour have not been explored so far that need further investigation.

2.2.5.1 Inconsistent findings

Differences in methodological approaches, such as the measurement of green space, could have led to inconsistent findings. Measures of exposure to green space from included studies consisted of land cover-based metrics, distance to green space, and in-person observations, as well as subjective measurements of green space-related satisfaction, the amount of time spent outdoors, access to private gardens, and perceived connectedness to nature. There were 20 associations between green space quantity and prosocial behaviour in the expected direction, but only two associations were statistically significant. Meanwhile, five associations were reported in unexpected direction, of which one association was statistically significant. The small number of statistically significant associations in expected direction might be due to limitations in measurements. Specifically, NDVI as the common measure for area-level green space has some limitations, such as its inability to distinguish different types of green space (e.g., park, garden, etc.) and does not take into account the quality of green space including abandoned or unsafe areas (Villeneuve et al., 2018). Previous studies reported that parental concern on children's safety for playing outdoors might discourage green space use (Sefcik et al., 2019; Strife & Downey, 2009). Therefore, adequate quantity of neighbourhood green space available might not fully lead to its utilisation due to other characteristics are paid attention for children's use, such as green space quality.

Parental report on green space-related satisfaction measured in a study in Bradford, UK (McEachan et al., 2018) could be considered as a proxy of green space quality. While the higher parental satisfaction with green space was associated with greater prosocial behaviour among south Asian children, none of the green space quantity indicators was identified as a predictor of prosocial behaviour. Since children are reliant on their parents to chaperon them to green spaces, parental perceptions whether the aspects of green space quality (e.g., safety, physically attractive, etc.) meet their acceptable level might be a more reliable measurement for children's access to and use of green space. It can be an important factor for children's contact with green space than the amount of neighbourhood green space (Feng & Astell-Burt, 2017d). Three studies on child health in Australia confirmed that favourable green space quality – defined subjectively by asking parents to what extent they agreed that good parks, playgrounds, and play spaces were available in the neighbourhood – was associated with higher child wellbeing (Feng & Astell-Burt, 2017c, 2017d) and general health (Feng & Astell-Burt, 2017a) independently of the green space quantity. One of those studies also reported that green space quality was a stronger determinant of children's externalising behaviours (conduct and hyperactive problems), as measured by the SDQ, than green space quantity (Feng & Astell-Burt, 2017c). This might suggest that parental report on green space quality matters in evaluating the relationship between green space and child health-related outcomes.

Out of three studies from Spain, Lithuania, UK assessing children's time spent in green space, studies that expressed time as annual total hours during the last school period and holidays in Spain (Amoly et al., 2014) and total minutes per week in summer and winter months in the UK (McEachan et al., 2018) might be prone to recall bias, leading to non-significant associations with prosocial behaviour. Meanwhile, having access to a private garden was negatively associated with prosocial behaviour in Scotland, UK, which may be because private gardens might promote less social interaction compared to public green space (Richardson et al., 2017). In addition, the use of different measurements (Connectedness to Nature Index for Parents of Preschool Children vs. combined Connection to Nature Index and Connectedness to Nature Scale) and to whom perceived connection to nature (parental report vs. self-report) was asked might generate different findings between studies in Hong Kong (Sobko et al., 2018) and Australia (Whitten et al., 2018).

The statistically significant associations between green space and prosocial behaviour were more apparent in experimental studies, which might be due to assessments of green space exposure. The more consistent association in experimental studies could be possibly due to the use of in-person observation. While cross-sectional and longitudinal studies commonly used area-level of, proximity to green space, or other subjective measurements as proxies of green space exposure, in-person observation in experimental was potentially a more accurate assessment of use and direct contact with green space among children. Indeed, having direct contact with green space may enable children to gain necessary benefits for prosocial development.

2.2.5.2 Effect modifiers and mediators of the association

Findings from the studies in this review indicating that socio-demographic background moderates associations between green space and prosocial behaviour might suggest that green space inequalities exist in some settings. For example, ethnic background was found to moderate the association between green space-related satisfaction and prosocial behaviour among children in Bradford, UK (McEachan et al., 2018). Within the study context in Bradford, south Asian families were found with less green space quantity and they reported less time spent in green space by their children and lower green space-related satisfaction compared to those from white British communities. A study in Kaunas, Lithuania reported an association in the non-hypothesised direction among children whose mothers had high education (Balseviciene et al., 2014). High socio-economic families in Kaunas live in suburban areas (more expensive than residing in cities) with an adequate amount of residential greenness available, but it does not promote outdoor activities due to parental concern of children's safety. Inversely, in Scotland, UK, a positive association was observed among children from high-education households (Richardson et al., 2017). These families had more green space available in their neighbourhoods, where a lack of safety might be less of an issue. In addition, this study also found a statistically significant association between green space measured as total natural space and prosocial behaviour among girls only. The characteristics of natural spaces (e.g., amenity areas, playing fields) might be more important for mentally-stimulating play and prosocial development among girls (Richardson et al., 2017). Furthermore, a moderation effect of grade level (as proxy for children's age) may indicate short-term increase in prosocial behaviour among younger, but negative impact on older children (van Dijk-Wesselius et al., 2018). To conclude, depending on the study settings, moderating variables or effect modifiers may work in different ways.

The conceptual model described in Chapter 1 suggests different pathways linking green space to child prosocial behaviour. Unfortunately, none of the included studies analysed potential mediators to test plausible linking pathways. Current literature indicates that mediators may influence this association. A study conducted among adult samples by Zhang et al. (2014) confirmed that mental health and wellbeing aspects (e.g., positive emotions) mediated the association between green space exposure and prosocial behaviour. In addition, Chen et al. (2019) reported bidirectional relationships between subjective well-being and prosocial behaviour among elementary school-aged children, of which, wellbeing leads to greater prosocial behaviour. Given the well-established relationships between green space and child mental well-being (Feng & Astell-Burt, 2017c, 2017d; Flouri et al., 2014; McCormick, 2017; Vanaken & Danckaerts, 2018), it is plausible that mental health may mediate the association between green space and prosocial behaviour. Moreover, physical activity may also influence the green space-prosocial behaviour relationship. Recent growing literature suggest that exposure to local green space improved physical activity among children (Akpinar, 2017; Roemmich et al., 2006; Sanders et al., 2015). Physical activity performed with other children can encourage social interactions and promote prosocial behaviour. Studies among Peruvian (Pawlowski et al., 2016) and Dutch children (Moeijes et al., 2018) confirmed that participation in a sport group fostered prosocial behaviour. A systematic review among the general population also showed that outdoor sports, in particular, can help increase prosocial behaviour (Eigenschenk et al., 2019). Therefore, child mental health and physical activity may potentially explain the relationship between green space and prosocial behaviour that needs further investigation.

In general, this review summarises preliminary evidence on the positive association between green space exposure and prosocial behaviour with some reported potential effect modifiers. However, the current available evidence available is not sufficient to infer causal associations. The longitudinal studies had short periods of observation (2 to 4 years) and did not account for time-variant measures of green space and prosocial behaviour. This prevents the examination of possible variations in prosocial behaviour as a response to changes in green space exposure over time. According to the conceptual framework in Chapter 1, the accumulation of exposure to green space might elevate the benefits for prosocial behaviour development and greater impact may be observed during the late childhood as the sensitive period. Therefore, testing this hypothesis in longitudinal studies will provide new insights that will be beneficial for policy recommendations. In addition, mediation analyses are needed to test mechanistic pathways that may underlie the documented associations between green space and prosocial behaviour.

2.2.5.3 Strengths and limitations

To our knowledge, this is the first systematic review evaluating the relationship between green space and prosocial behaviour. The findings are presented and discussed by different measures of green space exposure with additional explanations on potential effect modifiers. The use of nine databases with keywords adopted from current published systematic reviews, no restriction on publication date, and screening of references of included studies allowed a comprehensive search. The process of developing and reporting this review following the PRISMA guidelines lends credibility to the findings.

There are some limitations of the evidence reviewed and review method. Firstly, there was only a limited number of longitudinal studies which preclude drawing causal inferences. The findings from experimental studies without control groups are also prone to low internal validity. Secondly, area-level measures of green space varied by study and resulted in mixed-findings, making it difficult to define absolute amount of green space needed in the neighbourhood for positive development of prosocial behaviour. Thirdly, all studies were from high-income countries. Thus, findings can be applicable to these countries, including high-income countries with hot climates and rapidly growing populations where the presence of green space is substantial for mitigating harmful environmental stressors (e.g., heat) and bridging people to the community (e.g., social interactions). However, findings may not be widely applicable to middle- and low-income countries. A limitation of the review method is that some articles that were not published in English may not have been retrieved.

2.2.5.4 Future research directions

This review provides preliminary evidence of positive associations between green space exposure and prosocial behaviour. However, experimental studies are just as limited as observational studies, the exposure to green space can be randomly assigned, but individual compliance in reality is agentic. Therefore, it might lead to the question of what aspects or characteristics of green space might further influence the use of green space. It is conceivable that individuals might not use green space if it is not well-maintained, physically attractive, or generally of poor quality. Therefore, the quality of green space might be an important aspect that should be considered in understanding the potential benefits of green space on human health.

Green space quality has been associated with health outcomes independently of the green space quantity (van Dillen et al., 2012). In addition, green space quality was identified to be more strongly associated with mental health outcomes than green space quantity (de Vries et al., 2013; Feng & Astell-Burt, 2018; Francis et al., 2012). Comparing between objective and subjective measurements of quality, expert-determined quality of green space involving audit tools or checklist, physical observation, GIS analyses often do not take into account the appraisal of laypeople (e.g., residents) of their environment. Laypeople are more likely to know about their environment and more qualified to assess the green space quality (Hur et al., 2010). Since they have day-to-day experiences and live in the neighbourhood, their perceptions of nearby green space are likely to be consequential for successful policymaking. The importance of subjective quality compared to objective quality of green space was noted by a study in the Netherlands (Zhang et al., 2017). This study found that subjective quality mediated the association between objective quality of green space and neighbourhood satisfaction. It strongly indicates that the perceived quality of green space was a proximate determinant for neighbourhood satisfaction and might apply to other outcomes, such as prosocial behaviour. Green space quality might be an important determinant for further study in relation to prosocial behaviour since low evidence was found on green space quantity and green space quality is less studied in relation to prosocial behaviour.

New studies with greater methodological rigor (e.g., longitudinal studies that examine time-variant measures of green space quality and prosocial behaviour for change-on-change analyses) are required to edge closer to causal inferences and evidence-based policy recommendations. Based on a conceptual model described in Chapter 1, using a longitudinal approach may also help to understand to what extent the accumulation of green space exposure affects the levels of prosocial behaviour in different stages of development, particularly during critical and sensitive periods of the green space-prosocial behaviour association. Assessment of potential mediators could help to test plausible pathways linking green space to prosocial behaviour. Moreover, measuring green space exposure as perceived quality is needed due to a sensitive measurement in relation to child health and behaviour outcomes. Lastly, given reported effect modifiers from previous studies, analysis of green space and prosocial behaviour should be tested across strata of other variables (e.g., socio-economic status).

2.2.6 Summary

Overall, the current evidence shows that exposure to higher levels of green space may be associated with greater prosocial behaviour. Different measurements of green space exposure led to mixed findings. Area-level green space measures were less consistent in demonstrating statistically significant associations between green space and prosocial behaviour, whereas associations were more consistent when green space was measured using in-person observation. The number of studies was too few to draw conclusions on subjective green space measurements. Further investigation on the association between green space and prosocial behaviour is warranted, especially with studies employing longitudinal designs to confirm temporality and sensitive period, as well as, capable of testing potential effect modifiers, mediators, and measures of green space quality.

Chapter 3: Research methodology

3.1 Preface

Findings from the systematic review in Chapter 2 identify the needs to undertake further studies to examine the longitudinal association between green space quality and prosocial behaviour, examining potential effect modifiers, and testing possible linking pathways. Chapter 3 provides information about the methodological aspect of conducting empirical studies to answer research questions 2 to 4 in addressing the aforementioned research gaps. This thesis used cohort data retrieved from the nationally representative Longitudinal Study of Australian Children (LSAC). This chapter covers information about LSAC, variables used in this research, statistical analysis, and ethical considerations.

3.2 Study design, data, and sample

3.2.1 Overview of LSAC

This PhD research used data from *Growing Up in Australia,* the Longitudinal Study of Australian Children (LSAC). LSAC is a nationally representative population-based longitudinal study which documents developmental, health, and wellbeing outcomes of children in Australia from infancy to adolescence. This project was initiated and funded by the Australian Government Department of Family and Community Services (FaCS) as part of the Government's *Stronger Families and Communities Strategy* (Australian Institute of Family Studies, 2004). LSAC's study content and methodology is managed by the Australian Institute of Family Studies (AIFS) in collaboration with the Department of Social Services (DSS) as a funding curator and the Australian Bureau of Statistics

(ABS) which is in charge of data collection and processing, with advice and consultation provided by LSAC Consortium Advisory Group (CAG).

LSAC aims to assess the impact of Australian's unique environment that includes economic, social, and cultural aspects on children by gathering comprehensive information that helps create a greater understanding of the determinants of children's development and wellbeing. This longitudinal study collects information on children, family, and neighbourhood characteristics that serve as either protective or risk factors for children's health and wellbeing. There are several key points being addressed in this study. These include assessing developmental outcomes among Australian children, examining a range of behaviours related to developmental outcomes, investigating aspects of children's environment (e.g., families, schools/institutions, and communities) that may have important impacts on child outcomes, and identifying the government's role in supporting children to achieve better developmental outcomes (Australian Institute of Family Studies, 2002, 2004).

3.2.2 Study design of LSAC

After being piloted in 2002-2003, the recruitment for the main study was conducted in March-November 2004 (Wave 1). More than 10,000 children and their families participated. LSAC comprises two cohorts (cross-sequential designs): the "baby" (B) cohort of children aged 0-1 year in 2004 (born in March 2003-February 2004) and the "kindergarten" (K) cohort of children aged 4-5 years (born in March 1999-February 2000) (Edwards, 2012).

Potential participants for LSAC were extracted from Medicare (formerly the Health Insurance Commission) enrolment database. Medicare is the national provider of universal healthcare and has the most comprehensive and up-to-date database of permanent residents and citizens. Children were recruited using a two-stage clustered design, involving the selection of postcodes and then children. As the first step, the probability proportional to size approach was applied to select representative postcodes. This also took into account the stratification by state, capital city versus rest of state area (non-capital cities), and urban-rural status to warrant geographically proportional samples. This step was then followed by the recruitment of children from the selected 311 postcodes, with about 20 and 40 children selected per postcode in the smaller states and the larger states, respectively (Australian Institute of Family Studies, 2005).

Cohort	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Wave 7
Year	2004	2006	2008	2010	2012	2014	2016
B cohort	0-1 years	2-3 years	4-5 years	6-7 years	8-9 years	10-11 years	12-13 years
K cohort	4-5 years	6-7 years	8-9 years	10-11 years	12-13 years	14-15 years	16-17 years

Figure 3.1 Two cohorts of LSAC (Australian Institute of Family Studies, 2018)

For the first recruitment in 2004 (Wave 1), a total of 8,921 and 9,893 parents or caregivers from sampled postcodes were invited to participate in respective cohorts (B and K cohort, respectively), 57.2% for the B cohort and 50.4% for the K cohort agreed to participate from those approached, whilst opt-out was the largest source of sample loss, accounting for 32.6% and 37.5% for the B and K cohort, respectively. The remaining families were unable to be contacted. The follow-up interviews were conducted biennially and questionnaires were mailed out between waves. Data were mostly supplied by parents or caregivers via face-to-face interview, with some sections of data collection utilising children and teachers self-report. Meanwhile, other data collection methods used included time-use diaries, audio computer self-assisted interview, left-behind survey, interviewer observations, and physical measurements (e.g., height, weight, girt, body fat, head circumference, and blood pressure) (Australian Institute of Family Studies, 2005, 2018).

Currently, LSAC has reached its eighth wave in 2018. A declining response rate has been observed in LSAC from 90% in Wave 2 to 60-62% in Wave 8.

3.2.3 Study samples

For this thesis, datasets from the K cohort Waves 1 (children aged 4-5 years) to 6 (14-15 years) were used because data on green space quality were not documented in Wave 7 (16-17 years) (Department of Social Services et al., 2020). Meanwhile, B-cohort data were not used due to a shorter period of observation with data for both green space quality and prosocial behaviour available (Waves 3 to 7). The number of children from the K cohort that were successfully documented in Wave 1 and then biennially followed up (Wave 2 onwards) is presented in Table 3.1. For the empirical studies presented in Chapters 4 to 6, missing data on the outcome (prosocial behaviour) were removed, whilst children's records with missing values for the independent variables or exposures were not omitted to avoid further sample loss.

Table 3.1 Number of children documented by wave

Waves	Female	Male	Total	%*
Wave 1 (4-5 years)	2,447	2,536	4,983	100%
Wave 2 (6-7 years)	2,188	2,276	4,464	90%
Wave 3 (8-9 years)	2,120	2,211	4,331	87%
Wave 4 (10-11 years)	2,037	2,132	4,169	84%
Wave 5 (12-13 years)	1,936	2,020	3,956	79%
Wave 6 (14-15 years)	1,739	1,798	3,537	71%

**Response rates for each wave were calculated using Wave 1 as the baseline.*

3.3 Variables

3.3.1 Main exposure

The main exposure or independent variable in this research is neighbourhood green space quality. This was assessed using parental or caregiver perceptions of the availability of good quality green space in their neighbourhood. Caregivers were asked to rate on a Likert-scale, the extent to which they agreed with the statement: "*There are good parks, playgrounds and play spaces in this neighbourhood*". Responses were recorded as "*strongly agree*", "*agree*", *disagree*", and "*strongly disagree*". Caregivers provided their assessments on green space quality in all waves of data (Waves 1 to 6). This statement has been widely used in the Australian context to assess green space quality in relation to health-related outcomes among children (Feng & Astell-Burt, 2017a, 2017c, 2017d) and mothers (Feng & Astell-Burt, 2018, 2019).

The "neighbourhood" in the wording of the item is subjectively defined by caregivers (Department of Social Services et al., 2020). However, in this thesis, the term "neighbourhood" refers to the statistical area, level 2 (SA2), which is the smallest geographical area variable available in LSAC. SA2s were determined by the ABS to be representative of communities with 10,000 residents, on average (range from 3,000 to 25,000 residents). This statistical area was used to classify and represent some suburbs within cities; and areas outside of cities where communities can interact socially and economically, denoted by the presence of transport and commercial hubs (Australian Bureau of Statistics, 2011). Some previous studies on green space and health outcomes in Australia also used SA2 to define neighbourhood (Feng & Astell-Burt, 2017a, 2017d; Sanders et al., 2015).

Given the small percentages for responses recorded as "*strongly disagree*" and "*disagree*", both were combined to form a new category, "do not agree". Meanwhile, other two categories, "*agree*" and "*strongly agree*" were kept separate due to adequate percentages for each. This also helped to disentangle the associations for green space quality reported as moderately good ("*agree*") and very good (*"strongly agree*") that had occurred out in a previous study (Feng & Astell-Burt, 2018). These three categories of responses to green space quality were used to assess the associations between green space quality and child prosocial behaviour presented in Chapters 4 and 5 in this thesis. Meanwhile, for mediation analysis presented in Chapters 6 and 7, categories of caregiver-reported green space quality were recoded as "do not agree" (for "*strongly disagree*" and "*disagree*") and "agree" (for "*agree*" and "*strongly agree*") due to the shortcomings of mediation analysis which only allows for binary or continuous exposure (see Sub-chapter 3.4 Statistical analysis).

3.3.2 Outcomes and potential mediating variables

3.3.2.1 Prosocial behaviour

Child prosocial behaviour in this study was evaluated based on caregiver reports using the prosocial domain of Goodman (1997)'s Strengths and Difficulties Questionnaire (SDQ) which has been used in a number of studies on green space and child prosocial behaviour (Putra et al., 2020). The SDQ – a multi-dimensional behavioural screening tool for child wellbeing – has been widely considered as a validated measure and internationally used in multicultural settings (Croft et al., 2015; Goodman & Goodman, 2009; Hall et al., 2019; Richardson et al., 2017; Theunissen et al., 2015; Williamson et al., 2010). The 25-item SDQ consists of five subscales, namely emotional symptoms, conduct problems, hyperactivity-inattention, peer problems, and prosocial behaviour. Each subscale has five items and the response to each item is scored 0, 1, or 2 (a score of 2 is the most negative for other domains, but the most positive for the prosocial behaviour domain) (Richardson et al., 2017).

The total score for prosocial behaviour ranges from 0 to 10 with a higher score indicating better prosocial behaviour. In addition, the total score of prosocial behaviour can also be classified into three categories: normal (6-10), borderline (5), and abnormal (0-4). For the empirical studies in this thesis, prosocial behaviour was treated as a continuous variable and expressed as a total score, similar to the majority of previous studies in the area (Putra et al., 2020). The items employed to assess prosocial behaviour from the SDQ are presented in Table 3.2 (Goodman, 1997). In this thesis, prosocial behaviour was investigated as the main outcome in empirical studies presented in Chapters 4, 5, and 6, and tested as a candidate mediator in Chapter 7.

Table 3.2 Prosocial behaviour questions from the SDQ

Items	Responses and Scores		
	Not True (0)	**Somewhat True** (1)	**Certainly True** (2)
"Considerate of other people's feelings"			
"Shares readily with other children"			
"Helpful if someone is hurt, upset or feeling ill"			
"Kind to younger children"			
"Often volunteers to help others (parents, teachers, other children)"			

3.3.2.2 Physical activity

Child physical activity was assessed using four indicators, namely total daily minutes of physical activity on weekdays and weekend days, children's choice for free time to engage in physical activity or other activities during their free time, and physical activity enjoyment. Time-use diaries (TUDs) were considered as a direct method of measuring physical activity. Children's activity data from TUDs were extracted to generate variables of weekday and weekend physical activity. The TUDs for first three-wave (Waves 1, 2, and 3) were completed by primary caregivers who documented their children's activities in over separate randomly allocated 24-hour periods for one weekday and one weekend day. A full 24-hour period was partitioned into 96 15-minute periods and caregivers were asked to complete the diaries by picking any of 26 pre-coded activities and could select up to six simultaneous activities in the same period (e.g., eating during screen-time) (Australian Institute of Family Studies, 2007).

For the remaining waves (Waves 4, 5, and 6), from 10-11 years of age onwards, pre-coded activities completed by caregivers were not applied, but TUDs were administrated to children by allowing them to record the start and end times, and the order of their activities over a single randomly selected weekday or weekend day. Interviewers coded and inputted the list of activities filled out by children during the interview one day after the diary completion. Interviewers were also able to ask for contextual information regarding with whom the child was and where the child was throughout the recorded-activity day. The coding process of children's activities was guided by a coding framework, and hence, recorded activities among children are comparable (Australian Institute of Family Studies, 2014).

From TUDs, the total amount of time (in minutes) for activities representing physical activity were calculated, following the procedure used in a previous study (Sanders, 2016). A list of activities from TUDs categorised as physical activity for each wave is presented in Table 3.3. For the first three waves, the number of 15-minute intervals that represented physical activity was multiplied by 15 to calculate daily minutes in physical activity. For the last three waves, the durations of activities identified as physical activity was added together. For the analysis, results on weekend and weekday physical activity were not combined since previous findings found discrepancies in the association between features of public open spaces, including green space, and weekend and weekday physical activity (Sanders et al., 2015; Timperio et al., 2008).

Table 3.3 Physical activity from TUD items

Waves	Physical activity
1	"Other play, other activities"; "other exercise- swim/dance/run about"; "walk for travel or for fun"; "ride bicycle, trike, etc (travel or fun)".
2-3	"Active free play"; "organised sport/physical activity"; "walk for travel or for fun"; "ride bicycle, trike, etc (travel or fun)".
4	"Active activities"; "ball games, riding a bike, scooter, skateboard, skipping, running, games and other free activities"; "travel by bike, scooter, skateboard, etc"; "travel by foot"; "organised individual sport"; "organised team sports and training"; "taking pet for a walk".
5	"Active activities not elsewhere classified"; "active club activities"; "travel by bike, scooter, skateboard, etc"; "travel by foot"; "organised individual sport"; "organised team sports and training"; "unstructured active play"; "walking pets/playing with pets".
6	"Active activities not elsewhere classified"; "active club activities"; "travel by bike, scooter, skateboard, etc"; "travel by foot"; "organised team sports and training, organised individual sport and training, or unstructured active play: archery/shooting sports; athletics/gymnastics; fitness/gym/exercise; ball sports; martial arts/dancing; motor sports/roller sports/cycling; others"; "walking pets/playing with pets".

There were two other indicators that indirectly measured aspects of physical activity by asking caregivers about their children's physical activity-related behaviours. To determine children's choice for free time, caregivers were asked: "*What does [child] usually do when she/he has a choice about how to spend free time?*". The response option "*usually chooses active pastimes*" was reassigned as "active" and "*usually chooses inactive pastimes*" or "*just as likely to choose active as inactive pastimes*" were reassigned as "inactive or impartial". Meanwhile, another indicator, physical activity enjoyment, was based on caregiver perceptions of the extent to which their children enjoyed doing physical activity, based on answers to the question: "*How much does [child] enjoy physical activity or exercise?*". A 5-point Likert-scale was adopted with scores ranging from 1 for "*very much dislikes activity*" =1 to 5 for "*very much likes activity*". Scores of 4-5 were grouped as "enjoy" and scores of 1-3 were grouped as "impartial or does not enjoy". These indirect measures of physical activity were adopted from a previous study (Sallis et al., 2002). The present research followed the procedures of a previous study (Sanders et al., 2015) to re-categorise the choice for free time and physical activity enjoyment variables. All physical activity variables were tested as candidate mediators in Chapter 6 and examined as child outcomes in Chapter 7.

3.3.2.2 Social interaction

This program of research used available LSAC data to measure child social interaction. Caregiver responses to the following question – *"How often does the study child see or spend time with the following people? Your neighbours"* – at all time points were used as a proxy measure for child social interaction with friends. Responses were recorded as "*no contact*", "*rarely*", "*a few times a year*", "*at least every month*", "*at least every week*", and "*every day*". This question was initially used in LSAC as a measure of social contact under the topic of social capital (Australian Institute of Family Studies, 2020). The responses were then dichotomised as "no contact and rarely" (for "*do not have"*, "*no contact"*, "*rarely*", and "*a few times a year*"); and "sometimes and often" (for "*at least every month*", "*at least every week*", "*every day*"). In this research, child social interaction was tested as a candidate mediator of the association between green space quality and child prosocial behaviour (presented in Chapter 6).

3.2.3.4 Mental health

Child mental health was evaluated using the caregiver reported TDS from the SDQ (Goodman, 1997) which has been validated as a measure of child mental health (Goodman & Goodman, 2009). TDS is calculated by totalling scores on four SDQ subscales comprising emotional symptoms, conduct problems, hyperactivity-inattention, and peer problems. Each subscale has a total score ranging from 0 to 10 with the more negative or worse outcomes indicated by a higher score. Therefore, TDS ranges from 0 to 40 with higher scores indicating increasing difficulties.

Another two secondary mental health indicators were generated by dividing TDS into two different outcomes, namely the internalising subscale (combining emotional and peer symptoms) and externalising subscale (combining conduct and hyperactive problems). Both secondary indicators indicate whether children are prone to internalise negative emotional states (e.g., anxiety, worry, nervousness) or externalise them (e.g., impulsiveness, aggressiveness). The present study followed the procedures of previous studies (Feng & Astell-Burt, 2017d; Richardson et al., 2017) to calculate TDS, internalising and externalising subscales using the items presented in Table 3.4 that were measured in each wave of LSAC. The mediating effects of mental health variables on the associations between green space and prosocial behaviour were investigated in Chapter 6, whereas these were treated as child health outcomes in Chapter 7.

Table 3.4 TDS questions from the SDQ

Items	Responses and Scores		
	Not True (0)	**Somewhat True** (1)	**Certainly True** (2)
Hyperactive problem			
"Restless, overactive, cannot stay still for long"			
"Constantly fidgeting or squirming"			
"Easily distracted, concentration wanders"			
"Thinks things out before acting" *			
"Sees tasks through to the end, good attention span" *			
Emotional problem			
"Often complains of headaches, stomach aches or sickness"			

"Many worries, often seems worried"	
"Often unhappy, downhearted or tearful"	
"Nervous or clingy in new situations, easily loses confidence"	
"Has many fears, is easily scared"	
Peer problem	
"Rather solitary, tends to play alone"	
*"Has at least one good friend" **	
*"Generally liked by other children" **	
"Picked on or bullied by other children"	
"Gets on better with adults than with other children"	
Conduct problem	
"Often has temper tantrums or hot tempers"	
*"Generally obedient, usually does what adults request" **	
"Often fights with other children or bullies them"	
"Often lies or cheats"	
"Steals from home, school or elsewhere"	

Note: *Score for these items were reverse-coded: 2 for "not true", 1 for "somewhat true", and 0 for "certainly true".

3.3.3.5 Health-related quality of life

Caregivers reported children's health-related quality of life (HRQOL) using the Paediatric Quality of Life Inventory (PedsQL) 4.0 that has shown good validity and reliability (Varni et al., 2006; Varni et al., 2003). A total of 23 items from the PedsQL were used to measure four domains of HRQOL. The items comprised 8 for physical functioning and 5 for each of social, emotional, and school functioning (Table 3.5). Caregivers rated items on a 5-point Likert-scale from "*never*" =0 to "*almost always*" =4. Responses for each item were then assigned with weights (0=100, 1=75, 2=50, 3=25, 4=0). Average scores for each dimension were calculated by dividing the total score by the number of items. A higher average score (ranging from 0 to 100) indicates better

HRQOL. The psychosocial health score was generated by combining the total score from three dimensions of HRQOL (emotional, school, and social functioning) and then dividing by the number of items. In addition, the mean total quality of life (QOL) score was calculated in the same way, taking into account four main dimensions of HRQOL (physical, emotional, social, school functioning). The procedures to calculate scores for all HRQOL variables were informed by past studies (Vella et al., 2018; Wong et al., 2017). Similar to mental health variables, HRQOL variables were examined as candidate mediators in Chapter 6 and child health outcomes in Chapter 7.

Table 3.5 HRQOL questions from the PedsQL

Items	**Responses and Scores** ***(0=never; 1=almost never; 2=sometimes; 3=often; 4=almost always)***				
	0	**1**	**2**	**3**	**4**
Physical functioning (*problems with…)*					
"Walking more than one block"					
"Running"					
"Participating in sports activity or exercise"					
"Lifting something heavy"					
"Taking a bath or shower by him or herself"					
"Doing chores around the house"					
"Having hurts or aches"					
"Low energy level"					
Emotional functioning (*problems with…)*					
"Feeling afraid or scared"					
"Feeling sad or blue"					
"Feeling angry",					
"Trouble sleeping"					
"Worry about what will happen to him/her"					
Social functioning (*problems with…)*					
"Getting along with other children"					
"Other kids not wanting to be his or her friend"					
"Getting teased by other children"					

"Not being able to do things that other children his/her age can do"
"Keeping up when playing with other children"
School functioning (*problems with…*)
"Paying attention in class"
"Forgetting things"
"Keeping up with schoolwork"
"Missing school because of not feeling well"
"Missing school to go to the doctor or hospital"

3.3.3.5 Caregiver mental health

Caregiver mental health was examined as a candidate mediator of the association between green space quality and child prosocial behaviour (presented in Chapter 6). Findings from past work suggest the potential role of green space in shaping mental health among mothers (Feng & Astell-Burt, 2018; McEachan et al., 2016) and in the adult population in general (Houlden et al., 2018; van den Berg et al., 2015). In addition, a causal pathway from caregiver mental health to child behaviour, including prosocial behaviour, was also reported (Fletcher et al., 2011; Hay & Pawlby, 2003; Kim-Cohen et al., 2005; van der Waerden et al., 2015). Therefore, the synthesis of these current findings suggests that caregiver mental health may be a potential mediator of the association between green space quality and child prosocial behaviour.

In LSAC, mental health among caregivers were assessed using the Kessler 6 Psychological Distress Scale (K6). This measures non-specific psychological distress (Kessler et al., 2002) and has been validated to screen people who are at risk of serious mental health problems (Furukawa et al., 2003). Caregivers were asked to respond to 6 questions regarding the frequency of feeling nervous, hopeless, etc. in the last four weeks (1= "*none of the time*" to 5= "*all of the time*"). The scores were totalled (ranging from 6 to 30) with a higher score indicating an increased risk of mental illness, following the procedure from a previous study (Feng & Astell-Burt, 2018). K6 questions are presented in Table 3.6.

Table 3.6 K6 questions

Items	**Responses and Scores** ***(1=none of the time; 2=a little of the time; 3=some of the time; 4=most of the time; 5=all of the time)***				
	1	**2**	**3**	**4**	**5**
"In the past 4 weeks about how often…"					
"Did you feel nervous?"					
"Did you feel hopeless?"					
"Did you feel restless or fidgety?"					
"Did you feel that everything was an effort?"					
"Did you feel so sad that nothing could you cheer you up?"					
"Did you feel worthless?"					

3.3.3 Other independent variables

There were several independent variables included in this research that were investigated as confounding variables and/or effect modifiers (Table 3.7). Confounding variables are those that commonly compete with the main exposure or the exposure of interest in generating the outcome. The presence of confounders might lead to biased estimates when establishing the relationship or causality between two variables unless appropriate statistical methods are applied to adjust for the effect of confounders (McNamee, 2003; Skelly et al., 2012). Confounding variables for this research were selected following an examination of previous studies on green space and child health in the Australian context (Feng & Astell-Burt, 2017a, 2017c, 2017d). Meanwhile, effect modifiers are variables for which the effects of exposure on the outcome vary, strengthen, or weaken at different values of effect modifiers (VanderWeele & Robins, 2007). These variables are important when researchers want to investigate whether the association between the exposure and the outcome is the same across different sub-groups of the population (Mackinnon, 2011). Potential effect modifiers of the association between green space quality and prosocial behaviour were informed by findings from the systematic review presented in Chapter 2. Other independent variables included in this research were classified as individual/child, family, or neighbourhood characteristics. Brief descriptions for each variable are supplied in the following table. These variables were measured in all waves of data.

Table 3.7 Brief description for other independent variables

Variables	Description and/or justification
Individual characteristics	
Child's age	Child's age was measured according to waves, expressed as a categorical variable with values grouped in every 2-year of age (e.g., 4-5 years; 6-7 years; 8-9 years; 10-11 years; 12-13 years; 14-15 years). Current literature suggests that prosocial behaviour might increase as children get older and then decline in early adolescence (Eisenberg et al., 2015).
Child's sex	Child's sex (female; male) was included in the analysis due to previous study findings suggesting that prosocial behaviour differs between boys and girl (Abdi, 2010; Kok et al., 2018).
Child speaks a language other than English at home	Language spoken by children at home (yes; no) represents ethnicity. Previous findings showed that ethnic background was associated with prosocial behaviour (Smith et al., 2019; Zimmerman & Levy, 2000). In addition, in the Australian context, gaps in resources accessibility and health outcomes have been identified in different ethnicities (Marmot, 2011; Ou et al., 2010). This could reflect differences in green space exposure among ethnicities. A previous study found that ethnicity was an

	effect modifier of the green space quality – prosocial behaviour association among children (McEachan et al., 2018).
Child Indigenous status	Similar to the above, Indigenous status – defined as whether the child is Aboriginal or Torres Strait Islander (yes; no) – also represents ethnicity. Findings from a previous study suggest that Indigenous status is associated with prosocial behaviour (Dray et al., 2016).
Family characteristics	
Caregiver education	The highest education obtained by any of caregivers in the family (≤ high school; >high school) represents family socioeconomic status. Caregiver educational level has been identified as a determinant for child prosocial behaviour (Karmakar & Ghosh, 2012; Silke et al., 2018). Moreover, caregiver education was found to be an effect modifier of the green space-prosocial behaviour association (Balseviciene et al., 2014).
Family weekly income	Poverty has been linked with unfavourable prosocial behaviour (Bandy & Ottoni-Wilhelm, 2012; Karmakar & Ghosh, 2012). Family weekly income in this present study combined both caregivers' income (in thousand AUD) (Blakemore et al., 2006; Sanders et al., 2015).
Family structure	Family structure was categorised as a one-caregiver or two-caregiver family. A previous study reported the association between family structure and prosocial behaviour (Padilla-Walker et al., 2015).
Number of siblings	The number of siblings included biological and non-biological (e.g., adopted, step-) sibling in the household. Previous studies suggest that the presence of siblings or sibling interactions influenced prosocial behaviour (Finch et al., 2018; Hughes et al., 2018).
Neighbourhood characteristics	
Neighbourhood safety	Caregiver perceptions of neighbourhood safety may play an important role on the use of green space among children (Lovasi

	et al., 2013; Sefcik et al., 2019; Strife & Downey, 2009). In this research, caregivers were asked to rate to the extent to which they agreed with the following statement: "*This is a safe neighbourhood.*". Responses were classified as "do not agree", "agree", and "strongly agree".
Socio Economic Index for Areas (SEIFA)	The Index of Relative Socioeconomic Disadvantage from SEIFA was constructed using principal component analysis involving some socioeconomic parameters, such as employment, education, income, and housing (Australian Bureau of Statistics, 2006). A lower score on this index indicates an area of higher deprivation or disadvantage. This was then grouped into tertiles for this research: "high", "moderate", and "low" disadvantaged areas. The inclusion of this neighbourhood characteristic was due to findings from prior work suggesting that the presence of green space quantity and quality was found to vary by area-level socioeconomic status within the Australian context (Astell-Burt et al., 2014; Feng & Astell-Burt, 2017d).
Accessibility-Remoteness Index of Australia (ARIA)	ARIA classifies neighbourhoods based on the accessibility to some service centres in road distances (Department of Health and Aged Care, 2001). Neighbourhoods were categorised as "highly accessible", "moderately accessible", "accessible", and "remote to very remote" areas.

3.4 Statistical analysis

Data management and analyses were primarily performed using STATA 14.2. In addition, another software package, such as the MLwiN V3.01 (Rasbash et al., 2017) was employed to handle some shortcomings of STATA. Two main statistical analyses were used in this research, as follows.

3.4.1 Multilevel regression analysis

Multilevel regression analysis was used to identify the association between green space quality and child prosocial behaviour (addressing research question 2). This statistical technique uses the hierarchical linear model, allowing the analysis of data that are collected at multiple levels or following a structured hierarchy, and it takes into account the interaction between group-level and individual-level attributes. It is a suitable analysis to consider independent variables at any level, including different social contexts at diverse higher levels and individual characteristics that are clustered within one or more higher levels where the dependent variable lies at the lowest or individual level unit (Diez-Roux, 2000; Tom et al., 1999).

While common regression techniques are unable to deal with hierarchically contextual factors, a model constructed from this approach helps disentangle the effects of explanatory variables operating at different group levels (Subramanian et al., 2003). This approach helps to address clustering effects since individuals living in the same area are more likely to possess similar exposure and access to resources, thus their health status might be similar to each other. Importantly, this statistical analysis helps to avoid ecological and atomistic fallacy. Ecological fallacy (or ecological inference fallacy) refers to drawing the conclusion or inference at the lower level unit (e.g., individual level) using the group-level attributes, while atomistic fallacy is the opposite situation (Diez Roux, 2002).

The main advantage of using multilevel regression to predict a dependent variable based on independent variables at different levels (two levels or more) is to help correctly estimate standard errors and avoid the risk of Type 1 error (Reise & Duan, 1999). This method also allows for unbalanced data which means that the number of observations in one cluster or class of data need not be the same as in other clusters of classes of data. Moreover, multilevel models also permit missing data. Individuals can be retained in the analysis when they drop out or are lost to follow-up at later periods of observations. Furthermore, this statistical method also allows for time-varying covariates (Bingenheimer & Raudenbush, 2004; Kwok et al., 2008).

Multilevel regression analysis is suitable for LSAC data that are characterised by hierarchically structured longitudinal data accumulated by repeated measures where events or observations are nested within individuals, considering an assumption of correlated or dependent observations (Goldstein, 2011; Hair Jr. & Fávero, 2019; Van Der Leeden, 1998). In the analysis of the longitudinal association between green space quality and prosocial behaviour, the outcome (prosocial behaviour) observed in each wave was predicted by caregiver-reported green space quality documented at the same level (observation level), sociodemographic data at the individual level (e.g., child's sex, ethnicity), and area socioeconomic status at the neighbourhood level (e.g., SEIFA, ARIA). Therefore, three-level multilevel models were fitted that included observations (level 1), individuals or children (level 2), and neighbourhoods or SA2s (level 3) (Figure 3.2). Children's records or observations documented in each wave that were clustered within individuals create a longitudinal data structure; and individuals that were nested within SA2s addressed clustering of, or correlations between individuals living in the same neighbourhood. It is also conceivable that individuals might be clustered within multiple SA2s due to residential movement that happened during the follow-up period. Therefore, a cross-classified data structure was also considered using the Markov chain Monte Carlo (MCMC) method (Browne et al., 2001). Multilevel regression analyses presented in Chapters 4 and 5 were conducted using the MLwiN V3.01 (Rasbash et al., 2017).

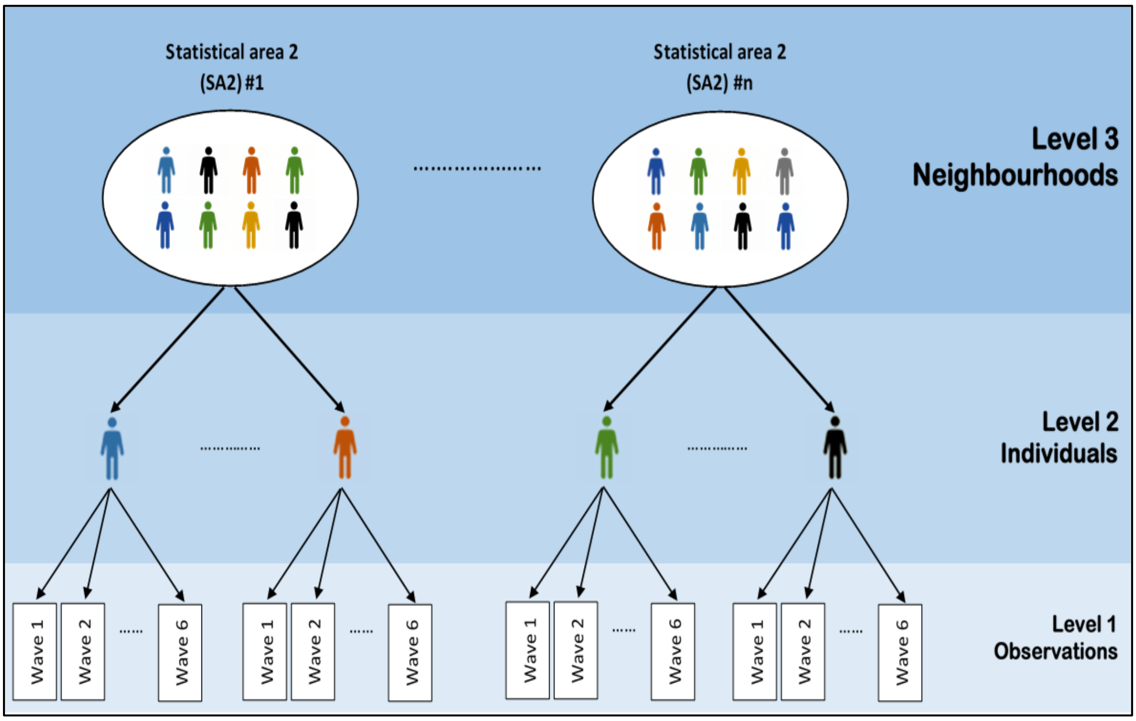

Figure 3.2 Multilevel models using LSAC data

3.4.2 Causal mediation analysis

Mediation analysis was applied to explore the presence of an intervening variable or a mediator which lies in the causal chain between an independent and a dependent variable (for addressing research questions 3 and 4 in Chapters 6 and 7, respectively). Mediation analysis examines whether the effect of the independent variable on the dependent variable occurs via a mediator (Lapointe-Shaw et al., 2018; Lee et al., 2019). The total effect can be divided into direct and indirect effects. An indirect effect indicates that the exposure works through a mediator of interest in influencing the outcome. Meanwhile, a direct effect posits that the exposure works directly to influence the outcome or through other mechanisms that do not involve the mediator (MacKinnon et al., 2007).

This research used causal mediation analysis to test candidate mediators of the association between green space quality and prosocial behaviour, as well as to investigate whether prosocial behaviour lies in the pathway between green space quality and child health-related outcomes. Causal mediation analysis uses the counterfactual or potential outcomes approach that compares the outcome based on different scenarios of the values of the exposure and mediator. This method serves as a step forward in mediation analysis with emphasis on the causal basis (Valente et al., 2020). The counterfactual framework divides the total effect of the exposure on the outcome into the natural indirect effect (NIE); and the natural direct effect (NDE) (Liu et al., 2016; Richiardi et al., 2013; Valeri & Vanderweele, 2013). NIE captures the contrast of the effects of exposure on the outcome in relation to the change in the mediator. Meanwhile, NDE indicates the effect of exposure on the outcome, with the value of the mediator assumed to be what it naturally would have been in the absence of exposure.

Causal mediation analysis helps address the potential bias coming from the traditional method of mediation analysis propagated by Baron and Kenny (1986). Incorrect statistical analysis and flawed conclusions could arise from using the traditional approach which estimates the indirect effect by combining two standard regression coefficients of exposure-mediator and mediator-outcome models (Richiardi et al., 2013). Causal mediation analysis also can overcome other limitations of the traditional method, including the need for a statistically significant total effect between the exposure and the outcome to investigate a mediator, the low statistical power to test the indirect effect, and the assumption of no presence of exposure-mediator interaction (Hayes, 2009; Rijnhart et al., 2021; Valeri & Vanderweele, 2013; Zhao et al., 2010). Another strength is that causal mediation analysis can deal with non-linear relationships and can be applied to mediation models with continuous and categorical variables (Lee et al., 2019).

Given the nature of LSAC data with repeated measures (Waves 1 to 6), the lagged mediation model was used to assess candidate mediators. Green space quality as the exposure (X) at Wave$_{(N)}$, candidate mediators (M) at Wave$_{(N+1)}$, and the outcomes (Y) at Wave$_{(N+2)}$ were fitted in several mediation models (Figure 3.3). This mediation model also controlled for the influence of child, family, and neighbourhood characteristics from the same wave as the exposure. The earlier measure of the outcome was also considered as a confounder since it could be a strong predictor of the later outcome. Causal mediation analysis in this research was carried out in STATA 14.2 using the "paramed" macro. NIE and NDE are constructed based on two estimated parametric regression models that include models for the mediator conditional on the exposure and confounders; and for the outcome conditional on the exposure, the mediator, and confounders. The "paramed" macro allows continuous or binary mediators and exposures, and continuous, binary, or count outcomes. Categorical variables of covariates need to be coded as dummy variables (Valente et al., 2020).

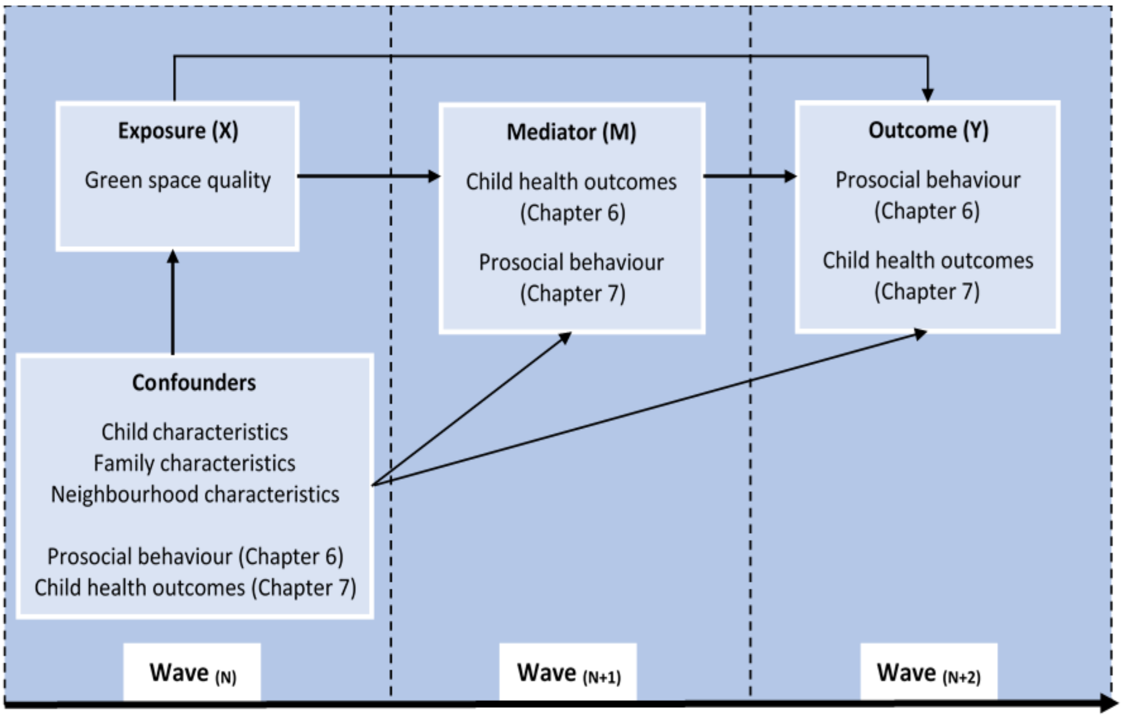

Figure 3.3 Mediation analysis

3.5 Ethical considerations

The AIFS Ethics Committee, a registered Human Research Ethics Committee (HREC) with the National Health and Medical Research Council (NHMRC), has approved the methodology and survey content of LSAC. For this PhD research, ethics approval has been provided by the HREC, University of Wollongong (No. 2019/433) (Appendix A). In addition, access to LSAC dataset has been granted by the Australian Data Archive on behalf of the data owners: DSS, AIFS, and ABS (Appendix B).

Chapter 4: Association between green space quality and child prosocial behaviour

4.1 Preface

Findings from the systematic review presented in Chapter 2 suggest several research gaps in the association between green space quality and child prosocial behaviour. While the association between green space "quantity" and prosocial behaviour was found weak, there is a paucity of study attempting to investigate the potential role of the "quality" of green space in shaping the development of child prosocial behaviour. Therefore, more studies are warranted to draw a firm conclusion on the association between green space quality and child prosocial behaviour. In addition, current evidence was mostly based on cross-sectional data that could not support the causality and whether the effect of quality green space on prosocial behaviour is consistent across childhood.

This chapter aimed to understand to the extent to which the availability of quality green space is associated with prosocial behaviour across childhood and adolescence. This study also involved sensitivity analyses to identify potential differences in associations between green space quality and prosocial behaviour by child's sex and history of residential movement. The study presented in this chapter is as it was published (Appendix D) with minor adjustments for tables, figures, referencing style, and overall thesis formatting requirements. Findings from this study are important to the possibility of undertaking the subsequent studies that aimed to understand whether accumulation of or changes in the availability of quality green space can influence the development of prosocial behaviour; and identify potential pathways linking green space quality to prosocial behaviour.

Citation

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Author contributions

I Gusti Ngurah Edi Putra, Thomas Astell-Burt, and Xiaoqi Feng conceptualised and designed the study. I Gusti Ngurah Edi Putra conducted the analysis, interpreted the results, wrote, and revised original draft of the manuscript. Thomas Astell-Burt, Dylan P. Cliff, Stewart A. Vella, and Xiaoqi Feng provided critical inputs throughout the process, and reviewed and edited the manuscript draft. All authors approved the final version of the manuscript.

The findings from this chapter were virtually presented at the following events:

1. School of Health and Society Research Seminar, Faculty of the Arts, Social Sciences and Humanities, University of Wollongong on 22 April 2020 (Appendix I),
2. The 14th Biennial Conference of the Asian Association of Social Psychology (AASP) 2021 on 31 July 2021 (Appendix K).

4.2 The published article: “Association between green space quality and prosocial behaviour: A 10-year multilevel longitudinal analysis of Australian children”

4.2.1 Abstract

Background: Current evidence from studies on green space and child prosocial behaviour suggests a paucity of studies investigating the plausible role of green space quality in shaping the development of prosocial behaviour. This study aimed to examine the longitudinal association between green space quality and prosocial behaviour among children and adolescents.

Methods: This study analysed 10-year longitudinal data (2004-2014) from the Longitudinal Study of Australian Children (LSAC), a nationally representative cohort study. Prosocial behaviour that covers positive behaviours (e.g., sharing, helping) was measured using a prosocial scale from Goodman’s Strengths and Difficulties Questionnaire (SDQ). Caregiver perceptions on the availability of “good” parks, playgrounds, and play space in the neighbourhood assessed green space quality. Multilevel linear regression models were used to examine potential changes in prosocial behaviour across childhood in relation to green space quality. A two-way interaction term between green space and age was fitted to assess potential differences in the effect of green space quality by age. Sensitivity analyses by child’s sex and history of residential movement were also performed.

Results: From the analysis of 24,418 observations nested in 4,969 children, prosocial behaviour was relatively high (mean=8.13 out of 10; SD=1.79) and about balanced proportions between girls (48.74%) and boys (51.26%) were included. Prosocial behaviour was higher among children whose caregivers agreed (β=0.10; 95%CI=0.04,

0.16) and strongly agreed (β=0.20; 95%CI=0.13, 0.27) to having quality green space in their neighbourhood. The benefit of exposure to favourable green space on prosocial behaviour was similar among both children who changed and did not change neighbourhood, but reported higher among boys than girls. Children compared to adolescents tended to benefit more from the presence of quality green space.

Conclusion: Green space quality was positively associated with child prosocial behaviour. Boys and young children tended to benefit more from quality green space. Future research might seek to identify preferred characteristics of green space, and to understand how these preferences vary by gender and age, to best support the development of prosocial behaviour across childhood and adolescence.

4.2.2 Introduction

Empirical studies suggest that nearby green space in urban settings is beneficial for child health and wellbeing. The presence of urban green space potentially buffers air-related pollutant that then become protective against asthma and other respiratory health problems among children (Eldeirawi et al., 2019; Feng & Astell-Burt, 2017b; Tischer et al., 2017). Neighbourhood green space can also provide attractive places for playing opportunities that enhance physical activity and/or reduce screen time (Akpinar, 2017; Buck et al., 2015; Roemmich et al., 2006; Sanders et al., 2015). Moreover, green space provides space for social recreation and less attention-demanding settings that help improve child mental health and wellbeing (Feng & Astell-Burt, 2017c, 2017d; Flouri et al., 2014; McCormick, 2017; Vanaken & Danckaerts, 2018). However, the potential benefit of neighbourhood green space for other important aspects of child positive development, such as prosocial behaviour, has received less attention (Putra et al., 2020). This leaves unanswered questions regarding the extent to which nearby greenery influences prosocial behaviour or if certain characteristics of nearby greenery, such as quality, are more strongly associated with child prosocial behaviour.

Prosocial behaviour among children covers a range of positive behaviours that benefit others that can include sharing, helping, comforting, and cooperating (Dunfield, 2014; Hammond et al., 2015; Hay, 1994; Piotrowski et al., 2015; Wittek & Bekkers, 2015). Promoting the development of prosocial behaviours from early childhood is essential due to positive impacts on psychological and social functioning (Aknin et al., 2015; Aknin et al., 2012; Caputi et al., 2012; Carlo et al., 2012; Collie et al., 2018; Eisenberg et al., 2015; Gerbino et al., 2018; Proctor & Linley, 2014; Yang et al., 2019), as well as, health-related outcomes and behaviours (Flouri & Sarmadi, 2016; Flynn et al., 2015; Qureshi et al., 2019). A published systematic review suggests that exposure to nearby green space may potentially increase prosocial behaviour among children and adolescents (Putra et al., 2020). Three pathways linking green space to the development of prosocial behaviour adopted from past work (Markevych et al., 2017) were theorised, including: (i) harm mitigation (e.g., reducing exposure to environmental stressors that negatively influence cognitive development during the early life, such as air pollution); (ii) building capacities (e.g., facilitating social interactions and physical activity); and (iii) restoring capacities (e.g., providing restorative effects and stress recovery that increase positive emotionality). Accumulated exposure to green space may bring greater benefits for prosocial behaviour development and the pattern may also vary as children get older (Putra et al., 2020).

However, evidence has been equivocal as to the role of neighbourhood green space in promoting the development of prosocial behaviour among children (Putra et al., 2020). Inconsistent findings on the association between green space and prosocial behaviour may be contingent upon the way in which green space exposure is measured. Therefore, aspects of green space that are more relevant to the development of child prosocial acts remain less clear. Studies taking into account neighbourhood green space quantity (e.g., residential nearby greenness, percentage of green space) showed weak, positive associations with prosocial behaviour (Amoly et al., 2014; Andrusaityte et al., 2019; Balseviciene et al., 2014; McEachan et al., 2018; Odgers et al., 2012; Richardson et al., 2017; Van Aart et al., 2018). Meanwhile, only one study has measured the association between green space quality – defined by subjective parental satisfaction on frequently visited green space – in relation to prosocial behaviour (McEachan et al., 2018). Even though an association in the hypothesised direction was reported, the insufficient number of studies on green space quality and prosocial behaviour prevents researchers from drawing a solid conclusion, suggesting more studies are required.

It is also conceivable that children's exposure to green space is not fully determined by the amount of neighbourhood green space available since they count on parents to accompany them into nearby green space, particularly among those in the early years (Feng & Astell-Burt, 2017a, 2017d). Parental or caregiver perceptions on whether nearby green space meet their reasonable quality level might play an essential role in determining children's contact with green space rather than the quantity of green space available locally. Previous studies among Australian children suggest that caregiver assessments on the availability of favourable neighbourhood green space quality was associated with child mental wellbeing (Feng & Astell-Burt, 2017c, 2017d) and general health (Feng & Astell-Burt, 2017a) independently of green space quantity (e.g., percentage of residential green space). Moreover, the association was more pronounced for caregiver-reported green space quality in relation to children's externalising behaviours (hyperactive and conduct problems) than green space quantity (Feng & Astell-Burt, 2017c). Therefore, caregiver reports on the quality of neighbourhood green space may matter in evaluating association between green space and prosocial behaviour among children.

Accordingly, this study examined longitudinal association between green space quality and prosocial behaviour. The data collected from the Longitudinal Study of Australian Children over a period of 10 years were used to examine the patterning of prosocial behaviour between age 4 and 15 in relation to caregiver-reported quality of neighbourhood green space. Using longitudinal data also helps to address the limitation of the current evidence which is mostly based upon cross-sectional data (Putra et al., 2020). Besides, the use of longitudinal approach also enables to examine whether the benefit of exposure to quality green space is consistent across all ages of the cohort since older children or adolescents have much freedom to decide how and where to spend their time outside. Specifically, this study asks: "*To what extent is the availability of quality green space associated with developmental trajectories in prosocial behaviour across childhood?*". This study hypothesised that exposure to favourable green space quality is associated with greater prosocial behaviour.

4.2.3. Methods

4.2.3.1 Data

This study used data from the Longitudinal Study of Australian Children (LSAC), a nationally population-based representative cohort study carried out by the Department of Social Services (DSS) in a collaboration with the Australian Institute of Family Studies (AIFS) and the Australian Bureau of Statistics (ABS). Participants were sampled from the enrolment database of Medicare, Australia's universal health insurance scheme. A two-stage clustered design was applied. First, representative postcodes were selected using probability proportional to size approach, stratified by state or territory and by capital city statistical division versus rest of state area to ensure selected samples geographically proportionate to areas across urban and rural communities. Second, children had equal chance about one in 25 to be selected. They were recruited from selected 311 postcodes, about 40 and 20 children per postcode in the larger states and the smaller states, respectively. Full details of LSAC methodology can be found elsewhere (Australian Institute of Family Studies, 2005, 2018).

Data for the present study were drawn from the "Kindergarten" (K) cohort Waves 1 (children aged 4-5 years) to 6 (14-15 years) that took place from 2004 to 2014. Waves 1 to 6 consistently documented data on green space quality and child prosocial behaviour, whereas the most recent wave (Wave 7) did not collect information about green space quality. For the first recruitment in 2004, 9,893 caregivers were invited to participate, of which 50.4% (4,983) were successfully recruited. Response rates for biennial follow-up were initially high about 90% and then reduced to 79.4% and 71% by Wave 5 and 6, respectively. Data were primarily collected from caregivers with some additional sections completed by self-report of children and teachers. Data collection methods included face-to-face interview, mail-out questionnaires, time-use diaries, audio computer self-assisted interview, left-behind survey, interviewer observations, and physical measurements. For this study, records with missing values on prosocial behaviour were excluded whereas any missing data on explanatory variables were retained to avoid further sample loss.

4.2.3.2 Prosocial behaviour

Prosocial behaviour was measured using the prosocial scale from the Goodman's Strengths and Difficulties Questionnaire (SDQ). The SDQ is a multi-dimensional behavioural screening tool of child wellbeing that has been widely considered as a valid measure and internationally used in multicultural settings (Richardson et al., 2017;

Theunissen et al., 2015). Caregivers were asked to respond to five statements regarding their children's behaviour as follows: *"considerate of other people's feelings"*, *"share readily with other children"*, *"helpful if someone is hurt, upset or feeling ill"*, *"kind to younger children"*, and *"often volunteers to help others (parents, teachers, other children)"*. Three responses with different assigned scores for each statement were given: not true (0), somewhat true (1), certainly true (2). Caregiver report of prosocial behaviour was expressed in a total score ranging from 0 to 10 with a higher score indicating greater prosocial behaviour.

4.2.3.3 Green space quality

To assess green space quality, this study used caregiver perceptions regarding the availability of the reasonable quality of local green space that were measured in each wave. Caregivers were asked to rate on a Likert-scale statement, how strongly they agree or disagree towards the following statement: "*There are good parks, playgrounds and play spaces in this neighbourhood*". The responses were recorded as "*strongly disagree*", "*disagree*", "*agree*", *and* "*strongly agree*". This statement has been used to measure green space quality in relation to child wellbeing (Feng & Astell-Burt, 2017c, 2017d) and general health (Feng & Astell-Burt, 2017a). The inclusion of "good" in the wording question enables caregivers to acknowledge whether the green space available locally meets their acceptable quality level (Feng & Astell-Burt, 2017a, 2017d). Moreover, by not imposing an *a-priori* definition of what constitutes green space quality, it affords the caregiver the opportunity to perceive and decide the most valuable attributes to green space quality (Feng & Astell-Burt, 2019). Another strength of using caregiver subjective report is that caregivers mostly regulate children's outdoor activities and hence, their perceptions on green space quality to a large extent have the direct influence on children's spending time in green space (Datar et al., 2013). Due to the small percentages of responses given as “*disagree*” and “*strongly disagree*”, both were collapsed into a single category “do not agree”, whereas “*agree*” and “*strongly agree*” responses were not grouped due to high percentages for each response and also to help disentangle the effect of green space that was perceived in different levels of good quality, which is in line with previous work (Feng & Astell-Burt, 2018).

4.2.3.4 Covariates

Some variables that might be associated with green space use, prosocial behaviour, and influence the green space-prosocial behaviour association were included. The child’s age (categorised in two-year age groups according to waves), sex (male, female) and ethnicity indicators including if the child was Indigenous (Australian aboriginal or Torres Strait Islander) and if the child spoke a language other than English at home were variables collected at an individual level. In addition, measures of family socio-economic status, such as educational level of the caregiver who had the highest qualification in the family (categorised as high: > high school, low: ≤high school) and combined weekly income of caregivers (in thousand AUD) (Blakemore et al., 2006; Sanders et al., 2015) were taken into account. Other family-level variables were family structure (one-caregiver, two-caregiver family) and the number of siblings.

Since exposure to green space might vary by neighbourhood socioeconomic status within the Australian context (Astell-Burt et al., 2014), this study also explored the Index of Relative Socioeconomic Disadvantage from the Socio-economic Indexes for Areas (SEIFA) as a potential confounder. The index is developed using principal component analysis taking into account some indicators, such as education, employment, income, and housing (Australian Bureau of Statistics, 2006). A lower index score indicates higher disadvantage area and was classified into tertiles for this study (“high”, “moderate”, “low”). Moreover, the Accessibility-Remoteness Index of Australia (ARIA) classifies neighbourhood as accessible and remote communities in terms of accessibility to some services centres based on road distances (Department of Health and Aged Care, 2001) that was included in the analyses. Importantly, neighbourhood safety becomes caregivers’ concern for children’s outdoor play, which, in turn, can influence the use of green space among children (Sefcik et al., 2019; Strife & Downey, 2009). Therefore, neighbourhood safety was included in this study by asking caregivers to rate on a Likert-scale statement: *“This is a safe neighbourhood.”* Responses were regrouped as “do not agree” (for “*strongly disagree*” and “*disagree*”), “agree”, and “strongly agree”.

4.2.3.5 Data analysis

Descriptive statistics were used to describe characteristics of study samples across waves. Multilevel linear regression using MLwIN V3.01 (Rasbash et al., 2017) was then applied to test cross-sectional and longitudinal associations between green space quality and prosocial behaviour. For cross-sectional analyses performed in each wave, two-level multilevel linear regression models with children at level 1 and statistical areas, level 2 (SA2s) at level 2 were fitted. Meanwhile, three-level multilevel models were fitted in longitudinal analysis with children’s observations at each wave (level 1) that were nested within individuals (level 2) and SA2s (level 3). Multilevel regression models allow the analysis of data that are collected at different levels or structured hierarchical data with repeated measures (Hair Jr. & Fávero, 2019). It takes into account the clustering effects since individuals are nested in a sample of neighbourhood, as well as, the interactions between group- and individual-level attributes (Diez-Roux, 2000; Subramanian et al., 2003). It is also suitable for the longitudinal data with repeated measures as observations or events documented over time are nested within individuals, taking into account an assumption of dependent or correlated observations (Goldstein, 2011; Van Der Leeden, 1998). In addition, LSAC datasets also captured residential movement from one to another neighbourhood (SA2) (n=1,860; 37.43%) which indicates that participants were nested within multiple SA2s. Hence, the cross-classified data structure was taken into account using the Markov chain Monte Carlo (MCMC) method (Browne et al., 2001), running two chains of 50,000 iterations following a burn-in of 20,000. Fixed part parameter estimates reported were adjusted coefficients (β) along with 95% credible intervals (CIs).

4.2.3.6 Ethical consideration

The methodology and survey contents of LSAC have been approved by the AIFS Ethics Committee, and written informed consent was given by all participants. Ethics approval for this present study was obtained from the Human Research Ethics Committee, University of Wollongong (No. 2019/433).

4.2.4 Results

4.2.4.1 Cross-sectional association between green space quality and prosocial behaviour

Table 4.1 presents sample characteristics across waves. Only child records with complete information on prosocial behaviour were analysed. Specifically, the number of included samples from participants surveyed at consecutive waves were as follows: Wave 1 = 4,969; Wave 2 = 4,333; Wave 3 = 3,793; Wave 4 = 4,109; Wave 5 = 3,847; and Wave 6 = 3,367. These all were counted for 24,418 (95.98%) from a total of 25,440 observations documented in the K-cohort Waves 1 to 6 (omitted observations = 1,022 or 4.02%).

Prosocial behaviour score increased from Wave 1 and peaked at Wave 4 when children were aged 10-11 years and then decreased. Meanwhile, the proportion of caregivers who reported “strongly” agree in regards to green space of good quality available in their neighbourhood increased over time. Based on family characteristics, household socioeconomic status improved over time as indicated by gradual increase in the percentages of high-educated caregivers and household weekly income. The percentages of single-caregiver family and number of siblings the child had, fluctuated in a 10-year observation period. The percentages of caregivers who strongly agreed the neighbourhood where they lived was safe also increased by wave. Further, changing proportions of neighbourhood socio-economic status expressed within SEIFA and ARIA categories can indicate residential movement from one to another neighbourhood that occurred during the study period.

Table 4.2 shows significant associations between green space quality and child prosocial behaviour across waves, except at Waves 3 and 6. Prosocial behaviour was statistically higher among children whose caregivers strongly agreed that the quality of green space in their neighbourhood was good than children to caregivers who did not agree. However, except at Wave 5, there were no statistically significant differences in child prosocial behaviour among those caregivers who moderately agreed and disagreed for the availability of good green space quality. The cross-sectional analyses also showed that girls consistently had higher prosocial behaviour compared to boys across waves. However, other variables were not consistently associated with prosocial behaviour for each wave.

Table 4.1 Characteristics of children across waves

Variables	Wave 1 (4-5 years) n (%*)	Wave 2 (6-7 years) n (%*)	Wave 3 (8-9 years) n (%*)	Wave 4 (10-11 years) n (%*)	Wave 5 (12-13 years) n (%*)	Wave 6 (14-15 years) n (%*)	Total (Waves 1 to 6) n (%*)
Total sample	4,969	4,333	3,793	4,109	3,847	3,367	24,418
Dependent variable							
Prosocial behaviour, mean (SD)	7.73 (1.80)	8.20 (1.74)	8.22 (1.75)	8.47 (1.69)	8.24 (1.77)	7.99 (1.88)	8.13 (1.79)
Main independent variable							
Green space quality							
Do not agree	1,118 (23.39)	583 (13.01)	747 (20.62)	663 (17.27)	807 (21.88)	465 (14.65)	4,383 (18.65)
Agree	2,366 (47.77)	1,724 (38.75)	1,801 (47.77)	2,049 (50.21)	1,704 (44.25)	1,645 (49.70)	11,289 (46.29)
Strongly agree	1,465 (28.38)	1,058 (22.96)	1,234 (31.26)	1,338 (32.25)	1,324 (33.52)	1,247 (35.28)	7,716 (30.27)
missing/not reported	*20 (0.46)*	*968 (25.28)*	*11 (0.35)*	*9 (0.27)*	*12 (0.35)*	*10 (0.38)*	*1,030 (4.80)*
Individual characteristics							
Child's sex							
Female	2,443 (48.86)	2,121 (48.83)	1,865 (48.94)	2,011 (48.87)	1,880 (48.21)	1,660 (48.71)	11,980 (48.74)
Male	2,526 (51.14)	2,212 (51.17)	1,928 (51.06)	2,098 (51.13)	1,967 (51.79)	1,707 (51.29)	12,438 (51.26)
Child Indigenous status							
Not Indigenous	4,780 (96.06)	4,184 (96.28)	3,696 (96.83)	3,993 (96.26)	3,747 (97.35)	3,294 (97.48)	23,694 (96.65)
Indigenous	187 (3.91)	147 (3.69)	95 (3.13)	114 (3.71)	100 (2.65)	73 (2.52)	716 (3.33)
missing/not reported	*2 (0.03)*	*2 (0.03)*	*2 (0.04)*	*2 (0.04)*			*8 (0.02)*
Child speaks a language other than English							
No	4,356 (86.24)	3,849 (85.99)	3,422 (87.72)	3,694 (86.77)	3,546 (89.48)	3,067 (88.57)	21,934 (87.34)
Yes	613 (13.76)	484 (14.01)	371 (12.28)	415 (13.23)	301 (10.52)	300 (11.43)	2,484 (12.66)
Family characteristics							
Caregiver education							
≤ High school	918 (20.33)	654 (17.77)	457 (15.04)	464 (14.36)	375 (11.68)	263 (9.89)	3,131 (15.26)
> High school	4,048 (79.62)	3,678 (82.21)	3,335 (84.93)	3,644 (85.58)	3,470 (88.27)	3,101 (90.04)	21,276 (84.69)
missing/not reported	*3 (0.05)*	*1 (0.02)*	*1 (0.03)*	*1 (0.06)*	*2 (0.05)*	*3 (0.07)*	*11 (0.05)*
Family weekly income (in thousands), mean (SD)	1.27 (0.86)	1.52 (1.13)	1.78 (1.27)	1.86 (1.50)	2.12 (1.56)	2.28 (1.64)	1.76 (1.40)

Family structure							
One-caregiver family	692 (14.89)	629 (16.40)	522 (16.03)	642 (18.60)	644 (17.78)	581 (19.69)	3,710 (17.07)
Two-caregiver family	4,277 (85.11)	3,704 (83.60)	3,271 (83.97)	3,466 (81.34)	3,202 (82.19)	2,786 (80.31)	20,706 (82.91)
missing/not reported				*1 (0.06)*	*1 (0.03)*		*2 (0.01)*
Number of siblings, mean (SD)	1.51 (1.07)	1.60 (1.08)	1.62 (1.06)	1.68 (1.14)	1.62 (1.10)	1.52 (1.07)	1.59 (1.09)
Neighbourhood characteristics							
Neighbourhood safety							
Do not agree	419 (9.30)	181 (4.51)	196 (6.24)	187 (5.40)	450 (12.84)	127 (4.47)	1,560 (7.22)
Agree	2,881 (57.93)	2,002 (44.80)	2,078 (55.53)	2,235 (55.52)	1,777 (46.13)	1,783 (54.32)	12,756 (52.46)
Strongly agree	1,652 (32.40)	1,145 (24.51)	1,502 (37.70)	1,681 (38.90)	1,609 (40.70)	1,449 (40.88)	9,038 (35.38)
missing/not reported	*17 (0.38)*	*1,005 (26.18)*	*17 (0.45)*	*6 (0.19)*	*11 (0.34)*	*8 (0.33)*	*1,064 (4.95)*
Area disadvantage (SEIFA)							
High	1,786 (37.19)	1,497 (36.54)	1,254 (35.71)	1,608 (42.36)	1,453 (40.63)	1,214 (39.26)	8,812 (38.55)
Moderate	1,609 (32.94)	1,501 (33.71)	1,506 (39.28)	1,124 (27.23)	1,188 (30.42)	1,043 (30.45)	7,971 (32.34)
Low	1,574 (29.87)	1,335 (29.74)	1,033 (25.02)	1,376 (30.38)	1,205 (28.92)	1,109 (30.28)	7,632 (29.10)
missing/not reported				*1 (0.02)*	*1 (0.02)*	*1 (0.01)*	*3 (0.01)*
Area accessibility (ARIA)							
Highly accessible	2,692 (55.28)	2,299 (55.83)	1, 993 (53.28)	2,122 (53.12)	1,952 (51.62)	1,708 (51.07)	12,766 (53.55)
Accessible	1,160 (24.07)	1,068 (24.86)	967 (26.06)	1,073 (26.74)	1,052 (27.80)	907 (27.81)	6,227 (26.07)
Moderately accessible	855 (16.12)	736 (14.99)	642 (16.17)	723 (16.15)	669 (16.55)	610 (17.16)	4,235 (16.14)
Remote to very remote	216 (3.80)	183 (3.50)	140 (3.22)	153 (3.19)	143 (3.23)	107 (2.97)	942 (3.35)
missing/not reported	*46 (0.73)*	*47 (0.83)*	*51 (1.27)*	*38 (0.80)*	*31 (0.80)*	*35 (0.98)*	*248 (0.89)*

**weighted percentage*

Table 4.2 Multilevel linear regression of the adjusted cross-sectional associations between green space quality and prosocial behaviour

Variables	Wave 1 (4-5 years) β (95% CI)	Wave 2 (6-7 years) β (95% CI)	Wave 3 (8-9 years) β (95% CI)	Wave 4 (10-11 years) β (95% CI)	Wave 5 (12-13 years) β (95% CI)	Wave 6 (14-15 years) β (95% CI)
Main independent variable						
Green space quality *(ref: Do not agree)*						
Agree	0.06 (-0.07, 0.19)	0.04 (-0.13, 0.21)	0.09 (-0.06, 0.24)	0.15 (-0.01, 0.29)	**0.17 (0.03, 0.32)**	0.09 (-0.11, 0.28)
Strongly agree	**0.26 (0.11, 0.40)**	**0.29 (0.10, 0.48)**	0.10 (-0.06, 0.27)	**0.24 (0.07, 0.41)**	**0.26 (0.09, 0.43)**	0.07 (-0.15, 0.29)
Demographic characteristics						
Child's sex *(ref: Male)*						
Female	**0.51 (0.41, 0.61)**	**0.70 (0.58, 0.82)**	**0.77 (0.66, 0.88)**	**0.70 (0.60, 0.80)**	**0.63 (0.52, 0.74)**	**0.67 (0.55, 0.79)**
Child Indigenous status (*ref: Indigenous)*						
Not Indigenous	0.11 (-0.16, 0.37)	**0.45 (0.07, 0.82)**	0.07 (-0.28, 0.42)	0.31 (-0.01, 0.62)	-0.02 (-0.36, 0.32)	0.09 (-0.33, 0.52)
Child speaks a language other than English (*ref: No)*						
Yes	**0.18 (0.03, 0.33)**	0.14 (-0.06, 0.34)	0.19 (-0.07, 0.30)	0.07 (-0.10, 0.24)	**-0.22 (-0.43, -0.01)**	-0.13 (-0.35, 0.09)
Family characteristics						
Caregiver education (*ref: ≤ High school)*						
> High school	**0.17 (0.03, 0.31)**	0.10 (-0.07, 0.28)	**0.21 (0.03, 0.38)**	0.14 (-0.03, 0.30)	**0.30 (0.12, 0.49)**	**0.34 (0.10, 0.58)**
Family weekly income (in thousands)	**0.08 (0.02, 0.14)**	-0.01 (-0.06, 0.05)	**0.05 (0.01, 0.10)**	0.03 (-0.01, 0.07)	0.01 (-0.03, 0.05)	**0.06 (0.02, 0.10)**
Family structure *(ref: One-caregiver family)*						
Two-caregiver family	0.09 (-0.07, 0.25)	0.06 (-0.13, 0.25)	0.04 (-0.13, 0.22)	0.08 (-0.07, 0.23)	**0.26 (0.10, 0.42)**	0.09 (-0.09, 0.27)
Number of siblings	**-0.08 (-0.13, -0.03)**	0.02 (-0.08, 0.04)	**-0.07 (-0.13, -0.02)**	**-0.09 (-0.14, -0.05)**	**-0.08 (-0.13, -0.03)**	**-0.06 (-0.13, -0.01)**
Neighbourhood characteristics						
Neighbourhood safety *(ref: Do not agree)*						
Agree	0.03 (-0.16, 0.21)	0.02 (-0.24, 0.28)	0.17 (-0.08, 0.42)	0.01 (-0.24, 0.25)	0.13 (-0.05, 0.32)	-0.01 (-0.35, 0.32)
Strongly agree	**0.38 (0.18, 0.58)**	0.15 (-0.14, 0.43)	**0.40 (0.13, 0.66)**	0.18 (-0.08, 0.44)	**0.36 (0.14, 0.55)**	0.29 (-0.06, 0.65)

Area disadvantage (SEIFA) *(ref: High)*						
Moderate	**0.13 (0.01, 0.25)**	0.06 (-0.08, 0.21)	0.09 (-0.04, 0.22)	0.05 (-0.08, 0.17)	0.08 (-0.05, 0.22)	0.06 (-0.10, 0.21)
Low	-0.03 (-0.17, 0.10)	0.04 (-0.12, 0.21)	0.06 (-0.10, 0.22)	-0.01 (-0.14, 0.13)	-0.02 (-0.17, 0.14)	-0.04 (-0.22, 0.13)
Area accessibility (ARIA) *(ref: Highly accessible)*						
Accessible	-0.02 (-0.15, 0.12)	0.01 (-0.14, 0.15)	0.04 (-0.10, 0.18)	**0.13 (0.01, 0.26)**	0.03 (-0.10, 0.17)	0.05 (-0.10, 0.21)
Moderately accessible	0.04 (-0.11, 0.19)	0.02 (-0.16, 0.20)	-0.03 (-0.20, 0.14)	0.03 (-0.12, 0.18)	0.02 (-0.15, 0.19)	0.06 (-0.13, 0.25)
Remote to very remote	-0.09 (-0.34, 0.17)	0.06(-0.24, 0.37)	-0.18 (-0.48, 0.12)	0.03 (-0.25, 0.30)	-0.23 (-0.53, 0.06)	-0.18 (-0.54, 0.19)
Random effects, variance (95% CI)						
Level 2: Statistical Area 2	0.53 (-1.11, 2.17)	0.88 (-1.22, 2.98)	1.11 (-0.43, 2.64)	0.00 (0.00, 0.00)	0.59 (-0.89, 2.07)	0.00 (0.00, 0.00)
Level 1: Participant	2.51 (0.87, 4.16)	1.90 (-0.20, 4.00)	1.70 (0.17, 3.23)	2.61 (2.49, 2.72)	2.31 (0.82, 3.79)	3.27 (3.11, 3.43)

β: adjusted regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

4.2.4.2 Longitudinal association between green space quality and prosocial behaviour

Four multilevel linear regression models were developed to assess longitudinal association between green space quality and prosocial behaviour. The first model investigated unadjusted longitudinal green space quality-prosocial behaviour association. The second model included child characteristics (age, sex, Indigenous status, language spoken at home). Further, this model was followed by the inclusion of family characteristics (caregiver education, family weekly income, family structure, number of siblings) (Model 3), and neighbourhood characteristics (neighbourhood safety, area disadvantage, area accessibility) (Model 4). These models enabled to observe the change in the magnitude of green space quality-prosocial behaviour associations after adding different groups of covariates sequentially. The smaller value of deviance information criterion (DIC) indicates the better model that fits the data (Li et al., 2017). The findings suggest that the model adjusted for all covariates (Model 4) is better than other models (DIC= 84598.70).

Table 4.3 shows that green space quality remained significantly associated with prosocial behaviour in the expected direction upon adjustment for all covariates. A dose-response relationship was apparent where favourable perceptions of green space quality was associated with greater prosocial behaviour. Children whose caregivers rated the availability of good quality of local green space as “agree” (β=0.10; 95%CI=0.04, 0.16) and “strongly agree” (β=0.20; 95%CI=0.13, 0.27) had higher prosocial behaviour compared to those children to caregivers who did not agree, respectively. The child’s age was also significantly associated with prosocial behaviour. Generally, girls had significantly higher prosocial behaviour than boys (β=0.66; 95%CI=0.61, 0.70). Prosocial behaviour score was also found to be higher among non-Indigenous than Indigenous children. Another ethnicity indicator, whether children speaking a language other than

English at home, was not associated with prosocial behaviour. While higher caregiver education, increased household weekly income, and living in two-caregiver families were associated with greater prosocial behaviour, the association for the number of siblings was in the opposite direction. For neighbourhood circumstances, caregivers who argued that the place where they lived was considerably safe also reported for a higher score on their child's prosocial behaviour. Moreover, only area disadvantage was associated with prosocial behaviour whilst area accessibility was not.

A two-way interaction term between green space quality and age was fitted into the model (as presented in Table 4.4). The findings suggest that the influence of green space quality did not significantly vary across childhood. Based on the DIC value, adding an interaction term between green space quality and age into the model did not suggest a better model that fits the data. Further, Figure 4.1 presents hump-shaped association between prosocial behaviour and age. Generally, prosocial behaviour improved during childhood and then decreased in adolescence. The benefit of exposure to more favourable green space quality relative to unfavourable quality was evident and relatively consistent, but appeared to slightly weaken at the end of the cohort.

Table 4.3 Multilevel linear regression of adjusted longitudinal associations between green space quality and prosocial behaviour

Variables	Model 1 Unadjusted β (95% CI)	Model 2 Adjusted β (95% CI)	Model 3 Adjusted β (95% CI)	Model 4 Adjusted β (95% CI)
Main independent variable				
Green space quality *(ref: Do not agree)*				
Agree	**0.14 (0.08, 0.20**)	**0.11 (0.05, 0.17)**	**0.09 (0.03, 0.15)**	**0.10 (0.04, 0.16)**
Strongly agree	**0.38 (0.31, 0.44)**	**0.34 (0.28, 0.41)**	**0.31 (0.24, 0.37)**	**0.20 (0.13, 0.27)**
Demographic characteristics				
Child's age *(ref: 4-5 years)*				
6-7 years		**0.49 (0.41, 0.56)**	**0.47 (0.40, 0.54)**	**0.46 (0.39, 0.54)**
8-9 years		**0.49 (0.42, 0.56)**	**0.47 (0.40, 0.54)**	**0.44 (0.37, 0.52)**
10-11 years		**0.74 (0.67, 0.81)**	**0.72 (0.65, 0.79)**	**0.70 (0.63, 0.77)**
12-13 years		**0.54 (0.47, 0.61)**	**0.50 (0.43, 0.58)**	**0.49 (0.42, 0.56)**
14-15 years		**0.28 (0.21, 0.36)**	**0.23 (0.16, 0.31)**	**0.21 (0.13, 0.29)**
Child's sex *(ref: Male)*				
Female		**0.65 (0.60, 0.69)**	**0.65 (0.61, 0.70)**	**0.66 (0.61, 0.70)**
Child Indigenous status (*ref: Indigenous)*				
Not Indigenous		**0.29 (0.16, 0.42)**	**0.18 (0.05, 0.32)**	**0.17 (0.03, 0.30)**
Child speaks a language other than English (*ref: No)*				
Yes		0.17 (-0.06, 0.09)	0.03 (-0.05, 0.10)	0.05 (-0.03, 0.13)
Family characteristics				
Caregiver education (*ref: ≤ High school)*				
> High school			**0.19 (0.12, 0.26)**	**0.19 (0.12, 0.26)**
Family weekly income (in thousands)			**0.04 (0.02, 0.05)**	**0.04 (0.02, 0.06)**
Family structure *(ref: One-caregiver family)*				
Two-caregiver family			**0.13 (0.06, 0.20)**	**0.11 (0.04, 0.18)**
Number of siblings			**-0.08 (-0.10, -0.05)**	**-0.07 (-0.10, -0.05)**

Neighbourhood characteristics				
Neighbourhood safety *(ref: Do not agree)*				
Agree				0.08 (-0.01, 0.17)
Strongly agree				**0.32 (0.22, 0.42)**
Area disadvantage (SEIFA) *(ref: High)*				
Moderate				**0.08 (0.02, 0.13)**
Low				0.00 (-0.06, 0.06)
Area accessibility (ARIA) *(ref: Highly accessible)*				
Accessible				0.04 (-0.02, 0.10)
Moderately accessible				0.03 (-0.04, 0.10)
Remote to very remote				-0.09 (-0.21, 0.03)
Random effects, variance (95% CI)				
Level 3: Statistical Area 2	0.05 (-0.01, 0.02)	0.03 (-0.04, 0.09)	0.01 (-0.01, 0.03)	0.02 (-0.02, 0.05)
Level 2: Participant	1.62 (1.37, 1.87)	1.51 (1.28, 1.73)	1.53 (1.30, 1.76)	1.51 (1.28, 1.75)
Level 1: Observation	1.48 (1.23, 1.73)	1.41 (1.20, 1.62)	1.38 (1.15, 1.60)	1.39 (1.16, 1.61)
Deviance Information Criterion (DIC)	87379.25	86168.44	85765.32	84598.70

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

Table 4.4 Multilevel linear regression of adjusted longitudinal associations between green space quality and prosocial behaviour and effect modification by age

Variables	Adjusted β (95% CI)
Interaction term	
Green space quality*child's age *(ref: Do not agree – 4-5 years)*	
Agree – 6-7 years	-0.02 (-0.22, 0.19)
Agree – 8-9 years	0.05 (-0.14, 0.24)
Agree – 10-11 years	0.07 (-0.12, 0.27)
Agree – 12-13 years	0.12 (-0.07, 0.30)
Agree – 14-15 years	-0.01 (-0.22, 0.20)
Strongly agree – 6-7 years	-0.08 (-0.30, 0.14)
Strongly agree – 8-9 years	-0.15 (-0.36, 0.06)
Strongly agree – 10-11 years	-0.10 (-0.30, 0.11)
Strongly agree – 12-13 years	-0.03 (-0.23, 0.18)
Strongly agree – 14-15 years	-0.21 (-0.43, 0.02)
Main independent variable	
Green space quality *(ref: Do not agree)*	
Agree	0.06 (-0.06, 0.18)
Strongly agree	**0.29 (0.15, 0.42)**
Demographic characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**0.50 (0.32, 0.67)**
8-9 years	**0.47 (0.31, 0.62)**
10-11 years	**0.69 (0.53, 0.85)**
12-13 years	**0.43 (0.28, 0.59)**
14-15 years	**0.29 (0.10, 0.47)**
Child's sex *(ref: Male)*	
Female	**0.65 (0.61, 0.70)**
Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	**0.16 (0.03, 0.30)**
Child speaks a language other than English (*ref: No)*	
Yes	0.05 (-0.02, 0.13)
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	**0.19 (0.12, 0.26)**
Family weekly income (in thousands)	**0.04 (0.02, 0.06)**
Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.11 (0.04, 0.18)**
Number of siblings	**-0.07 (-0.10, -0.05)**
Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	0.08 (-0.02, 0.17)
Strongly agree	**0.32 (0.22, 0.42)**

Area disadvantage (SEIFA) *(ref: High)*	
Moderate	**0.08 (0.02, 0.13)**
Low	0.00 (-0.06, 0.06)
Area accessibility (ARIA) *(ref: Highly accessible)*	
Accessible	0.04 (-0.02, 0.10)
Moderately accessible	0.03 (-0.04, 0.09)
Remote to very remote	-0.09 (-0.21, 0.03)
Random effects, variance (95% CI)	
Level 3: Statistical Area 2	0.01 (-0.01, 0.01)
Level 2: Participant	1.52 (1.29, 1.75)
Level 1: Observation	1.39 (1.16, 1.62)
Deviance Information Criterion (DIC)	84662.66

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

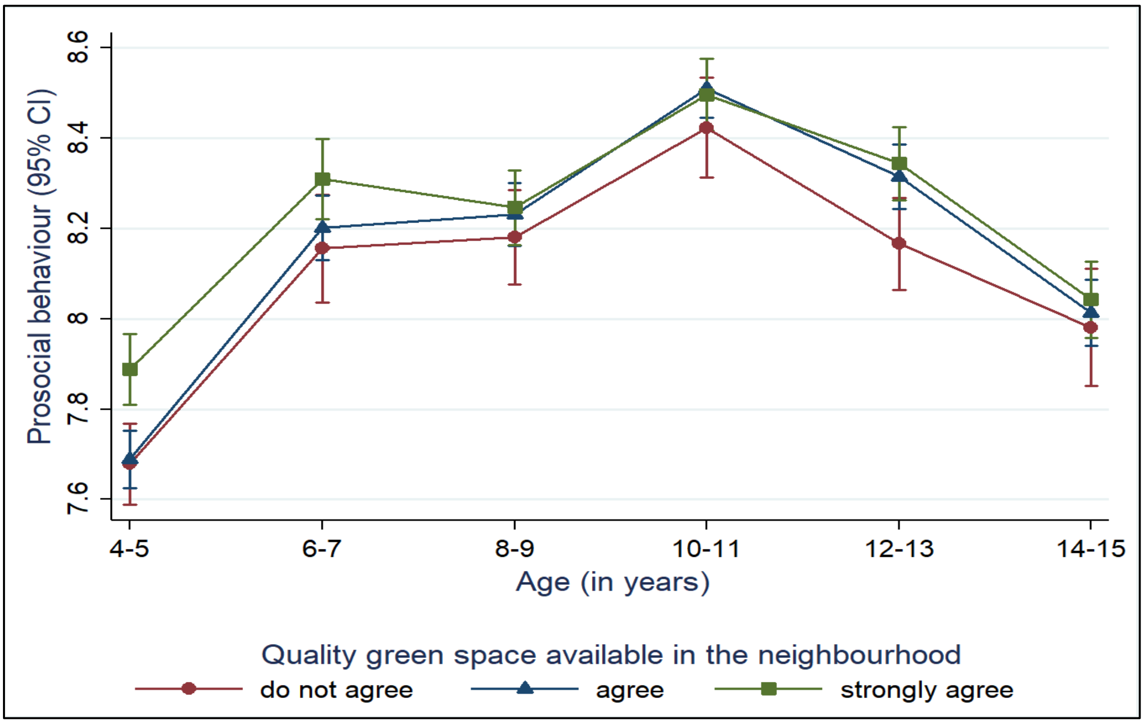

Figure 4.1 Prosocial behaviour development by different levels of quality green space

Sensitivity analyses were also performed to identify potential differences in association between green space quality and prosocial behaviour by child's sex and history of changing neighbourhood. Table 4.5 suggests that aforementioned association was found to be stronger among boys than girls. Interaction analysis indicated significant interaction between green space quality and age in sex-separated models (Table 4.6). Adding this interaction term resulted in the better model for boys, indicated by smaller DIC values compared to the model without interaction term, but not for girls. In addition, the influence of better quality of neighbourhood green space was less convincing among girls due to the level of prosocial behaviour was relatively same in different qualities of green space, except at the age of 12-13 years (Figure 4.2). On the other hand, the pattern among boys was similar to all samples which the effect tended to weaken in adolescence. These findings indicate that boys benefited more by the presence of favourable green space quality than girls, particularly those in younger age groups (Figure 4.3).

Out of 4,969 children involved in this study, 1,860 (37.43%) children changed neighbourhood during the study period. Table 4.7 suggests that green space quality reported by caregivers was associated with prosocial behaviour irrespective of whether children moved or remained in the same neighbourhood. Fitting the interaction term yielded better models, but no significant interaction between green space quality and age was found for both models (Table 4.8). Among children living in the same neighbourhood, the influence of quality green space appeared to slightly weaken in adolescence, similar to analysis among full samples (Figure 4.4). Interestingly, the benefit of exposure to quality green space among children who relocated appeared in late childhood, but then weakened at the end of the cohort (Figure 4.5).

Table 4.5 Multilevel linear regression of adjusted longitudinal associations between green space quality and prosocial behaviour disaggregated by child's sex

Variables	Girls		Boys	
	Unadjusted β (95% CI)	Adjusted β (95% CI)	Unadjusted β (95% CI)	Adjusted β (95% CI)
Main independent variable				
Green space quality *(ref: Do not agree)*				
Agree	**0.09 (0.01, 0.17)**	0.07 (-0.01, 0.15)	**0.18 (0.09, 0.27)**	**0.13 (0.04, 0.22)**
Strongly agree	**0.26 (0.17, 0.34)**	**0.13 (0.04, 0.22)**	**0.49 (0.40, 0.59)**	**0.27 (0.16, 0.38)**
Demographic characteristics				
Child's age *(ref: 4-5 years)*				
6-7 years		**0.56 (0.46, 0.66)**		**0.37 (0.26, 0.49)**
8-9 years		**0.58 (0.49, 0.68)**		**0.31 (0.20, 0.42)**
10-11 years		**0.81 (0.72, 0.90)**		**0.60 (0.49, 0.71)**
12-13 years		**0.56 (0.46, 0.66)**		**0.43 (0.31, 0.54)**
14-15 years		**0.31 (0.21, 0.41)**		**0.13 (0.01, 0.25)**
Child Indigenous status (*ref: Indigenous)*				
Not Indigenous		**0.32 (0.15, 0.50)**		-0.01 (-0.22, 0.21)
Child speaks a language other than English (*ref: No)*				
Yes		-0.05 (-0.14, 0.05)		**0.14 (0.02, 0.26)**
Family characteristics				
Caregiver education (*ref: ≤ High school)*				
> High school		**0.19 (0.10, 0.28)**		**0.19 (0.08, 0.30)**
Family weekly income (in thousands)		**0.03 (0.01, 0.06)**		**0.04 (0.01, 0.06)**
Family structure *(ref: One-caregiver family)*				
Two-caregiver family		**0.16 (0.07, 0.25)**		0.06 (-0.04, 0.16)
Number of siblings		**-0.07 (-0.10, -0.05)**		**-0.07 (-0.11, -0.04)**

Neighbourhood characteristics				
Neighbourhood safety *(ref: Do not agree)*				
Agree		0.06 (-0.07, 0.18)		0.09 (-0.05, 0.24)
Strongly agree		**0.22 (0.09, 0.35)**		**0.40 (0.25, 0.54)**
Area disadvantage (SEIFA) *(ref: High)*				
Moderate		**0.14 (0.07, 0.21)**		0.02 (-0.06, 0.11)
Low		0.02 (-0.06, 0.10)		-0.02 (-0.11, 0.08)
Area accessibility (ARIA) *(ref: Highly accessible)*				
Accessible		0.02 (-0.06, 0.09)		0.06 (-0.02, 0.15)
Moderately accessible		**0.16 (0.07, 0.25)**		**-0.10 (-0.20, -0.01)**
Remote to very remote		0.06 (-0.10, 0.23)		**-0.22 (-0.40, -0.05)**
Random effects, variance (95% CI)				
Level 3: Statistical Area 2	0.02 (-0.02, 0.06)	0.01 (-0.01, 0.02)	0.03 (-0.07, 0.13)	0.14 (-0.14, 0.42)
Level 2: Participant	0.95 (0.70, 1.21)	0.95 (0.68, 1.21)	1.88 (1.53, 2.22)	1.72 (1.29, 2.14)
Level 1: Observation	1.57 (1.31, 1.82)	1.46 (1.20, 1.73)	1.54 (1.22, 1.85)	1.52 (1.19, 1.86)
Deviance Information Criterion (DIC)	41883.40	40638.29	45306.19	44430.84

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

Table 4.6 Multilevel linear regression of adjusted longitudinal associations between green space quality and prosocial behaviour and effect modification by age, disaggregated by child's sex

Variables	Girls	Boys
	Adjusted β (95% CI)	Adjusted β (95% CI)
Interaction term		
Green space quality*child's age *(ref: Do not agree – 4-5 years)*		
Agree – 6-7 years	-0.24 (-0.51, 0.03)	0.20 (-0.11, 0.51)
Agree – 8-9 years	-0.18 (-0.43, 0.07)	**0.29 (0.01, 0.58)**
Agree – 10-11 years	-0.06 (-0.32, 0.19)	0.20 (-0.09, 0.49)
Agree – 12-13 years	0.00 (-0.24, 0.25)	0.23 (-0.06, 0.51)
Agree – 14-15 years	-0.14 (-0.42, 0.14)	0.12 (-0.21, 0.44)
Strongly agree – 6-7 years	-0.27 (-0.56, 0.03)	0.09 (-0.24, 0.42)
Strongly agree – 8-9 years	**-0.30 (-0.57, -0.04)**	0.02 (-0.29, 0.33)
Strongly agree – 10-11 years	-0.11 (-0.38, 0.17)	-0.13 (-0.44, 0.19)
Strongly agree – 12-13 years	-0.02 (-0.28, 0.25)	-0.05 (-0.35, 0.25)
Strongly agree – 14-15 years	-0.13 (-0.42, 0.17)	-0.28 (-0.62, 0.06)
Main independent variable		
Green space quality *(ref: Do not agree)*		
Agree	0.16 (-0.01, 0.32)	-0.04 (-0.22, 0.14)
Strongly agree	**0.25 (0.08, 0.43)**	**0.33 (0.12, 0.53)**
Demographic characteristics		
Child's age *(ref: 4-5 years)*		
6-7 years	**0.76 (0.54, 0.99)**	0.25 (-0.01, 0.50)
8-9 years	**0.76 (0.55, 0.97)**	0.17 (-0.08, 0.41)
10-11 years	**0.87 (0.65, 1.09)**	**0.54 (0.29, 0.78)**
12-13 years	**0.56 (0.36, 0.77)**	**0.33 (0.10, 0.56)**
14-15 years	**0.42 (0.17, 0.66)**	0.17 (-0.11, 0.45)

Child Indigenous status (*ref: Indigenous)*		
Not Indigenous	**0.32 (0.15, 0.50)**	-0.01 (-0.22, 0.21)
Child speaks a language other than English (*ref: No)*		
Yes	-0.05 (-0.15, 0.05)	**0.14 (0.03, 0.25)**
Family characteristics		
Caregiver education (*ref: ≤ High school)*		
> High school	**0.19 (0.10, 0.28)**	**0.19 (0.08, 0.30)**
Family weekly income (in thousands)	**0.03 (0.01, 0.06)**	**0.04 (0.01, 0.06)**
Family structure *(ref: One-caregiver family)*		
Two-caregiver family	**0.16 (0.07, 0.25)**	0.06 (-0.04, 0.16)
Number of siblings	**-0.07 (-0.10, -0.05)**	**-0.07 (-0.11, -0.04)**
Neighbourhood characteristics		
Neighbourhood safety *(ref: Do not agree)*		
Agree	0.05 (-0.07, 0.17)	0.09 (-0.06, 0.23)
Strongly agree	**0.21 (0.08, 0.34)**	**0.40 (0.25, 0.55)**
Area disadvantage (SEIFA) *(ref: High)*		
Moderate	**0.14 (0.06, 0.21)**	0.02 (-0.06, 0.10)
Low	0.02 (-0.06, 0.10)	-0.02 (-0.11, 0.07)
Area accessibility (ARIA) *(ref: Highly accessible)*		
Accessible	0.02 (-0.06, 0.09)	0.06 (-0.03, 0.15)
Moderately accessible	**0.16 (0.07, 0.24)**	**-0.10 (-0.21, -0.01)**
Remote to very remote	0.06 (-0.10, 0.23)	**-0.22 (-0.40, -0.05)**
Random effects, variance (95% CI)		
Level 3: Statistical Area 2	0.03 (-0.02, 0.08)	0.01 (-0.01, 0.01)
Level 2: Participant	0.92 (0.65, 1.19)	1.17 (1.52, 2.19)
Level 1: Observation	1.47 (1.21, 1.74)	1.52 (1.19, 1.85)
Deviance Information Criterion (DIC)	40681.62	44428.10

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

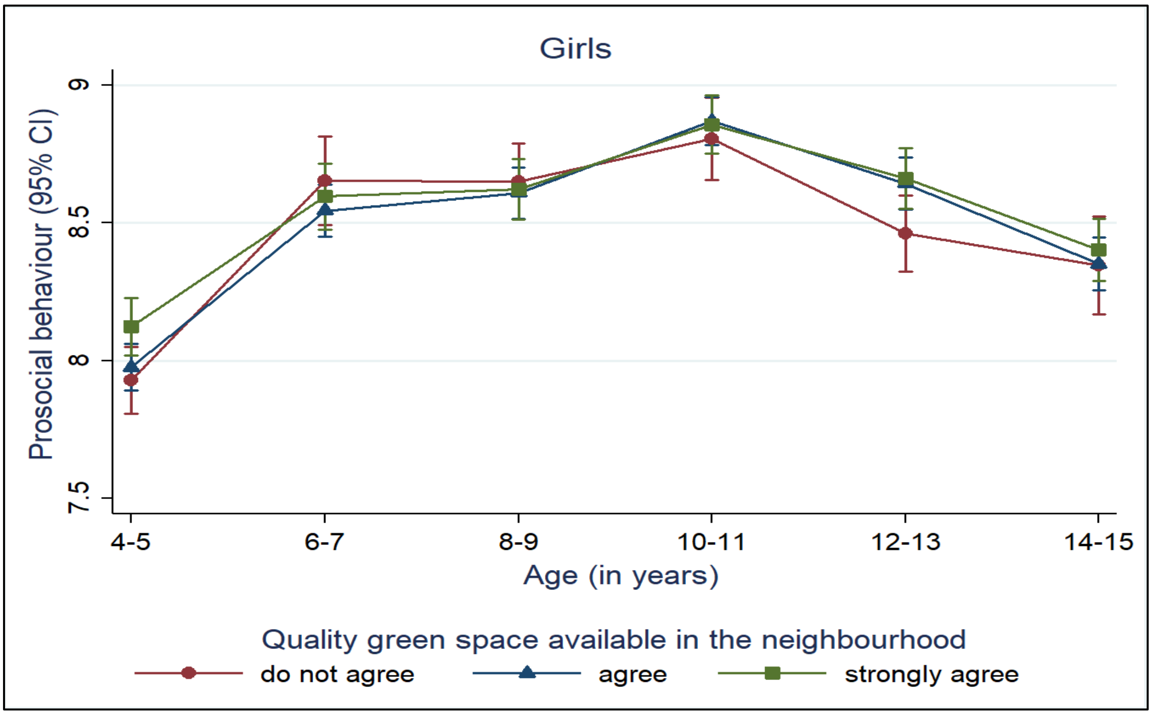

Figure 4.2 Prosocial behaviour development among girls by different levels of quality green space

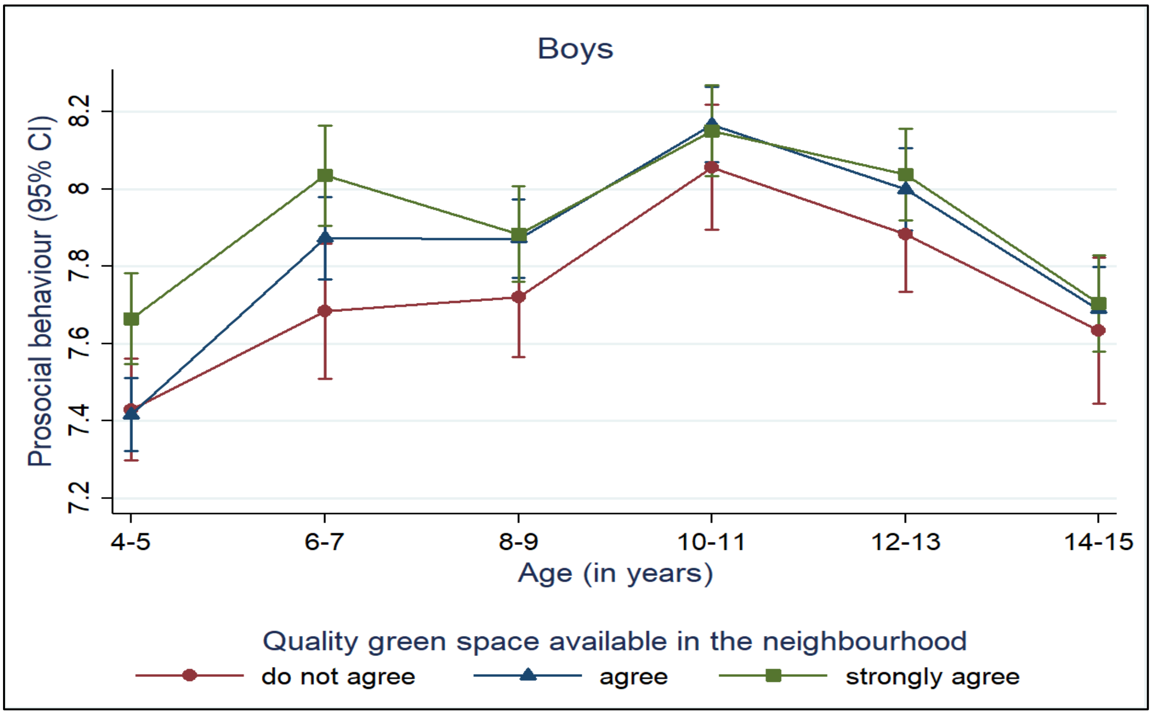

Figure 4.3 Prosocial behaviour development among boys by different levels of quality green space

Table 4.7 Multilevel linear regression of adjusted longitudinal associations between green space quality and prosocial behaviour disaggregated by history of changing neighbourhood

Variables	Children who did not change neighbourhood		Children who changed neighbourhood	
	Unadjusted β (95% CI)	Adjusted β (95% CI)	Unadjusted β (95% CI)	Adjusted β (95% CI)
Main independent variable				
Green space quality *(ref: Do not agree)*				
Agree	**0.12 (0.05, 0.20)**	**0.08 (0.01, 0.16)**	**0.16 (0.06, 0.26)**	**0.13 (0.03, 0.23)**
Strongly agree	**0.41 (0.32, 0.49)**	**0.23 (0.14, 0.32)**	**0.34 (0.23, 0.44)**	**0.17 (0.06, 0.28)**
Demographic characteristics				
Child's age *(ref: 4-5 years)*				
6-7 years		**0.43 (0.34, 0.53)**		**0.51 (0.39, 0.63)**
8-9 years		**0.46 (0.36, 0.55)**		**0.43 (0.31, 0.55)**
10-11 years		**0.76 (0.66, 0.85)**		**0.62 (0.50, 0.74)**
12-13 years		**0.54 (0.45, 0.64)**		**0.41 (0.29, 0.53)**
14-15 years		**0.26 (0.16, 0.36)**		**0.15 (0.02, 0.27)**
Child's sex *(ref: Male)*				
Female		**0.63 (0.57, 0.69)**		**0.69 (0.62, 0.76)**
Child Indigenous status (*ref: Indigenous)*				
Not Indigenous		**0.25 (0.07, 0.43)**		0.02 (-0.20, 0.23)
Child speaks a language other than English (*ref: No)*				
Yes		**0.11 (0.01, 0.21)**		-0.01 (-0.13, 0.12)
Family characteristics				
Caregiver education (*ref: ≤ High school)*				
> High school		**0.20 (0.11, 0.29)**		**0.18 (0.08, 0.29)**
Family weekly income (in thousands)		**0.04 (0.02, 0.06)**		**0.03 (0.01, 0.06)**

Family structure *(ref: One-caregiver family)*				
Two-caregiver family		**0.17 (0.08, 0.27)**		0.04 (-0.06, 0.14)
Number of siblings		**-0.06 (-0.09, -0.03)**		**-0.09 (-0.12, -0.06)**
Neighbourhood characteristics				
Neighbourhood safety *(ref: Do not agree)*				
Agree		0.10 (-0.02, 0.23)		0.05 (-0.09, 0.19)
Strongly agree		**0.30 (0.17, 0.43)**		**0.33 (0.17, 0.48)**
Area disadvantage (SEIFA) *(ref: High)*				
Moderate		**0.09 (0.02, 0.16)**		0.05 (-0.03, 0.14)
Low		0.02 (-0.06, 0.10)		-0.03 (-0.12, 0.07)
Area accessibility (ARIA) *(ref: Highly accessible)*				
Accessible		**0.13 (0.05, 0.20)**		-0.06 (-0.15, 0.03)
Moderately accessible		0.08 (-0.01, 0.16)		-0.03 (-0.14, 0.08)
Remote to very remote		**-0.21 (-0.38, -0.04)**		0.02 (-0.15, 0.20)
Random effects, variance (95% CI)				
Level 3: Statistical Area 2	0.02 (-0.04, 0.08)	0.02 (-0.05, 0.09)	0.41 (-0.21, 1.03)	0.04 (-0.01, 0.08)
Level 2: Participant	1.60 (1.36, 1.84)	1.46 (1.22, 1.70)	0.87 (0.19, 1.55)	1.23 (0.68, 1.77)
Level 1: Observation	1.46 (1.23, 1.68)	1.39 (1.17, 1.61)	1.87 (1.33, 2.41)	1.70 (1.17, 2.23)
Deviance Information Criterion (DIC)	52203.08	50717.71	35950.93	34627.07

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

Table 4.8 Multilevel linear regression of adjusted longitudinal associations between green space quality and prosocial behaviour and effect modification by age, disaggregated by history of changing neighbourhood

Variables	Children who did not change neighbourhood	Children who changed neighbourhood
	Adjusted β (95% CI)	Adjusted β (95% CI)
Interaction term		
Green space quality*child's age *(ref: Do not agree – 4-5 years)*		
Agree – 6-7 years	0.10 (-0.16, 0.36)	-0.21 (-0.54, 0.12)
Agree – 8-9 years	0.11 (-0.13, 0.35)	-0.06 (-0.37, 0.25)
Agree – 10-11 years	-0.02 (-0.26, 0.23)	0.23 (-0.09, 0.54)
Agree – 12-13 years	0.11 (-0.13, 0.35)	0.11 (-0.19, 0.42)
Agree – 14-15 years	-0.04 (-0.31, 0.23)	0.07 (-0.28, 0.42)
Strongly agree – 6-7 years	0.01 (-0.27, 0.28)	-0.21 (-0.58, 0.15)
Strongly agree – 8-9 years	-0.10 (-0.36, 0.16)	-0.21 (-0.54, 0.12)
Strongly agree – 10-11 years	-0.21 (-0.47, -0.05)	0.09 (-0.24, 0.43)
Strongly agree – 12-13 years	-0.10 (-0.36, 0.15)	0.10 (-0.22, 0.42)
Strongly agree – 14-15 years	-0.25 (-0.53, 0.04)	-0.10 (-0.47, 0.28)
Main independent variable		
Green space quality *(ref: Do not agree)*		
Agree	0.04 (-0.12, 0.19)	-0.10 (-0.10, 0.30)
Strongly agree	**0.33 (0.16, 0.50)**	0.22 (-0.01, 0.44)
Demographic characteristics		
Child's age *(ref: 4-5 years)*		
6-7 years	**0.38 (0.16, 0.60)**	**0.69 (0.40, 0.97)**
8-9 years	**0.43 (0.23, 0.63)**	**0.53 (0.27, 0.78)**
10-11 years	**0.83 (0.62, 1.04)**	**0.47 (0.21, 0.74)**
12-13 years	**0.52 (0.32, 0.72)**	**0.32 (0.07, 0.58)**
14-15 years	**0.36 (0.13, 0.59)**	0.14 (-0.17, 0.45)
Child's sex *(ref: Male)*		
Female	**0.63 (0.57, 0.69)**	**0.69 (0.62, 0.76)**

Child Indigenous status (*ref: Indigenous)*		
Not Indigenous	**0.25 (0.07, 0.42)**	0.02 (-0.21, 0.24)
Child speaks a language other than English (*ref: No)*		
Yes	**0.11 (0.13, 0.21)**	-0.01 (-0.13, 0.12)
Family characteristics		
Caregiver education (*ref: ≤ High school)*		
> High school	**0.20 (0.11, 0.29)**	**0.19 (0.08, 0.29)**
Family weekly income (in thousands)	**0.04 (0.02, 0.06)**	**0.03 (0.01, 0.06)**
Family structure *(ref: One-caregiver family)*		
Two-caregiver family	**0.17 (0.08, 0.27)**	0.04 (-0.06, 0.14)
Number of siblings	**-0.06 (-0.09, -0.03)**	**-0.09 (-0.12, -0.06)**
Neighbourhood characteristics		
Neighbourhood safety *(ref: Do not agree)*		
Agree	0.10 (-0.02, 0.22)	0.04 (-0.10, 0.18)
Strongly agree	**0.31 (0.17, 0.44)**	**0.32 (0.17, 0.47)**
Area disadvantage (SEIFA) *(ref: High)*		
Moderate	**0.09 (0.02, 0.17)**	0.05 (-0.04, 0.14)
Low	0.02 (-0.06, 0.10)	-0.03 (-0.13, 0.07)
Area accessibility (ARIA) *(ref: Highly accessible)*		
Accessible	**0.13 (0.05, 0.20)**	-0.06 (-0.15, 0.02)
Moderately accessible	0.08 (-0.01, 0.16)	-0.04 (-0.14, 0.07)
Remote to very remote	**-0.21 (-0.38, -0.04)**	0.20 (-0.15, 0.19)
Random effects, variance (95% CI)		
Level 3: Statistical Area 2	0.02 (-0.01, 0.04)	0.03 (-0.08, 0.13)
Level 2: Participant	1.48 (1.25, 1.71)	1.27 (0.73, 1.80)
Level 1: Observation	1.39 (1.17, 1.61)	1.66 (1.16, 2.17)
Deviance Information Criterion (DIC)	50688.70	34568.15

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

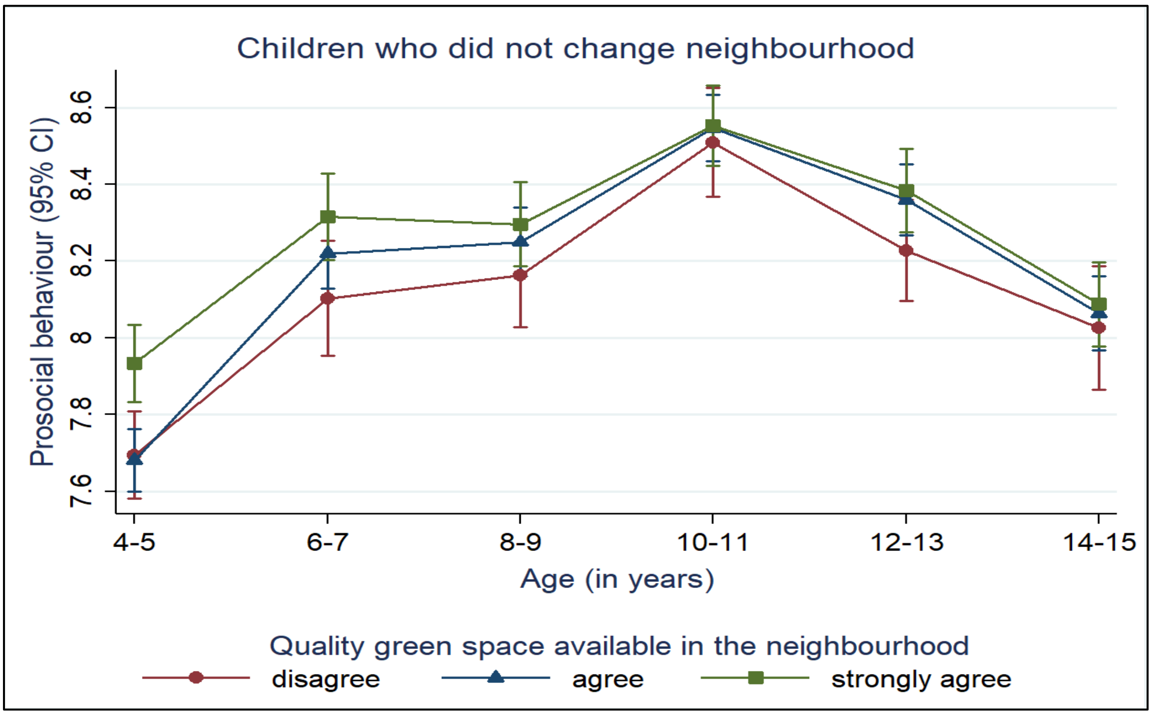

Figure 4.4 Prosocial behaviour development among children who did not change neighbourhood by different levels of quality green space

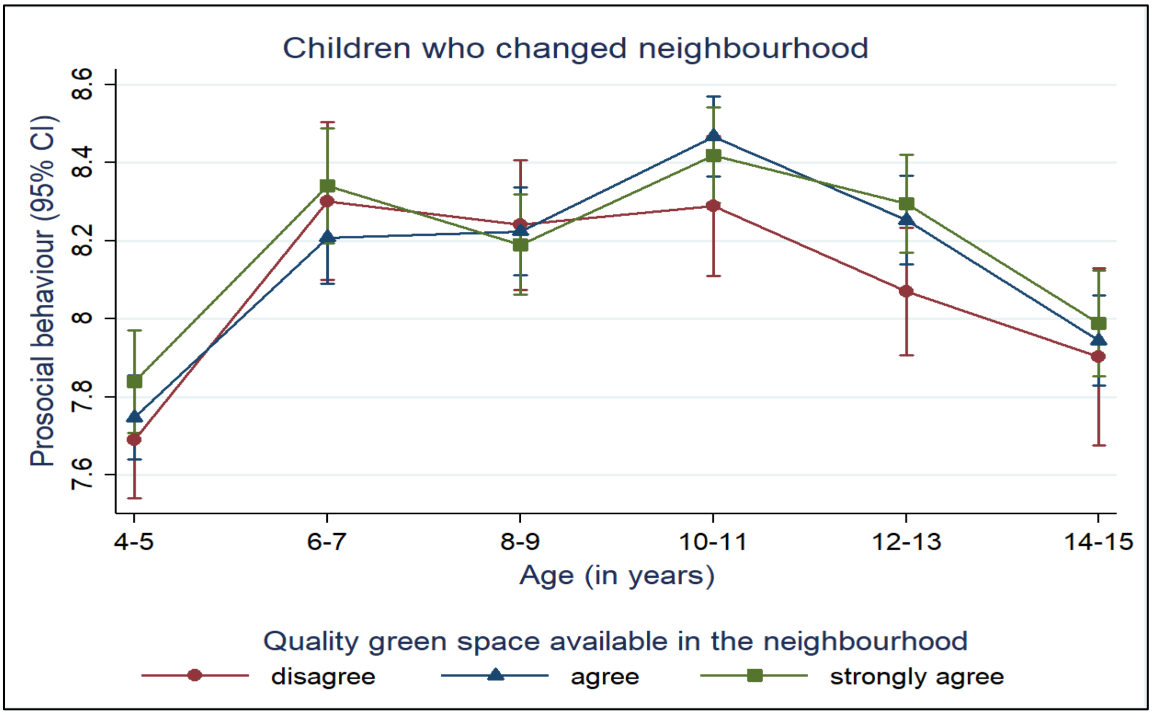

Figure 4.5 Prosocial behaviour development among children who changed neighbourhood by different levels of quality green space

4.2.5 Discussion

4.2.5.1 Association between green space quality and prosocial behaviour

Overall, the key finding from this study is that green space quality was associated with prosocial behaviour among children in the hypothesised direction after controlling for all socio-demographic characteristics at individual, family, and neighbourhood levels. The results are supportive of previous findings from observational studies focusing upon green space quantity (Richardson et al., 2017), proximity to green space (Balseviciene et al., 2014), children's spending time in green space (Andrusaityte et al., 2019), green space-related satisfaction (McEachan et al., 2018), as well as, interventional studies making use of in-person observation to assess green space exposure (Bates et al., 2018; Carrus et al., 2015; Dopko et al., 2019; Park et al., 2016; van Dijk-Wesselius et al., 2018). This study extends previous work by examining the green space quality, as well as, using the longitudinal approach to describe patterns of the association between green space and prosocial behaviour by age. This is the only second study investigating association between green space quality and prosocial behaviour. It is also the first study using a long period of observation (10 years). Just three longitudinal studies exist with short periods of observation (2 to 4 years) in this regard (McEachan et al., 2018; Richardson et al., 2017; Van Aart et al., 2018). Therefore, this study represents a good addition to current knowledge on green space and the development of prosocial behaviour.

Sensitivity analysis by child's sex found that the influence of quality green space was more pronounced among boys than girls, suggesting boys benefited more from the presence of quality green space in the neighbourhood. This might be due to the wording in the question used to assess green space quality that emphasises on parks, playgrounds, and play spaces. According to a noted psychologist, Eleanor Maccoby, boys and girls show different play preferences and styles and are not appealing to each other (Edwards et al., 2001); thus, they tend to play separately, particularly in large peer groups. Some theories and studies also suggest that play patterns among children tend to be gendered where boys are more likely to play farther away from home and engage in physical or active play when outdoors compared to girls (Eriksson et al., 2019; Pate et al., 2013; Torkar & Rejc, 2015). Boys are more likely to be involved in rough play style, space-consuming play and using sport equipment (e.g., soccer, basketball, etc.) (Børve & Børve, 2017). Meanwhile, girls have more enjoyment in play with smoothly flowing interaction and style (Edwards et al., 2001). A previous study conducted in playground settings suggest that girls enjoyed playing tag games, creating or making things, walking, sitting, and relaxing (Hyndman & Chancellor, 2015). Therefore, parks and play areas assessed in this present study perhaps offer attractive places for active play among boys that play important roles to foster the development of prosocial behaviour. Previous findings also suggest that the presence of boys in public playgrounds was negatively associated with girls' physical activity since boys tend to monopolise or occupy more space when playing (Reimers et al., 2018). In addition, girls are often found to play near home or indoors that might be due to caregivers have more concerns about the quality of play areas and safety for outdoor play among girls. While boys might be allowed to play outdoor independently, caregivers might have restrictions on unsupervised outdoor play among girls (Soori & Bhopal, 2002). This is supported by findings from a systematic review suggesting that caregivers' support or encouragement was associated with time spent for outdoor play among girls (Boxberger & Reimers, 2019).

The analysis by Richardson et al. (2017) of the Growing Up in Scotland survey found that increased total natural space was associated with higher prosocial behaviour among girls only. Natural spaces that include amenity areas might be more important for girls that are less involved in active play than boys. Therefore, different indicators of green space exposure might partially explain the inconsistent findings. Although quality parks and playgrounds may be just as important for boys in this context, findings from this study also indicate that girls had greater prosocial behaviour than boys in general. That might be due to personal factors (e.g., gender) that strongly influence child prosocial behaviour, which is consistent with prior work (Abdi, 2010; Kok et al., 2018).

Findings from sub-sample analyses among children who changed and did not change neighbourhood during the study period suggest that green space quality was consistently associated with prosocial behaviour among both groups. While the age-related pattern of green space quality-prosocial behaviour association among children living in the same neighbourhood was similar to the full samples, a different pattern was observed among those who have ever moved. The benefit of exposure to quality green space appeared in late childhood. This might be due to the majority of families moved to more affluent neighbourhoods with better quality of green space in the middle of the cohort. This is in line with findings from descriptive statistics suggesting the improvement of family socioeconomic status over time. By contrast, the remaining families under the unfavourable socioeconomic condition might move to deprived neighbourhoods with low quality of green space available. This potentially widens the disparities of prosocial behaviour by different exposures to green space quality. Further investigation is needed in this regard. Nevertheless, previous literature found that moving to greener areas bring better health outcomes, particularly mental health and wellbeing (Alcock et al., 2014).

Another important finding from this study was a hump-shaped association between prosocial behaviour and age. In alignment with data in the literature (Carlo et al., 2007; Eisenberg et al., 2015), prosocial behaviour appeared to increase during childhood and then started to decline in adolescence. The developmental level in late childhood is closely related to sympathy (Eisenberg et al., 2015). The pubertal development associated with increases in empathic concern might help explain the high level of prosocial behaviour during late childhood, and its decline in the later period (i.e., adolescence) (Masten et al., 2013). In addition, self-oriented modes of prosocial moral reasoning increase during adolescence and were found to be negatively associated with prosocial behaviour (Carlo et al., 2007; Carlo et al., 1996). Even though the exposure to quality green space was associated with better prosocial behaviour, it may not be sufficient to lessen the developmental decline in prosocial behaviour in adolescence.

Findings from the analysis among full and separate samples (Figure 4.1, 4.3, and 4.4, respectively) showed that exposure to quality green space during childhood is more important than in later period (adolescence) for the development of prosocial behaviour. Childhood could be considered as the critical period for association between green space and prosocial behaviour. Prosocial behaviour can intensively increase in complexity and frequency during childhood (Brownell, 2013; Dunfield, 2014). Frequent social interactions count as an important part of the nature of prosocial behaviour development (Oerlemans et al., 2018). Nearby green space provides attractive places that enable frequent social contacts among children through playing and engagement with others. Interactions with peers during play help children move beyond egocentrism (Warash et al., 2017) and offer opportunities for sharing, helping, and cooperating (Acar & Torquati, 2015) that foster prosocial behaviour during the critical period. In addition, the restorative effect of green space can potentially lead to positive emotionality, which, in turn, exhibits prosocial tendencies (Zhang et al., 2014). With high reliance on caregivers, children's contact with green space might be directly determined by the extent to which caregivers perceived that neighbourhood green space is of good quality and not a harm-inducing place. Therefore, caregiver perceptions on green space quality may largely influence children’s visit to and duration spent in green space, which, in turn, can enable the development of prosocial behaviour.

The effect of quality green space on prosocial behaviour was found to weaken in adolescence (Wave 6, 14-15 years). This might also indicate that caregiver perceptions on green space quality might be less important for adolescents' prosocial behaviour. The cognitive development among adolescents might help them assess the quality of neighbourhood environments more independently and they have much higher autonomous control in deciding how and where to spend time outside compared to young children dependent upon their caregivers (Choudhury et al., 2006; Sanders, 2013). Adult perceptions of the neighbourhood cannot fully represent adolescents’ thoughts on their surroundings (Nicole, 2004). In addition, the weak effect of favourable green space quality on adolescents’ prosocial behaviour might be due to types of green spaces assessed in this study, such as playgrounds and play space that are less relevant for adolescents’ activities. Studies from Finland (Mäkinen & Tyrväinen, 2008) and Netherlands (Bloemsma Lizan et al.) reported that green space values among adolescents were associated with its ability to enable physical activity and social activities. Therefore, other types of green space, such as sport ovals and activity parks might more suit adolescents’ needs. Compared to young children, adolescents might use green space less since they tend to spend most of their time in schools and mostly do screen activities during leisure time (Pavlova & Silbereisen, 2015). Therefore, psychosocial environments in school settings might play an important role in promoting prosocial development among adolescents (Plenty et al., 2015).

4.2.5.3 Study limitations

It is important to acknowledge that the indicator of green space quality focuses on parks, playgrounds, and play spaces. Indeed, the statement did not explicitly take into account other types of green space that may provide benefits for children in different age groups, such as woodlands and sport ovals. It is not known whether caregivers assessed the quality of all or only some types of green space in accordance with the aforementioned statement. In addition, playgrounds and play spaces are often found in parks, but not at all. Furthermore, the statement used to measure green space quality based on the availability of good parks, playgrounds, and play spaces in the neighbourhood might indirectly assess the green space quantity as well. Families who did not have green space in the neighbourhood would perhaps give a response as “disagree” for the availability of quality green space.

The use of the subjective measure to assess green space quality might be more relevant than the objective measure. A previous study suggests that the subjective measure of green space quality matters, and it is a more proximate determinant of the outcome than the objective measure (Zhang et al., 2017). The subjective measure takes into account the appraisal of residents over their environment, and their opinion tends to be relevant and consequential for policymaking since they have day-to-day experiences living in the neighbourhood (Hur et al., 2010). By contrast, the objective measure determined by experts that involve physical observation and audit tools might ignore the residents’ appraisal. Nevertheless, changes in green space quality reported by caregivers over childhood in this study might not be reflective of changes in actual green space quality since some factors could influence caregiver perceptions.

Different expectations and perceptions regarding girls' and boys' risk-taking behaviour and vulnerability in public places can influence caregivers' assessment on the quality of resources available in the neighbourhood (Eriksson et al., 2019). Boys are expected to involve more in risk-taking behaviour than girls (Morrongiello et al., 2010), whereas more attention and protection given to girls (Morrow, 2006). Features of green space that seem good for boys might be a stress-inducing hazard in the eyes of caregivers for girls. Further, it is logical to assume that changes in caregiver reports of green space quality may reflect changes in perceptions of what quality means for caregivers due to changes in needs relative to child age. Characteristics of green space with respect to facilities and safety would be required differently for different age groups (Kaymaz et al., 2017). For instance, caregivers might prefer green space with lawns and exercise trails for their older children or teens, but caregivers with young children might value more green space designed to enable play, such as parks with playgrounds and perceived as safe.

The findings from previous work suggest that affluent neighbourhoods had actual better green space quantity (Astell-Burt et al., 2014) and quality (Hoffimann et al., 2017) than deprived neighbourhoods. Neighbourhood socioeconomic inequalities in caregiver perceptions on green space quality might be based on actual conditions. Moreover, caregiver reports on green space quality could be linked to the interactions between neighbourhood factors (e.g., area disadvantage) and individual factors (e.g., caregiver education). The collective resource model suggests that people with fewer resources might be dependent and benefit more from living in neighbourhoods with more collective material and social resources (Stafford & Marmot, 2003). People with low socioeconomic status living in affluent areas could be more reliant and aware of locally provided resources and tend to have more favourable neighbourhood perceptions. Therefore, low socioeconomic families might rate neighbourhood green space quality as more favourable than high socioeconomic families living in the same neighbourhood.

Accordingly, caregiver perceptions on green space quality might be a relevant measure in evaluating association between green scape and child outcomes due to children are dependent on caregivers. However, the subjective measure based on caregiver report could be dependent upon individual values, positionality, and related circumstances. Therefore, further studies are warranted in this regard to understand what characteristics of green space perceived as higher or lower quality by caregivers and factors influence their preferences on particular types or elements of green space. This information is important for urban planners to improve the quality of neighbourhood green space in a targeted manner. Furthermore, since adolescents might start assessing their surroundings more independently, future work needs to understand how adolescents perceive the quality of green space and its association with their prosocial behaviour and health outcomes.

4.2.6 Summary

Green space quality was associated with prosocial behaviour among children in the positive direction after accounting for several socioeconomic and area-level factors. The benefit of exposure to favourable green space was observed mainly during childhood, but weakened in adolescence. The effect of green space quality on prosocial behaviour appeared to be relatively similar irrespective of history of changing neighbourhood, but found to differ by sex. Boys benefited more by the presence of favourable green space quality in the neighbourhood. The findings from this study suggest the need to improve and maintain the quality of green space to support the development of prosocial behaviour across childhood and adolescence. In addition, identifying preferred characteristics of quality green for different genders and age groups is also vital to maximise the benefits of green space for all.

Chapter 5: Trajectory of caregiver perceived quality green space and the development of prosocial behaviour

5.1 Preface

Findings from the second study presented in Chapter 4 suggest the association between the availability of quality green space reported by caregivers and child prosocial behaviour. However, the previous study did not investigate whether children had different patterns of caregiver-reported quality green space across the study period. Using longitudinal data with repeated measures on green space quality helped disentangle trajectories of green space quality reported by caregivers over time and investigate which are more valuable for prosocial behaviour development.

In addition to the second study, this present (third) study, presented in Chapter 5, also contributed to answering the second research question: *"To what extent is the accumulation of, and changes in the availability of quality green space perceived by caregivers associated with the development of prosocial behaviour?"*. While the previous study in Chapter 4 aimed to establish the association, this present study extends the previous findings by examining the accumulation of quality green space perceived by caregivers over 10 years and whether this matters for the development of prosocial behaviour. Using latent class analysis, some trajectory classes were developed, denoting different levels of exposure to quality green space. In addition, this study examined the potential role of quality green space in reducing socioeconomic inequalities in prosocial behaviour. Furthermore, some potential effect modifiers of the association between trajectory classes of green space quality and prosocial behaviour were tested by fitting a two-way interaction term. The study presented in this chapter is as it was published (Appendix E) with minor adjustments for tables, figures, referencing style, and overall thesis formatting requirements. Findings from this study are essential as a basis for further investigation in identifying potential pathways linking green space quality to prosocial behaviour.

Citation

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The findings from this chapter were virtually presented at the following conferences:

1. The 4th Early Career Researchers Conference on Environmental Epidemiology – ISEE Young 2021, ISEE Europe Chapter and the Swiss TPH on 18-19 February 2021 (Appendix J),
2. The 14th Biennial Conference of the Asian Association of Social Psychology (AASP) 2021 on 31 July 2021 (Appendix K).

5.2 The published article: “Association between caregiver perceived green space quality and the development of prosocial behaviour from childhood to adolescence: Latent class trajectory and multilevel longitudinal analyses of Australian children over 10 years”

5.2.1 Abstract

Background: Studies investigating the potential role of neighbourhood green space quality on the development of prosocial behaviour among children are sparse. This study aimed to investigate the longitudinal association between caregiver perceived green space quality and child prosocial behaviour, and identify potential effect modifiers of the association.

Methods: This was a longitudinal study using data from the Longitudinal Study of Australian Children, involving 4,969 children aged 4-5 years that were biennially followed-up from 2004 to 2014. Prosocial behaviour was assessed using the prosocial scale from Goodman’s Strengths and Difficulties Questionnaire. Green space quality was measured based on caregiver perception of the availability of neighbourhood parks, playgrounds, and play spaces of good quality. Latent class analysis was used to partition children into groups denoting different levels of caregiver perceptions of green space quality accumulated over 10 years. Multinomial logistic regression was used to examine the likelihood of being in groups with favourable perception of green space quality. Multilevel linear regression was used to examine associations between trajectory groups and prosocial behaviour. Separate multivariate models were developed to assess the potential role of quality green space in reducing prosocial behaviour related inequalities. Furthermore, two-way interaction terms were added into the models to identify potential effect moderation.

Results: There were six trajectory classes of green space quality perceived by caregivers. The likelihood of being in groups with better green space quality varied by neighbourhood circumstances. Children with consistently very good quality green space had higher prosocial behaviour (β=0.35; 95%CI=0.23, 0.47) than those with low quality green space. Better prosocial behaviour was also observed among children whose caregiver perception of green space quality trended from good to very good (β=0.23; 95%CI=0.11, 0.35) and from very good to good (β=0.31; 95%CI=0.20, 0.42) compared to children with consistently low-quality green space. Very good quality green space perceived by caregivers over time potentially attenuates socioeconomic inequalities in prosocial behaviour. Green space quality-prosocial behaviour association was stronger among boys, children speaking only English at home, those living in more affluent areas, and remote areas.

Conclusion: Trajectory of caregiver perceived green space quality was positively associated with prosocial behaviour. The findings suggest that improving the quality of green space to be very good quality, particularly in deprived and less accessible areas may help improve prosocial behaviour in children and adolescents.

5.2.2 Introduction

Prosocial behaviour has been recognised as an important part of child and youth development (Dunfield, 2014). Being prosocial has been found to be associated with positive psychological, social, and health outcomes (Aknin et al., 2012; Caputi et al., 2012; Carlo et al., 2012; Collie et al., 2018; Flouri & Sarmadi, 2016; Flynn et al., 2015; Gerbino et al., 2018; Proctor & Linley, 2014; Qureshi et al., 2019; Yang et al., 2019), and therefore, promoting its development from early ages is important. Prosocial behaviour refers to a range of behaviours that bring benefits for, or promote positive relationships with others (Hay, 1994). Sharing, offering help, cooperating, and comforting are some examples of prosocial behaviour among children (Hammond et al., 2015; Piotrowski et al., 2015; Wittek & Bekkers, 2015).

Current evidence suggests that nearby green space may facilitate the development of child prosocial behaviour through three linking pathways: harm mitigation, building capacities, and restoring capacities (Markevych et al., 2017; Putra et al., 2020). Green space potentially reduces harmful environmental exposure (e.g., air pollution) that have detrimental effects on the cognitive development during susceptible periods (e.g., prenatal), which, in turn, influences the development of prosocial behaviour (Ren et al., 2019). The presence of green space might also buffer psychosocial stressors due to living in unfavourable neighbourhoods. Based on the building capacities pathway, nearby green space might facilitate social interactions and encourage children to be physically active that can potentially foster their prosocial behaviour (Di Bartolomeo & Papa, 2017). In addition, the restorative effect of green space helps develop prosocial tendencies through increasing positive emotionality via attention recovery (Kaplan, 1995; Ohly et al., 2016) and stress reduction (Ulrich, 1983).

Data on the association between green space quantity and child prosocial behaviour is weak and inconsistent; and the potential role of the quality of green space in influencing prosocial behaviour has received less attention (Putra et al., 2020). Understanding how children access nearby green space is important in evaluating the association between green space and child outcomes due to children, particularly at young ages, are dependent on their parents to access green space (Feng & Astell-Burt, 2017a, 2017d). Parents or caregivers also tend to regulate their child's outdoor activities (Datar et al., 2013; Kalish et al., 2010), and hence, caregiver perception of neighbourhood green space quality might have direct influence on children's contacts with and spending time in green space (Kaymaz et al., 2017). Therefore, caregiver perception of green space quality is a more relevant measure to examine green space-prosocial behaviour association among children than the amount of green space available locally.

According to life course epidemiology theory, exposure to social and physical factors during the life course potentially have long-term effects on developing disease risk or health outcomes in later life (Ben-Shlomo et al., 2014; Kuh et al., 2003). This implies that accumulated exposure to high quality relative to low quality green space across childhood may bring better benefits for the development of prosocial behaviour. Moreover, based on a theory of differential exposure (Diderichsen et al., 2018), uneven distribution of quality neighbourhood green space by socioeconomic groups within the Australian context (Feng & Astell-Burt, 2017d) might lead to prosocial behaviour inequalities. Meanwhile, greater exposure to green space was found to narrow socioeconomic inequalities in health outcomes due to "salutogenic" effects (Mitchell & Popham, 2008; Mitchell et al., 2015). However, there is no study exploring the potential role of quality green space in reducing child prosocial behaviour related inequalities, indicating studies are needed to fill this knowledge gap.

Another theory, differential effect posits that the effect of cause(s) differs by socioeconomic strata (Diderichsen et al., 2018). The effects of exposure to the same quality level of green space might vary by children's characteristics. Previous work showed that association between green space and prosocial behaviour varied by some socioeconomic variables. For example, the child's sex (Richardson et al., 2017) and ethnic background (McEachan et al., 2018) were found as effect modifiers. Studies conducted in the UK (Richardson et al., 2017) and Lithuania (Balseviciene et al., 2014) reported the modifying effect of caregiver education on green space-prosocial behaviour association. Given the modifying effect of socioeconomic characteristics may work differently in different study contexts, further investigation is warranted in this regard.

A previous analysis using data from the Longitudinal Study of Australian Children (LSAC) investigated the association between caregiver agreement on the quality of neighbourhood green space (i.e., do not agree, agree, strongly agree) and child prosocial behaviour (Putra et al., 2021b). Using multilevel regression analysis, quality green space reported by caregivers was positively associated with child prosocial behaviour. Additional sensitivity analyses suggest the stronger association among boys, but no differences in the association by the history of residential movement. While that study aimed to establish the association, this present study is dedicated to unpacking the potential relevance of socially stratified life-course processes that may underpin that association using more appropriate statistical methods. This present study used latent class analysis to pattern the accumulation of, changes in the availability, or differences in trajectories of caregiver perceptions of green space quality accumulated over time and then investigated whether the trajectories influence the development of children's prosocial behaviour. In addition, this present study examined whether the accumulation of quality green space perceived by caregivers can narrow socioeconomic inequalities in prosocial behaviour, which is currently missing from the literature. Furthermore, investigating potential modifying effects of ethnicity, and family and neighbourhood socioeconomic status on the association between trajectories of green space quality and prosocial behaviour was not within the scope of the previous study, but presented in this current study. Therefore, this present study extends the previous work by examining the association between trajectory classes of caregiver perceived green space quality and prosocial behaviour, investigating the potential role of green space quality in narrowing inequalities in prosocial behaviour, and testing potential effect modifiers. Findings from this study potentially provide substantive addition to the current knowledge and help inform potential targeted interventions.

This present study makes use of LSAC, the same dataset as was used in the previous analysis (Putra et al., 2021b). As stated before, this present study extends previous findings with different study objectives. Specifically, this study aimed to answer following questions: *"To what extent is the accumulation of, and changes in the availability of quality green space perceived by caregivers associated with the development of prosocial behaviour from childhood to adolescence?"*, *"To what extent does quality green space perceived by caregivers attenuate child prosocial behaviour related inequalities?"*, and *"To what extent do socioeconomic characteristics modify the association between caregiver-perceived green space quality and child prosocial behaviour?"*. This study hypothesised that better green space quality perceived by caregivers over time is associated with greater prosocial behaviour and attenuates prosocial behaviour inequalities, and some socioeconomic characteristics may modify the association between green space quality and prosocial behaviour.

In this study, the term, "green space" refers to public areas with natural vegetation that can include any amenities that enhance its quality and utilisation. Following LSAC data, the presence of good parks, playgrounds, and play spaces was used to define quality green space in this study. In the Australian context, a park is defined as "an area of land within a town, set aside for public use, often landscaped with trees and gardens, and with recreational and other facilities" (Australian Government, 2018). Parks in Australia are often found as recreational and public areas with trees, mown grassland, gardens that can include other facilities such as playgrounds, play spaces, walking and nature trails, etc.

Although the survey question from LSAC specifies 'parks', it may also be assumed that other aspects of nearby greenery such as reserves and linear green spaces along river corridors might be subsumed within the definition by responding caregivers. Since this study assessed green space quality, its definition was not only limited to public areas with vegetation, but also the presence of any facilities to support the utilisation.

5.2.3 Methods

5.2.3.1 Study design and samples

This was a longitudinal study using data from the older, "Kindergarten" (K) cohort of the Longitudinal Study of Australian Children (LSAC). This nationally representative cohort study is a large-scale project conducted in collaboration by three national bodies: Department of Social Services (DSS), Australian Institute of Family Studies (AIFS), and Australian Bureau of Statistics (ABS). Further detailed information regarding LSAC methodology is available elsewhere (Australian Institute of Family Studies, 2005, 2018). In brief, the Medicare enrolment database was used to recruit the participants. This study applied a two-stage clustered design by selecting representative postcodes at the first step, taking into account geographical stratification by state, capital city statistical division, and urban-rural communities. At the second step, children were recruited from selected 311 postcodes. For the K cohort, 4,983 children aged 4-5 years with their caregivers were successfully recruited in 2004 (Wave 1) and were then biennially followed-up (Wave 2 and hereafter). Initial follow-up rates were about 90% which declined to around 70% by Wave 6 (2014).

This present study used child records from Waves 1 to 6 since data on green space quality and prosocial behaviour were consistently collected in these waves. Cases with missing values on the outcome (prosocial behaviour) were omitted. A total of 24,418 (95.98%)

records were included in the analysis from 25,440 records from Waves 1 to 6. Compared to the analytic sample, the children's observations with missing data for prosocial behaviour had higher proportions of Indigenous children, children who spoke a language other than English at home, children who lived in a single-caregiver household, with caregivers who had ≤ high school education, in less safety neighbourhood, in disadvantage, and remote areas. Children with missing data also had more siblings and a lower family weekly income compared to children in the analytic sample (Table 5.1).

Table 5.1 Different characteristics between children's observations without (analytic sample) and with missing data on prosocial behaviour

Variables	Observations without missing data on prosocial behaviour	Observations with missing data on prosocial behaviour	p-value
	n= 24,418 (%*)	n=1,022 (%*)	
Individual characteristics			
Child's sex			
Female	11,980 (48.74)	487 (46.89)	0.377[a]
Male	12,438 (51.26)	535 (53.11)	
Child Indigenous status			
Not Indigenous	23,694 (96.65)	960 (93.51)	<0.001[a]
Indigenous	716 (3.33)	62 (6.49)	
missing/not reported	*8 (0.02)*		
Child speaks a language other than English			
No	21,934 (87.34)	780 (68.50)	<0.001[a]
Yes	2,484 (12.66)	242 (31.50)	
Family characteristics			
Caregiver education			
≤ High school	3,131 (15.26)	230 (27.04)	<0.001[a]
> High school	21,276 (84.69)	770 (70.75)	
missing/not reported	*11 (0.05)*	*22 (2.21)*	
Family weekly income (in thousands), mean (SD)	1.76 (1.40)	1.32 (1.06)	<0.001[b]
Family structure			
One-caregiver family	3,710 (17.07)	220 (23.61)	<0.001[a]
Two-caregiver family	20,706 (82.91)	783 (74.45)	
missing/not reported	*2 (0.02)*	*19 (1.94)*	
Number of siblings, mean (SD)	1.59 (1.09)	2.01 (1.43)	<0.001[b]
Neighbourhood characteristics			
Neighbourhood safety			
Do not agree	1,560 (7.22)	52 (5.21)	0.031[a]
Agree	12,756 (52.46)	351 (33.55)	
Strongly agree	9,038 (35.38)	209 (19.38)	
missing/not reported	*1,064 (4.95)*	*410 (41.86)*	
Area disadvantage (SEIFA)			
High	8,812 (38.55)	477 (51.44)	<0.001[a]
Moderate	7,971 (32.34)	324 (29.72)	
Low	7,632 (29.10)	221 (18.84)	
missing/not reported	*3 (0.01)*		
Area accessibility (ARIA)			
Highly accessible	12,766 (53.55)	549 (58.57)	0.034[a]
Accessible	6,227 (26.07)	239 (22.18)	
Moderately accessible	4,235 (16.14)	161 (13.88)	
Remote to very remote	942 (3.35)	54 (3.62)	
missing/not reported	*248 (0.89)*	*19 (1.74)*	

**weighted percentage; [a]Chi-square test; [b]Independent sample t-test*

5.2.3.2 Prosocial behaviour

Caregiver report on the prosocial scale from Goodman's Strengths and Difficulties Questionnaire (SDQ) was used to assess child prosocial behaviour. The SDQ is considered as a valid measure and widely applied to assess child wellbeing in different settings (Richardson et al., 2017; Theunissen et al., 2015). Caregivers were asked to give a response as not true, somewhat true, or certainly true (each option was scored as 0, 1, and 2, respectively) for the five statements: *"considerate of other people's feelings"*, *"share readily with other children"*, *"helpful if someone is hurt, upset or feeling ill"*, *"kind to younger children"*, and *"often volunteers to help others (parents, teachers, other children)"*. The total score was summed up, resulting in a range of 0 to 10, with a greater score indicates better child prosocial behaviour.

5.2.3.3 Green space quality

Green space quality was measured using caregiver perception on the quality of neighbourhood green space. Caregivers were asked to rate on the following statement: "*There are good parks, playgrounds and play spaces in this neighbourhood*". Four responses were provided: "*strongly disagree*", "*disagree*", "*agree*", and "*strongly agree*". Previous studies have used this statement to measure green space quality in relation to general health (Feng & Astell-Burt, 2017a) and wellbeing (Feng & Astell-Burt, 2017c, 2017d) among children. Caregiver responses as "*disagree*" and "*strongly disagree*" were grouped into a new category "do not agree" due to small percentages for each initial response, whilst other responses as "*agree*" and "*strongly agree*" remained unchanged as was done in previous studies (Feng & Astell-Burt, 2018; Putra et al., 2021b). Their perceptions on green space quality over a period of 10 years (Waves 1 to 6) were then grouped into some trajectory classes (see the sub-section of data analysis).

5.2.3.4 Covariates

Potential influences of other variables were taken into account. The child's sex (male, female), age groups according to waves (Wave 1: 4-5 years to Wave 6: 14-15 years), Indigenous status (yes: Australian aboriginal or Torres Strait Islander, no), and speaking a language other than English at home (yes, no) represented individual characteristics. Meanwhile, family's characteristics consisted of the highest educational level of the caregiver in the family (≤ high school, > high school), a total weekly income of caregivers (in thousand AUD) (Blakemore et al., 2006; Sanders et al., 2015), family structure (one-caregiver, two-caregiver family), and the number of siblings. Further, area-level socioeconomic circumstances included area disadvantage, measured using Index of Relative Socioeconomic Disadvantage from the Socio-economic Indexes for Areas (SEIFA) (Australian Bureau of Statistics, 2006) (classified as "high", "moderate", "low"), area accessibility, determined using the Accessibility-Remoteness Index of Australia (ARIA) (Department of Health and Aged Care, 2001) (classified as "highly accessible", "accessible", "moderately accessible", "remote to very remote" areas), and neighbourhood safety, assessed using caregiver reports on the statement: *"This is a safe neighbourhood."* (responses were re-regrouped as "do not agree", "agree", and "strongly agree").

5.2.3.5 Data analysis

Latent class analysis was conducted using STATA to categorise a group of child observations into trajectory classes based on caregiver reports on ordinal variables of green space quality across the study period (MacDonald, 2018; Porcu & Giambona, 2016). This analysis is commonly used to partition samples into subgroups where samples in the same group share a similar scoring pattern on some measured variables (Kongsted & Nielsen, 2017). Multinomial logistic regression was used to identify factors associated with trajectory class membership. Following the identification of trajectory groups, MLwIN V3.01 (Rasbash et al., 2017) was employed to run multilevel linear regression analysis to examine longitudinal associations between trajectory classes and prosocial behaviour. Three-level multilevel models were fitted with participants' observations at each wave at level 1, nested within the individual at level 2 and statistical areas, level 2 (SA2s) at level 3. This analysis is suitable for structured hierarchical data (Hair Jr. & Fávero, 2019), and takes into account the assumption of correlated observations for longitudinal analysis with repeated-measure data (Goldstein, 2011; Van Der Leeden, 1998). In addition, cross-classified model was performed using the Markov chain Monte Carlo (MCMC) method (Browne et al., 2001), since individuals were nested within multiple SA2s in the study period (the number of children who ever moved to different SA2s = 1,860; 37.43%).

Different multilevel linear regression models were developed to assess longitudinal associations between trajectory groups and prosocial behaviour by adding different groups of covariates. Better model was indicated by smaller values of deviance information criterion (DIC) (Li et al., 2017). Adjusted regression coefficients (β) along with 95% credible intervals (CIs) were reported. Furthermore, separate multivariate models by trajectory classes were developed to identify whether accumulated caregiver perceptions of quality green space potentially attenuate prosocial behaviour related inequalities. In addition, possible modifying effects of socioeconomic characteristics on green space quality-prosocial behaviour association were tested by fitting two-way interaction terms. Potential effect modifiers that were tested in this study included child's sex, Indigenous status, language spoken at home, caregiver education, neighbourhood safety, area disadvantage, and area accessibility.

5.2.3.6 Ethical considerations

The ethics approval for LSAC was obtained from the AIFS Ethics Committee. The Human Research Ethics Committee, University of Wollongong also approved this present study (No. 2019/433).

5.2.4 Results

Table 5.2 describes the baseline characteristics of 4,969 children. Prosocial behaviour among children aged 4-5 years was relatively high (mean=7.73; SD=1.80). About equal proportions between girls (48.86%) and boys (51.14%) were involved from the first commencement. Only few children were reported as Indigenous (3.91%) and spoke a language other than English at home (13.76%). Regarding household socioeconomic conditions, most caregivers had above high school education level (79.62%) and the family-combined income was approximately AUD 1,270 per week. Most children lived in two-caregiver families (85.11%) and had one to two siblings. A majority of caregivers agreed (47.77%) or strongly agreed (28.38%) that the green space in their neighbourhoods was of good quality. Caregivers also tended to consider their neighbourhood as safe (57.93% and 32.40% for "agree" and "strongly agree", respectively). In addition, nearly 30% of children lived in affluent areas and more than half (55.28%) lived in highly accessible areas.

Table 5.2 Baseline characteristics of children (Wave 1)

Variables	n= 4,969 (%*)
Dependent variable	
Prosocial behaviour, mean (SD)	7.73 (1.80)
Main independent variable	
Green space quality	
Do not agree	1,118 (23.39)
Agree	2,366 (47.77)
Strongly agree	1,465 (28.38)
missing/not reported	*20 (0.46)*
Individual characteristics	
Child's sex	
Female	2,443 (48.86)
Male	2,526 (51.14)
Child Indigenous status	
Not Indigenous	4,780 (96.06)
Indigenous	187 (3.91)
missing/not reported	*2 (0.03)*
Child speaks a language other than English	
No	4,356 (86.24)
Yes	613 (13.76)
Family characteristics	
Caregiver education	
≤ High school	918 (20.33)
> High school	4,048 (79.62)
missing/not reported	*3 (0.05)*
Family weekly income (in thousands), mean (SD)	1.27 (0.86)
Family structure	
One-caregiver family	692 (14.89)
Two-caregiver family	4,277 (85.11)
Number of siblings, mean (SD)	1.51 (1.07)
Neighbourhood characteristics	
Neighbourhood safety	
Do not agree	419 (9.30)
Agree	2,881 (57.93)
Strongly agree	1,652 (32.40)
missing/not reported	*17 (0.38)*
Area disadvantage (SEIFA)	
High	1,786 (37.19)
Moderate	1,609 (32.94)
Low	1,574 (29.87)
Area accessibility (ARIA)	
Highly accessible	2,692 (55.28)
Accessible	1,160 (24.07)
Moderately accessible	855 (16.12)
Remote to very remote	216 (3.80)
missing/not reported	*46 (0.73)*

**weighted percentage*

5.2.4.1 Trajectory groups of caregiver perception of green space quality

There were six classes estimated using latent class analysis that represented groups of children who experienced different trajectories of caregiver perception of green space quality over a 10-year period (Figure 5.1). The number of classes was determined based on the lowest value of the Bayesian Information Criterion (BIC) (Nylund et al., 2007). Class 1 ("consistently in low quality") consisted of 4.43% of participants whose caregivers predominantly perceived low quality green space across the study period. Class 2 ("consistently in between low and good quality") included children whose caregivers rated neighbourhood green space between low and good quality over a period of 10 years (22.72%). Class 3 ("consistently in good quality") accounted for 28.17% of the sample with good quality green space. Those in Class 4 whose caregivers perceived good quality green space earlier and then very good quality as their children got older (referred as "increasing quality from good to very good" class) (11.31%). Whereas, caregiver perceptions of green space quality for children in Class 5 (20.19%) trended from very good quality to good quality across childhood (referred as "decreasing quality from very good to good" class). The last one, Class 6 ("consistently in very good quality") represented those children whose caregivers reported for very good quality green space over time, which accounted for 13.18% of the sample. Upward or downward mobilities of any trajectory class in any time point suggest that the class also included some children's observations that had slightly different patterns from the overall pattern of that class.

Characteristics of children, family, and neighbourhood by trajectory classes are presented in Table 5.3). Multinomial logistic regression was used to identify the likelihood of being in Classes 2 to 6 relative to Class 1 "consistently in low quality" (Table 5.4). There were no significant differences in the likelihood of being in any classes with better quality green space relative to class with consistent low quality green space by child's sex, ethnicity, caregiver education, family income, family structure, and number of siblings. However, living in neighbourhoods that were perceived to be safer and living in more accessible areas were significantly associated with increased likelihood of being in classes with better quality green space (Classes 2 to 6) relative to Class 1. Similarly, children in Classes 3 to 6 were more likely to live in less disadvantage areas, relative to those in Class 1.

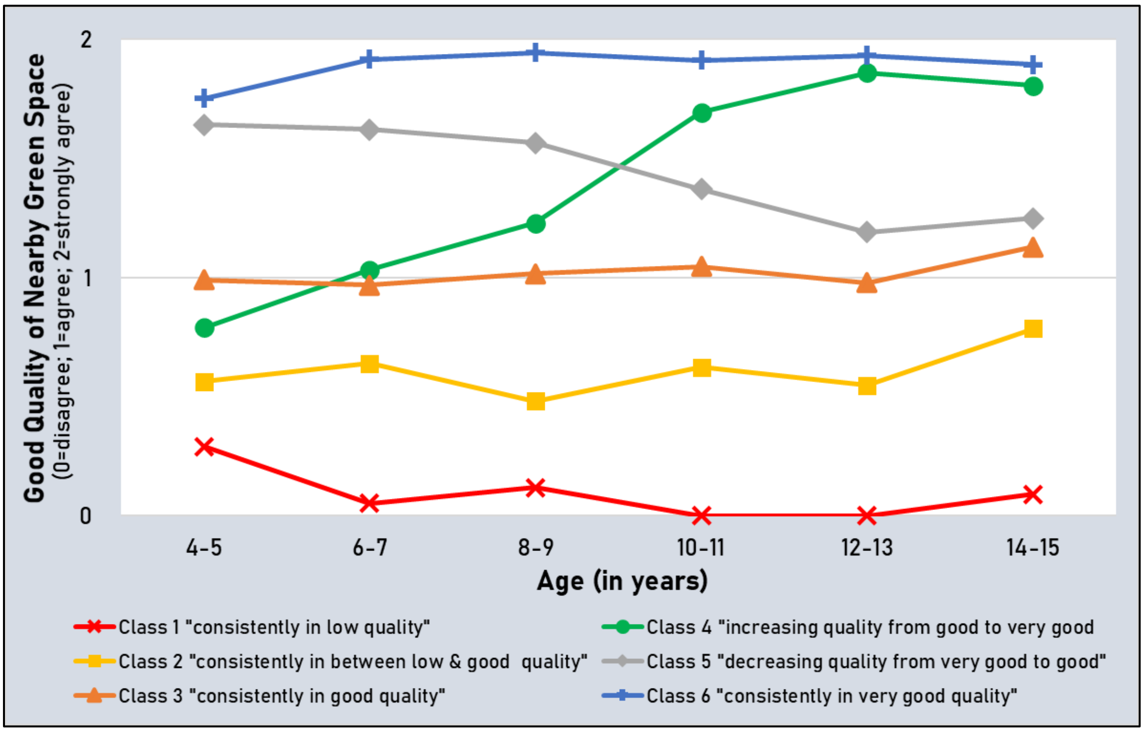

Figure 5.1 Different trajectory classes of caregiver perception of green space quality

Table 5.3 Characteristics of children's observations by trajectory classes

Variables	Total observation = 24,418 (%*)	Trajectory Classes n (%*)					
		Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Dependent variable							
Prosocial behaviour, mean (SD)	8.13 (1.79)	7.95 (1.81)	7.96 (1.91)	8.00 (1.79)	8.22 (1.77)	8.27 (1.68)	8.43 (1.64)
Individual characteristics							
Child's sex							
Female	11,980 (48.74)	578 (46.67)	2,708 (50.26)	3,138 (48.63)	1,400 (46.28)	2,419 (49.63)	1,737 (48.23)
Male	12,438 (51.26)	633 (53.33)	2,635 (49.74)	3,343 (51.37)	1,634 (53.72)	2,372 (50.37)	1,821 (51.77)
Child Indigenous status							
Not Indigenous	23,694 (96.65)	1,172 (97.34)	5,127 (95.33)	6,311 (96.77)	2,922 (96.40)	4,658 (97.06)	3,504 (97.98)
Indigenous	716 (3.33)	39 (2.66)	212 (4.64)	170 (3.23)	108 (3.44)	133 (2.94)	54 (2.02)
missing/not reported	*8 (0.02)*		*4 (0.02)*		*4 (0.16)*		
Child speaks a language other than English							
No	21,934 (87.34)	1,133 (91.57)	4,750 (86.75)	5,777 (85.96)	2,706 (86.49)	4,306 (87.53)	3,262 (89.95)
Yes	2,484 (12.66)	78 (8.43)	593 (13.25)	704 (14.04)	328 (13.51)	485 (12.47)	296 (10.05)
Family characteristics							
Caregiver education							
≤ High school	3,131 (15.26)	181 (17.27)	900 (19.41)	948 (17.25)	291 (11.99)	525 (13.18)	286 (9.52)
> High school	21,276 (84.69)	1,030 (82.73)	4,436 (80.45)	5,533 (82.75)	2,742 (87.96)	4,263 (86.77)	3,272 (90.48)
missing/not reported	*11 (0.05)*		*7 (0.14)*		*1 (0.04)*	*3 (0.05)*	
Family weekly income (in thousands), mean (SD)	1.76 (1.40)	1.55 (1.24)	1.51 (1.09)	1.67 (1.23)	1.96 (1.62)	1.79 (1.35)	2.25 (1.68)
Family structure							
One-caregiver family	3,710 (17.07)	188 (17.92)	1,003 (21.19)	989 (16.80)	358 (13.46)	740 (17.14)	432 (13.61)
Two-caregiver family	20,706 (82.91)	1,023 (82.08)	4,339 (78.77)	5,492 (83.20)	2,675 (86.49)	4,051 (82.86)	3,126 (86.39)
missing/not reported	*2 (0.02)*		*1 (0.05)*		*1 (0.04)*		
Number of siblings, mean (SD)	1.59 (1.09)	1.65 (1.14)	1.70 (1.18)	1.60 (1.09)	1.62 (1.08)	1.50 (1.02)	1.48 (0.95)

Neighbourhood characteristics							
Neighbourhood safety							
Do not agree	1,560 (7.22)	190 (18.50)	569 (12.00)	478 (7.88)	85 (3.05)	182 (4.08)	56 (1.83)
Agree	12,756 (52.46)	644 (52.12)	2,899 (54.27)	4,434 (68.47)	1,245 (40.40)	2,535 (52.55)	999 (28.71)
Strongly agree	9,038 (35.38)	328 (25.17)	1,586 (27.79)	1,269 (18.41)	1,575 (51.57)	1,881 (38.61)	2,399 (66.25)
missing/not reported	*1,064 (4.95)*	*49 (4.22)*	*289 (5.95)*	*300 (18.41)*	*129 (4.98)*	*193 (4.76)*	*104 (3.21)*
Area disadvantage (SEIFA)							
High	8,812 (38.55)	691 (59.14)	2,698 (52.40)	2,364 (39.11)	988 (35.71)	1,469 (32.03)	602 (18.28)
Moderate	7,971 (32.34)	370 (29.27)	1,725 (31.30)	2,264 (34.47)	901 (29.31)	1,631 (33.99)	1,080 (31.44)
Low	7,632 (29.10)	150 (11.59)	919 (16.28)	1,852 (26.40)	1,144 (39.97)	1,691 (33.97)	1,876 (50.28)
missing/not reported	*3 (0.01)*		*1 (0.01)*	*1 (0.01)*	*1 (0.01)*		
Area accessibility (ARIA)							
Highly accessible	12,766 (53.55)	313 (28.16)	1,824 (37.06)	3,763 (60.36)	1,633 (53.79)	2,788 (59.35)	2,445 (68.81)
Accessible	6,227 (26.07)	368 (30.31)	1,833 (34.05)	1,523 (23.44)	749 (25.82)	1,053 (23.04)	701 (20.85)
Moderately accessible	4,235 (16.14)	423 (33.83)	1,267 (22.39)	933 (12.69)	504 (15.87)	750 (14.21)	358 (8.82)
Remote to very remote	942 (3.35)	89 (6.11)	376 (5.75)	199 (2.54)	131 (3.99)	118 (2.22)	29 (0.93)
missing/not reported	*248 (0.89)*	*18 (1.59)*	*43 (0.75)*	*63 (0.97)*	*17 (0.52)*	*82 (1.18)*	*25 (0.59)*

**weighted percentage*

Number of children in each class: Class 1 (220; 4.43%), Class 2 (1,129; 22.72%), Class 3 (1,400; 28.17%), Class 4 (562; 11.31%), Class 5 (1,003; 20.19%), Class 6 (655; 13.18%), Total (4,969).

Number of children's observation from Waves 1 to 6 in each class: Class 1 (1,211; 4.96%), Class 2 (5,343; 21.88%), Class 3 (6,481; 26.54%), Class 4 (3,034; 12.43%), Class 5 (4,791; 19.62%), Class 6 (3,558; 14.57%), Total (24,418).

Table 5.4 Factors associated with trajectory class membership

Variables	Class 2 "consistently in between low & good quality"	Class 3 "consistently in good quality"	Class 4 "increasing quality from good to very good"	Class 5 "decreasing quality from very good to good"	Class 6 "consistently in very good quality"
	Reference group: Class 1 "consistently in low quality"				
	Adjusted RRR (95%CI)	**Adjusted RRR (95%CI)**	**Adjusted RRR (95%CI)**	**Adjusted RRR (95%CI)**	**Adjusted RRR (95%CI)**
Demographic characteristics					
Child's age *(ref: 4-5 years)*					
6-7 years	**0.86 (0.76, 0.98)**	**0.82 (0.72, 0.94)**	0.92 (0.79, 1.08)	0.89 (0.77, 1.02)	0.98 (0.84, 1.14)
8-9 years	**0.80 (0.70, 0.92)**	**0.77 (0.67, 0.89)**	**0.76 (0.65, 0.89)**	**0.77 (0.66, 0.89)**	**0.78 (0.67, 0.92)**
10-11 years	**0.79 (0.68, 0.91)**	**0.78 (0.67, 0.90)**	**0.79 (0.67, 0.93)**	**0.73 (0.63, 0.86)**	**0.72 (0.61, 0.85)**
12-13 years	0.85 (0.72, 1.00)	0.90 (0.76, 1.07)	0.89 (0.74, 1.08)	0.87 (0.73, 1.04)	**0.79 (0.65. 0.95)**
14-15 years	**0.75 (0.62, 0.90)**	**0.77 (0.64, 0.94)**	**0.72 (0.58, 0.89)**	**0.70 (0.57, 0.86)**	**0.63 (0.51, 0.78)**
Child's sex *(ref: Male)*					
Female	1.17 (0.88, 1.55)	1.05 (0.80, 1.39)	0.97 (0.71, 1.31)	1.13 (0.84, 1.51)	1.08 (0.80, 1.46)
Child Indigenous status (*ref: Indigenous)*					
Not Indigenous	0.78 (0.34, 1.82)	0.73 (0.31, 1.72)	0.43 (0.17, 1.05)	0.57 (0.23, 1.40)	0.62 (0.24, 1.64)
Child speaks a language other than English (*ref: No)*					
Yes	1.69 (0.99, 2.87)	1.14 (0.66, 1.95)	1.27 (0.72, 2.22)	1.11 (0.65, 1.92)	0.89 (0.50, 1.60)
Family characteristics					
Caregiver education (*ref: ≤ High school)*					
> High school	0.90 (0.63, 1.28)	0.91 (0.64, 1.30)	1.20 (0.79, 1.83)	1.19 (0.82, 1.73)	1.27 (0.83, 1.95)
Family weekly income (in thousands)	0.99 (0.84, 1.15)	1.02 (0.87, 1.19)	1.14 (0.97, 1.35)	1.04 (0.89, 1.22)	1.17 (0.99, 1.38)

Family structure *(ref: One-caregiver family)*					
Two-caregiver family	0.76 (0.54, 1.08)	0.89 (0.62, 1.28)	0.85 (0.58, 1.25)	0.75 (0.51, 1.09)	0.68 (0.45, 1.01)
Number of siblings	1.06 (0.93, 1.21)	1.01 (0.89, 1.16)	1.03 (0.90, 1.18)	0.93 (0.81, 1.07)	0.95 (0.83, 1.10)
Neighbourhood characteristics					
Neighbourhood safety *(ref: Do not agree)*					
Agree	**1.69 (1.29, 2.21)**	**2.99 (2.23, 4.00)**	**4.36 (3.02, 6.29)**	**4.40 (3.13, 6.20)**	**4.82 (3.18, 7.32)**
Strongly agree	**1.98 (1.44, 2.71)**	**2.08 (1.47, 2.95)**	**13.09 (8.65, 19.80)**	**8.14 (5.55, 11.96)**	**29.56 (18.74, 46.63)**
Area disadvantage (SEIFA) *(ref: High)*					
Moderate	1.14 (0.88, 1.46)	**1.52 (1.16, 2.00)**	**1.43 (1.06, 1.94)**	**1.69 (1.27, 2.23)**	**2.32 (1.66, 3.24)**
Low	1.34 (0.93, 1.94)	**2.02 (1.37, 2.94)**	**2.70 (1.78, 4.09)**	**2.69 (1.81, 4.01)**	**5.01 (3.20, 7.85)**
Area accessibility (ARIA) *(ref: Highly accessible)*					
Accessible	0.92 (0.61, 1.34)	**0.38 (0.24, 0.58)**	**0.40 (0.25, 0.62)**	**0.33 (0.21, 0.52)**	**0.25 (0.15, 0.41)**
Moderately accessible	**0.56 (0.37, 0.83)**	**0.23 (0.15, 0.35)**	**0.25 (0.16, 0.40)**	**0.23 (0.14, 0.36)**	**0.14 (0.08, 0.23)**
Remote to very remote	0.83 (0.51, 1.35)	**0.23 (0.12, 0.44)**	**0.32 (0.15, 0.65)**	**0.18 (0.10, 0.32)**	**0.06 (0.02, 0.16)**

RRR: relative-risk ratios; CI=credible interval; bold=p-value<0.05

5.2.4.2 Longitudinal association between trajectory classes of caregiver perception of green space quality and prosocial behaviour

Table 5.5 shows that the final model accounting for all covariates (Model 4) was the best model that fits the data (DIC=84760.42). Children whose caregivers predominantly rated very good quality green space over time (β=0.35; 95%CI=0.23, 0.47) had greater prosocial behaviour than those whose caregivers consistently reported low quality green space. Caregivers who perceived quality green space trended from good to very good (β=0.23; 95%CI=0.11, 0.35) and from very good to good (β=0.31; 95%CI=0.20, 0.42) reported higher levels of child prosocial behaviour compared to caregivers who consistently perceived low quality green space, respectively. However, association was not significant for those children who were in classes of consistently “good quality” and “between low and good quality” green space compared to those who were in consistently “low quality” green space, respectively.

Table 5.5 Multilevel linear regression of longitudinal associations between trajectory classes of caregiver perception of green space quality and prosocial behaviour

Variables	Model 1 Unadjusted β (95% CI)	Model 2 Adjusted β (95% CI)	Model 3 Adjusted β (95% CI)	Model 4 Adjusted β (95% CI)
Main independent variable				
Trajectories class *(ref: Class 1 "consistently in low quality")*				
Class 2 "consistently in between low & good quality"	0.08 (-0.04, 0.19)	0.07 (-0.04, 0.18)	0.08 (-0.02, 0.19)	0.07 (-0.05, 0.18)
Class 3 "consistently in good quality"	0.07 (-0.04, 0.18)	0.09 (-0.02, 0.19)	0.08 (-0.03, 0.18)	0.11 (-0.01, 0.22)
Class 4 "increasing quality from good to very good"	**0.29 (0.18, 0.41)**	**0.31 (0.19, 0.43)**	**0.28 (0.16, 0.39)**	**0.23 (0.11, 0.35)**
Class 5 "decreasing quality from very good to good"	**0.36 (0.25, 0.48)**	**0.36 (0.25, 0.47)**	**0.34 (0.23, 0.45)**	**0.31 (0.20, 0.42)**
Class 6 "consistently in very good quality"	**0.50 (0.38, 0.61)**	**0.49 (0.38, 0.60)**	**0.44 (0.33, 0.55)**	**0.35 (0.23, 0.47)**
Demographic characteristics				
Child's age *(ref: 4-5 years)*				
6-7 years		**0.46 (0.39, 0.53)**	**0.46 (0.39, 0.53)**	**0.47 (0.39, 0.54)**
8-9 years		**0.49 (0.42, 0.57)**	**0.47 (0.40, 0.55)**	**0.45 (0.37, 0.52)**
10-11 years		**0.75 (0.68, 0.83)**	**0.73 (0.66, 0.81)**	**0.71 (0.64, 0.78)**
12-13 years		**0.54 (0.47, 0.62)**	**0.51 (0.44, 0.59)**	**0.49 (0.42, 0.57)**
14-15 years		**0.30 (0.22, 0.37)**	**0.26 (0.18, 0.33)**	**0.23 (0.15, 0.31)**
Child's sex *(ref: Male)*				
Female		**0.64 (0.60, 0.68)**	**0.64 (0.60, 0.68)**	**0.66 (0.61, 0.70)**
Child Indigenous status (*ref: Indigenous)*				
Not Indigenous		**0.31 (0.18, 0.44)**	**0.20 (0.07, 0.33)**	**0.18 (0.04, 0.31)**
Child speaks a language other than English *(ref: No)*				
Yes		0.01 (-0.06, 0.08)	0.02 (-0.05, 0.09)	0.05 (-0.03, 0.13)

Family characteristics				
Caregiver education (*ref: ≤ High school)*				
> High school			**0.18 (0.11, 0.24)**	**0.18 (0.11, 0.25)**
Family weekly income (in thousands)			**0.03 (0.01, 0.05)**	**0.03 (0.02, 0.05)**
Family structure *(ref: One-caregiver family)*				
Two-caregiver family			**0.14 (0.07, 0.20)**	**0.11 (0.04, 0.18)**
Number of siblings			**-0.08 (-0.10, -0.05)**	**-0.07 (-0.09, -0.05)**
Neighbourhood characteristics				
Neighbourhood safety *(ref: Do not agree)*				
Agree				0.07 (-0.02, 0.16)
Strongly agree				**0.29 (0.20, 0.39)**
Area disadvantage (SEIFA) *(ref: High)*				
Moderate				**0.07 (0.02, 0.12)**
Low				-0.02 (-0.08, 0.04)
Area accessibility (ARIA) *(ref: Highly accessible)*				
Accessible				0.06 (-0.01, 0.11)
Moderately accessible				0.04 (-0.02, 0.11)
Remote to very remote				-0.05 (-0.17, 0.07)
Random effects, variance (95% CI)				
Level 3: Statistical Area 2	0.01 (-0.01, 0.01)	0.02 (-0.01, 0.05)	0.01 (-0.01, 0.01)	0.01 (-0.01, 0.01)
Level 2: Participant	1.50 (1.26, 1.75)	1.38 (1.15, 1.61)	1.42 (1.18, 1.67)	1.75 (1.30, 1.75)
Level 1: Observation	1.60 (1.35, 1.84)	1.54 (1.31, 1.77)	1.50 (1.20, 1.74)	1.84 (1.16, 1.60)
Deviance Information Criterion (DIC)	92209.47	91114.71	90664.54	84760.42

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

5.2.4.3 Assessment of the potential role of quality green space perceived by caregivers in reducing prosocial behaviour related inequalities

Multivariate models were disaggregated by different trajectory classes of perceived green space quality (Table 5.6). Overall, hump-shaped associations between age and prosocial behaviour were observed irrespective of trajectory classes. In addition, girls' prosocial behaviour was consistently higher than boys across classes, but the prosocial gap by child's sex appeared to narrow in the multivariate model of Class 6 ("consistently in very good quality"). Similarly, household economic position-related inequalities in child prosocial behaviour were less pronounced in this class. In addition, there were small, non-statistically significant differences in child prosocial behaviour by caregiver education and family income. Moreover, no inequalities in prosocial behaviour were evident by neighbourhood safety and area disadvantage in children whose caregivers consistently perceived very good quality green space over time.

Table 5.6 Multilevel linear regression of longitudinal associations between socioeconomic characteristics and prosocial behaviour disaggregated by trajectory classes

Variables	Class 1 "consistently in low quality"	Class 2 "consistently in between low & good quality"	Class 3 "consistently in good quality"	Class 4 "increasing quality from good to very good"	Class 5 "decreasing quality from very good to good"	Class 6 "consistently in very good quality"
	Adjusted β (95% CI)	Adjusted β (95% CI)	Adjusted β (95% CI)	Adjusted β (95% CI)	Adjusted β (95% CI)	Adjusted β (95% CI)
Demographic characteristics						
Child's age *(ref: 4-5 years)*						
6-7 years	**0.41 (0.06, 0.77)**	**0.47 (0.30, 0.64)**	**0.54 (0.39, 0.68)**	**0.45 (0.23, 0.66)**	**0.52 (0.36, 0.69)**	**0.29 (0.10, 0.48)**
8-9 years	0.30 (-0.03, 0.64)	**0.46 (0.30, 0.63)**	**0.48 (0.34, 0.63)**	**0.46 (0.24, 0.67)**	**0.49 (0.33, 0.65)**	**0.34 (0.15, 0.52)**
10-11 years	**0.57 (0.24, 0.90)**	**0.71 (0.54, 0.87)**	**0.81 (0.67, 0.95)**	**0.72 (0.51, 0.93)**	**0.67 (0.51, 0.82)**	**0.62 (0.44, 0.81)**
12-13 years	**0.55 (0.20, 0.89)**	**0.35 (0.18, 0.52)**	**0.63 (0.48, 0.77)**	**0.49 (0.27, 0.70)**	**0.44 (0.28, 0.60)**	**0.50 (0.31, 0.69)**
14-15 years	0.20 (-0.16, 0.55)	0.12 (-0.06, 0.29)	**0.31 (0.15, 0.46)**	**0.29 (0.07, 0.51)**	**0.27 (0.11, 0.44)**	0.13 (-0.07, 0.33)
Child's sex *(ref: Male)*						
Female	**0.74 (0.53, 0.95)**	**0.79 (0.69, 0.89)**	**0.73 (0.65, 0.82)**	**0.89 (0.77, 1.01)**	**0.48 (0.39, 0.58)**	**0.37 (0.26, 0.48)**
Child Indigenous status (*ref: Indigenous)*						
Not Indigenous	0.42 (-0.20, 1.04)	0.28 (-0.01, 0.55)	0.06 (-0.22, 0.34)	0.30 (-0.04, 0.64)	-0.04 (-0.35, 0.27)	0.03 (-0.43, 0.49)
Child speaks a language other than English *(ref: No)*						
Yes	**0.59 (0.13, 1.04)**	0.02 (-0.15, 0.19)	**0.18 (0.04, 0.33)**	0.03 (-0.18, 0.24)	-0.09 (-0.25, 0.08)	-0.09 (-0.29, 0.11)
Family characteristics						
Caregiver education (*ref: ≤ High school)*						
> High school	**0.34 (0.03, 0.65)**	**0.24 (0.10, 0.38)**	**0.30 (0.17, 0.43)**	**0.31 (0.09, 0.53)**	-0.05 (-0.21, 0.11)	-0.07 (-0.28, 0.14)
Family weekly income (in thousands)	**0.11 (0.02, 0.19)**	**0.06 (0.01, 0.11)**	0.03 (-0.01, 0.07)	0.03 (-0.01, 0.06)	**0.05 (0.01, 0.09)**	0.01 (-0.21, 0.21)
Family structure *(ref: One-caregiver family)*						
Two-caregiver family	-0.10 (0.42, 0.21)	0.05 (-0.10, 0.20)	0.03 (-0.10, 0.16)	**0.37 (0.17, 0.58)**	0.09 (-0.05, 0.24)	**0.24 (0.06, 0.42)**

Number of siblings	**-0.13 (-0.23, -0.04)**	**-0.11 (-0.15, -0.06)**	**-0.05 (-0.10, -0.01)**	**-0.13 (-0.19, -0.07)**	-0.02 (-0.07, 0.03)	-0.06 (-0.12, 0.01)
Neighbourhood characteristics						
Neighbourhood safety *(ref: Do not agree)*						
Agree	0.02 (-0.27, 0.32)	0.09 (-0.07, 0.26)	-0.07 (-0.24, 0.10)	0.32 (-0.05, 0.69)	**0.29 (0.04, 0.54)**	-0.14 (-0.06, 0.30)
Strongly agree	0.27 (-0.07, 0.60)	**0.47 (0.29, 0.65)**	0.18 (-0.01, 0.36)	**0.42 (0.04, 0.79)**	**0.42 (0.16, 0.70)**	0.11 (-0.32, 0.55)
Area disadvantage (SEIFA) *(ref: High)*						
Moderate	**-0.29 (-0.52, -0.06)**	0.10 (-0.01, 0.22)	**0.16 (0.05, 0.26)**	0.01 (-0.15, 0.17)	-0.01 (-0.13, 0.12)	0.07 (-0.10, 0.24)
Low	**-0.57 (-0.91, -0.22)**	0.10 (-0.05, 0.25)	0.05 (-0.06, 0.17)	**-0.23 (-0.40, -0.06)**	0.02 (-0.11, 0.15)	-0.07 (-0.25, 0.10)
Area accessibility (ARIA) *(ref: Highly accessible)*						
Accessible	0.13 (-0.16, 0.43)	-0.09 (-0.22, 0.04)	**0.20 (0.09, 0.31)**	**-0.24 (-0.40, -0.07)**	0.05 (-0.08, 0.18)	**0.18 (0.03, 0.32)**
Moderately accessible	0.01 (-0.29, 0.31)	-0.01 (-0.15, 0.14)	0.12 (-0.01, 0.25)	**-0.41 (-0.61, -0.21)**	**0.23 (0.08, 0.38)**	0.02 (-0.19, 0.22)
Remote to very remote	-0.41 (-0.86, 0.05)	-0.04 (-0.25, 0.18)	-0.04 (-0.30, 0.22)	-0.06 (-0.38, 0.26)	-0.25 (-0.56, 0.07)	0.50 (-0.10, 1.10)
Random effects, variance (95% CI)						
Level 3: Statistical Area 2	0.08 (-0.22, 0.37)	0.01 (-0.02, 0.03)	0.04 (-0.07, 0.14)	0.20 (-0.36, 0.75)	0.25 (-0.14, 0.64)	0.07 (-0.12, 0.25)
Level 2: Participant	1.51 (0.71, 2.31)	1.52 (0.90, 2.14)	1.74 (1.28, 2.20)	0.82 (0.07, 1.56)	0.73 (0.05, 1.40)	1.43 (0.95, 1.92)
Level 1: Observation	1.37 (0.65, 2.08)	1.72 (1.11, 2.33)	1.18 (0.74, 1.61)	1.74 (1.08, 2.40)	1.68 (1.03, 2.33)	1.16 (0.70, 1.62)

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

5.2.4.4 Assessment of the potential role of socioeconomic characteristics in modifying association between caregiver perception of green space quality and child prosocial behaviour

DIC values were used to assess whether adding an interaction term would result in a better model that fits the data compared to the model without an interaction term (Model 4 in Table 5.5) and changes in DIC were also reported (Tables 5.7.1 to 5.7.7). Boys in Classes 5 ("decreasing quality from very good to good") and 6 ("consistently in very good quality") exhibited better prosocial behaviour than girls, indicating association was stronger among boys. Caregiver perception of better quality nearby green space (Classes 2 to 6) was found to be associated with higher prosocial behaviour among children who only spoke English at home. Similarly, associations between green space quality and prosocial behaviour emerged stronger among children in Classes 2 to 6 living in moderate and low disadvantage areas. Further, among children in Classes 4 ("increasing quality from good to very good") and 6 ("consistently in very good quality"), associations between green space quality and prosocial behaviour were stronger among children living in remote areas. However, children in Class 4 ("increasing quality from good to very good") and living in moderately accessible areas had lower prosocial behaviour. The benefit of very good quality green space relative to low quality green space on prosocial behaviour was relatively consistent in all age groups (Figure 5.2).

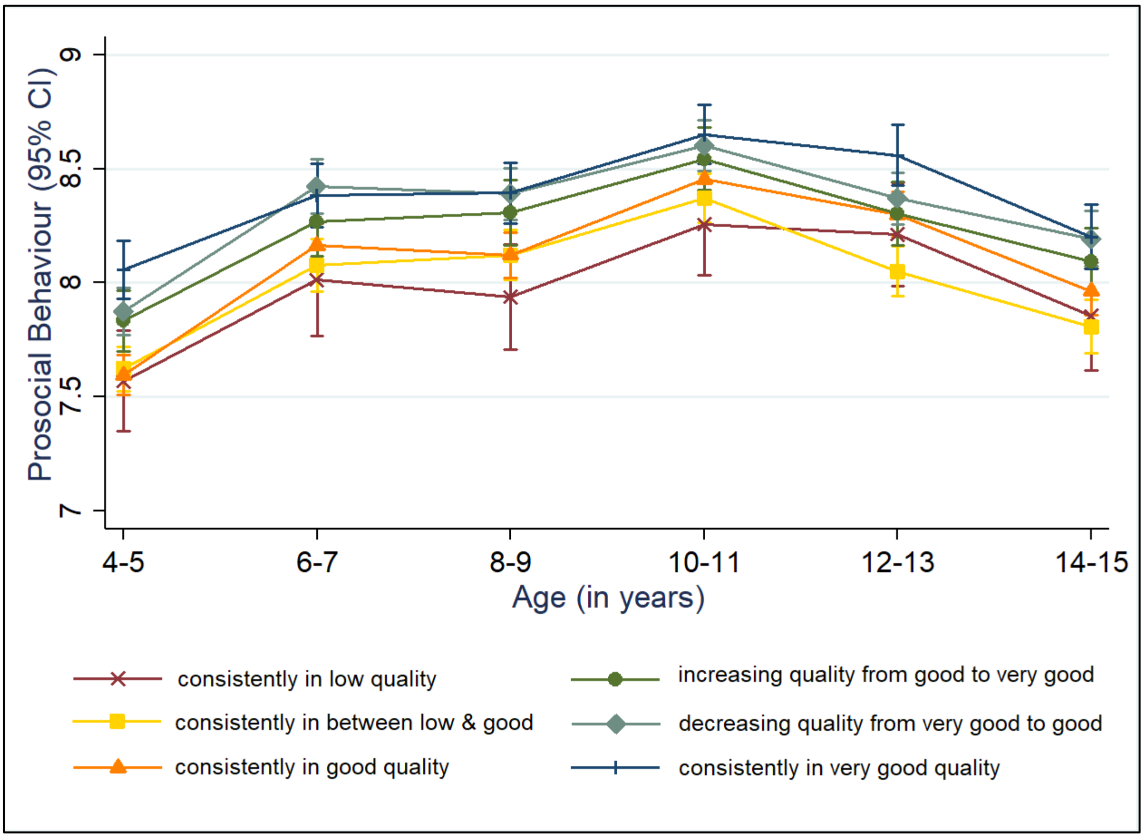

Figure 5.2 Prosocial behaviour development by different trajectory classes

Table 5.7 Potential effect modifiers on associations between trajectory classes of green space quality and prosocial behaviour

Table 5.7.1 Effect modification by child's sex

Variables	Adjusted β (95% CI)
Interaction term	
Trajectory class*child's sex *(ref: Class 1 – Female)*	
Class 2 – Male	-0.07 (-0.29, 0.15)
Class 3 – Male	-0.01 (-0.23, 0.21)
Class 4 – Male	-0.18 (-0.41, 0.06)
Class 5 – Male	**0.23 (0.01, 0.45)**
Class 6 – Male	**0.35 (0.12, 0.57)**
Main independent variable	
Trajectories class *(ref: Class 1 "consistently in low quality")*	
Class 2 "consistently in between low & good quality"	0.10 (-0.06, 0.26)
Class 3 "consistently in good quality"	0.11 (-0.05, 0.27)
Class 4 "increasing quality from good to very good"	**0.33 (0.16, 0.50)**
Class 5 "decreasing quality from very good to good"	**0.20 (0.03, 0.36)**
Class 6 "consistently in very good quality"	**0.17 (0.01, 0.34)**
Demographic characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**0.47 (0.40, 0.54)**
8-9 years	**0.45 (0.37, 0.52)**
10-11 years	**0.71 (0.64, 0.78)**
12-13 years	**0.49 (0.42, 0.57)**
14-15 years	**0.23 (0.15, 0.31)**
Child's sex *(ref: Male)*	
Female	**0.71 (0.51, 0.91)**
Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	**0.18 (0.04, 0.31)**
Child speaks a language other than English (*ref: No)*	
Yes	0.05 (-0.02, 0.13)
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	**0.19 (0.12, 0.26)**
Family weekly income (in thousands)	**0.03 (0.02, 0.05)**

Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.11 (0.04, 0.18)**
Number of siblings	**-0.07 (-0.09, -0.05)**
Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	0.07 (-0.02, 0.16)
Strongly agree	**0.30 (0.20, 0.39)**
Area disadvantage (SEIFA) *(ref: High)*	
Moderate	**0.07 (0.02, 0.13)**
Low	-0.02 (-0.08, 0.05)
Area accessibility (ARIA) *(ref: Highly accessible)*	
Accessible	0.05 (-0.01, 0.11)
Moderately accessible	0.05 (-0.02, 0.12)
Remote to very remote	-0.05 (-0.17, 0.07)
Random effects, variance (95% CI)	
Level 3: Statistical Area 2	0.01 (-0.01, 0.01)
Level 2: Participant	1.53 (1.31, 1.75)
Level 1: Observation	1.37 (1.15, 1.58)
Deviance Information Criterion (DIC)	84651.71
Δ DIC	-109.42

β: regression coefficient; CI=credible interval; Δ DIC= the change of DIC from a model without the interaction term (DIC=84760.42); bold=p-value<0.05

The model was adjusted for all covariates: child's age, sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, and area accessibility.

Table 5.7.2 Effect modification by child Indigenous status

Variables	Adjusted β (95% CI)
Interaction term	
Trajectory class *child Indigenous status *(ref: Class 1 – Non-Indigenous)*	
Class 2 – Indigenous	-0.06 (-0.69, 0.57)
Class 3 – Indigenous	0.18 (-0.46, 0.82)
Class 4 – Indigenous	-0.21 (-0.87, 0.47)
Class 5 – Indigenous	0.37 (-0.29, 1.02)
Class 6 – Indigenous	0.26 (-0.48, 1.01)
Main independent variable	
Trajectories class *(ref: Class 1 "consistently in low quality")*	
Class 2 "consistently in between low & good quality"	0.07 (-0.05, 0.18)
Class 3 "consistently in good quality"	0.10 (-0.01, 0.21)
Class 4 "increasing quality from good to very good"	**0.24 (0.12, 0.37)**
Class 5 "decreasing quality from very good to good"	**0.30 (0.18, 0.42)**
Class 6 "consistently in very good quality"	**0.34 (0.22, 0.47)**
Demographic characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**0.47 (0.39, 0.55)**
8-9 years	**0.45 (0.37, 0.52)**
10-11 years	**0.71 (0.64, 0.78)**
12-13 years	**0.49 (0.42, 0.57)**
14-15 years	**0.23 (0.15, 0.31)**
Child's sex *(ref: Male)*	
Female	**0.66 (0.61, 0.70)**
Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	0.26 (-0.32, 0.83)
Child speaks a language other than English (*ref: No)*	
Yes	0.05 (-0.02, 0.13)
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	**0.18 (0.11, 0.25)**
Family weekly income (in thousands)	**0.03 (0.02, 0.05)**
Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.11 (0.04, 0.18)**
Number of siblings	**-0.07 (-0.09, -0.05)**

Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	0.07 (-0.02, 0.16)
Strongly agree	**0.30 (0.20, 0.39)**
Area disadvantage (SEIFA) *(ref: High)*	
Moderate	**0.07 (0.02, 0.13)**
Low	-0.02 (-0.08, 0.04)
Area accessibility (ARIA) *(ref: Highly accessible)*	
Accessible	0.06 (-0.01, 0.11)
Moderately accessible	0.05 (-0.02, 0.11)
Remote to very remote	-0.05 (-0.17, 0.07)
Random effects, variance (95% CI)	
Level 3: Statistical Area 2	0.01 (-0.01, 0.01)
Level 2: Participant	1.54 (1.32, 1.76)
Level 1: Observation	1.37 (1.15, 1.58)
Deviance Information Criterion (DIC)	84665.66
Δ DIC	-94.76

β: regression coefficient; CI=credible interval; Δ DIC= the change of DIC from a model without the interaction term (DIC=84760.42); bold=p-value<0.05

The model was adjusted for all covariates: child's age, sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, and area accessibility.

Table 5.7.3 Effect modification by child's language spoken at home

Variables	Adjusted β (95% CI)
Interaction term	
Green space quality*spoke a language other than English	
(ref: Class 1 – Yes)	
Class 2 – No	**0.55 (0.11, 0.99)**
Class 3 – No	**0.49 (0.06, 0.93)**
Class 4 – No	**0.47 (0.01, 0.93)**
Class 5 – No	**0.74 (0.29, 1.18)**
Class 6 – No	**0.72 (0.26, 1.18)**
Main independent variable	
Trajectories class *(ref: Class 1 "consistently in low quality")*	
Class 2 "consistently in between low & good quality"	**-0.45 (-0.88, -0.02)**
Class 3 "consistently in good quality"	-0.36 (-0.78, 0.06)
Class 4 "increasing quality from good to very good"	-0.21 (-0.66, 0.24)
Class 5 "decreasing quality from very good to good"	-0.38 (-0.81, 0.06)
Class 6 "consistently in very good quality"	-0.32 (-0.77, 0.13)
Demographic characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**0.47 (0.39, 0.55)**
8-9 years	**0.45 (0.37, 0.52)**
10-11 years	**0.71 (0.64, 0.78)**
12-13 years	**0.49 (0.42, 0.56)**
14-15 years	**0.23 (0.15, 0.30)**
Child's sex *(ref: Male)*	
Female	**0.66 (0.61, 0.70)**
Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	**0.19 (0.05, 0.32)**
Child speaks a language other than English (*ref: No)*	
Yes	**0.62 (0.20, 1.03)**
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	**0.19 (0.11, 0.26)**
Family weekly income (in thousands)	**0.04 (0.02, 0.05)**
Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.11 (0.04, 0.18)**
Number of siblings	**-0.07 (-0.09, -0.05)**

Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	0.08 (-0.02, 0.17)
Strongly agree	**0.30 (0.20, 0.40)**
Area disadvantage (SEIFA) *(ref: High)*	
Moderate	**0.07 (0.02, 0.13)**
Low	-0.02 (-0.08, 0.05)
Area accessibility (ARIA) *(ref: Highly accessible)*	
Accessible	0.06 (-0.01, 0.12)
Moderately accessible	0.05 (-0.02, 0.12)
Remote to very remote	-0.05 (-0.17, 0.07)
Random effects, variance (95% CI)	
Level 3: Statistical Area 2	0.01 (-0.01, 0.01)
Level 2: Participant	1.54 (1.32, 1.76)
Level 1: Observation	1.37 (1.15, 1.58)
Deviance Information Criterion (DIC)	84671.67
Δ DIC	-88.75

β: regression coefficient; CI=credible interval; Δ DIC= the change of DIC from a model without the interaction term (DIC=84760.42); bold=p-value<0.05

The model was adjusted for all covariates: child's age, sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, and area accessibility.

Table 5.7.4 Effect modification by caregiver education

Variables	Adjusted β (95% CI)
Interaction term	
Green space quality*caregiver education *(ref: Class 1 – >High school)*	
Class 2 – ≤ High school	0.02, (-0.33, 0.30)
Class 3 – ≤ High school	-0.04 (-0.36, 0.27)
Class 4 – ≤ High school	-0.11 (-0.47, 0.25)
Class 5 – ≤ High school	0.27 (-0.05, 0.60)
Class 6 – ≤ High school	0.34 (-0.02, 0.70)
Main independent variable	
Trajectories class *(ref: Class 1 "consistently in low quality")*	
Class 2 "consistently in between low & good quality"	0.07 (-0.05, 0.19)
Class 3 "consistently in good quality"	0.11 (-0.01, 0.23)
Class 4 "increasing quality from good to very good"	**0.24 (0.11, 0.37)**
Class 5 "decreasing quality from very good to good"	**0.28 (0.16, 0.40)**
Class 6 "consistently in very good quality"	**0.32 (0.19, 0.45)**
Demographic characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**0.47 (0.39, 0.54)**
8-9 years	**0.45 (0.37, 0.52)**
10-11 years	**0.71 (0.64, 0.78)**
12-13 years	**0.49 (0.42, 0.56)**
14-15 years	**0.23 (0.15, 0.30)**
Child's sex *(ref: Male)*	
Female	**0.66 (0.61, 0.70)**
Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	**0.17 (0.03, 0.31)**
Child speaks a language other than English (*ref: No)*	
Yes	0.06 (-0.02, 0.13)
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	0.23 (-0.05, 0.52)
Family weekly income (in thousands)	**0.04 (0.02, 0.05)**
Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.11 (0.04, 0.18)**
Number of siblings	**-0.07 (-0.09, -0.05)**

Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	0.07 (-0.03, 0.16)
Strongly agree	**0.29 (0.19, 0.39)**
Area disadvantage (SEIFA) *(ref: High)*	
Moderate	**0.07 (0.02, 0.12)**
Low	-0.02 (-0.08, 0.04)
Area accessibility (ARIA) *(ref: Highly accessible)*	
Accessible	0.06 (-0.01, 0.11)
Moderately accessible	0.04 (-0.03, 0.11)
Remote to very remote	-0.06 (-0.17, 0.07)
Random effects, variance (95% CI)	
Level 3: Statistical Area 2	0.01 (-0.01, 0.01)
Level 2: Participant	1.53 (1.31, 1.75)
Level 1: Observation	1.37 (1.16, 1.59)
Deviance Information Criterion (DIC)	84710.51
Δ DIC	-49.91

β: regression coefficient; CI=credible interval; Δ DIC= the change of DIC from a model without the interaction term (DIC=84760.42); bold=p-value<0.05

The model was adjusted for all covariates: child's age, sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, and area accessibility.

Table 5.7.5 Effect modification by neighbourhood safety

Variables	Adjusted β (95% CI)
Interaction term	
Green space quality*neighbourhood safety (*ref: Class 1 – Do not agree)*	
Class 2 – Agree	0.20 (-0.11, 0.52)
Class 2 – Strongly agree	0.32 (-0.03, 0.67)
Class 3 – Agree	0.02 (-0.30, 0.34)
Class 3 – Strongly agree	0.03 (-0.32, 0.39)
Class 4 – Agree	0.39 (-0.07, 0.86)
Class 4 – Strongly agree	0.21 (-0.27, 0.70)
Class 5 – Agree	0.37 (-0.01, 0.75)
Class 5 – Strongly agree	0.28 (-0.13, 0.68)
Class 6 – Agree	-0.11 (-0.63, 0.42)
Class 6 – Strongly agree	-0.09 (-0.54, 0.35)
Main independent variable	
Trajectories class *(ref: Class 1 "consistently in low quality")*	
Class 2 "consistently in between low & good quality"	-0.14 (-0.43, 0.14)
Class 3 "consistently in good quality"	0.10 (-0.19, 0.39)
Class 4 "increasing quality from good to very good"	-0.04 (-0.47, 0.40)
Class 5 "decreasing quality from very good to good"	0.01 (-0.34, 0.36)
Class 6 "consistently in very good quality"	0.46 (-0.05, 0.97)
Demographic characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**0.47 (0.40, 0.55)**
8-9 years	**0.45 (0.37, 0.52)**
10-11 years	**0.71 (0.64, 0.79)**
12-13 years	**0.49 (0.42, 0.57)**
14-15 years	**0.23 (0.15, 0.31)**
Child's sex *(ref: Male)*	
Female	**0.66 (0.61, 0.70)**
Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	**0.17 (0.04, 0.31)**
Child speaks a language other than English (*ref: No)*	
Yes	0.05 (-0.02, 0.13)
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	**0.18 (0.11, 0.25)**

Family weekly income (in thousands)	**0.03 (0.02, 0.05)**
Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.11 (0.04, 0.18)**
Number of siblings	**-0.07 (-0.09, -0.05)**
Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	-0.08 (-0.36, 0.19)
Strongly agree	0.16 (-0.15, 0.47)
Area disadvantage (SEIFA) *(ref: High)*	
Moderate	**0.07 (0.02, 0.13)**
Low	-0.02 (-0.08, 0.04)
Area accessibility (ARIA) *(ref: Highly accessible)*	
Accessible	0.06 (-0.01, 0.11)
Moderately accessible	0.05 (-0.02, 0.11)
Remote to very remote	-0.05 (-0.18, 0.07)
Random effects, variance (95% CI)	
Level 3: Statistical Area 2	0.01 (-0.01, 0.01)
Level 2: Participant	1.52 (1.29, 1.75)
Level 1: Observation	1.38 (1.15, 1.61)
Deviance Information Criterion (DIC)	84771.02
Δ DIC	10.60

β: regression coefficient; CI=credible interval; Δ DIC= the change of DIC from a model without the interaction term (DIC=84760.42); bold=p-value<0.05

The model was adjusted for all covariates: child's age, sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, and area accessibility.

Table 5.7.6 Effect modification by area disadvantage

Variables	Adjusted β (95% CI)
Interaction term	
Green space quality*area disadvantage (SEIFA) (*ref: Class 1 – High)*	
Class 2 – Moderate	**0.38 (0.14, 0.63)**
Class 2 – Low	**0.58 (0.24, 0.91)**
Class 3 – Moderate	**0.40 (0.16, 0.65)**
Class 3 – Low	**0.43 (0.10, 0.75)**
Class 4 – Moderate	**0.35 (0.08, 0.62)**
Class 4 – Low	**0.40 (0.06, 0.74)**
Class 5 – Moderate	0.24 (-0.02, 0.49)
Class 5 – Low	**0.39 (0.06, 0.72)**
Class 6 – Moderate	**0.30 (0.02, 0.58)**
Class 6 – Low	0.26 (-0.09, 0.60)
Main independent variable	
Trajectories class *(ref: Class 1 "consistently in low quality")*	
Class 2 "consistently in between low & good quality"	-0.14 (-0.28, 0.11)
Class 3 "consistently in good quality"	0.08 (-0.07, 0.23)
Class 4 "increasing quality from good to very good"	0.07 (-0.10, 0.24)
Class 5 "decreasing quality from very good to good"	**0.19 (0.03, 0.35)**
Class 6 "consistently in very good quality"	**0.28 (0.09, 0.47)**
Demographic characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**0.47 (0.39, 0.54)**
8-9 years	**0.44 (0.37, 0.52)**
10-11 years	**0.71 (0.63, 0.78)**
12-13 years	**0.49 (0.42, 0.56)**
14-15 years	**0.22 (0.15, 0.30)**
Child's sex *(ref: Male)*	
Female	**0.65 (0.61, 0.70)**
Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	**0.18 (0.04, 0.32)**
Child speaks a language other than English (*ref: No)*	
Yes	0.05 (-0.03, 0.12)
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	**0.18 (0.11, 0.25)**

Family weekly income (in thousands)	**0.04 (0.02, 0.05)**
Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.12 (0.05, 0.19)**
Number of siblings	**-0.07 (-0.09, -0.05)**
Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	0.06 (-0.03, 0.16)
Strongly agree	**0.29 (0.19, 0.39)**
Area disadvantage (SEIFA) *(ref: High)*	
Moderate	**-0.26 (-0.48, -0.04)**
Low	**-0.42 (-0.73, -0.11)**
Area accessibility (ARIA) *(ref: Highly accessible)*	
Accessible	0.06 (-0.01, 0.11)
Moderately accessible	0.04 (-0.03, 0.11)
Remote to very remote	-0.05 (-0.18, 0.07)
Random effects, variance (95% CI)	
Level 3: Statistical Area 2	0.03 (-0.02, 0.09)
Level 2: Participant	1.48 (1.22, 1.74)
Level 1: Observation	1.29 (1.05, 1.53)
Deviance Information Criterion (DIC)	84639.28
Δ DIC	-121.14

β: regression coefficient; CI=credible interval; Δ DIC= the change of DIC from a model without the interaction term (DIC=84760.42); bold=p-value<0.05

The model was adjusted for all covariates: child's age, sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, and area accessibility.

Table 5.7.7 Effect modification by area accessibility

Variables	Adjusted β (95% CI)
Interaction term	
Green space quality*area accessibility (ARIA)	
(*ref: Class 1 – Highly accessible)*	
Class 2 – Accessible	-0.08 (-0.37, 0.21)
Class 2 – Moderately accessible	-0.03 (-0.32, 0.25)
Class 2 – Remote to very remote	0.41 (-0.05, 0.87)
Class 3 – Accessible	0.17 (-0.11, 0.46)
Class 3 – Moderately accessible	0.07 (-0.22, 0.35)
Class 3 – Remote to very remote	0.41 (-0.08, 0.90)
Class 4 – Accessible	-0.17 (-0.47, 0.14)
Class 4 – Moderately accessible	**-0.35 (-0.70, -0.04)**
Class 4 – Remote to very remote	**0.51 (0.03, 1.00)**
Class 5 – Accessible	0.05 (-0.24, 0.34)
Class 5 – Moderately accessible	0.20 (-0.10, 0.49)
Class 5 – Remote to very remote	0.29 (-0.24, 0.82)
Class 6 – Accessible	0.24 (-0.06, 0.55)
Class 6 – Moderately accessible	0.10 (-0.22, 0.42)
Class 6 – Remote to very remote	**1.01 (0.35, 1.85)**
Main independent variable	
Trajectories class *(ref: Class 1 "consistently in low quality")*	
Class 2 "consistently in between low & good quality"	0.07 (-0.14, 0.28)
Class 3 "consistently in good quality"	0.01 (-0.19, 0.22)
Class 4 "increasing quality from good to very good"	**0.29 (0.08, 0.50)**
Class 5 "decreasing quality from very good to good"	**0.23 (0.02, 0.44)**
Class 6 "consistently in very good quality"	**0.24 (0.03, 0.45)**
Demographic characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**0.47 (0.40, 0.54)**
8-9 years	**0.45 (0.37, 0.52)**
10-11 years	**0.71 (0.64, 0.78)**
12-13 years	**0.49 (0.42, 0.57)**
14-15 years	**0.23 (0.15, 0.31)**
Child's sex *(ref: Male)*	
Female	**0.66 (0.61, 0.70)**

Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	**0.58 (0.01, 0.29)**
Child speaks a language other than English (*ref: No)*	
Yes	0.04 (-0.03, 0.12)
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	**0.18 (0.11, 0.25)**
Family weekly income (in thousands)	**0.03 (0.02, 0.05)**
Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.12 (0.05, 0.19)**
Number of siblings	**-0.08 (-0.10, -0.05)**
Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	0.07 (-0.02, 0.17)
Strongly agree	**0.30 (0.20, 0.40)**
Area disadvantage (SEIFA) *(ref: High)*	
Moderate	**0.07 (0.01, 0.12)**
Low	**-0.02 (-0.08, -0.04)**
Area accessibility (ARIA) *(ref: Highly accessible)*	
Accessible	0.01 (-0.26, 0.27)
Moderately accessible	0.01 (-0.25, 0.27)
Remote to very remote	**-0.48 (-0.90, -0.07)**
Random effects, variance (95% CI)	
Level 3: Statistical Area 2	0.01 (-0.01, 0.03)
Level 2: Participant	1.51 (1.26, 1.76)
Level 1: Observation	1.38 (1.13, 1.62)
Deviance Information Criterion (DIC)	84712.96
Δ DIC	-47.46

β: regression coefficient; CI=credible interval; Δ DIC= the change of DIC from a model without the interaction term (DIC=84760.42); bold=p-value<0.05

The model was adjusted for all covariates: child's age, sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, and area accessibility.

5.2.5 Discussion

5.2.5.1 Association between trajectory classes and prosocial behaviour

The important finding from this study was that trajectory groups of caregiver perception of green space quality in a 10-year period were associated with prosocial behaviour. Children whose caregivers tended to rate neighbourhood green space as very good quality had greater prosocial behaviour than those whose caregivers perceived neighbourhood green space as low quality over time. Therefore, findings suggest that accumulated caregiver perceptions of very good quality green space potentially bring greater benefits for the development of prosocial behaviour. This point becomes a strength of this study that was able to disentangle differences in caregiver perceptions of green space quality and whether they matter for child prosocial behaviour. In addition, the current evidence on green space-prosocial behaviour association is mostly based on cross-sectional approach and only a few of longitudinal studies exist with short observation period (2-4 years) (Putra et al., 2020). Current longitudinal studies examining green space quantity as a proxy of exposure to green space among children tended to assume that the quantity is stable during the study period (McCormick, 2017; Vanaken & Danckaerts, 2018), ignoring potential influences of changes in green space quality in relation to child health-related outcomes. Furthermore, results from this study also suggest a humped-shape association between prosocial behaviour and age. The decline of prosocial behaviour in adolescence has been discussed in the literature (Carlo et al., 2007; Carlo et al., 1996; Eisenberg et al., 2015).

The results showed that caregiver perception of very good quality green space may attenuate socioeconomic inequalities in child prosocial behaviour. Sub-group analyses indicate attenuated inequalities in prosocial behaviour by caregiver educational level, family income, neighbourhood safety, and area disadvantage among children in Class 6 (“consistently in very good quality”). The salutogenic effects of quality green space may lessen the negative effect of growing in unfavourable socioeconomic family and neighbourhood. A study from the UK reported that income-related inequalities in mortality from circulatory diseases and all-cause mortality were less pronounced among populations in the greenest areas (Mitchell & Popham, 2008). Similarly, past work using data from multiple European countries found that mental health inequalities by subjective socioeconomic position were narrower among people who reported better access to recreational or green areas (Mitchell et al., 2015). People with low socioeconomic status but living in greener areas might gain health benefits from using green space than their counterparts in similar level of socioeconomic position, but without access to green space.

No significant association between child’s sex and trajectory class membership was reported, indicating both girls and boys seem to have equal access to quality green space. However, boys tended to benefit more from the availability of quality green space than girls. This finding might be explained by gendered playing activities (Eriksson et al., 2019). This study measured the quality of green space limited to parks, playgrounds, and play spaces. Boys are more likely to use these types of green space since they tend to participate in active outdoors plays than girls (Pate et al., 2013; Reimers et al., 2018). In addition, caregiver perceptions on different vulnerabilities and risk-taking behaviours between boys and girls in public places (Morrongiello et al., 2010) potentially play important roles in determining types and characteristics of green space appropriate to their child's gender. Evidence from Scotland suggest that total natural space was positively associated with prosocial behaviour among girls only (Richardson et al., 2017). Natural spaces perhaps seem more appealing for girls and girls may be less physically active compared to boys. Nevertheless, this study found that prosocial behaviour among girls was higher than boys in general. This is in alignment with previous literature suggesting personal factors (e.g., gender) play important roles in influencing prosocial behaviour among children, of which girls tend to have higher prosocial behaviour (Abdi, 2010; Beutel & Johnson, 2004; Pursell et al., 2008).

The child's ethnicity, particularly whether the child spoke a language other than English at home modified green space quality-prosocial behaviour association. The finding is similar to results from the Born in Bradford cohort study which showed that the ethnic background was an effect modifier of the association between green space-related satisfaction and child prosocial behaviour (McEachan et al., 2018). Ethnic minority families in Bradford, UK reported for triple count of green space-related inequality: less neighbourhood green space quantity, less satisfaction with green space, and less time spent by their children in green spaces. However, findings on the factors associated with trajectory class membership indicate no differences of the likelihood of being in classes with good or very good quality green space (Classes 2 to 6) relative to a class with low quality (Class 1) between children who spoke a language other than English and who did not. Even though the similar likelihood of being in good green space quality groups was reported by different ethnicities, ethnic minorities might less enjoy and use good green space since they may feel unsafe from being attacked, discrimination, and exclusion from dominant cultural group that can deter them from accessing nearby green space (Roe et al., 2016).

Even though neighbourhood safety was not a significant effect modifier in this study, living in neighbourhood perceived to be safe was associated with an increased likelihood of being in groups with better quality green space relative to the group with consistently low-quality green space. Previous work suggests that caregiver concern on safety might discourage children from spending time in green space and doing outdoor activities

(Cecil-Karb & Grogan-Kaylor, 2009; Lovasi et al., 2013; Nicksic et al., 2018). Positive association between neighbourhood safety and green space quality might also indicate that neighbourhood safety (e.g., less crime, low road volume) is considered as an attribute of good quality of green space by some caregivers. Besides, safety concerns tend to be less reported in affluent neighbourhoods (Carson et al., 2010; Wilson et al., 2004), where people may have better local green space due to greater resources to improve and maintain the quality of green space. Furthermore, both safety and pleasing aspects of local parks were noted as important factors for driving to nature among guardians in Philadelphia, US (Sefcik et al., 2019).

Green space quality-prosocial behaviour association was also found contingent upon neighbourhood socioeconomic status in this current study. Caregiver perception of quality green space was associated with higher prosocial behaviour among children living in less deprived areas. This might be due to the disparities in the availability of quality green space by area socioeconomic circumstances since findings also suggest that living in more affluent neighbourhoods was associated with an increased likelihood of being in trajectory classes with favourable green space quality. This aligns with previous studies suggesting that both green space quantity (Astell-Burt et al., 2014) and quality (Feng & Astell-Burt, 2017d) was substantively lower in deprived neighbourhoods within the Australian context. Similarly, an analysis of socioeconomic inequalities in green space quality in Portugal showed that green spaces in low socioeconomic neighbourhoods presented significantly more safety concerns, lack of equipment, and had less amenities (Hoffimann et al., 2017). Nevertheless, findings also suggest that caregiver perceptions of very good quality green space accumulated over time potentially attenuate prosocial behaviour inequalities by area disadvantage.

Furthermore, those living in less accessible or more remote areas were less likely to be in trajectory groups with better green space quality. However, children in remote areas tended to benefit more from the good to very good quality green space. Children in remote areas might be more reliant on locally available resources (e.g., high green space quality) than those in highly accessible areas. The collective resource model also suggests that people with limited resources might be more aware of and dependent on locally provided resources in their neighbourhood (Stafford & Marmot, 2003). In addition, the high density of quality green space in highly accessible areas may suggest a lack of variability that might contribute to the inability to identify its influence on prosocial behaviour development to some extent.

5.2.5.2 Strengths and limitations

This study used a longitudinal approach with 10-year collected data that helped improve the quality of current evidence and allowed to examine the patterning of green space quality-prosocial behaviour association across childhood. The use of a rigorous statistical method such as latent class analysis helps construct a variable of trajectory classes based on biennially collected data on green space quality. This enabled to investigate whether different caregiver perceptions of green space quality accumulated over a period of 10 years matter for the development of prosocial behaviour, providing stronger support for causality for the findings in this study. Furthermore, the measure of green space quality which is based on caregiver reports in this study have been used by previous studies within the Australian context (Feng & Astell-Burt, 2017a, 2017c, 2017d; Putra et al., 2021b). The advantage of using this measure is that caregivers largely determine children's outdoor play (Kalish et al., 2010), and hence, how caregivers perceive the quality of nearby green space tends to have direct influence on children's contact with green space. Using perceived measures also allows caregivers to differently weight various attributes of nearby green space that are viewed as important for their children to arrive at an overall measure (Datar et al., 2013).

The limitation of this study was related to caregiver-reported green space quality. The changes in caregiver reports of the quality of neighbourhood green space over time might not reflect the actual changes or changes to physical features of green space since their perceptions could be contingent upon several factors. For example, gendered playing patterns may play important roles for caregivers in deciding what characteristics of green spaces are suitable for boys and girls (Eriksson et al., 2019). In addition, changes in perceptions of green space quality might represent changes in needs as children get older due to different age groups would require different characteristics of greenspace in terms of facilities and safety (Kaymaz et al., 2017). Furthermore, based on collective resource model, people from low socioeconomic status might be more dependent on resources available in the neighbourhood and they might tend to have more favourable perceptions (Stafford & Marmot, 2003). Further studies are needed to investigate valuable attributes that constitute green space quality perceived by caregivers and the associated factors.

5.2.6 Summary

This study found that higher quality green space perceived by caregivers accumulated over time was associated with better prosocial behaviour. The likelihood of being in trajectory classes with higher quality green space was not equitably observed across neighbourhoods within the Australian context. Caregiver perception of very good quality green space accumulated over time may potentially attenuate socioeconomic inequalities in prosocial behaviour. In addition, the association between green space quality and prosocial behaviour appeared to differ by some individual (e.g., child’s sex, language spoken at home) and neighbourhood characteristics (e.g., area disadvantage, area accessibility). The findings from this study suggest the need to improve the quality of green space to be “very good quality” to increase the benefits for the development of prosocial behaviour, particularly in deprived and less accessible areas.

Chapter 6: Mediators of the association between green space quality and child prosocial behaviour

6.1 Preface

Earlier findings from the second and third studies, presented in Chapters 4 and 5, respectively, suggest clear evidence on the association between green space quality and prosocial behaviour. However, no study appears to test mediators of the association between green space quality and child prosocial behaviour, suggesting more studies are required to address this evidence gap. Therefore, this present (fourth) study, presented in Chapter 6, represented an important step forward in the literature by testing plausible pathways linking green space quality to prosocial behaviour. Findings from studies presented in previous chapters in this thesis served as a basis for this investigation.

Potential mediators were selected based on the understanding of a conceptual framework of mechanistic pathways linking green space to health outcomes proposed by multidisciplinary experts in terms of building capacities and restoring capacities. By adopting this conceptual model, this study specifically aimed to answer the third research question: *"To what extent do physical activity, social interaction, and mental health mediate the association between green space quality and prosocial behaviour?"*. This study tested 15 candidate mediators (four physical activity variables, one social interaction variable, three child mental health variables, six child HRQOL variables, and one caregiver mental health variable) in separate four mediation models for each candidate mediator. Additional analyses by modelling child-reported prosocial behaviour were also conducted to identify the consistency of the aforementioned variables in mediating the association between green space quality and prosocial behaviour. The study presented in this chapter is as it was published (Appendix F) with minor adjustments for tables, figures, referencing style, and overall thesis formatting requirements.

Citation

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Author contributions

I Gusti Ngurah Edi Putra conceptualised and designed the study, analysed and interpreted the data, wrote the original draft, and revised the manuscript. Thomas Astell-Burt, Dylan P. Cliff, Stewart A. Vella, and Xiaoqi Feng contributed to the interpretation of the results, provided critical inputs, and reviewed and edited the draft manuscript. All authors approved the final version of the manuscript.

6.2 The published article: “Do physical activity, social interaction, and mental health mediate the association between green space quality and child prosocial behaviour?”

6.2.1 Abstract

Potential pathways linking green space quality to prosocial behaviour have not been investigated so far. This study aimed to examine 15 candidate mediators of the association between green space quality and prosocial behaviour across physical activity, social interaction, health-related quality of life (HRQOL), and child and caregiver mental health. This study analysed data of 4,969 children aged 4-5 years that were observed for 10 years (2004-2014), retrieved from the Longitudinal Study of Australian Children. Caregiver perceptions of the availability of good neighbourhood parks, play spaces, and playgrounds were used to evaluate green space quality. Prosocial behaviour was measured based on caregiver reports of the prosocial subscale from the Strengths and Difficulties Questionnaire. Causal mediation analysis was used to fit each candidate mediator in a single mediation model. Additional analyses were conducted to strengthen the findings by modelling green space quality, candidate mediators with child-reported prosocial behaviour. Findings from this study suggest weak evidence of physical activity mediation, with only physical activity enjoyment displaying moderate mediation consistency. Child social interaction and caregiver mental health showed low mediation consistency. In addition, moderate-to-high and low-to-high mediation consistency was found for child mental health and HRQOL indicators, respectively. Mediation by candidate mediators appeared to manifest more in late childhood. Mediation models using child-reported prosocial behaviour tended to show weaker mediation compared to caregiver-reported prosocial behaviour models. To conclude, green space quality may indirectly influence prosocial behaviour among children via several pathways. Improving

the quality of neighbourhood green space may support physical activity enjoyment, social interaction, mental health among children, which in turn, may potentially foster the development of prosocial behaviour.

6.2.2 Introduction

Prosocial behaviours are defined as behaviours that "benefit others or at very least promote harmonious relations with others" (Hay, 1994, p. 33). Child prosocial behaviour can be denoted by the presence of some positive behaviours, such as offering help, sharing, being cooperative, and comforting (Hammond et al., 2015; Piotrowski et al., 2015; Wittek & Bekkers, 2015). Evidence suggests that prosocial behaviour is associated with favourable outcomes across psychological, health, and social domains, such as better academic achievement (Caprara et al., 2014; Gerbino et al., 2018), quality peer relationships (Caputi et al., 2012; Rabaglietti et al., 2013), happiness (Aknin et al., 2015; Aknin et al., 2012), and lower reported behavioural problems and aggression (Flynn et al., 2015; Obsuth et al., 2015). This indicates that encouraging the development of prosocial behaviour from the earliest years in life may be crucial to achieving better health and behavioural outcomes among children.

A previous critical review concluded that exposure to green space may be positively associated with the development of prosocial behaviour among children and adolescents (Putra et al., 2020). However, there was weak evidence that the quantity of green space – an amount of green space available within a neighbourhood (e.g., percentage of green space) – was associated with child prosocial behaviour. Meanwhile, there is a paucity of studies concerning green space quality – characteristics of green space that can influence its utilisation – in relation to prosocial behaviour. Relative to green space quantity, the quality might be more important due to preferences for a particular aspect of green space that can influence one's decision to visit and spend time in green space (Fongar et al., 2019). Moreover, children tend to be reliant on their caregivers for accessing nearby green space (Feng & Astell-Burt, 2017a, 2017d) and caregivers tend to determine young children's outdoor activities (Kalish et al., 2010). Caregiver perceptions of green space quality can serve as an important measure in evaluating the association between green space quality and child prosocial behaviour.

Previous analyses found the associations between green space quality reported by caregivers and the development of prosocial behaviour among children (Putra et al., 2021a, 2021b). However, potential underlying mechanisms linking green space quality to child prosocial behaviour have not been tested so far. Therefore, rigorous testing of candidate mediators can help strengthen our understandings of how a putative intervention (i.e., increasing the quality of green space) may cause a desirable change in the outcome of interest (i.e., an increase in prosocial behaviour). This present study aimed to assess candidate mediators of the association between green space quality and child prosocial behaviour.

Potential mechanisms linking green space to child prosocial behaviour

This study adopted potential pathways linking green space to health outcomes proposed by multidisciplinary experts that include building capacities, restoring capacities, and harm mitigation (Markevych et al., 2017; Putra et al., 2020). Based on the building capacities pathway, green space can provide attractive places for children to participate in physical activity (Akpinar, 2017; Sanders et al., 2015; Ward et al., 2016), and then can bring more opportunities to be prosocial with peers (Di Bartolomeo & Papa, 2017). Nearby green space can also promote and encourage social interactions (Aram et al., 2019; Hong et al., 2018; Jennings & Bamkole, 2019) that are an integral part of prosocial behaviour development. This is in agreement with social network theory which contends that recurrent interactions offer opportunities to cooperate and build trust, and then encourage individuals to act prosocially towards each other (Wittek & Bekkers, 2015). Social interactions may be an important mediator as children get older. Older children widen their social contacts and networks (e.g., friendships) that can help increase prosocial behaviour in frequency and complexity (Abrams et al., 2015; Hay & Cook, 2007).

The restoring capacities pathway is based on two main theoretical perspectives – stress reduction theory (SRT) (Ulrich, 1983) and attention restoration theory (ART) (Kaplan, 1995; Ohly et al., 2016). Positive emotionality due to exposure to green space later can lead to prosocial behaviour. A study by Zhang et al. (2014) in adults found that positive emotions mediated the association between beautiful greenery in the lab setting and prosocial behaviour. Goldy and Piff (2020) also suggest that exposure to nature can enhance prosocial behaviour due to increased positive emotions. This indicates that a positive emotional state or mental health aspect can potentially explain the association between green space quality and child prosocial behaviour. In addition, the restorative effect of green space can influence the quality of life (Holt et al., 2019; McCracken et al., 2016), which, in turn, may lead to prosocial behaviour. Furthermore, the restoration pathway might encompass trough improving caregiver mental health in supporting the development of prosocial behaviour. Prior studies suggest that exposure to green space was associated with better mental health among mothers (Feng & Astell-Burt, 2018; McEachan et al., 2016). Meanwhile, caregiver mental health was associated with child behaviour, including prosocial behaviour (Fletcher et al., 2011; Hay & Pawlby, 2003; Kim-Cohen et al., 2005). Therefore, these previous findings potentially suggest that caregiver mental health might also mediate the association between green space quality and child prosocial behaviour.

The last pathway, harm mitigation, might work by reducing harmful environmental stressors that have detrimental influences on the development of child prosocial behaviour. For example, the presence of green space potentially alleviates air-related pollution that negatively affects child cognitive growth during windows of susceptibility (e.g., prenatal), which, in turn, can influence the development of prosocial behaviour (Ren et al., 2019). Past work suggests that the decline in air-related pollution partially mediated the association between green space and child cognitive development (Dadvand et al., 2015; Liao et al., 2019). Besides, exposure to quality green space might lessen the negative impact of growing up in a disadvantaged neighbourhood or low-income household on the development of prosocial behaviour. Previous literature found that an unfavourable family socioeconomic situation (e.g., low caregiver income and/or education) was associated with lower child prosocial behaviour (Silke et al., 2018). In addition, children living in deprived neighbourhoods were reported to behave less prosocially towards others (Safra et al., 2016). Meanwhile, "salutogenic" (health improving) effects due to green space exposure can narrow socioeconomic inequalities in health outcomes (Mitchell & Popham, 2008; Mitchell et al., 2015; Wang & Lan, 2019). Findings from current published literature also showed that exposure to quality green space over time potentially attenuates socioeconomic inequalities in child prosocial behaviour (Putra et al., 2021a).

This study only tested restoring and building capacities pathways in explaining the association between green space quality and child prosocial behaviour due to the unavailability of air pollution data to examine harm mitigation pathway. Meanwhile, the harm mitigation pathway of green space through buffering negative impacts of living in unfavourable neighbourhood conditions has been tested (Putra et al., 2021a). This study sought to answer the following question: *"To what extent do physical activity, social interaction, and mental health mediate the association between green space quality and prosocial behaviour?"*. According to the framework explained above, physical activity and social interaction representing the building capacities; and health-related quality of life (HRQOL), child and caregiver mental health representing the restoring capacities pathway were tested as candidate mediators of the association between green space quality and child prosocial behaviour. This study hypothesised that candidate mediators across physical activity, social interaction, HRQOL, mental health mediate the green space quality-prosocial behaviour association.

6.2.3 Methods

6.2.3.1 Study design and samples

This study employed the Kindergarten (K) cohort data from the Longitudinal Study of Australian Children (LSAC), a nationally representative dataset. This cohort biennially follows up 4,983 children aged 4-5 years (born in March 1999-February 2000) from the commencement in 2004 (Wave 1). Three national agencies, Australian Institute of Family Studies (AIFS), Australian Bureau of Statistics (ABS), and Department of Social Services (DSS), undertake this project. A list of children was obtained from Australia's universal healthcare (Medicare) enrolment database. LSAC's sampling applied a two-stage clustered design. Postcodes, where eligible children lived, were selected using probability proportiona to size approach, considering the stratifications by state, the capital city or the rest of the state area, and urban-rural status. This step was followed by recruiting children residing within 311 selected postcodes. Data were predominantly supplied by parents or caregivers through face-to-face interviews, and some sections were completed by teachers and the studied children. Further detail information about LSAC's methodology and content is available elsewhere (Australian Institute of Family Studies, 2005, 2018).

Children's records from Waves 1 (4-5 years) to 6 (14-15 years) (2004-2014) were used in this present study because data on green space quality and prosocial behaviour were consistently documented in the aforementioned waves. Children who were missing data on the outcome (prosocial behaviour) were excluded. This makes the final number of 24,418 (95.98%) observations used in the analysis out of 25,440 observations. The information on the number of observations in each wave is presented in Table 6.1. The primary data collection of which this present study was based on was approved by the AIFS Ethics Committee. This present study also obtained ethics approval from the Human Research Ethics Committee, University of Wollongong (No. 2019/433).

6.2.3.2 Outcome: Prosocial behaviour

Child prosocial behaviour was assessed using caregiver reports of the prosocial subscale from Goodman (1997)'s Strengths and Difficulties Questionnaires (SDQ). The SDQ has been widely used in diverse settings and considered as a validated screening tool of child wellbeing (Croft et al., 2015; Hall et al., 2019; Williamson et al., 2010). The prosocial subscale consists of five items depicting children's positive behaviour that include, *"considerate of other people's feelings"*, *"share readily with other children"*, *"helpful if someone is hurt, upset or feeling ill"*, *"kind to younger children"*, and *"often volunteers to help others (parents, teachers, other children)"*. Caregivers' responses as "*not true*", "*somewhat true*", and "*certainly true*" for each item were scored as 0, 1, and 2, respectively. Better child prosocial behaviour was indicated by a higher score, with a possible range of 0-to-10 for a total score.

6.2.3.3 Exposure: Green space quality

Green space quality was subjectively measured by asking caregivers to what extent they agreed with the following statement, "*There are good parks, playgrounds and play spaces in this neighbourhood*". This caregiver-reported approach has been recently applied to examine the association between green space quality and child outcomes within the Australian context (Feng & Astell-Burt, 2017a, 2017c, 2017d; Putra et al., 2021a, 2021b). Four response options from strongly disagree to strongly agree were collapsed into two categories: "disagree" (for "*strongly disagree*" and "*disagree*"); and "agree" (for "*agree*" and "*strongly agree*") to enable causal mediation analyses.

6.2.3.4 Candidate mediator 1: Physical activity

Four variables representing physical activity were used, including weekday physical activity, weekend physical activity, the choice for free time, and physical activity enjoyment. Data on weekday and weekend physical activity were extracted from time-use diaries (TUDs). TUDs serve as a short measurement period for child behaviour, documenting two 24-hour periods of child activities on a randomly allocated weekday and weekend day. The first three waves (Wave 1, 2, 3) used a "light" TUD filled out by caregivers, recording their children's activities in a full 24-hour period, divided into 96 15-minute periods. Caregivers were able to choose from a list of 26 pre-coded activities and could pick up to six concurrent activities (e.g., eating during screen-time) for each 15-minute period (Australian Institute of Family Studies, 2007). For the remaining waves (Wave 4, 5, 6), children could record the sequence of their activities throughout a single randomly allocated day (weekday or weekend). Interviewers inputted and coded the diary using a coding framework (Australian Institute of Family Studies, 2014). The total amount of time (in minutes) allocated for physical activity (e.g., organised individual and team sports, non-organised activities – running games, riding a bicycle, ball games; taking a pet for a walk, etc.) was calculated separately for weekdays and weekend days, following a previous study on green space and physical activity using LSAC data (Sanders et al., 2015).

Other indicators, such as the choice for free time and physical activity enjoyment were measured based upon caregiver reports. The choice for free time was determined by asking caregivers, "*What does [child] usually do when she/he has a choice about how to spend free time?*" The response "*usually chooses active pastimes*" was coded as "active", while the responses "*usually chooses inactive pastimes*" or "*just as likely to choose active as inactive pastimes*" were coded as "impartial or inactive". The information on the choice for free time was not collected in Waves 4 and 6. To measure children's physical activity enjoyment, caregivers were asked to rate from "*very much dislikes activity*" =1 to "*very much likes activity"* =5 on a question, "*How much does [child] enjoy physical activity or exercise?"*. Responses were dichotomised as "enjoy" (score 4-5); and "impartial or does not enjoy" (score 1-3). This question was not asked to caregivers in Waves 2 and 3. Re-grouping categories of the choice for free time and physical activity enjoyment was informed by a previous study (Sanders et al., 2015).

6.2.3.5 Candidate mediator 2: Social interaction

Children's contacts with neighbours reported by their caregivers were used as a proxy for social interaction. Caregivers were asked to answer a question, *"How often does the study child see or spend time with the following people? Your neighbours"*. Answers were combined into two categories: "no contact and rarely" (for "*do not have*", "*no contact*", "*rarely*", and "*a few times a year*"); and "sometimes and often" (for "*at least every month*", "*at least every week*", and "*every day*").

6.2.3.6 Candidate mediator 3: Child mental health

This study used the total difficulties score (TDS) from Goodman (1997)'s SDQ to evaluate child mental health. TDS was computed by summing four domains from the SDQ (i.e., emotional symptoms, conduct problems, hyperactivity-inattention, peer problems). This tool has been validated as a measure for child mental health (Goodman & Goodman, 2009). Each of the subscales that form TDS (e.g., emotional symptoms, etc.) has a total score ranging from 0 to 10 with the more negative or worse outcome indicated by a higher score. Therefore, TDS ranges from 0 to 40 with a higher score representing increasing difficulties. Two other secondary mental health indicators were generated by partitioning TDS into an internalising subscale that informs children's tendency to internalise negative emotional state (e.g., anxiety, worry) by combining emotional symptoms and peer problems; and an externalising subscale that indicates whether children are prone to externalise negative feelings (e.g., impulsiveness, aggressiveness) by combining conduct problems and hyperactivity-inattention. A previous study suggests while children reported more symptoms than their caregivers, caregiver reports on symptoms and impacts were found to be more consistent (Van Roy et al., 2010).

6.2.3.7 Candidate mediator 4: Child health-related quality of life (HRQOL)

HRQOL indicators were assessed using the PedsQL 4.0 (Varni et al., 2003; Varni et al., 2002). The caregiver-report version of the PedsQL has shown good validity and reliability (Varni et al., 2006; Varni et al., 2003). The PedsQL consists of 23 items that assess four dimensions of HRQOL: physical (8 items), emotional, social, and school functioning (5 items for each). Caregivers were asked to rate each item on a 5-scale (0=never to 4=almost always). Answers were then reverse-scored with assigned weights (0=100, 1=75, 2=50, 3=25, 4=0). The mean of each subscale ranging from 0 to 100 was computed with a higher score indicating better HRQOL. Moreover, psychosocial health was constructed by summing up three subscales (emotional, social, and school functioning) and then divided by the number of items. Similarly, the average score of the total quality of life (QOL) was also calculated. Caregiver reports of the PedsQL 4.0 have found to result in almost similar scores to the self-report version by children among an Australian sample (Williams et al., 2005). However, parent-reported version tends to be underreported compared to self-reported HRQOL (Bakas et al., 2012).

6.2.3.8 Candidate mediator 5: Caregiver mental health

In addition to child mental health, caregiver mental health was also tested as a candidate mediator. In LSAC, caregiver mental health was measured using the Kessler 6 Psychological Distress Scale (K6). The K6 is a screening tool for the risk of serious mental health problems which has been validated (Furukawa et al., 2003). Primary caregivers were asked to answer 6 questions on how often they felt nervous, hopeless, etc. in last 30 days (1= "*none of the time*" to 5= "*all of the time*"). Caregiver psychological distress was expressed as total scores ranging from 6 to 30 with higher scores represent increasing psychological distress.

6.2.3.9 Confounders

Some potential confounders from individual, family, and neighbourhood levels informed by previous studies (Feng & Astell-Burt, 2017d; Putra et al., 2021a, 2021b) were accounted in the analysis (Figure 6.1). The child's sex; Indigenous background (Australian aboriginal or Torres Strait Islander); and whether or not the child's family spoke a non-English language at home represented individual characteristics. Variables within family circumstances included caregiver education (≤ high school, > high school); household weekly income in thousand AUD (Blakemore et al., 2006; Sanders et al., 2015); the number of siblings that the study child had; and family structure (one-caregiver, two-caregiver family). Moreover, neighbourhood characteristics consisted of area accessibility classified as "accessible" and "remote" areas, measured using the Accessibility-Remoteness Index of Australia (ARIA) (Department of Health and Aged Care, 2001); area disadvantage classified into two categories: "low-and-moderate" disadvantaged and "high" disadvantaged areas, determined using the Index of Relative Socioeconomic Disadvantage from the Socio-economic Indexes for Areas (SEIFA) (Australian Bureau of Statistics, 2006); and caregiver perceptions of neighbourhood safety (responses were re-categorised as "disagree" and "agree"), assessed using the following statement, *"This is a safe neighbourhood."* The analysis also controlled prosocial behaviour from baseline wave since earlier prosocial behaviour can be a strong predictor of later prosocial behaviour (Obsuth et al., 2015).

6.2.3.10 Data analysis

Descriptive statistics was used to present the characteristics of the respondents. Single causal mediation analysis by fitting each candidate mediator in separate mediation models was then employed to examine whether 15 candidate mediators (four physical activity variables, one social interaction variable, three child mental health variables, six child HRQOL variables, and one caregiver mental health variable) explained the association between green space quality and child prosocial behaviour. Causal mediation analysis is based on the counterfactual approach that decomposes the total causal effect of the exposure (X) on the outcome (Y) into the natural direct effect (NDE) and natural indirect effect (NIE). NDE captures the effect of the exposure (X) on the outcome (Y) via pathways that do not involve the mediator (M). Meanwhile, NIE corresponds to the effect of exposure (X) on the outcome (Y) that works through the mediator (M) (Richiardi et al., 2013). The counterfactual framework can help enhance the validity and interpretation of mediation analysis and address potential bias in the traditional approach to mediation analysis (Liu et al., 2016; Richiardi et al., 2013). In the traditional approach, the potential mediator is assessed by comparing two standard regression models with and without conditioning on the mediator that may lead to incorrect statistical analysis and flawed conclusions (Richiardi et al., 2013). This mediation technique has been increasingly used by studies in the public health-related field (Dendup et al., 2021; Hossin et al., 2019; Straatmann et al., 2020).

Due to the data structure with repeated measures on the exposure, mediators, and outcome, this study used the temporal or lagged panel model mediation. This involved modelling green space quality at $\text{Wave}_{(N)}$ as the exposure (X), physical activity, social interaction, HRQOL, and mental health at $\text{Wave}_{(N+1)}$ as candidate mediators (M), with prosocial behaviour at $\text{Wave}_{(N+2)}$ as the outcome (Y). This model controlled for confounders at the same time point as the exposure (Figure 6.1). The lagged panel model mediation has been used by some previous studies using LSAC data (Chung et al., 2018; Vella et al., 2018; Walters, 2020). There were four mediation models developed for each candidate mediator in this study. However, due to a change in the approach to physical activity data collection, only three and two mediation models could be developed for the choice for free time and physical activity enjoyment as candidate mediators, respectively.

To identify potential same-source bias since the information of most variables was collected from a single source (caregiver reports), this study involved additional analyses by performing mediation analyses using self- or children's reports on the outcome (prosocial behaviour). Self-reports of prosocial behaviour were collected in Wave 4 and hereafter. Therefore, three mediation models (W2→3→4; W3→4→5; W4→5→6) were estimated using caregiver reports on green space quality and candidate mediators with child self-reports on prosocial behaviour. Meanwhile, two models were developed for the choice for free time and physical activity enjoyment, respectively. Data on the exposure (green space quality) were only collected from caregivers, precluding modelling using self-reported green space quality. Even though teacher-reported prosocial behaviour was also available, that was not included in additional analyses since a previous study suggests that teacher-reported indicators may be sub-optimal in studies of neighbourhood green space (Feng & Astell-Burt, 2017c).

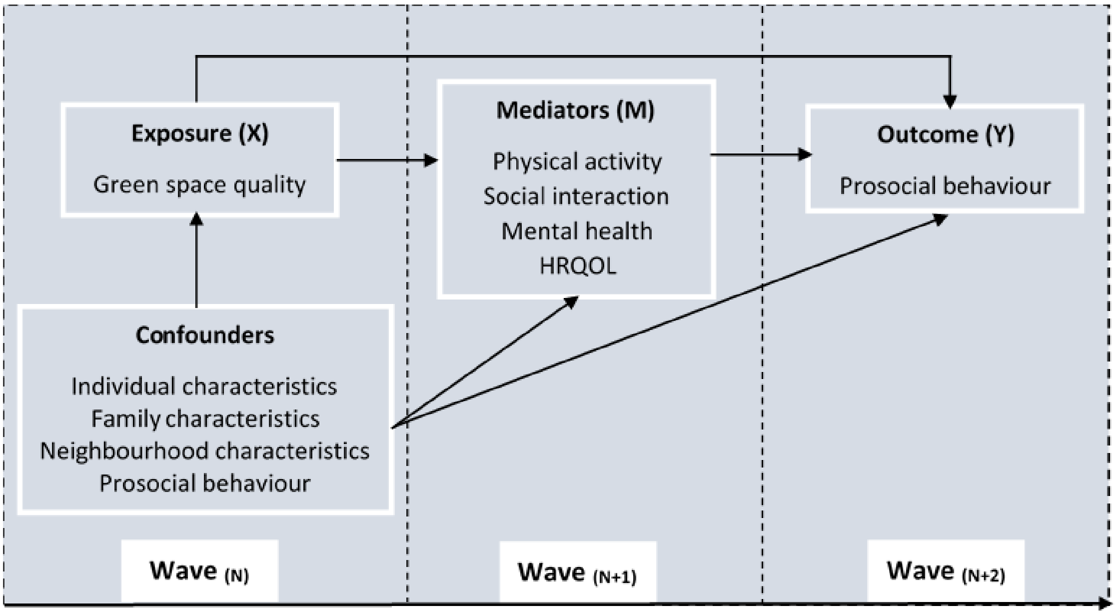

Figure 6.1 Directed acyclic graphs of mediation analysis

All analyses were conducted in STATA 14.2 using the "paramed" command (Valente et al., 2020). Results were presented as adjusted regression coefficients (β) for NDE, NIE, and total effect along with bias-corrected 95% confidence intervals (CIs) from bootstrapping with 1000 resamples. Proportion mediated (NIE/total effect) was also calculated. Findings of the mediation analyses were reported to four decimal places to capture the small influences of candidate mediators and precisely report 95% CIs.

6.2.4 Results

6.2.4.1 Sample characteristics

Table 6.1 presents the trends of individual, family, and neighbourhood characteristics from Waves 1 to 6 (2004-2014). Nearly similar proportions of boys and girls were involved and followed-up from commencement in 2004. Less than 5% of children were Indigenous, and no more than 15% of children spoke a language other than English at home. Household socioeconomic status improved by waves, indicated by the increased proportions of caregivers in the family who completed more than high school education and the increased average of family weekly income. Children were also reported to have one to two siblings in the family and the majority lived with two caregivers. Furthermore, around 76% of caregivers reported having quality green space in their neighbourhood and more than 80% of caregivers considered their neighbourhood as safe. Most of the children lived in less disadvantaged and accessible areas.

Child prosocial behaviour was in the normal range (score>5) across waves and the overall average of prosocial behaviour score was relatively high (8.13/10). The amount of physical activity time on weekdays fluctuated in 10 years, but on weekend days declined as children got older. Even though caregiver reports on the choice for free time and physical activity enjoyment were not collected for two waves, respectively, the available data suggested that the proportions of children who chose to be active during free time and enjoyed being physically active decreased by age. Moreover, children's contact with neighbours tended to decline in adolescence. Most of the child mental health (internalising, externalising subscale, TDS) and HRQOL indicators (physical, emotional, social functioning, psychosocial health, total QOL) fluctuated during the study period, except for school functioning which decreased by waves. Caregiver psychological stress was also found to vary across waves.

Table 6.1 Sample characteristics

Variables	Wave 1 (4-5 years) n (%[a])	Wave 2 (6-7 years) n (%[a])	Wave 3 (8-9 years) n (%[a])	Wave 4 (10-11 years) n (%[a])	Wave 5 (12-13 years) n (%[a])	Wave 6 (14-15 years) n (%[a])	Total (Waves 1 to 6) n (%[a])
Total sample	4,969	4,333	3,793	4,109	3,847	3,367	24,418
Dependent variable							
Prosocial behaviour, mean (SD)	7.73 (1.80)	8.20 (1.74)	8.22 (1.75)	8.47 (1.69)	8.24 (1.77)	7.99 (1.88)	8.13 (1.79)
Main independent variable							
Green space quality							
Do not agree	1,118 (23.39)	583 (13.01)	747 (20.62)	663 (17.27)	807 (21.88)	465 (14.65)	4,383 (18.65)
Agree	3,831 (76.15)	2,782 (61.71)	3,035 (79.03)	3,437 (82.46)	3,028 (77.76)	2,892 (84.97)	19,005 (76.55)
missing/not reported	*20 (0.46)*	*968 (25.28)*	*11 (0.35)*	*9 (0.27)*	*12 (0.35)*	*10 (0.38)*	*1,030 (4.80)*
Candidate mediating variables							
Weekday PA (in minutes), mean (SD)[b]	147.37 (122.91)	78.13 (83.00)	86.86 (92.91)	117.21 (98.29)	87.60 (91.23)	69.30 (87.59)	100.69 (101.92)
Weekend PA (in minutes), mean (SD)[b]	223.23 (141.05)	158.38 (119.72)	154.00 (126.46)	128.58 (117.61)	112.91 (114.30)	77.66 (99.84)	167.27 (133.46)
Choice for free time							
Impartial or inactive	2,654 (55.01)	2,427 (57.42)	2,208 (59.75)	-	2,347 (62.13)	-	9,636 (58.29)
Active	2,310 (44.88)	1,904 (42.55)	1,582 (40.17)		1,489 (37.51)		7,285 (41.57)
missing/not reported	*5 (0.11)*	*2 (0.03)*	*3 (0.08)*		*11 (0.36)*		*21 (0.14)*
PA enjoyment							
Impartial or not enjoy	334 (6.87)	-	-	274 (6.77)	378 (10.36)	486 (15.08)	1,472 (9.35)
Enjoy	4,635 (93.13)			3,774 (91.69)	3,401 (87.87)	2,750 (80.91)	14,560 (89.02)
missing/not reported				*61 (1.54)*	*68 (1.78)*	*131 (4.01)*	*260 (1.63)*
Contacts with neighbours							
No contact and rarely	1,612 (32.08)	1,401 (31.38)	1,575 (42.32)	1,717 (42.30)	1,854 (48.27)	2,079 (62.13)	10,238 (41.93)
Sometimes and often	2,548 (51.24)	1,996 (44.20)	2,184 (56.72)	2,372 (57.11)	1,966 (50.89)	1,272 (37.36)	12,338 (50.53)
missing/not reported	*809 (16.68)*	*939 (24.41)*	*34 (0.96)*	*20 (0.59)*	*27 (0.85)*	*16 (0.50)*	*1,842 (7.54)*

Internalising subscale, mean (SD)	3.47 (2.74)	3.27 (2.83)	3.23 (2.94)	3.66 (3.25)	3.53 (3.12)	3.62 (3.16)	3.46 (1.00)
Externalising subscale, mean (SD)	6.13 (3.72)	4.93 (3.30)	4.65 (3.41)	4.77 (3.48)	4.20 (3.37)	3.90 (3.35)	4.85 (3.53)
Total difficulties score (TDS), mean (SD)	9.60 (5.37)	8.20 (5.17)	7.88 (5.47)	8.43 (5.82)	7.73 (5.59)	7.52 (5.61)	8.31 (5.54)
Physical functioning, mean (SD)	82.62 (12.42)	82.14 (15.07)	83.01 (15.23)	77.41 (20.56)	82.37 (16.51)	79.77 (20.25)	81.20 (17.00)
Emotional functioning, mean (SD)	72.02 (14.79)	73.96 (14.96)	72.85 (16.34)	73.30 (17.00)	75.43 (17.38)	74.22 (18.53)	73.58 (16.56)
Social functioning, mean (SD)	82.68 (16.16)	80.13 (17.37)	78.51 (18.23)	78.76 (19.41)	81.81 (18.46)	79.23 (18.90)	80.24 (18.17)
School functioning, mean (SD)	86.95 (15.26)	78.14 (17.09)	75.59 (17.34)	74.31 (17.49)	73.29 (17.63)	71.19 (18.40)	76.80 (17.96)
Psychosocial health, mean (SD)	79.56 (12.36)	77.38 (13.69)	75.64 (14.39)	75.45 (14.96)	76.82 (14.97)	74.88 (15.76)	76.68 (14.44)
Total quality of life (QOL), mean (SD)	80.74 (11.12)	79.05 (12.78)	78.21 (13.27)	76.15 (15.29)	78.75 (13.97)	76.58 (15.63)	78.28 (13.81)
Caregiver psychological distress, mean (SD)	10.18 (3.85)	9.24 (3.55)	9.62 (3.76)	9.65 (3.99)	9.33 (4.04)	9.40 (3.98)	9.58 (3.87)
Confounders: individual characteristics							
Child's sex							
Female	2,443 (48.86)	2,121 (48.83)	1,865 (48.94)	2,011 (48.87)	1,880 (48.21)	1,660 (48.71)	11,980 (48.74)
Male	2,526 (51.14)	2,212 (51.17)	1,928 (51.06)	2,098 (51.13)	1,967 (51.79)	1,707 (51.29)	12,438 (51.26)
Child Indigenous status							
Not Indigenous	4,780 (96.06)	4,184 (96.28)	3,696 (96.83)	3,993 (96.26)	3,747 (97.35)	3,294 (97.48)	23,694 (96.65)
Indigenous	187 (3.91)	147 (3.69)	95 (3.13)	114 (3.71)	100 (2.65)	73 (2.52)	716 (3.33)
missing/not reported	*2 (0.03)*	*2 (0.03)*	*2 (0.04)*	*2 (0.04)*			*8 (0.02)*
Child speaks a language other than English							
No	4,356 (86.24)	3,849 (85.99)	3,422 (87.72)	3,694 (86.77)	3,546 (89.48)	3,067 (88.57)	21,934 (87.34)
Yes	613 (13.76)	484 (14.01)	371 (12.28)	415 (13.23)	301 (10.52)	300 (11.43)	2,484 (12.66)
Confounders: family characteristics							
Caregiver education							
≤ High school	918 (20.33)	654 (17.77)	457 (15.04)	464 (14.36)	375 (11.68)	263 (9.89)	3,131 (15.26)
> High school	4,048 (79.62)	3,678 (82.21)	3,335 (84.93)	3,644 (85.58)	3,470 (88.27)	3,101 (90.04)	21,276 (84.69)
missing/not reported	*3 (0.05)*	*1 (0.02)*	*1 (0.03)*	*1 (0.06)*	*2 (0.05)*	*3 (0.07)*	*11 (0.05)*
Family weekly income (in thousands), mean (SD)	1.27 (0.86)	1.52 (1.13)	1.78 (1.27)	1.86 (1.50)	2.12 (1.56)	2.28 (1.64)	1.76 (1.40)

Family structure							
One-caregiver family	692 (14.89)	629 (16.40)	522 (16.03)	642 (18.60)	644 (17.78)	581 (19.69)	3,710 (17.07)
Two-caregiver family	4,277 (85.11)	3,704 (83.60)	3,271 (83.97)	3,466 (81.34)	3,202 (82.19)	2,786 (80.31)	20,706 (82.91)
missing/not reported				*1 (0.06)*	*1 (0.03)*		*2 (0.01)*
Number of siblings, mean (SD)	1.51 (1.07)	1.60 (1.08)	1.62 (1.06)	1.68 (1.14)	1.62 (1.10)	1.52 (1.07)	1.59 (1.09)
Confounders: neighbourhood characteristics							
Neighbourhood safety							
Do not agree	419 (9.30)	181 (4.51)	196 (6.24)	187 (5.40)	450 (12.84)	127 (4.47)	1,560 (7.22)
Agree	4,533 (90.33)	3,147 (69.31)	3,580 (93.23)	3,916 (94.41)	3,386 (86.82)	3,232 (95.20)	21,794 (87.84)
missing/not reported	*17 (0.38)*	*1,005 (26.18)*	*17 (0.45)*	*6 (0.19)*	*11 (0.34)*	*8 (0.33)*	*1,064 (4.95)*
Area disadvantage (SEIFA)							
High	1,786 (37.19)	1,497 (36.54)	1,254 (35.71)	1,608 (42.36)	1,453 (40.63)	1,214 (39.26)	8,812 (38.55)
Moderate and low	3,183 (62.81)	2,836 (63.46)	2,539 (64.29)	2,500 (57.62)	2,393 (59.35)	2,152 (60.73)	15,603 (61.44)
missing/not reported				*1 (0.02)*	*1 (0.02)*	*1 (0.01)*	*3 (0.01)*
Area accessibility (ARIA)							
Accessible	4,707 (95.47)	4,103 (95.67)	3,602 (95.51)	3,918 (96.01)	3,673 (95.97)	3,225 (96.05)	23,228 (95.76)
Remote	216 (3.80)	183 (3.50)	140 (3.22)	153 (3.19)	143 (3.23)	107 (2.97)	942 (3.35)
missing/not reported	*46 (0.73)*	*47 (0.83)*	*51 (1.27)*	*38 (0.80)*	*31 (0.80)*	*35 (0.98)*	*248 (0.89)*

n=number of samples; [a]=weighted percentages; [b]=children completed TUD for only one day (weekday or weekend day) at Waves 4 to 6; SD=standard deviation; PA=physical activity; (–) = data not available at waves

6.2.4.2 Assessments of mediation by physical activity, social interaction, and mental health

Seven mediation models were developed in this study, consisting of four and three mediation models predicting caregiver-reported and child-reported prosocial behaviour, respectively (Tables 6.2 and 6.3). Generally, mediation models using self-reports on prosocial behaviour showed lower proportions mediated compared to models using caregiver-reported prosocial behaviour. Indirect effects of some candidate mediators were also no longer statistically significant in some mediation models using child-reported prosocial behaviour. The mediation consistency was then assessed by grouping candidate mediators into three categories based on the proportion of mediation models with statistically significant indirect effects. These groups consisted of (i) low (<50% or <4/7 models), (ii) moderate (50%-74% or 4-5/7 models), and (iii) high consistency (≥75% or ≥6/7 models) (Table 6.4).

Out of four indicators of child physical activity, only physical activity enjoyment was found as a mediator with moderate consistency. Physical activity enjoyment mediated associations between green space quality and prosocial behaviour in one mediation model (W4→5→6) for each of caregiver-reported and child-reported prosocial behaviour, with the proportion mediated being 5.14% and 13.82%, respectively. These accounted for two mediation models with significant indirect effects out of four mediation models. However, the indirect effects of the other three physical activity indicators (weekday, weekend physical activities, and choice for free time) were not statistically significant. This indicates very weak evidence for a mediating pathway via physical activity.

Children's contacts with neighbours as a proxy for social interactions also explained the green space quality-prosocial behaviour association with low consistency. Statistically significant indirect effects via social interaction were found in three models for caregiver-reported prosocial behaviour only, but none in child-reported prosocial behaviour models. The highest proportion mediated by social interaction was 25.76% in caregiver-reported prosocial behaviour model (W2→3→4).

This study found moderate-to-high mediation consistency of child mental health indicators. Internalising subscale and TDS displayed high mediation consistency, as both mediated the associations between green space quality and prosocial behaviour in all mediation models for both caregiver-reported and child-reported prosocial behaviour. Meanwhile, externalising subscale showed moderate mediation consistency. For child mental health indicators, TDS was found to have the highest proportion mediated, up to 85.43% in caregiver-reported (W2→3→4) and 45.43% in child-reported (W4→5→6) prosocial behaviour models.

Only psychosocial health from HRQOL indicators demonstrated high mediation consistency, whereas other indicators from this scale showed weak (i.e., physical, emotional, school functioning) and moderate consistency (i.e., social functioning, total QOL). Social functioning contributed the highest proportion mediated in caregiver-reported prosocial behaviour model, accounting for 85.56% (W2→3→4) and psychosocial health in child-reported prosocial model, by 32.61% (W4→5→6). In addition, low mediation consistency for caregiver psychological distress was reported, with the proportion mediated up to 24.38% and 24.33% in caregiver-reported (W1→2→3) and child-reported (W4→5→6) mediation models, respectively.

For the majority of candidate mediators with statistically significant indirect effects, the mediation appeared to manifest more in later waves for caregiver-reported (W3→4→5; W4→5→6) and child-reported (W4→5→6) prosocial behaviour models, except for social interaction. In addition, the direct effects of green space quality on prosocial behaviour tended to strengthen in late childhood (W3→4→5) and then decline in adolescence (W4→5→6).

Table 6.2 Mediation analyses of the association between green space quality and caregiver-reported prosocial behaviour

Waves	Weekday PA	Weekend PA	The choice for Free Time	PA Enjoyment
	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)
Wave 1 → 2 → 3				
Natural direct effect (NDE)	0.0131 (-0.1248, 0.1570)	0.0170 (-0.1169, 0.1703)	0.0347 (-0.0882, 0.1607)	-
Natural indirect effect (NIE)	0.0011 (-0.0016, 0.0083)	-0.0001 (-0.0045, 0.0029)	0.0001 (-0.0015, 0.0041)	
Total effect	0.0142 (-0.1232, 0.1585)	0.0169 (-0.1170, 0.1701)	0.0348 (-0.0870, 0.1633)	
Proportion mediated (NIE/total)	0.0775	0.0059	0.0029	
Wave 2 → 3 → 4				
Natural direct effect (NDE)	-0.0449 (-0.1937, 0.1341)	-0.0316 (-0.1800, 0.1418)	0.0270 (-0.1188, 0.1712)	-
Natural indirect effect (NIE)	0.0017 (-0.0022, 0.0119)	-0.0030 (-0.0162, 0.0028)	-0.0003 (-0.0063, 0.0023)	
Total effect	-0.0432 (-0.1896, 0.1286)	-0.0346 (-0.1855, 0.1342)	0.0267 (-0.1163, 0.1725)	
Proportion mediated (NIE/total)	0.1489	0.0867	0.0111	
Wave 3 → 4 → 5				
Natural direct effect (NDE)	**0.1581 (0.0036, 0.3236)**	**0.3124 (0.0294, 0.5989)**	-	**0.2090 (0.0844, 0.3626)**
Natural indirect effect (NIE)	0.0004 (-0.0015, 0.0070)	-0.0010 (-0.0224, 0.0098)		0.0027 (-0.0007, 0.0150)
Total effect	**0.1585 (0.0048, 0.3249)**	**0.3114 (0.0245, 0.5916)**		**0.2117 (0.0875, 0.3659)**
Proportion mediated (NIE/total)	0.0025	0.0032		0.0128
Wave 4 → 5 → 6				
Natural direct effect (NDE)	0.1293 (-0.0720, 0.3087)	0.1015 (-0.2639, 0.4714)	0.1489 (-0.0138, 0.3158)	0.1422 (-0.0200, 0.3156)
Natural indirect effect (NIE)	-0.0001 (-0.0057, 0.0031)	0.0064 (-0.0068, 0.0428)	-0.0003 (-0.0065, 0.0047)	**0.0077 (0.0002, 0.0204)**
Total effect	0.1292 (-0.0740, 0.3080)	0.1079 (-0.2613, 0.4767)	0.1487 (-0.0149, 0.3167)	0.1499 (-0.0144, 0.3172)
Proportion mediated (NIE/total)	0.0008	0.0593	0.0020	0.0514

Table 6.2 Mediation analyses of the association between green space quality and caregiver-reported prosocial behaviour *(Continued 1)*

Waves	Contacts with Neighbours	Internalising Subscale	Externalising Subscale	Total Difficulties Scores
	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)
Wave 1 → 2 → 3				
Natural direct effect (NDE)	0.0344 (-0.0926, 0.1631)	0.0052 (-0.1199, 0.1140)	0.0123 (-0.1156, 0.1423)	0.0229 (-0.1035, 0.1441)
Natural indirect effect (NIE)	**0.0096 (0.0022, 0.0232)**	**0.0255 (0.0021, 0.0469)**	0.0223 (-0.0097, 0.0528)	**0.0650 (0.0078, 0.1085)**
Total effect	0.0440(-0.0823, 0.1757)	0.0307 (-0.0940, 0.1417)	0.0346 (-0.0928, 0.1702)	0.0879 (-0.0531, 0.2198)
Proportion mediated (NIE/total)	0.2182	0.8306	0.6445	0.7495
Wave 2 → 3 → 4				
Natural direct effect (NDE)	0.0196 (-0.1194, 0.1731)	0.0160 (-0.1298, 0.1745)	0.0063 (-0.1306, 0.1338)	0.0044 (-0.1338, 0.1478)
Natural indirect effect (NIE)	**0.0068 (0.0011, 0.0245)**	**0.0143 (0.0015, 0.0375)**	0.0214 (-0.0027, 0.0465)	**0.0258 (0.0026, 0.0552)**
Total effect	0.0264 (-0.1122, 0.1816)	0.0303 (-0.1142, 0.1949)	0.0277 (-0.1133, 0.1625)	0.0302 (-0.1126, 0.1698)
Proportion mediated (NIE/total)	0.2576	0.4719	0.7726	0.8543
Wave 3 → 4 → 5				
Natural direct effect (NDE)	**0.2131 (0.0695, 0.3436)**	**0.1973 (0.0575, 0.3399)**	**0.1857 (0.0467, 0.3308)**	**0.1770 (0.0355, 0.3114)**
Natural indirect effect (NIE)	**0.0068 (0.0006, 0.0184)**	**0.0306 (0.0145, 0.0644)**	**0.0390 (0.0165, 0.0660)**	**0.0496 (0.0265, 0.0800)**
Total effect	**0.2199 (0.0795, 0.3530)**	**0.2279 (0.0863, 0.3766)**	**0.2247 (0.0861, 0.3774)**	**0.2266 (0.0879, 0.3677)**
Proportion mediated (NIE/total)	0.0309	0.1343	0.1736	0.2189
Wave 4 → 5 → 6				
Natural direct effect (NDE)	0.1554 (-0.0265, 0.3197)	0.0991 (-0.0805, 0.2602)	0.1004 (-0.0496, 0.2704)	0.0786 (-0.0828, 0.2524)
Natural indirect effect (NIE)	0.0002 (-0.0015, 0.0064)	**0.0500 (0.0270, 0.0793)**	**0.0507 (0.0192, 0.0911)**	**0.0724 (0.0461, 0.1186)**
Total effect	0.1556 (-0.0270, 0.3208)	0.1491 (-0.0227, 0.3147)	0.1511 (-0.0078, 0.3240)	0.1510 (-0.0137, 0.3321)
Proportion mediated (NIE/total)	0.0013	0.3354	0.3355	0.4795

Table 6.2 Mediation analyses of the association between green space quality and caregiver-reported prosocial behaviour *(Continued 2)*

Waves	Physical Functioning	Emotional Functioning	Social Functioning	School Functioning
	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)
Wave 1 → 2 → 3				
Natural direct effect (NDE)	0.0265 (-0.0923, 0.1781)	0.0194 (-0.1060, 0.1521)	0.0106 (-0.1129, 0.1539)	0.0196 (-0.1150, 0.1543)
Natural indirect effect (NIE)	0.0049 (-0.0106, 0.0245)	0.0108 (-0.0031, 0.0240)	**0.0185 (0.0001, 0.0386)**	0.0130 (-0.0005, 0.0332)
Total effect	0.0314 (-0.0872, 0.1762)	0.0302 (-0.0913, 0.1653)	0.0291 (-0.1009, 0.1797)	0.0326 (-0.0968, 0.1764)
Proportion mediated (NIE/total)	0.1561	0.3576	0.6357	0.3988
Wave 2 → 3 → 4				
Natural direct effect (NDE)	0.0131 (-0.1273, 0.1425)	0.0234 (-0.1107, 0.1779)	0.0039 (-0.1426, 0.1449)	0.0219 (-0.1240, 0.1598)
Natural indirect effect (NIE)	0.0132 (-0.0015, 0.0324)	0.0047 (-0.0061, 0.0207)	**0.0231 (0.0068, 0.0421)**	0.0079 (-0.0002, 0.0231)
Total effect	0.0263 (-0.1206, 0.1565)	0.0281 (-0.1035, 0.1874)	0.0270 (-0.1205, 0.1686)	0.0298 (-0.1194, 0.1687)
Proportion mediated (NIE/total)	0.5019	0.1673	0.8556	0.2651
Wave 3 → 4 → 5				
Natural direct effect (NDE)	**0.2151 (0.0706, 0.3611)**	**0.2128 (0.0732, 0.3547)**	**0.2102 (0.0753, 0.3498)**	**0.2126 (0.0695, 0.3485)**
Natural indirect effect (NIE)	**0.0115 (0.0004, 0.0250)**	0.0127 (-0.0021, 0.0316)	**0.0200 (0.0076, 0.0385)**	**0.0146 (0.0047, 0.0296)**
Total effect	**0.2267 (0.0770, 0.3712)**	**0.2255 (0.0855, 0.3722)**	**0.2302 (0.0915, 0.3678)**	**0.2272 (0.0868, 0.3624)**
Proportion mediated (NIE/total)	0.0507	0.0563	0.0869	0.0643
Wave 4 → 5 → 6				
Natural direct effect (NDE)	0.1202 (-0.0602, 0.2908)	0.1153 (-0.0449, 0.2977)	0.1139 (-0.0525, 0.2718)	0.1184 (-0.0462, 0.2903)
Natural indirect effect (NIE)	**0.0281 (0.0104, 0.0555)**	**0.0348 (0.0172, 0.0649)**	**0.0342 (0.0147, 0.0628)**	**0.0304 (0.0131, 0.0535)**
Total effect	0.1483 (-0.0282, 0.3216)	0.1501 (-0.0132, 0.3300)	0.1481 (-0.0205, 0.3104)	0.1487 (-0.0138, 0.3250)
Proportion mediated (NIE/total)	0.1895	0.2318	0.2309	0.2044

Table 6.2 Mediation analyses of the association between green space quality and caregiver-reported prosocial behaviour *(Continued 3)*

Waves	**Psychosocial Health**	**Total QOL**	**Caregiver Psychological Distress**
	Adjusted β (95%CI)	**Adjusted β (95%CI)**	**Adjusted β (95%CI)**
Wave 1 → 2 → 3			
Natural direct effect (NDE)	0.0094 (-0.1264, 0.1453)	0.0129 (-0.1118, 0.1527)	0.0214 (-0.1043, 0.1451)
Natural indirect effect (NIE)	**0.0207 (0.0005, 0.0414)**	0.0175 (-0.0085, 0.0353)	0.0069 (-0.0030, 0.0143)
Total effect	0.0301 (-0.1065, 0.1639)	0.0304 (-0.1010, 0.1643)	0.0283 (-0.1134, 0.1453)
Proportion mediated (NIE/total)	0.6877	0.5757	0.2438
Wave 2 → 3 → 4			
Natural direct effect (NDE)	0.0111 (-0.1395, 0.1523)	0.0077 (-0.1318, 0.1496)	0.0292 (-0.1008, 0.1709)
Natural indirect effect (NIE)	**0.0167 (0.0028, 0.0371)**	**0.0196 (0.0026, 0.0414)**	0.0014 (-0.0061, 0.0115)
Total effect	0.0278 (-0.1227, 0.1707)	0.0273 (-0.1091, 0.1748)	0.0306 (-0.1021, 0.1712)
Proportion mediated (NIE/total)	0.6007	0.7180	0.0458
Wave 3 → 4 → 5			
Natural direct effect (NDE)	**0.2006 (0.0504, 0.3398)**	**0.1999 (0.0640, 0.3443)**	**0.2135 (0.0764, 0.3626)**
Natural indirect effect (NIE)	**0.0255 (0.0096, 0.0433)**	**0.0248 (0.0102, 0.0415)**	**0.0078 (0.0005, 0.0181)**
Total effect	**0.2261 (0.0765, 0.3680)**	**0.2247 (0.0866, 0.3685)**	**0.2213 (0.0839, 0.3711)**
Proportion mediated (NIE/total)	0.1128	0.1104	0.0353
Wave 4 → 5 → 6			
Natural direct effect (NDE)	0.1015 (-0.0674, 0.2772)	0.0990 (-0.0666, 0.2502)	0.1237 (-0.0377, 0.3039)
Natural indirect effect (NIE)	**0.0490 (0.0274, 0.0870)**	**0.0506 (0.0255, 0.0828)**	**0.0308 (0.0160, 0.0577)**
Total effect	0.1505 (-0.0151, 0.3343)	0.1496 (-0.0184, 0.3146)	0.1545 (-0.0079, 0.3344)
Proportion mediated (NIE/total)	0.3256	0.3382	0.1994

PA= physical activity; QOL= quality of life; β= regression coefficient; CI=confidence interval; (–) = mediator was not collected at waves; bold=p-value<0.05. The model was adjusted for all covariates from baseline wave: child's sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, area accessibility, and prosocial behaviour from the baseline wave.

Table 6.3 Mediation analyses of the association between green space quality and child-reported prosocial behaviour

Waves	Weekday PA	Weekend PA	Choice for Free Time	PA Enjoyment
	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)
Wave 2 → 3 → 4				
Natural direct effect (NDE)	0.0410 (-0.1334, 0.2264)	-0.0105 (-0.1927, 0.1580)	0.0744 (-0.0954, 0.2547)	-
Natural indirect effect (NIE)	-0.0004 (-0.0086, 0.0036)	-0.0007 (-0.0101, 0.0019)	-0.0005 (-0.0085, 0.0019)	
Total effect	0.0406 (-0.1320, 0.2271)	-0.0112 (-0.1918, 0.1549)	0.0739 (-0.0967, 0.2539)	
Proportion mediated (NIE/total)	0.0098	0.0625	0.0067	
Wave 3 → 4 → 5				
Natural direct effect (NDE)	0.0847 (-0.0949, 0.1636)	0.3037 (-0.0356, 0.6571)	-	0.1323 (-0.0041, 0.2873)
Natural indirect effect (NIE)	0.0001 (-0.0038, 0.0047)	0.0024 (-0.0115, 0.0311)		0.0083 (-0.0017, 0.0264)
Total effect	0.0848 (-0.0957, 0.2630)	0.3061 (-0.0328, 0.6471)		**0.1406 (0.0017, 0.2936)**
Proportion mediated (NIE/total)	0.0012	0.0078		0.0590
Wave 4 → 5 → 6				
Natural direct effect (NDE)	0.1046 (-0.0687, 0.3089)	0.0031 (-0.3873, 0.3943)	0.1183 (-0.0437, 0.3070)	0.1010 (-0.0799, 0.2957)
Natural indirect effect (NIE)	-0.0009 (-0.0124, 0.0022)	0.0028 (-0.0146, 0.0387)	-0.0011 (-0.0097, 0.0159)	**0.0162 (0.0016, 0.0374)**
Total effect	0.1037 (-0.0729, 0.3106)	0.0059 (-0.3907, 0.3910)	0.1172 (-0.0413, 0.3154)	0.1172 (-0.0717, 0.3064)
Proportion mediated (NIE/total)	0.0086	0.4746	0.0093	0.1382

Table 6.3 Mediation analyses of the association between green space quality and child-reported prosocial behaviour (*Continued 1*)

Waves	Contacts with Neighbours	Internalising Subscale	Externalising Subscale	Total Difficulties Scores
	Adjusted β (95%CI)	**Adjusted β (95%CI)**	**Adjusted β (95%CI)**	**Adjusted β (95%CI)**
Wave 2 → 3 → 4				
Natural direct effect (NDE)	0.0775 (-0.1071, 0.2436)	0.0679 (-0.1028, 0.2307)	0.0693 (-0.0988, 0.2475)	0.0656 (-0.1082, 0.2254)
Natural indirect effect (NIE)	0.0056 (-0.0007, 0.0217)	**0.0075 (0.0007, 0.0262)**	0.0061 (-0.0003, 0.0196)	**0.0099 (0.0016, 0.0277)**
Total effect	0.0831 (-0.1073, 0.2469)	0.0754 (-0.0980, 0.2391)	0.0754 (-0.0942, 0.2569)	0.0755 (-0.1030, 0.2345)
Proportion mediated (NIE/total)	0.0674	0.0995	0.0809	0.1311
Wave 3 → 4 → 5				
Natural direct effect (NDE)	0.1419 (-0.0023, 0.2996)	0.1376 (-0.0223, 0.2930)	0.1272 (-0.0267, 0.2714)	0.1257 (-0.0305, 0.2694)
Natural indirect effect (NIE)	0.0060 (-0.0010, 0.0190)	**0.0119 (0.0037, 0.0354)**	**0.0214 (0.0087, 0.0446)**	**0.0241 (0.0116, 0.0464)**
Total effect	**0.1479 (0.0030, 0.3023)**	0.1495 (-0.0104, 0.3081)	0.1486 (-0.0003, 0.2975)	0.1498 (-0.0038, 0.2967)
Proportion mediated (NIE/total)	0.0406	0.0796	0.1440	0.1609
Wave 4 → 5 → 6				
Natural direct effect (NDE)	0.1221 (-0.0209, 0.3334)	0.0814 (-0.0942, 0.2518)	0.0755 (-0.1002, 0.2429)	0.0639 (-0.0987, 0.2346)
Natural indirect effect (NIE)	0.0012 (-0.0024, 0.0168)	**0.0335 (0.0171, 0.0627)**	**0.0413 (0.0235, 0.0763)**	**0.0532 (0.0354, 0.0848)**
Total effect	0.1233 (-0.0150, 0.3357)	0.1149 (-0.0602, 0.2899)	0.1168 (-0.0586, 0.2850)	0.1171 (-0.0443, 0.2848)
Proportion mediated (NIE/total)	0.0097	0.2916	0.3536	0.4543

Table 6.3 Mediation analyses of the association between green space quality and child-reported prosocial behaviour (*Continued 2*)

Waves	Physical Functioning	Emotional Functioning	Social Functioning	School Functioning
	Adjusted β (95%CI)	**Adjusted β (95%CI)**	**Adjusted β (95%CI)**	**Adjusted β (95%CI)**
Wave 2 → 3 → 4				
Natural direct effect (NDE)	0.0717 (-0.1095, 0.2386)	0.0725 (-0.0948, 0.2558)	0.0681 (-0.1131, 0.2405)	0.0715 (-0.1112, 0.2388)
Natural indirect effect (NIE)	0.0015 (-0.0030, 0.0129)	0.0007 (-0.0017, 0.0103)	0.0047 (-0.0057, 0.0195)	0.0015 (-0.0021, 0.0134)
Total effect	0.0732 (-0.1068, 0.2376)	0.0732 (-0.0933, 0.2562)	0.0728 (-0.1049, 0.2459)	0.0730 (-0.1098, 0.2397)
Proportion mediated (NIE/total)	0.0205	0.0096	0.0646	0.0206
Wave 3 → 4 → 5				
Natural direct effect (NDE)	0.1409 (-0.0243, 0.2961)	0.1414 (-0.0037, 0.2979)	**0.1435 (0.0018, 0.2878)**	0.1378 (-0.0092, 0.2848)
Natural indirect effect (NIE)	0.0050 (-0.0070, 0.0171)	0.0073 (-0.0011, 0.0215)	0.0059 (-0.0026, 0.0182)	0.0082 (-0.0017, 0.0181)
Total effect	0.1459 (-0.0263, 0.3016)	**0.1487 (0.0061, 0.3076)**	**0.1494 (0.0101, 0.2992)**	0.1460 (-0.0009, 0.2928)
Proportion mediated (NIE/total)	0.0343	0.0490	0.0395	0.0562
Wave 4 → 5 → 6				
Natural direct effect (NDE)	0.1039 (-0.0532, 0.2684)	0.0915 (-0.0884, 0.2638)	0.0904 (-0.0759, 0.2664)	0.0851 (-0.0711, 0.2653)
Natural indirect effect (NIE)	**0.0096 (0.0011, 0.0263)**	**0.0216 (0.0100, 0.0472)**	**0.0268 (0.0128, 0.0549)**	**0.0294 (0.0141, 0.0557)**
Total effect	0.1135 (-0.0453, 0.2774)	0.1131 (-0.0720, 0.2880)	0.1172 (-0.0402, 0.2973)	0.1145 (-0.0414, 0.2880)
Proportion mediated (NIE/total)	0.0846	0.1910	0.2287	0.2567

Table 6.3 Mediation analyses of the association between green space quality and child-reported prosocial behaviour (*Continued 3*)

Waves	**Psychosocial Health**	**Total QOL**	**Caregiver Psychological Distress**
	Adjusted β (95%CI)	**Adjusted β (95%CI)**	**Adjusted β (95%CI)**
Wave 2 → 3 → 4			
Natural direct effect (NDE)	0.0700 (-0.1075, 0.2286)	0.0701 (-0.1055, 0.2390)	0.0782 (-0.0946, 0.2431)
Natural indirect effect (NIE)	0.0031 (-0.0032, 0.0171)	0.0031 (-0.0037, 0.0159)	0.0001 (-0.0032, 0.0066)
Total effect	0.0731 (-0.1016, 0.2325)	0.0732 (-0. 1021, 0.2440)	0.0783 (-0.0978, 0.2437)
Proportion mediated (NIE/total)	0.0424	0.0424	0.0013
Wave 3 → 4 → 5			
Natural direct effect (NDE)	0.1368 (-0.0057, 0.3003)	**0.1368 (0.0008, 0.3045)**	0.1456 (-0.0052, 0.3159)
Natural indirect effect (NIE)	**0.0122 (0.0037, 0.0291)**	**0.0116 (0.0017, 0.0305)**	0.0004 (-0.0054, 0.0098)
Total effect	**0.1490 (0.0076, 0.3141)**	**0.1484 (0.0127, 0.3134)**	0.1460 (-0.0049, 0.3172)
Proportion mediated (NIE/total)	0.0819	0.0782	0.0027
Wave 4 → 5 → 6			
Natural direct effect (NDE)	0.0771 (-0.0931, 0.2551)	0.0822 (-0.0700, 0.2762)	0.0905 (-0.0704, 0.2731)
Natural indirect effect (NIE)	**0.0373 (0.0216, 0.0685)**	**0.0319 (0.0172, 0.0540)**	**0.0291 (0.0144, 0.0576)**
Total effect	0.1144 (-0.0497, 0.2976)	0.1141 (-0.0458, 0.2975)	0.1196 (-0.0369, 0.3134)
Proportion mediated (NIE/total)	0.3261	0.2800	0.2433

PA= physical activity; QOL= quality of life; β= regression coefficient; CI=confidence interval; (–) = mediator was not collected at waves; bold=p-value<0.05. The model was adjusted for all covariates from baseline wave: child's sex, Indigenous status, language spoken at home, caregiver education, family weekly income, family structure, number of siblings, neighbourhood safety, area disadvantage, area accessibility, and prosocial behaviour from the baseline wave.

Table 6.4 Summary of findings from mediation analyses of the association between green space quality and prosocial behaviour

Candidate mediators	Number of mediation models with statistically significant indirect effects			Mediation consistency[a]
	Caregiver-reported prosocial behaviour (n=4)	Child-reported prosocial behaviour (n=3)	Total (n=7)	
Physical activity (PA)				
Weekday PA	0	0	0	-
Weekend PA	0	0	0	-
Choice for free time	0	0	0	-
PA enjoyment	1	1	2	Moderate[b]
Social interaction				
Contacts with neighbours	3	0	3	Low
Child mental health				
Internalising subscale	4	3	7	High
Externalising subscale	2	2	4	Moderate
TDS	4	3	7	High
Health-related quality of life				
Physical functioning	2	1	3	Low
Emotional functioning	1	1	2	Low
Social functioning	4	1	5	Moderate
School functioning	2	1	3	Low
Psychosocial health	4	2	6	High
Total QOL	3	2	5	Moderate
Caregiver mental health				
Psychological distress – K6	2	1	3	Low

PA= physical activity; TDS= total difficulties score; QOL= quality of life; K6= Kessler 6 Psychological Distress Scale; a=Mediation consistency was determined by the proportion of mediation models with statistically significant indirect effect: (i) low (<50% or <4/7 models), (ii) moderate (50%-74% or 4-5/7 models), and (iii) high (≥75% or ≥6/7 models). b=For physical activity enjoyment, a total of four mediation models (two models for each caregiver-reported and child-reported prosocial behaviour) were developed.

6.2.5 Discussion

This present study aimed to examine mechanistic pathways linking green space quality to prosocial behaviour across child physical activity, social interaction, HRQOL, child and caregiver mental health. Overall, findings from this study suggest that green space quality might indirectly influence the development of prosocial behaviour through physical activity enjoyment, social interaction, HRQOL, child and caregiver mental health with varying degree of mediation consistency. The proportions mediated were weaker in child-reported than caregiver-reported prosocial behaviour models.

Previous literature suggests that physical activity with peers or performed in a group can potentially boost social contacts, which, in turn, promotes trust and sense of belonging, and then fosters the development of prosocial behaviour (Di Bartolomeo & Papa, 2017; Moeijes et al., 2018; Pawlowski et al., 2016). In this present study, physical activity enjoyment was the only physical activity variable that mediated the association between green space quality and prosocial behaviour with moderate mediation consistency. Even though physical activity enjoyment might not fully represent the actual amount of time spent being physically active, enjoyment of physical activity has been identified as an important predictor for physical activity level (David et al., 2006; Moore et al., 2009). A previous study found that physical activity enjoyment mediated the association between peer support and adolescents' physical activity (Chen et al., 2017). Meanwhile, findings from a systematic review also confirmed that friendship quality and peer acceptance were associated with physical activity enjoyment among American adolescents (Fitzgerald et al., 2012). This implies that physical activity enjoyment might portray positive social-environmental aspects, such as peer presence and peer support that may lead to the development of prosocial behaviour. Other physical activity variables such as a total of minutes for weekday and weekend physical activity and the choice for free time did not mediate the association between green space quality and child prosocial behaviour. This might be because these physical activity variables do not specifically relate to social interactions. This present study also did not distinguish whether physical activity was carried out with peers or performed in a sports group.

Findings from this study also demonstrated mediation by children's contacts with neighbours as a proxy for child social interactions. Frequent social interaction offers on-going opportunities to develop and practice prosocial skills (Oerlemans et al., 2018). In agreement with social network theory, repeated interactions can lead to the trustworthiness and prosocial tendencies towards others (Wittek & Bekkers, 2015). The presence of neighbourhood green space can potentially provide attractive settings for having more social contacts with friends that substantially contribute to the development of prosocial behaviour. Mediation via social interactions appeared to weaken among adolescents (W4→5→6) in the caregiver-reported prosocial behaviour model. This might be due to adolescents tending to spend more of their social time with friends and they were more concerned about peer-related issues in using green space (Akpınar, 2020), but the social interaction measure, which assessed contacts with neighbours, not fully depicting their interactions with peers. This also helps explain no mediation by social interaction in child-reported prosocial behaviour models.

While the pathway from green space to child mental health has been confirmed by current reviews (McCormick, 2017; Oswald et al., 2020; Vanaken & Danckaerts, 2018), potential roles of child mental health in influencing prosocial behaviour have not been adequately discussed. Studies among adult and child samples found that positive feelings (e.g., happiness) can predict engagement in prosocial behaviour (Aknin et al., 2018). On the other hand, children with mental health problems such as conduct disorders and emotional problems may have difficulties in developing and maintaining friendships, which, in turn, negatively affects their prosocial development (Ogundele, 2018). Evidence from experimental studies among adults found that positive emotional state mediated the association between perceiving nature as beautiful and prosocial behaviour (Zhang et al., 2014). Positive emotionality due to exposure to nature can increase attention towards others (Goldy & Piff, 2020).

The HRQOL indicators from the PedsQL depict physical, social, and emotional aspects of an individual that can be closely related to mental health (Reinfjell et al., 2008). Therefore, explanation of mediation by child mental health on the association between green space quality and prosocial behaviour above could be applied for HRQOL. Comparing between child mental health and HRQOL indicators that were within the restoring capacities pathway, mental health indicators extracted from the SDQ (e.g., internalising, externalising subscales, TDS) were identified with higher proportions mediated. This might be due to these indicators being assessed using the same scale as prosocial behaviour where shared measurement effects could increase associations between both (Flouri & Sarmadi, 2016). Nevertheless, HRQOL indicators from PedsQL such as social functioning, psychosocial health, and total QOL were found with moderate-to-strong mediation consistency. These findings suggest that restoration pathway can explain the association between green space quality and child prosocial behaviour.

Caregiver psychological distress was found to be a mediator. Past studies showed that neighbourhood green space was associated with better mental health among mothers (Feng & Astell-Burt, 2018; McEachan et al., 2016). Positive associations between green space and adult mental health were also supported by published reviews (Houlden et al., 2018; van den Berg et al., 2015). Moreover, a pathway from caregiver mental health to child prosocial behaviour has been tested (Fletcher et al., 2011; Hay & Pawlby, 2003; van der Waerden et al., 2015). Caregiver mental health might influence parenting style and child-parent interaction that later can influence child behaviour (Kim-Cohen et al., 2005).

Mediation by the majority of candidate mediators tended to appear in late childhood. This might be due to the nature of prosocial behaviour development among older children which is influenced more by social environmental factors since they widen their social contacts and networks (e.g., friendship) (Abrams et al., 2015; Hay & Cook, 2007). The development of socio-cognitive abilities also offers opportunities for older children to practice prosocial acts (Eisenberg et al., 2015). Another important finding was that the direct effects of caregiver-reported green space quality on prosocial behaviour weakened in adolescence. Adolescents might start assessing neighbourhood environments and spending time outside more independently and hence, green space quality reported by their caregivers might have less influence on adolescents' prosocial behaviour (Putra et al., 2021b).

Compared to mediation models using caregiver reports on prosocial behaviour, findings from modelling child self-reports on prosocial behaviour as the outcome suggest lower proportions mediated or weaker mediation for the majority of candidate mediators. The higher proportions mediated from fitting the exposure, mediators, and outcome from the single source (caregiver reports) might be due to the associations being magnified by shared respondent variance (Flouri & Sarmadi, 2016). Nonetheless, consistent mediation in self-reported prosocial behaviour mediation models help strengthen the findings of this study.

Strengths and limitations

This study might be among the first to empirically investigate candidate mediators of the association between green space quality and prosocial behaviour among children and adolescents. Therefore, the findings potentially add to the current body of knowledge. This study also compared mediation analysis between caregiver-reported and child-reported prosocial behaviour with separate mediation models for each candidate mediator that allow comprehensive assessments on candidate mediators. The use of the HRQOL indicators from the PedsQL in addition to child mental health indicators from the SDQ strengthens the findings for the restoration pathway.

The absence of the quantitative assessment of the exposure (i.e., green space quantity) in relation to prosocial behaviour might be a weakness of this present study to some extent. However, main findings from a critical review of studies on green space and prosocial behaviour suggest a weak association between green space quantity and child prosocial behaviour (Putra et al., 2020). These findings might not be surprising since children's access to green space is more likely to be dependent on their caregivers' decision to visit and preference on particular aspects of green space viewed as good and suitable for children's outdoor activities (Akpınar, 2020; Datar et al., 2013; Kalish et al., 2010). Therefore, green space quality reported by caregivers might be a more relevant measure of the exposure to green space among children since their subjective assessment tend to have a direct influence on children's access to green space than the amount of green space available locally.

Another limitation was that multiple mediation analyses, neither serial nor parallel mediation models were not investigated. Therefore, the simultaneous influences of candidate mediators were not presented in this study. The pathway of harm mitigation such as reducing air pollution was not investigated in this study due to the unavailability of data in this regard. In addition, the measure of children's physical activity enjoyment which was based on caregivers' subjective assessment might not fully represent the actual situation regarding how much children enjoyed being physically active, particularly among older children or adolescents who tend to have unsupervised outdoor activities compared to younger children. Previous studies also found that the agreement between caregiver and child reports on children's physical activity is low (Koning et al., 2018; Rebholz et al., 2014), but caregiver reports can provide a more accurate assessment of children's physical activity for younger children (Sithole & Veugelers, 2008). Even though caregiver reports on children's physical activity enjoyment might not be fully reflective of the actual level of enjoyment among children, findings from mediation analyses showed that physical activity enjoyment evaluated by caregivers mediated the association between green space quality and prosocial behaviour, irrespective of to whom the prosocial subscale was asked. This provides stronger support of physical activity enjoyment as a consistent mediator of the association between green space quality and child prosocial behaviour. Moreover, frequent contacts with neighbours as a measure for social interactions might not fully capture children's and adolescents' social interactions with peers. Findings from modelling child self-reports compared to caregiver reports on prosocial behaviour suggest lower proportions mediated, indicating the same-source bias was present. In addition, the stronger mediators (TDS, internalising and externalising subscales) were drawn from the same questionnaire as the outcome variable. Further studies addressing these study limitations are warranted.

6.2.6 Summary

Green space quality may indirectly contribute to prosocial behaviour among children and adolescents through several pathways. Only physical activity enjoyment from physical activity indicators was found as a mediator, suggesting very weak evidence that physical activity mediated the association between green space quality and prosocial behaviour. Child social interaction and caregiver mental health were found to have low mediation consistency. In addition, indicators of child mental health and HRQOL served as mediators on the pathway from green space quality to prosocial behaviour with low-to-high mediation consistency. Findings from this study suggest ensuring neighbourhood green space quality that supports physical activity enjoyment, social interaction, and mental health may help enhance the development of prosocial behaviour among children.

Chapter 7: Prosocial behaviour as a mediator of the associations between green space quality and child health-related outcomes

7.1 Preface

A synthesis of findings from previous studies indicates potential bi-directional associations between prosocial behaviour and participation in physical activity, and between prosocial behaviour and mental health. Given the current evidence on positive impacts of green space and child health, prosocial behaviour might serve as one of the pathways linking green space quality to child health-related outcomes. However, no study has assessed prosocial behaviour as a mediator for green space quality–child health associations. Therefore, further investigation is warranted to address the evidence gap on whether prosocial behaviour is a missing link between green space quality and child health-related outcomes.

The last (fifth) study from this thesis, presented in Chapter 7, aimed to answer the fourth research question: *"To what extent does prosocial behaviour mediate the association between green space quality and child health-related outcomes?"*. This study investigated the plausible role of prosocial behaviour in mediating the associations between green space and child health outcomes that included physical activity (four variables), mental health (three variables), and health-related quality of life (HRQOL) (six variables). Several mediation models were developed to comprehensively investigate at which ages the mediation by prosocial behaviour was found to be stronger. Findings from this study potentially enrich the growing literature on green space and child health, particularly in mechanistic pathways linking green space quality to child health-related outcomes. The study presented in this chapter is as it was published (Appendix G) with minor adjustments for tables, figures, referencing style, and overall thesis formatting requirements.

Citation

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7.2 The published article: “Is prosocial behaviour a missing link between green space quality and child health-related outcomes?”

7.2.1 Abstract

Background: This study aimed to investigate prosocial behaviour – those behaviours that benefit others or enhance relationships with others – as a mediator of the associations between green space quality and child health-related outcomes (physical activity, mental health, and health-related quality of life (HRQOL)).

Methods: This study involved data from 4,983 children with 10-year follow-up (2004-2014), extracted from the Longitudinal Study of Australian Children. Green space quality (the exposure), prosocial behaviour (the candidate mediator), and child health-related outcomes were assessed biennially based on caregiver reports. Causal mediation analysis was used, with four mediation models developed for each outcome.

Results: Mediation by prosocial behaviour appeared in the late childhood mediation model with higher mediation proportions reported compared to models of earlier and middle childhood. Prosocial behaviour had moderate mediation consistency for the association between green space quality and physical activity enjoyment, but no mediation was evident for other physical activity variables. Prosocial behaviour had low mediation consistency for child mental health (internalising and externalising subscales). Similarly, low mediation consistency of prosocial behaviour was also evident for all HRQOL variables, such as physical, emotional, social, school functioning, psychosocial health, and total quality of life (QOL).

Conclusion: Prosocial behaviour partially mediated the association between green space quality and child health-related outcomes (physical activity enjoyment, mental health, and HRQOL). Better quality of neighbourhood green space that supports the development

of prosocial behaviour may result in better child health-related outcomes. Other physical activity variables might not specifically relate to social interactions, and therefore, no mediation by prosocial behaviour was apparent.

7.2.2 Introduction

The presence of neighbourhood green space – public areas or places that bear natural vegetation and are commonly used for outdoor activities (e.g., parks) – has been found to be associated with several positive child health and behavioural outcomes. Green space might buffer air pollution that has negative impacts on children's respiratory health (Hartley et al., 2020; Lambert et al., 2017). The positive effects of living in a greener neighbourhood are also reported on child mental health and wellbeing (McCormick, 2017; Oswald et al., 2020; Vanaken & Danckaerts, 2018) and health-related quality of life (Kim et al., 2016; McCracken et al., 2016). Some empirical studies found that green space can serve as attractive places to promote physical activity and/or reduce screen time among children (Akpinar, 2017; Sanders et al., 2015; Ward et al., 2016). Furthermore, previous studies also investigated potential pathways linking green space to health outcomes. A study by Wang et al. (2019) found that social cohesion mediated the association between green space and psychological distress among US adolescents (12-17 years). Dzhambov et al. (2018) also suggest serial mediation of restorative quality, social cohesion, and physical activity on the association between green space and mental health in youth. These mediators could explain some, but not all of the total effects of the association between green space and health outcomes, suggesting another potential mediator, such as prosocial behaviour which may be a missing link in the pathway.

Some studies have reported the potential role of green space in shaping prosocial behaviour development (Andrusaityte et al., 2019; Bates et al., 2018; McEachan et al., 2018; Richardson et al., 2017). Prosocial behaviour can be defined as behaviours that aim to benefit others or encourage better relationships with others (Hay, 1994). Among children, prosocial behaviour encompasses offering help, being cooperative, sharing, and comforting (Hammond et al., 2015; Wittek & Bekkers, 2015). Social network theory suggests that social interactions play an important role in the development of prosocial behaviour by providing opportunities to build trust and cooperate with others (Wittek & Bekkers, 2015). Prosocial behaviour can increase as children get older due to more contacts with social environment (e.g., friendships) (Abrams et al., 2015; Hay & Cook, 2007).

Findings from a systematic review indicate that green space quantity showed a relatively weak association with child prosocial behaviour (Putra et al., 2020). This may be because of variation in the quality of green space that could amplify or aggravate these associations. Moreover, how caregivers perceive the quality of green space might be especially important for determining whether younger children can draw maximum benefits from green space (Feng & Astell-Burt, 2017a, 2017d) since their outdoor activities are likely to involve being chaperoned (Datar et al., 2013; Kalish et al., 2010).

Previous longitudinal analyses showed that green space quality was associated with prosocial behaviour after controlling the influences of potential confounders across child, family, and neighbourhood characteristics (Putra et al., 2021a, 2021b). However, no studies appear to investigate whether prosocial behaviour mediates the association between green space quality and child health and behavioural outcomes. This paper aimed to help address this evidence gap.

Potential roles of prosocial behaviour in influencing child health-related outcomes

Prosocial behaviour might influence a child's participation in physical activity. A conceptual model by Eime et al. (2013) suggests potential bi-directional associations between psychosocial health and sport participation. Greater psychosocial assets, such as social networks may increase one's participation in organised sport. Besides, findings from previous studies on peer influences on physical activity among young people can help explain the association between prosocial behaviour and physical activity. The presence of peers (Beets et al., 2006; Salvy et al., 2008) and peer supports (Garcia et al., 2016; Voorhees et al., 2005; Zhang et al., 2012) have been found as correlates of physical activity. Positive social interaction with peers may also increase enjoyment and support the stability of physical activity (Fraser et al., 2019). On the other hand, negative social interactions, such as lack of peer support and social pressure might lead to dropping out of sport (Crane & Temple, 2015).

A theoretical perspective about cognitive development by Vygotsky potentially explains the association between prosocial behaviour and mental health (García-Carrión et al., 2019). This theory suggests that human interaction in a particular social and cultural context is vital for psychological functioning. Positive social interactions can potentially be a protective factor against mental health problems. Findings from a previous study also suggest that affiliation with prosocial peers was associated with positive emotionality in subsequent peer interaction that plays an important role in child mental wellbeing (Fabes et al., 2012). Moreover, past experimental studies among children found that prosocial behaviour, such as giving treats to others can lead to a "warm glow" or positive emotional reward for giving (Aknin et al., 2015; Aknin et al., 2012). Higher prosocial behaviour was also found to be associated with lower internalising and externalising problems (Flouri & Sarmadi, 2016; Flynn et al., 2015). Furthermore, the positive association between prosocial behaviour and quality of life among children was also reported by past work (Carona et al., 2020; Frontini et al., 2012; Larsen et al., 2020).

Due to the synthesis of previous findings, prosocial behaviour might lie in the causal pathway from green space quality to child health-related outcomes. This study specifically asks: "*To what extent does prosocial behaviour mediate associations between green space quality and child health-related outcomes (physical activity, mental health, and health-related quality of life)?*". This study hypothesised that prosocial behaviour potentially explains the associations between green space quality and child health-related outcomes.

7.2.3 Methods

7.2.3.1 Study design and samples

This study used 10-year of collected data (2004-2014) from the K-cohort of the Longitudinal Study of Australian Children (LSAC). LSAC was conducted by the Department of Social Services (DSS) in partnership with the Australian Institute of Family Studies (AIFS) and the Australian Bureau of Statistics (ABS). The K-cohort commenced with recruiting 4,983 children aged 4-5 years with their parents or caregivers in 2004 (referred to as Wave 1) and then biennially followed up (Wave 2 onwards). A list of eligible children was obtained from Medicare's enrolment database. In brief, this nationally representative cohort study employed a two-stage clustered design by selecting postcodes stratified by states, the capital city, and urban-rural status as the first step, and followed by recruiting children from selected postcodes at the second step. Data were mostly supplied by caregivers, and some sections were completed with teachers and children. Response rates were high, about 90% by Wave 2, and then decreased to around

70% by Wave 6 (2014). Further information about LSAC's methodology is available elsewhere (Australian Institute of Family Studies, 2005, 2018).

This present study used all records of children from the K-cohort Waves 1 to 6 due to the consistency of data on green space quality being collected. A total of 25,440 observations nested in 4,983 children as presented in Table 7.1 were analysed in this study. LSAC's methodology and data collection had obtained ethics approval from the AIFS Ethics Committee. The Human Research Ethics Committee, University of Wollongong approved this present study (No. 2019/433).

7.2.3.2 Exposure: Green space quality

The extent to which caregivers agreed with the following statement – *"There are good parks, playgrounds and play spaces in this neighbourhood"* – was used to assess green space quality. Four possible responses were re-categorised as agree (for "*strongly agree*" and "*agree*") and disagree (for "*disagree*" and "*strongly disagree*"). This statement has been used by previous studies to assess green space quality in relation to child outcomes within the context of Australia (Feng & Astell-Burt, 2017a, 2017c, 2017d; Putra et al., 2021a, 2021b, 2021c).

7.2.3.3 Candidate mediator: Prosocial behaviour

Child prosocial behaviour was measured using caregiver reports on a prosocial domain from the Strengths and Difficulties Questionnaires (SDQ) (Goodman, 1997). The SDQ has been considered as a validated tool to assess child well-being and widely applied in many settings (Croft et al., 2015; Goodman & Goodman, 2009; Hall et al., 2019; Williamson et al., 2010). Caregivers were asked to rate as "*not true*", "*somewhat true*", and "*certainly true*" (scored as 0, 1, and 2, respectively) on five following items, *"considerate of other people's feelings"*, *"share readily with other children"*, *"helpful if* *someone is hurt, upset or feeling ill"*, *"kind to younger children"*, and *"often volunteers to help others (parents, teachers, other children)"*. A total score was summed up with a possible range from 0-10 and a higher score indicates greater prosocial behaviour.

7.2.3.4 Outcome 1: Physical activity

Child physical activity variables used in this study included a total of minutes spent for weekday physical activity and weekend physical activity; children's choice for free time, and physical activity enjoyment. Data from time-use diaries (TUDs) were extracted to construct variables of weekday and weekend physical activity. For Waves 1 to 3, caregivers completed TUDs for both weekday and weekend days that were randomly allocated by selecting from the list of 26 pre-coded children's activities into 96 15-minute periods (24 hours) (Australian Institute of Family Studies, 2007). Meanwhile, children were able to fill out TUDs by recording the time-order sequence of their activities in a single randomly allocated day (weekday or weekend) for Waves 4 to 6. Activities were then coded by interviewers using a coding framework (Australian Institute of Family Studies, 2014). The total minutes for activities representing physical activity were calculated for each weekday and weekend day and treated as separate outcomes as was done in a previous study (Sanders et al., 2015).

The other two physical activity outcomes, such as physical activity enjoyment and choice for free time were determined based on the reports from caregivers. The following question, "*What does [child] usually do when she/he has a choice about how to spend free time?*" was used to assess the choice for free time. Responses given as "*usually chooses active pastimes*" were recorded as "active", and "*usually chooses inactive pastimes*" or "*just as likely to choose active as inactive pastimes*" were recorded as "inactive or impartial". Caregiver reports on children's choice for free time were not documented in Waves 4 and 6. Meanwhile, physical activity enjoyment was measured by asking caregivers, "*How much does [child] enjoy physical activity or exercise?*". Caregiver responses from "*very much dislikes activity*" =1 to "*very much likes activity*" =5 were recorded as "enjoy" (score 4-5) and "does not enjoy or impartial" (score 1-3). Physical activity enjoyment was not collected in Waves 2 and 3. Regrouping of these variables was informed by a previous study (Sanders et al., 2015).

7.2.3.5 Outcome 2: Child mental health

Total difficulties score (TDS) from the SDQ reported by caregivers was used to determine child mental health (Goodman, 1997). TDS was generated by adding up four other domains from the SDQ that include emotional, peer, hyperactive, and conduct problems (a total score ranging from 0 to 10 for each domain). The SDQ has been validated as a screening tool for child mental health (Croft et al., 2015; Goodman & Goodman, 2009; Hall et al., 2019; Williamson et al., 2010). TDS has a total score ranging from 0 to 40 with a higher score representing increasing difficulties. In addition, the other two outcomes were constructed by dividing TDS into internalising and externalising subscales. Internalising subscale – summing peer and emotional problems – indicates the negative emotional state that is internalised (e.g., worry, nervousness, anxiety), and externalising subscale – summing hyperactive and conduct problems – informs negative feelings that tend to be externalised (e.g., aggressiveness, impulsiveness).

7.2.3.6 Outcome 3: Child health-related quality of life (HRQOL)

Caregivers were asked to complete the Paediatric Quality of Life Scale (PedsQL) 4.0 (Varni et al., 2003; Varni et al., 2002) to assess child HRQOL. The PedsQL has 23 items to measure four dimensions of HRQOL, consisting of 8 items for physical functioning, and 5 items for each emotional, school, and social functioning. Caregivers rated each item on a 5-scale from 0 (never) to 4 (almost always) and then reverse-scored (0=100, 1=75, 2=50, 3=25, 4=0). The average for each dimension was computed with a higher score indicating better HRQOL. Also, psychosocial health was generated by summing three dimensions (emotional, school, and social functioning) and then divided by the number of items. The mean of total quality of life (QOL) was also calculated in the same way.

7.2.3.7 Confounders

Potential influences of confounders from individual or child, family, and neighbourhood characteristics were controlled in this study, following past work (Feng & Astell-Burt, 2017d; Putra et al., 2021b). Child characteristics included sex (male, female), Indigenous status (Indigenous, non-Indigenous), and speaking a language other than English at home (yes, no). Caregiver education (≤ high school, > high school), family weekly income, the number of siblings of the studied children, and family structure (one-caregiver, two-caregiver family) were variables representing family characteristics. Moreover, neighbourhood circumstances comprised area accessibility (accessible, remote areas), determined using the Accessibility-Remoteness Index of Australia (ARIA) (Department of Health and Aged Care, 2001), area disadvantage (low-and-moderate disadvantaged, high disadvantaged areas), assessed using the Index of Relative Socioeconomic Disadvantage from the Socio-economic Indexes for Areas (SEIFA) (Australian Bureau of Statistics, 2006), and perceptions of neighbourhood safety, by asking caregivers whether they agreed with the following statement: *"This is a safe neighbourhood."* (agree, disagree). Since the measure of child health status from the previous wave can be a strong predictor for health status in the later waves, confounders in this analysis also include child health-related outcomes measure from the baseline wave (Figure 7.1).

7.2.3.8 Data analysis

Descriptive statistics was used to present the samples' characteristics across waves. Prior to mediation analyses, we assessed the associations between socio-demographic characteristics and green space quality, and also between green space quality and prosocial behaviour adjusting for socio-demographic characteristics. Three-level multilevel models were developed using MLwIN 3.1 (Rasbash et al., 2017), taking into account hierarchal data structure where children's observations from Waves 1 to 6 at level 1, nested within the individuals or children at level 2 and nested within neighbourhoods – measured as statistical area, level 2 (SA2) – at level 3. In addition, Markov chain Monte Carlo (MCMC) estimation (Browne et al., 2001) was used to fit cross-classified models since some children were nested within multiple SA2s over time due to residential mobility.

This study used single causal mediation analysis by fitting prosocial behaviour as a single mediator of the associations between green space and each outcome variable (four physical activity variables, three mental health variables, and six HRQOL variables). Causal mediation analysis under the counterfactual framework can be used to partition the total effect of the exposure (X) on the outcome (Y) through the proposed mediator (natural indirect effect – NIE) and through other mechanisms that do not involve the mediator (natural direct effect – NDE) (Richiardi et al., 2013). The counterfactual approach to mediation analysis can potentially help address the potential bias in the traditional approach that comes from the incorrect statistical analysis (Liu et al., 2016; Richiardi et al., 2013). Causal mediation analysis has been applied in some previous studies (Dendup et al., 2021; Hossin et al., 2019; Straatmann et al., 2020).

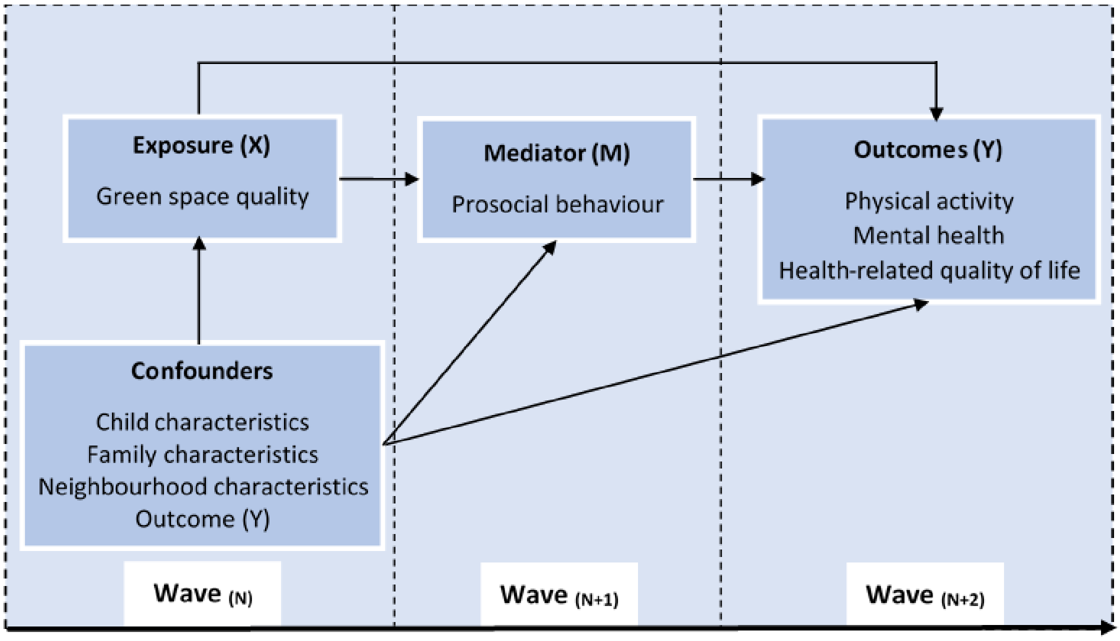

Figure 7.1 Directed acyclic graphs of mediation analysis

Due to the nature of data with repeated measures (Waves 1 to 6), this study used temporal mediation analysis or a lagged panel mediation model. This involved modelling the exposure (X) – green space quality – at $\text{Wave}_{(N)}$, prosocial behaviour as the mediator (M) at $\text{Wave}_{(N+1)}$, with child health-related outcomes (Y) at $\text{Wave}_{(N+2)}$ (Figure 7.1). This model took into account the influence of confounding variables from the same wave as the exposure. This mediation strategy has been applied by prior studies using LSAC data (Chung et al., 2018; Vella et al., 2018; Walters, 2020). Four mediation models were developed for each outcome variable in this study (W1→2→3; W2→3→4; W3→4→5; and W4→5→6). This study estimated NDE, NIE, and total effect expressed as adjusted regression coefficient (β) for continuous outcomes and adjusted odds ratio (OR) for binary outcomes along with 95% confidence intervals (CIs) calculated using bootstrapping for 1000 iterations. Proportion mediated by prosocial behaviour for each outcome was also calculated using the following equations: NIE/total effect for continuous outcomes and NDE×(NIE−1)/(NDE×NIE−1) for binary outcomes. The “paramed” command in STATA was used to conduct mediation analyses (Valente et al., 2020).

7.2.4 Results

7.2.4.1 Sample characteristics

From 25,440 observations nested within 4,983 children, nearly balanced proportions of girls and boys were recruited (Table 7.1). Indigenous children were accounted for no more than 4% of the sample and less than 15% of the children also spoke a non-English language at home. An increase of average household weekly income and percentages of caregivers who completed above high school education throughout waves indicated the improvement of family socioeconomic status. The majority of children, around 80%, lived in two-caregiver families. There were one or two siblings of the studied child predominantly reported in the family. Most of the caregivers reported that green space in their neighbourhood was of good quality and also perceived their neighbourhood as safe. In addition, the majority of children resided in more affluent and accessible areas.

On average, prosocial behaviour was relatively high (mean=8.13; SD=1.79). While the amount of weekday physical activity fluctuated, weekend physical activity decreased by age. The proportions of children who chose to be active during free time and enjoyed physical activity were found to decline as they became older. Indicators of child mental health (internalising, externalising subscales, TDS) fluctuated by waves. Similarly, the majority of HRQOL indicators also varied by waves, except for school functioning that decreased by age.

Table 7.1 Characteristics of samples across waves

Variables	Wave 1 (4-5 years) n (%[a])	Wave 2 (6-7 years) n (%[a])	Wave 3 (8-9 years) n (%[a])	Wave 4 (10-11 years) n (%[a])	Wave 5 (12-13 years) n (%[a])	Wave 6 (14-15 years) n (%[a])	Total (Waves 1 to 6) n (%[a])
Total sample	4,983	4,464	4,331	4,169	3,956	3,537	25,440
Dependent variables							
Weekday PA (in minutes), mean (SD)[b]	147.59 (122.99)	77.98 (82.96)	86.68 (93.06)	116.91 (97.98)	87.03 (91.02)	68.57 (87.14)	100.21 (101.75)
Weekend PA (in minutes), mean (SD)[b]	223.14 (141.06)	157.72 (119.53)	153.81 (126.50)	128.00 (117.39)	111.46 (113.78)	76.28 (99.03)	166.45 (133.36)
Choice for free time							
Impartial or inactive	2,662 (55.00)	2,511 (57.82)	2,537 (60.17)	-	2,392 (61.54)	-	10,102 (58.43)
Active	2,314 (44.84)	1,950 (42.10)	1,789 (39.70)		1,512 (36.82)		7,565 (41.11)
missing/not reported	*7 (0.16)*	*3 (0.07)*	*5 (0.13)*		*52 (1.64)*		*67 (0.46)*
PA enjoyment							
Impartial or not enjoy	334 (6.85)	-	-	278 (6.77)	387 (10.28)	505 (14.97)	1,504 (9.37)
Enjoy	4,648 (93.13)			3,815 (91.29)	3,463 (86.89)	2,812 (78.37)	14,738 (88.05)
missing/not reported	*1 (0.02)*			*76 (1.94)*	*106 (2.83)*	*220 (6.67)*	*403 (2.58)*
Internalising subscale, mean (SD)	3.47 (2.74)	3.28 (2.84)	3.24 (2.95)	3.67 (3.25)	3.53 (3.13)	3.62 (3.17)	3.46 (3.00)
Externalising subscale, mean (SD)	6.13 (3.72)	4.93 (3.30)	4.66 (3.47)	4.77 (3.47)	4.20 (3.37)	3.90 (3.35)	4.85 (3.53)
Total difficulties score (TDS), mean (SD)	9.60 (5.37)	8.21 (5.17)	7.90 (5.48)	8.43 (5.81)	7.74 (5.61)	7.52 (5.60)	8.32 (5.55)
Physical functioning, mean (SD)	82.60 (12.46)	82.14 (15.14)	82.96 (15.33)	77.40 (20.59)	82.37 (16.55)	79.74 (20.27)	81.18 (17.04)
Emotional functioning, mean (SD)	72.02 (14.80)	73.93 (14.98)	72.87 (16.34)	73.29 (17.00)	75.43 (17.43)	74.24 (18.53)	73.59 (16.57)
Social functioning, mean (SD)	82.66 (16.17)	80.11 (17.43)	78.46 (18.28)	78.69 (19.47)	81.77 (18.58)	79.19 (18.93)	80.20 (18.23)
School functioning, mean (SD)	86.92 (15.30)	78.15 (17.12)	75.57 (17.39)	74.27 (17.52)	73.30 (17.72)	71.16 (18.40)	76.79 (18.00)
Psychosocial health, mean (SD)	79.54 (12.37)	77.37 (13.69)	75.62 (14.42)	75.41 (14.99)	76.81 (15.07)	74.86 (15.76)	76.66 (14.47)
Total quality of life (QOL), mean (SD)	80.72 (11.15)	79.04 (12.81)	78.18 (13.33)	76.12 (15.32)	78.74 (14.07)	76.56 (15.64)	78.26 (13.85)

Main independent variable							
Green space quality							
Do not agree	1,121 (23.38)	594 (12.83)	863 (20.95)	663 (16.87)	809 (21.20)	465 (13.74)	4,515 (18.37)
Agree	3,841 (76.14)	2,821 (60.40)	3,453 (78.66)	3,445 (80.89)	3,032 (75.14)	2,896 (79.95)	19,488 (74.96)
missing/not reported	*21 (0.48)*	*1,049 (26.77)*	*15 (0.39)*	*61 (2.25)*	*115 (3.66)*	*176 (6.31)*	*1,437 (6.67)*
Candidate mediating variable							
Prosocial behaviour, mean (SD)	7.73 (1.80)	8.20 (1.74)	8.22 (1.75)	8.47 (1.69)	8.24 (1.77)	7.99 (1.88)	8.13 (1.79)
Confounders: individual characteristics							
Child's sex							
Female	2,447 (48.77)	2,188 (48.72)	2,120 (48.75)	2,037 (48.76)	1,936 (48.25)	1,739 (48.57)	12,467 (48.65)
Male	2,536 (51.23)	2,276 (51.28)	2,211 (51.25)	2,132 (51.24)	2,020 (51.75)	1,798 (51.43)	12,973 (51.35)
Child Indigenous status							
Not Indigenous	4,794 (96.07)	4,309 (96.22)	4,205 (96.31)	4,049 (96.13)	3,843 (97.09)	3,454 (97.37)	24,654 (96.49)
Indigenous	187 (3.90)	153 (3.75)	124 (3.65)	118 (3.83)	113 (2.91)	83 (2.63)	778 (3.49)
missing/not reported	*2 (0.03)*	*2 (0.03)*	*2 (0.04)*	*2 (0.03)*			*8 (0.02)*
Child speaks a language other than English							
No	4,359 (86.00)	3,947 (85.25)	3,865 (86.12)	3,727 (85.74)	3,629 (88.72)	3,187 (86.81)	22,714 (86.38)
Yes	624 (14.00)	517 (14.75)	466 (13.88)	442 (14.26)	327 (11.28)	350 (13.19)	2,726 (13.62)
Confounders: family characteristics							
Caregiver education							
≤ High school	923 (20.38)	683 (18.06)	561 (16.29)	482 (14.83)	407 (12.51)	305 (11.17)	3,361 (15.86)
> High school	4,056 (79.56)	3,780 (81.92)	3,769 (83.69)	3,682 (84.95)	3,542 (87.23)	3,217 (88.40)	22,046 (83.98)
missing/not reported	*4 (0.06)*	*1 (0.02)*	*1 (0.03)*	*5 (0.22)*	*7 (0.27)*	*15 (0.43)*	*33 (0.16)*
Family weekly income (in thousands), mean (SD)	1.27 (0.86)	1.51 (1.13)	1.74 (1.26)	1.85 (1.49)	2.08 (1.55)	2.21 (1.63)	1.74 (1.36)
Family structure							
One-caregiver family	697 (14.95)	660 (16.79)	623 (16.90)	652 (18.61)	674 (18.12)	624 (20.05)	3,930 (17.41)
Two-caregiver family	4,286 (85.05)	3,804 (83.21)	3,708 (83.10)	3,512 (81.17)	3,277 (81.68)	2,902 (79.61)	21,489 (82.48)
missing/not reported				*5 (0.22)*	*5 (0.19)*	*11 (0.34)*	*21 (0.11)*

Number of siblings, mean (SD)	1.51 (1.07)	1.61 (1.08)	1.68 (1.13)	1.69 (1.15)	1.64 (1.13)	1.55 (1.10)	1.61 (1.11)
Confounders: neighbourhood characteristics							
Neighbourhood safety							
Do not agree	420 (9.29)	183 (4.38)	244 (6.78)	188 (5.29)	450 (12.37)	127 (4.19)	1,612 (7.12)
Agree	4,544 (90.29)	3,195 (67.98)	4,064 (92.60)	3,923 (92.55)	3,392 (83.99)	3,236 (89.54)	22,354 (86.06)
missing/not reported	*19 (0.42)*	*1,086 (27.64)*	*23 (0.63)*	*58 (2.16)*	*114 (3.64)*	*174 (6.27)*	*1,474 (6.83)*
Area disadvantage (SEIFA)							
High	1,794 (37.24)	1,564 (37.33)	1,468 (36.91)	1,645 (42.93)	1,516 (41.43)	1,302 (40.30)	9,289 (39.21)
Moderate and low	3,189 (62.76)	2,900 (62.67)	2,863 (63.09)	2,523 (57.06)	2,439 (58.55)	2,234 (59.69)	16,148 (60.79)
missing/not reported				*1 (0.02)*	*1 (0.02)*	*1 (0.01)*	*3 (0.01)*
Area accessibility (ARIA)							
Accessible	4,721 (95.49)	4,225 (95.63)	4,104 (95.30)	3,973 (95.97)	3,774 (95.95)	3,380 (96.01)	24,177 (95.70)
Remote	216 (3.78)	192 (3.57)	162 (3.24)	158 (3.25)	149 (3.21)	119 (2.97)	996 (3.37)
missing/not reported	*46 (0.73)*	*47 (0.80)*	*65 (1.46)*	*38 (0.78)*	*33 (0.84)*	*38 (1.02)*	*267 (0.93)*

n=number of samples; [a]=weighted percentages; [b]=children completed TUD for only one day (weekday or weekend day) at Waves 4 to 6; SD=standard deviation; PA=physical activity; (–) = data not available at waves

Findings from multilevel analysis presented in Table 7.2 found that neighbourhood characteristics were strongly associated with caregiver-perceived green space quality. Caregivers who perceived their neighbourhood as safe, living in more affluent, and in accessible areas were more likely to live in the neighbourhood with good quality green space nearby. Neighbourhood safety and green space quality might be closely aligned and bi-directional in terms of causation. Table 7.3 presents confounders-adjusted association between green space quality and prosocial behaviour. Children whose caregivers perceived good green space available in the neighbourhood statistically significant had a higher score of prosocial behaviour after adjusting the influence of child, family, and neighbourhood characteristics. Child characteristics (e.g., sex, age) were found as strong correlates of prosocial behaviour.

Table 7.2 Factors associated with caregiver perceived green space quality

Variables	Adjusted OR (95% CI)
Individual characteristics	
Child's age *(ref: 4-5 years)*	
6-7 years	**1.55 (1.32, 1.82)**
8-9 years	1.12 (0.96 1.29)
10-11 years	**1.71 (1.46, 2.01)**
12-13 years	1.03 (0.87, 1.21)
14-15 years	**1.94 (1.61, 2.33)**
Child's sex *(ref: Male)*	
Female	1.02 (0.88, 1.20)
Child Indigenous status (*ref: Indigenous)*	
Not Indigenous	**1.51 (1.04, 2.19)**
Child speaks a language other than English (*ref: No)*	
Yes	1.16 (0.90, 1.48)
Family characteristics	
Caregiver education (*ref: ≤ High school)*	
> High school	1.14 (0.93, 1.39)
Family weekly income (in thousands)	**1.23 (1.16, 1.30)**
Family structure *(ref: One-caregiver family)*	
Two-caregiver family	**0.81 (0.67, 0.99)**
Number of siblings	0.94 (0.88, 1.00)
Neighbourhood characteristics	
Neighbourhood safety *(ref: Do not agree)*	
Agree	**5.29 (4.35, 6.42)**
Area disadvantage (SEIFA) *(ref: High)*	
Moderate and low	**2.21 (1.93, 2.52)**
Area accessibility (ARIA) *(ref: Highly accessible)*	
Remote	**0.31 (0.22, 0.44)**

OR: odds ratio; CI=credible interval; ref=reference group; bold=p-value<0.05

Table 7.3 Associations between green space quality and child prosocial behaviour

Variables	β (95% CI)	Adjusted β (95% CI)
Independent variable		
Green space quality *(ref: Do not agree)*		
Agree	**0.15 (0.09, 0.21)**	**0.09 (0.03, 0.14)**
Confounders: individual characteristics		
Child's age *(ref: 4-5 years)*		
6-7 years		**0.48 (0.42, 0.53)**
8-9 years		**0.49 (0.43, 0.55)**
10-11 years		**0.75 (0.69, 0.80)**
12-13 years		**0.56 (0.50, 0.62)**
14-15 years		**0.28 (0.21, 0.34)**
Child's sex *(ref: Male)*		
Female		**0.65 (0.58, 0.71)**
Child Indigenous status (*ref: Indigenous)*		
Not Indigenous		**0.22 (0.02, 0.41)**
Child speaks a language other than English (*ref: No)*		
Yes		0.03 (-0.07, 0.13)
Confounders: family characteristics		
Caregiver education (*ref: ≤ High school)*		
> High school		**0.13 (0.05, 0.21)**
Family weekly income (in thousands)		**0.03 (0.01, 0.05)**
Family structure *(ref: One-caregiver family)*		
Two-caregiver family		0.06 (-0.02, 0.13)
Number of siblings		**-0.10 (-0.12, -0.07)**
Confounders: neighbourhood characteristics		
Neighbourhood safety *(ref: Do not agree)*		
Agree		**0.12 (0.03, 0.20)**
Area disadvantage (SEIFA) *(ref: High)*		
Moderate and low		**0.08 (0.02, 0.13)**
Area accessibility (ARIA) *(ref: Highly accessible)*		
Remote		-0.02 (-0.18, 0.14)

β: regression coefficient; CI=credible interval; ref=reference group; bold=p-value<0.05

7.2.4.2 Assessments of mediation by prosocial behaviour

Four mediation models were created to investigate the mediation by prosocial behaviour for each of the associations between green space quality and child health-related outcomes. However, a change in the approach to physical activity data collection yielded that only two and three mediation models could be developed for the choice for free time and physical activity enjoyment, respectively (Table 7.4). Findings from causal mediation analyses suggest that the mediation consistency of prosocial behaviour was considered moderate for the associations between green space quality and physical activity enjoyment (two models with statistically significant indirect effect out of three mediation models). However, no mediation by prosocial behaviour was evident for other physical activity variables, such as weekday, weekend physical activity, and choice for free time.

Prosocial behaviour was identified with low mediation consistency for associations between green space quality and child mental health, such as internalising and externalising subscales, with only one out of four models displaying statistically significant indirect effect. No statistically significant mediation by prosocial behaviour was observed for TDS. Moreover, the mediating effect of prosocial behaviour was also reported with low mediation consistency for each HRQOL indicator (physical, emotional, social, school functioning, psychosocial health, and total QOL). Furthermore, findings suggest that the mediation by prosocial behaviour appeared to manifest in the last mediation model only (W4→5→6). Proportions mediated by prosocial behaviour were also generally found to be higher in this mediation model.

Table 7.4 Assessments of prosocial behaviour as a candidate mediator

Waves	Weekday PA	Weekend PA	Choice for Free Time	PA Enjoyment
	Adjusted β (95%CI)	**Adjusted β (95%CI)**	**Adjusted OR (95%CI)**	**Adjusted OR (95%CI)**
Wave 1 → 2 → 3				
Natural direct effect (NDE)	-8.7637 (-20.5279, 0.4683)	3.7675 (-10.2756, 17.6063)	1.0881 (0.9387, 1.2946)	-
Natural indirect effect (NIE)	-0.1877 (-0.9449, 0.1991)	0.3606 (-0.4907, 1.1267)	1.0006 (0.9963, 1.0071)	
Total effect	-8.9515 (-20.6840, 0.4391)	4.1281 (-10.0445, 17.9608)	1.0888 (0.9380, 1.2931)	
Proportion mediated	0.0210	0.0874	0.0074	
Wave 2 → 3 → 4				
Natural direct effect (NDE)	-2.1563 (-14.3681, 9.3228)	6.8477 (-19.4436, 33.9001)	-	1.1092 (0.6953, 1.5789)
Natural indirect effect (NIE)	-0.0171 (-0.6017, 0.2394)	-0.1377 (-4.3012, 0.4128)		1.0121 (0.9992, 1.0661)
Total effect	-2.1734 (-14.1650, 9.9115)	6.7100 (-19.2275, 33.0687)		1.1226 (0.7054, 1.6169)
Proportion mediated	0.0079	0.0205		0.1095
Wave 3 → 4 → 5				
Natural direct effect (NDE)	-6.2390 (-17.8209, 4.9051)	11.5796 (-13.2802, 36.4373)	1.1130 (0.9370, 1.3450)	1.3078 (0.9945, 1.7512)
Natural indirect effect (NIE)	0.0381 (-0.4127, 0.5641)	-0.5242 (-2.7450, 0.1362)	1.0056 (0.9986, 1.0174)	**1.0160 (1.0020, 1.0400)**
Total effect	-6.2009 (-17.9847, 4.9110)	11.0554 (-14.3750, 35.9403)	1.1192 (0.9393, 1.3491)	**1.3287 (1.0130, 1.7745)**
Proportion mediated	0.0061	0.0453	0.0523	0.0637
Wave 4 → 5 → 6				
Natural direct effect (NDE)	-4.0302 (-15.9381, 7.5937)	-10.9604 (-35.4084, 12.9434)	-	0.9232 (0.6706, 1.2112)
Natural indirect effect (NIE)	0.3090 (-0.1457, 1.3031)	1.2213 (-0.0869, 6.4942)		**1.0437 (1.0204, 1.0982)**
Total effect	-3.7212 (-15.7617, 7.3433)	-9.7391 (-34.1258, 15.2339)		0.9636 (0.7092, 1.2857)
Proportion mediated	0.0830	0.1114		N/A

Table 7.4 Assessments of prosocial behaviour as a candidate *(Continued 1)*

Waves	Internalising Subscale	Externalising Subscale	Total Difficulties Scores	Physical Functioning
	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)	Adjusted β (95%CI)
Wave 1 → 2 → 3				
Natural direct effect (NDE)	**-0.2235 (-0.4407, -0.0192)**	-0.1351 (-0.3438, 0.0861)	-0.3361 (-0.7197, 0.0088)	**1.2547 (0.0953, 2.4327)**
Natural indirect effect (NIE)	-0.0119 (-0.0419, 0.0152)	-0.0087 (-0.0439, 0.0362)	-0.0108 (-0.0620, 0.0548)	0.1135 (-0.0009, 0.2944)
Total effect	**-0.2354 (-0.4456, -0.0291)**	-0.1438 (-0.3557, 0.0894)	-0.3469 (-0.7384, 0.0174)	**1.3682 (0.1897, 2.5521)**
Proportion mediated	0.0506	0.0605	0.0311	0.0830
Wave 2 → 3 → 4				
Natural direct effect (NDE)	-0.2449 (-0.5159, 0.0310)	**-0.3115 (-0.5928, -0.0715)**	**-0.5273 (-0.9761, -0.1473)**	0.4601 (-1.3919, 2.2651)
Natural indirect effect (NIE)	-0.0049 (-0.0584, 0.0169)	-0.0076 (-0.0812, 0.0187)	-0.0010 (-0.1025, 0.0508)	0.0371 (-0.0281, 0.2817)
Total effect	-0.2498 (-0.5227, 0.0193)	**-0.3191 (-0.6157, -0.0905)**	**-0.5283 (-1.0011, -0.1393)**	0.4972 (-1.3512, 2.2987)
Proportion mediated	0.0196	0.0238	0.0019	0.0746
Wave 3 → 4 → 5				
Natural direct effect (NDE)	**-0.2474 (-0.4985, -0.0156)**	-0.1236 (-0.3406, 0.0827)	-0.3317 (-0.6793, 0.0357)	**1.7586 (0.4845, 3.0219)**
Natural indirect effect (NIE)	-0.0209 (-0.0506, 0.0124)	-0.0128 (-0.0443, 0.0146)	-0.0227 (-0.0767, 0.0333)	0.0777 (-0.0149, 0.2074)
Total effect	**-0.2683 (-0.5027, -0.0238)**	-0.1364 (-0.3546, 0.0802)	-0.3544 (-0.7137, 0.0077)	**1.8363 (0.5185, 3.1473)**
Proportion mediated	0.0779	0.0938	0.0641	0.0423
Wave 4 → 5 → 6				
Natural direct effect (NDE)	-0.1863 (-0.4521, 0.0607)	-0.2165 (-0.4407, 0.0076)	-0.3652 (-0.7809, 0.0167)	1.5042 (-0.3180, 3.3420)
Natural indirect effect (NIE)	**-0.0340 (-0.08456, -0.0026)**	**-0.0380 (-0.0759, -0.0001)**	-0.0576 (-0.1437, 0.0110)	**0.2353 (0.0884, 0.5247)**
Total effect	-0.2263 (-0.5146, 0.0019)	**-0.2545 (-0.4817, -0.0274)**	**-0.4228 (-0.8687, -0.0372)**	1.7395 (-0.1051, 3.6447)
Proportion mediated	0.1502	0.1493	0.1363	0.1353

Table 7.4 Assessments of prosocial behaviour as a candidate mediator *(Continued 2)*

Waves	Emotional Functioning	Social Functioning	School Functioning	Psychosocial Health
	Adjusted β (95%CI)	**Adjusted β (95%CI)**	**Adjusted β (95%CI)**	**Adjusted β (95%CI)**
Wave 1 → 2 → 3				
Natural direct effect (NDE)	1.0922 (-0.0526, 2.2612)	1.2379 (-0.0904, 2.7452)	**1.6025 (0.2338, 2.9085)**	**1.2166 (0.2128, 2.1893)**
Natural indirect effect (NIE)	0.1073 (-0.0075, 0.2527)	0.1144 (-0.0464, 0.3148)	0.1250 (-0.0162, 0.2993)	0.0905 (-0.0180, 0.2235)
Total effect	**1.1995 (0.0357, 2.3365)**	**1.3523 (0.0134, 2.9015)**	**1.7275 (0.3641, 3.0482)**	**1.3071 (0.3011, 2.2879)**
Proportion mediated	0.0895	0.0846	0.0724	0.0692
Wave 2 → 3 → 4				
Natural direct effect (NDE)	0.4115 (-0.8659, 1.9036)	1.1938 (-0.6110, 2.7798)	0.3519 (-1.1463, 1.6757)	0.5983 (-0.6360, 1.7566)
Natural indirect effect (NIE)	0.0692 (-0.0521, 0.3098)	0.0635 (-0.0939, 0.3596)	0.0688 (-0.0531, 0.2826)	0.0481 (-0.0843, 0.2419)
Total effect	0.4807 (-0.7899, 2.0729)	1.2573 (-0.5454, 2.7990)	0.4207 (-1.0237, 1.8142)	0.6464 (-0.5424, 1.8638)
Proportion mediated	0.1440	0.0505	0.1635	0.0744
Wave 3 → 4 → 5				
Natural direct effect (NDE)	1.2753 (-0.0189, 2.6453)	**2.0731 (0.6930, 3.6456)**	**1.8809 (0.5800, 3.0890)**	**1.6597 (0.6247, 2.7871)**
Natural indirect effect (NIE)	0.1372 (-0.0523, 0.3127)	0.1441 (-0.0452, 0.3274)	0.1450 (-0.0015, 0.3261)	0.1202 (-0.0247, 0.2774)
Total effect	**1.4125 (0.0439, 2.7922)**	**2.2172 (0.8218, 3.7853)**	**2.0259 (0.7475, 3.2710)**	**1.7799 (0.6649, 2.9090)**
Proportion mediated	0.0940	0.0650	0.0716	0.0675
Wave 4 → 5 → 6				
Natural direct effect (NDE)	0.2813 (-1.2486, 1.6770)	**1.8686 (0.1500, 3.5840)**	0.7334 (-0.6613, 2.3435)	0.7669 (-0.5525, 1.9954)
Natural indirect effect (NIE)	**0.2773 (0.0998, 0.6387)**	**0.2352 (0.0635, 0.5192)**	**0.2669 (0.0863, 0.5700)**	**0.2132 (0.0607, 0.4683)**
Total effect	0.5586 (-0.9504, 2.0319)	**2.1038 (0.3354, 3.8227)**	1.0003 (-0.4184, 2.6393)	0.9801 (-0.3144, 2.2695)
Proportion mediated	0.4964	0.1118	0.2668	0.2175

Table 7.4 Assessments of prosocial behaviour as a candidate mediator *(Continued 3)*

Waves	Total QOL
	Adjusted β (95%CI)
Wave 1 → 2 → 3	
Natural direct effect (NDE)	**1.2113 (0.3507, 2.1853)**
Natural indirect effect (NIE)	0.0884 (-0.0117, 0.2065)
Total effect	**1.2997 (0.3975, 2.2221)**
Proportion mediated	0.0680
Wave 2 → 3 → 4	
Natural direct effect (NDE)	0.4820 (-0.8027, 1.6418)
Natural indirect effect (NIE)	0.0359 (-0.0542, 0.2239)
Total effect	0.5179 (-0.7809, 1.7863)
Proportion mediated	0.0693
Wave 3 → 4 → 5	
Natural direct effect (NDE)	**1.6531 (0.6042, 2.6758)**
Natural indirect effect (NIE)	0.0919 (-0.0443, 0.2167)
Total effect	**1.7450 (0.6364, 2.7323)**
Proportion mediated	0.0527
Wave 4 → 5 → 6	
Natural direct effect (NDE)	1.0426 (-0.3742, 2.3006)
Natural indirect effect (NIE)	**0.2191 (0.0737, 0.5081)**
Total effect	1.2617 (-0.1253, 2.5744)
Proportion mediated	0.1737

PA= physical activity; QOL= quality of life; β= regression coefficient; OR= odds ratio; CI= confidence interval; (–) = outcome was not collected at waves; bold=p-value<0.05. Proportion mediated was calculated as NIE/total effect for continuous outcomes; and NDE×(NIE−1)/(NDE×NIE−1) for binary outcomes. The mediation model was adjusted for all confounders from baseline wave: individual, family, neighbourhood characteristics, and earlier measure of health status (outcome). N/A= not applicable, the proportion mediated could not be calculated for mediation model of PA enjoyment (W4→5→6) due to different direction of OR between NDE and NIE.

7.2.5 Discussion

Findings from this study outline the potential role of prosocial behaviour in mediating the associations between green space quality and child health-related outcomes. The analyses found statistically significant mediation by prosocial behaviour for the associations between green space quality and physical activity enjoyment, mental health, and HRQOL. Mediation by prosocial behaviour was considered with moderate mediation consistency for the green space quality – physical activity enjoyment associations. Prosocial behaviour involves positive social interactions among children that include cooperation, helping, and sharing (Hammond et al., 2015; Wittek & Bekkers, 2015). This can be practically identified by the presence of peer support and prosocial peers during physical activity that can have positive influences on the enjoyment of physical activity. A previous study found that peer support was associated with enjoyment of physical activity and later could lead to physical activity among adolescents (Chen et al., 2017). A systematic review by Fitzgerald et al. (2012) also suggests that the quality of friendship and peer acceptance were found as correlates of physical activity enjoyment among adolescents. Prosocial behaviour might stimulate a positive and supportive atmosphere among children that helps increase the enjoyment of physical activity.

Prosocial behaviour appeared with low mediation consistency for the associations between green space quality and child mental health (internalising and externalising subscales). Quality green space might provide attractive settings for children to play and then learn and practise prosocial acts with friends (Putra et al., 2021b; Putra et al., 2020). Social interactions containing prosocial characteristics can support social and cognitive development and later serve as a protective factor against child mental health problems (García-Carrión et al., 2019). A study by Fabes et al. (2012) also suggests that greater connection with prosocial peers could potentially lead to positive emotionality in later peer interactions. Prosocial behaviour such as giving has been found to be associated with happiness among children (Aknin et al., 2015; Aknin et al., 2012). Findings from previous longitudinal studies also demonstrated that prosocial behaviour predicts lower internalising and externalising problems among children and adolescents (Flouri & Sarmadi, 2016; Flynn et al., 2015).

While past work tested a pathway from green space to child HRQOL (Kim et al., 2016; McCracken et al., 2016), findings from this present study suggest that prosocial behaviour might be a missing link in this pathway. In agreement with previous studies, prosocial behaviour was found to be positively associated with quality of life among children (Carona et al., 2020; Frontini et al., 2012; Larsen et al., 2020). Mediation by prosocial behaviour was observed for all domains of HRQOL, such as physical, emotional, social, school functioning, psychosocial health, and total QOL. Similar to the explanation for child mental health, positive social interactions may bring positive impacts on social and cognitive development (García-Carrión et al., 2019), which, in turn, influence HRQOL. Prosocial behaviour is also considered as one of the psychosocial assets (Leventhal et al., 2015). Therefore, this close link might help explain associations between prosocial behaviour and psychosocial health, and also other HRQOL domains, such as emotional, social, and school functioning that construct the psychosocial health indicator.

Another important finding from this study was that fitting prosocial behaviour as a mediator at Wave 5 (12-13 years) (mediation model: W4→5→6) showed a statistically significant mediating effect with higher proportions mediated, relative to younger ages. This might be due to late childhood as a sensitive period for the association between green space quality and prosocial behaviour (Putra et al., 2020). The broadening of social interactions (e.g., friendships) (Abrams et al., 2015; Hay & Cook, 2007) and the development of socio-cognitive abilities (Eisenberg et al., 2015) help older children to increase their prosocial behaviour in terms of frequency and complexity. The presence of quality green space in the neighbourhood potentially supports opportunities for older children to have social interactions outdoors with peers and enhance their prosocial behaviour development. Therefore, prosocial behaviour tended to strongly mediate the associations between green space quality and child health-related outcomes at these ages. However, findings from our prior analysis suggest that the association between quality green space and prosocial behaviour appeared to weaken in adolescence (Wave 6; 14-15 years) (Putra et al., 2021b). Characteristics of green space assessed in this study (e.g., parks, playgrounds, play spaces) might be less relevant for adolescents' activities. They also tend to start assessing the quality of and utilising surrounding environments more autonomously (Choudhury et al., 2006; Sanders, 2013). Therefore, caregiver perceived green space quality might be less important for adolescents' prosocial behaviour development relative to that of their younger counterparts. Unfortunately, this present study was not able to demonstrate whether mediation by prosocial behaviour in adolescence weakens compared to in childhood. Further investigation is needed in this regard.

Findings from this study support our hypothesis on the positive impacts of greater prosocial behaviour on better child health-related outcomes and also complement our previous analyses. Our earlier work aimed to investigate the mediators of the association between green space quality and child prosocial behaviour which was based on two out of three potential linking pathways (i.e., building and restoring capacities) conceptualised by multidisciplinary experts (Putra et al., 2021c). We found that better green space quality potentially increases child physical activity enjoyment, social interaction, HRQOL, and child and caregiver mental health, which in turn, may enhance the development of prosocial behaviour among children. Meanwhile, our synthesis of existing literature on the potential pathway from prosocial behaviour to child health-related outcomes became a basis for the investigation of prosocial behaviour as a linking pathway presented in this paper. Therefore, findings from both our earlier and present studies support bi-directional associations between prosocial behaviour and child health-related outcomes. To conclude, green space quality that supports the improvement of child health might provide better benefits for the development of prosocial behaviour, and vice versa.

Strengths and limitations

This study is among the first which investigates the potential role of prosocial behaviour in mediating the associations between green space quality and child physical activity, mental health, and HRQOL. This study also developed four mediation models for each association that enabled us to comprehensively assess the prosocial behaviour as a candidate mediator across childhood. It is also important to note that this study also adjusted the effect of the earlier measure of child health outcomes, and hence, the analyses and findings of mediation by prosocial behaviour could be considered robust. In addition, this study used a measure of green space quality was based upon caregiver reports that have been employed by earlier studies within the Australian context (Feng & Astell-Burt, 2017a, 2017c, 2017d; Putra et al., 2021a, 2021b, 2021c). Caregiver reports could be a relevant measure since children tend to be dependent on caregivers in accessing green space and doing outdoor activities (Datar et al., 2013; Kalish et al., 2010).

A limitation of this study was the potential same-source bias since all variables were derived from caregiver reports. In addition, this study did not take into account other factors that might confound the associations between green space quality, child prosocial behaviour and health-related outcomes, such as the degree of integration into the community for ethnic minorities, caregiver mental and/or physical illness that could limit caregivers' capacities to chaperone their children, etc. However, over-adjustment bias might occur when the model treats and adjusts for intermediate variables or mediators as the potential confounders (Schisterman et al., 2009). This present study included confounders that were informed by previous studies (Feng & Astell-Burt, 2017d; Putra et al., 2021b). This study was not able to assess mediation by prosocial behaviour in adolescence due to the unavailability of the data to develop the mediation model. The models were also limited by focussing on single mediators separately; multiple mediation in series or parallel may warrant further theorising and empirical assessment. Nevertheless, this study provides a basis for further investigation of the potential role of prosocial behaviour in explaining the associations between green space quality and child health and behavioural outcomes.

Findings from this study might not be widely generalised to other countries or settings that have different socioeconomic profiles, climate, and historical influences on urban planning. Other studies that are conducted in countries with similar socioeconomic conditions (e.g., high-income countries) and closely related settings in terms of population structure, urban landscape, and climate might yield findings that are more likely to be comparable with findings from this present study. Therefore, future studies will benefit from investigating the association between green space and child health and behaviour in different study contexts (e.g., low-income countries) in order to generate more in-depth knowledge. This also provides an important avenue for further inquiry on how the interactions between the availability of green space and socio-cultural factors that might hinder or drive the access to green space (e.g., social norms and values on green space use, authoritarian parenting practices, etc.) can influence child health and behaviour.

7.2.6 Summary

Prosocial behaviour may be one of the potential pathways linking green space quality to child health-related outcomes. Prosocial behaviour displayed moderate mediation consistency for the associations between green space quality and physical activity enjoyment. Low mediation consistency of prosocial behaviour was evident for the associations between green space quality and child mental health (internalising and externalising subscales), as well as between green space quality and each of the HRQOL indicators. Findings from this study suggest that higher green space quality supports the development of prosocial behaviour with positive impacts on child health.

Chapter 8: Discussion and Conclusion

8.1 Preface

This chapter is dedicated to the overall discussion of findings of the combined critical review of literature and empirical studies using nationally representative longitudinal data. The objectives of this thesis were to critically assess current evidence, investigate the association between green space quality and prosocial behaviour, identify potential effect modifiers, examine potential pathways linking green space quality to prosocial behaviour, and test the plausible role of prosocial behaviour in mediating associations between green space quality and child health-related outcomes. Five studies were carried out to address the research objectives.

Overall, findings from the systematic review highlighted a paucity of studies investigating the association between green space quality and child prosocial behaviour; and the lack of assessments on the effect modifiers and potential pathways linking green space to prosocial behaviour. Those became the basis for further investigation for the subsequent studies. Findings from the empirical studies indicate clear evidence on the longitudinal association between green space quality and child prosocial behaviour with some contingencies (e.g., child's sex, ethnicity). Moreover, some potential mechanisms linking green space quality to prosocial behaviour were documented. Prosocial behaviour was also found to mediate associations between green space quality and child health-related outcomes. The strengths and limitations, implications for further research and policy, and the overall conclusion are also presented in this chapter.

8.2 Summary of studies and key findings

8.2.1 Current evidence on associations between green space and prosocial behaviour

The first study – a published systematic review – was presented in Chapter 2 evaluated and critically assessed the current evidence on the associations between green space and prosocial behaviour among children and adolescents. The synthesis of findings extracted from 15 eligible studies provided the equivocal evidence on the role of green space in promoting the development of prosocial behaviour. The amount of green space available in the neighbourhood or green space "quantity" showed weak associations in relation to prosocial behaviour. However, only one study assessed the association between green space "quality" and prosocial behaviour among children. Even though the association was observed in the expected or hypothesised direction, the volume of evidence is not adequate to make confident conclusions. Importantly, most studies were cross-sectional in design, and hence, the temporal relationship could not be determined. Moreover, potential effect modifiers were not adequately assessed and none of the studies tested mechanistic pathways between green space and prosocial behaviour.

The weak association between green space quantity and prosocial behaviour might not be surprising, since children, particularly at younger ages are more likely to be dependent on being chaperoned by their caregivers (Feng & Astell-Burt, 2017a, 2017d). Children's outdoor activities tend to be limited and regulated by caregivers (Datar et al., 2013; Kalish et al., 2010). Caregiver perceptions of the availability of quality green space might potentially play a more important role in influencing children's access to, and time spent in, green space compared to the amount of green space available locally. Caregivers who perceived their neighbourhood green space to be of good quality are more likely to let their children spend time in green space (Kaymaz et al., 2017). Due to the importance of green space quality over quantity for children, the remaining four empirical studies used caregiver perceptions of neighbourhood green space quality as a proxy for children's exposure to green space.

8.2.2 Association between green space quality and child prosocial behaviour

Findings from the second study presented in Chapter 4 demonstrated the association between caregiver perceived green space quality in the neighbourhood ("disagree", "agree", and "strongly agree") and child prosocial behaviour among the sample studied. Overall, findings showed a dose-response relationship between to the extent the caregiver perceived the availability of quality green space and child prosocial behaviour ("agree": β=0.10; 95%CI=0.04, 0.16; "strongly agree": β=0.20; 95%CI=0.13, 0.27 compared to "disagree", respectively) after adjusting for potential confounders from child characteristics (age, sex, Indigenous status, speaking a language other than English at home), family characteristics (caregiver education, household weekly income, family structure, a number of siblings), and area-level characteristics (neighbourhood safety, area disadvantage, area accessibility).

To explore potential changes in the influence of quality green space on prosocial behaviour across childhood, a two-way interaction term between green space quality and age was fitted to develop multilevel growth curve models. Findings suggest that the benefit of high-quality green space relative to low quality as reported by caregivers, was relatively consistent from Waves 1 (4-5 years) to 5 (12-13 years) but found to weaken at later waves – Wave 6 (14-15 years). This supports the hypothesis that childhood might be a critical period for the association between green space quality and prosocial behaviour. Prosocial behaviour can progressively increase in childhood due to the expansion of social interaction as children get older (Abrams et al., 2015; Dunfield, 2014;

Hay & Cook, 2007). Social interaction is considered an important part of the development of prosocial behaviour (Oerlemans et al., 2018). Quality green space available in the neighbourhood potentially provides attractive settings for children that multiply opportunities for frequent social contacts through active play and positive interactions with peers, which, in turn, can enhance the development of prosocial behaviour.

The influence of quality green space appeared to decline in adolescence. Another finding from this study was the hump-shaped association between age and prosocial behaviour. In agreement with previous work (Carlo et al., 2007; Eisenberg et al., 2015), prosocial behaviour increased in childhood and declined in adolescence. Prosocial behaviour's developmental decline might help explain the weak green space quality-prosocial behaviour association in adolescence. In addition, caregiver-reported green space quality as a measure of exposure to green space might be less relevant for the development of prosocial behaviour among adolescents. First, adolescents tend to have higher autonomy and more control than their younger counterparts in deciding how and where spend their time (Choudhury et al., 2006; Sanders, 2013). Second, cognitive development helps adolescents to assess their surrounding environment more independently. Caregiver-reported neighbourhood environment may to some extent not represent adolescents' perceptions of their surroundings (Nicole, 2004). Third, types of green space evaluated in this study were limited to parks, playgrounds, and play spaces, but these might not be suitable for or reflect adolescents' activities. Therefore, research designed to strengthen understandings of how adolescents use neighbourhood green space and what aspects of green space they value could be important in designing spaces that support their prosocial behaviour development.

Findings from sensitivity analyses by generating multivariate models disaggregated by child's sex showed that boys tended to benefit more from the availability of quality neighbourhood green space than did girls. Types of green space assessed in this study focused on parks, playgrounds, and play spaces that might be more utilised by boys who are more engaged in active play compared to girls (Eriksson et al., 2019; Pate et al., 2013). Caregivers also tend to limit unsupervised outdoor activities among girls due to safety concerns (Boxberger & Reimers, 2019; Soori & Bhopal, 2002). However, prosocial behaviour was reported to be higher among girls than boys in general. This is supported by previous literature which suggests that gender was strongly associated with prosocial behaviour among children (Abdi, 2010; Kok et al., 2018). Moreover, green space quality was found to be consistently associated with prosocial behaviour irrespective of neighbourhood relocation.

8.2.3 Trajectory of caregiver perceived quality green space and the development of prosocial behaviour

The third study, presented in Chapter 5 provided a novel insight into how to disentangle the trajectories of caregiver perceived green space quality across the study period and whether these can influence the development of prosocial behaviour among children and adolescents. This is based on the understanding of life course epidemiology theory which suggests that exposure to social and physical environmental factors patterned or accumulated from prior stages of life (e.g., childhood and adolescence) might influence the development of particular health risks or outcomes in later life (e.g., adulthood) (Ben-Shlomo et al., 2014; Kuh et al., 2003). Six trajectory groups were identified using latent class analysis based on repeated caregiver reports on green space quality: Class 1 ("consistently in low quality"), Class 2 ("consistently in between low and good quality"), Class 3 ("consistently in good quality"), Class 4 ("increasing quality from good to very good"), Class 5 ("decreasing quality from very good to good"), and Class 6 ("consistently in very good quality"). The likelihood of being in trajectory groups with better quality green space was unevenly observed across neighbourhood circumstances. Children living in safer, more affluent, and more accessible areas were more likely to be in Classes 2 to 6 relative to Class 1. Therefore, these findings affirm previous evidence on neighbourhood socioeconomic inequalities in the availability of quality green space (Crawford et al., 2008; Hoffimann et al., 2017).

Overall, findings from multilevel linear regression accounting for the same socioeconomic confounders as undertaken done in the second study suggest that children in Classes 4, 5, and 6 had statistically significant higher prosocial behaviour than children in Class 1. Findings showed that the accumulated quality green space perceived by caregivers over time potentially strengthens the development of prosocial behaviour among children and adolescents. Fitting a two-way interaction term between trajectory classes and age to predict the growth curve model suggests that the benefit of the accumulated exposure to quality green space (Classes 4, 5, and 6) relative to low quality (Class 1) was consistent across all age groups. Therefore, these findings highlight the importance of the accumulated exposure to quality green space over time on the development of prosocial behaviour. This also complements findings from the second study that used the standard variable of green space quality indicating the influence of quality green space weakened in adolescence (Wave 6, 14-15 years).

According to the theory of differential exposure (Diderichsen et al., 2018), unequal distribution of the availability of quality green space by neighbourhood socioeconomic strata can lead to inequalities in prosocial behaviour. Meanwhile, previous studies suggest that better exposure to green space can buffer the effect of living in an unfavourable socioeconomic condition and reduce inequalities in health outcomes (Mitchell & Popham, 2008; Mitchell et al., 2015). Findings from separate multivariate models by trajectory classes showed that inequalities in child prosocial behaviour by different indicators of household socioeconomic status (e.g., caregiver educational level, family weekly income), and neighbourhood circumstances (safety, area disadvantage) were less pronounced among children in Class 6 ("consistently in very good quality"). These findings imply that accumulated exposure to quality green space across childhood potentially buffers the psychosocial stressors of growing up in unfavourable family and neighbourhood environments.

Another theory, differential effect or differential vulnerability (Diderichsen et al., 2018; Grzywacz et al., 2004; Schwartz et al., 2011), indicates that the influence of quality green space on prosocial behaviour might vary by individual, family, and neighbourhood characteristics. This understanding became the basis of investigating effect modifiers of the association between green space quality and child prosocial behaviour. By adding a two-way interaction term between green space quality and the potential effect modifier in separate multivariate models, associations between green space quality and prosocial behaviour were found to be stronger among boys, children who only spoke English at home, those living in less disadvantaged areas, and those in remote areas.

Stronger associations between the trajectory of green space quality and prosocial behaviour observed among boys might be due to gendered play activities that have been explained before (Eriksson et al., 2019; Pate et al., 2013). Weaker associations among children from ethnic minority families might potentially be due to less use and less enjoyment from spending time in green space. Feeling unsafe, fear of or experience of discrimination and exclusion from the dominant group can impede ethnic minorities' access to neighbourhood green space (Roe et al., 2016). Findings from previous studies on the lower availability of green space quantity (Astell-Burt et al., 2014; Dadvand et al., 2014; Schüle et al., 2019) and quality (Crawford et al., 2008; Feng & Astell-Burt, 2017d; Hoffimann et al., 2017) in deprived neighbourhoods, as the present study also found, could explain the modifying effect by area disadvantage. Furthermore, stronger associations between green space quality and prosocial behaviour among children living in remote areas could be explained by the collective resource model. This model contends that people in disadvantaged circumstances tend to be more reliant on resources available locally (Eriksson et al., 2019; Stafford & Marmot, 2003). Children living in remote areas might be more dependent on the availability of quality green space than those children in highly accessible areas. To conclude, these findings provide a deeper understanding of for whom and in what neighbourhood situations, associations between quality green space and the development of prosocial behaviour strengthen.

8.2.4 Mediators of the association between green space quality and child prosocial behaviour

Two studies (the second and third studies presented in Chapter 4 and 5, respectively) have demonstrated associations between green space quality and child prosocial behaviour. Meanwhile, previous studies within the Australian context found associations between green space and mental health (Feng & Astell-Burt, 2017c, 2017d) and physical activity (Sanders et al., 2015) among children. These demonstrable associations between the exposure (green space quality) and both candidate mediators (mental health, physical activity) and the outcome (prosocial behaviour) served as an important basis for further investigation on mediators. The fourth study, presented in Chapter 6, represented an important step forward in the literature by identifying potential linking mechanisms (mediating variables) in which green space quality may influence prosocial behaviour.

Candidate mediators were selected based on the understanding of three potential pathways linking green space to health outcomes proposed by multidisciplinary experts that consist of restoring and building capacities (as presented in Chapter 1 – Introduction). This study tested physical activity and social interaction representing building capacities and mental health and HRQOL representing restoring capacities as candidate mediators.

Findings from developing several mediation models suggest that both the building and restoring capacities pathways might explain the association between green space quality and prosocial behaviour. Physical activity enjoyment displayed moderate mediation consistency, but no mediation by other physical activity variables (weekend and weekday physical activity, the choice for free time) were reported. Social interaction and caregiver mental health were found as mediators with low mediation consistency. Moreover, child mental health and HRQOL served as mediators with moderate-to-high and low-to-high mediation consistency, respectively. Mediation by the aforementioned candidate mediators showed lower proportions mediated or weaker mediation in child-reported compared to caregiver-reported prosocial behaviour models. While the mediating or indirect effects tended to manifest more in late childhood, the direct effects – the effect through mechanisms that did not involve mediators – appeared to be weaker in adolescence. This aligns with the findings from the second study in Chapter 4 which demonstrated the weak confounders-adjusted association between green space quality and prosocial behaviour in adolescence.

The pathway of harm mitigation by reducing air-related pollution was not investigated in this study due to the unavailability of supporting data. Nevertheless, another possible explanation for the harm mitigation pathway is that quality green space might influence the development of prosocial behaviour by mitigating harmful environmental stressors of growing up in unfavourable family and neighbourhood circumstances. This has been tested in the third study by examining associations between socioeconomic characteristics and prosocial behaviour stratified by trajectory classes of quality green space. The inequalities in prosocial behaviour by socioeconomic status at family and neighbourhood levels attenuated among a group of children whose caregivers consistently perceived neighbourhood green space as of very good quality – Class 6 (“consistently in very good quality”). Therefore, exposure to quality green space overtime can buffer the negative consequences of unfavourable living conditions in relation to the development of prosocial behaviour.

8.2.5 Prosocial behaviour as a mediator of the associations between green space quality and child health-related outcomes

A synthesis from current literature suggests potential bi-directional associations between prosocial behaviour and participation in physical activity, as well as prosocial behaviour and mental health. Therefore, prosocial behaviour might plausibly mediate associations between green space quality and child health-related outcomes. The final (fifth) study, presented in Chapter 7, examined prosocial behaviour as a candidate mediator of the associations between green space quality and physical activity, mental health, and HRQOL. Findings indicated that prosocial behaviour displayed strong mediation consistency for associations between green space quality and physical activity enjoyment, but not for other physical activity outcomes. Low mediation consistency of prosocial behaviour was observed for child mental health. Similarly, prosocial behaviour served as a mediator with low mediation consistency for all child HRQOL indicators. These provide empirical evidence that prosocial behaviour might be a missing link between green space quality and child health that has not been investigated in the current literature.

Mediation by prosocial behaviour between green space quality and health-related outcomes was found to be stronger among older children (Wave 5; 12-13 years). Childhood could be considered a critical period for the association between green space quality and prosocial behaviour; and late childhood might be a sensitive period during which the influence of green space quality is even stronger compared to its influence in earlier childhood. By contrast, findings from the second study in Chapter 4 suggest that the influence of quality green space tended to weaken in adolescence (Wave 6; 14-15 years). Therefore, it is logical to assume that the mediating effect of prosocial behaviour for the associations between green space quality and child health-related outcomes might also weaken in adolescence. This assumption could not be tested due to unavailability of data with which to develop mediation models. Nonetheless, findings from the fourth study in Chapter 6 revealed that the direct effect of the associations between green space quality and prosocial behaviour attenuated in adolescence (14-15 years). Therefore, these findings perhaps support the assumption of the possibility of weak mediation by prosocial behaviour in adolescence due to weaker associations between green space quality and prosocial behaviour during this period.

8.3 Strengths and limitations of the thesis

Findings from a series of five studies presented in this thesis provide a novel insight into the role of green space in influencing child health and behaviour, particularly on the association between green space quality and child prosocial behaviour which has received limited research attention. This thesis presented findings from studies that might be among the first of the type in this area, such as a critical systematic review of green space and prosocial behaviour, and empirical studies on investigating the longitudinal associations between green space quality and prosocial behaviour using a long period of observation (10 years), testing potential linking mechanisms of green space quality to prosocial behaviour, and examining prosocial behaviour as a mediator of the associations between green space quality and child health-related outcomes. Therefore, findings from this thesis potentially enrich the current literature and serve as a basis for further investigation by other scholars in this field.

The methodology used in the studies presented in this thesis has some key strengths. First, the use of 10-year longitudinal data retrieved from LSAC represents an important step forward in investigating associations between green space quality and prosocial behaviour that have heavily relied on cross-sectional data. The evidence that was resulted from longitudinal data as presented in this thesis helped to provide stronger support for the causal relationship than previous studies that were cross-sectional in design. In addition, a long period of observation (10 years) enabled an examination of the pattern of the association between green space quality and prosocial behaviour as children grew older and determine ages at which quality green space is more important for prosocial behaviour.

The present study was based on data retrieved from LSAC, which is the first nationally longitudinal study designed to be representative of Australian children. In addition, the sample for this current study was based on the K-cohort which commenced with almost 5,000 children and retained approximately 3,500 children across the 10-year follow up. This represents an adequate sample size with a long period of observation. Typically, in neighbourhood research, the more environmental factors are distal to the individual, the smaller the observed effect sizes. Therefore, using an adequate sample size in green space research can have enough power to detect the effects. Findings from the second and third studies on the associations between green space quality and prosocial behaviour indicate the small effect sizes. The highest covariates-adjusted regression coefficients (β) for the standard variable and trajectory classes of green space quality accounted for 0.20 (caregiver responses as “strongly agree” vs. “do not agree”) and 0.35 (Class 6 “consistently in very good” vs. Class 1 “consistently in low quality”), respectively. Even though the adjusted effect sizes were small, those were higher compared to more proximate determinants of prosocial behaviour, such as individual-level (child’s ethnicities: Indigenous status, language spoken at home) and family-level factors (caregiver education, household income, family structure, number of siblings). These findings imply that green space quality is an important determinant of the development of prosocial behaviour. Moreover, the provision of quality green space as an intervention to support the development of prosocial behaviour may be cost-effective since it can provide impact for a large population over a long period compared to individual-focused intervention, and this has considerable public health importance.

The subjective measure of green space quality based on caregiver report should be considered as a strength of this study. Compared to objective measures, subjective measures of green space quality consider the appraisal by lay people (residents) who have daily experiences living in the neighbourhood. Their assessments of their neighbourhood are more relevant and important for policymaking (Hur et al., 2010). Since the study sample subjects are children, using caregiver-reported green space seems more relevant as children tend to be dependent on adults for spending time outdoors (Datar et al., 2013; Kalish et al., 2010). Using green space quantity might not serve as an adequate proxy of green space exposure among children since caregivers’ preferences on a particular aspect of green space to large extent can influence their decision to chaperone children to green space. Therefore, caregiver perceptions on the quality of neighbourhood green space can have a direct influence on children’s exposure to green space. In addition, the measure of green space quality based on caregiver agreement to the statement – the extent to which neighbourhood parks, playgrounds, and play spaces are of good quality – has been employed by past work within the Australian context (Feng & Astell-Burt, 2017a, 2017c, 2017d). The wording of the statement to evaluate green space quality in this study did not impose an *a-priori* definition. Hence, caregivers were able to differently weight various attributes that constitute quality green space suitable for their children to arrive at an overall measure (Datar et al., 2013).

The data analysis involving multilevel modelling and causal mediation analysis provided some important strengths. The strength of using a multilevel approach is that this technique accounts for the clustering effects of LSAC data since observations (level 1) were nested within individuals or children (level 2) and SA2s (level 3). This statistical method is also suitable for repeated-measure longitudinal data which takes into account the assumption of correlated observations (Goldstein, 2011; Hair Jr. & Fávero, 2019; Van Der Leeden, 1998). In addition, the Markov chain Monte Carlo (MCMC) method (Browne et al., 2001) was also used in the data analysis to fit the cross-classified data structure since some children were nested within multiple SA2s at different time points in the study. Using a multilevel regression approach with MCMC method helped correctly estimate standard errors and reduce the risk of type I error. Furthermore, the use of causal mediation approach represented the step forward in mediation analysis. This statistical method is based on the counterfactual framework that helps address the potential bias from the traditional approach. Bias potentially comes from the incorrect statistical analysis from comparing two standard regression models without and with conditioning on the assessed mediator (Liu et al., 2016; Richiardi et al., 2013).

Findings from this thesis should be interpreted with consideration to some limitations. The item wording used to assess green space quality in this study only focused on parks, playgrounds, and play spaces. Caregivers might not consider different types of green space that were not in that wording, such as sport ovals and woodlands that can bring benefit for children in different age groups. Playgrounds and play spaces assessed in this study are often located in parks in the Australian context, but not all. Moreover, changes of caregiver perceptions on green space quality might not reflect changes in actual condition. Their perceptions could be influenced by social norms or values regarding what attributes of green space are more relevant for different children's sex and age groups. Socioeconomic position might also have an influence on caregivers' preferences on what constitutes quality green space. Furthermore, caregiver-reported green space quality might be less relevant for adolescents who can start assessing their surrounding environment and spending time outdoors more independently relative to their younger counterparts. Future research to gauge differences in caregiver preferred characteristics of green space by different children's sex and age groups, and research to understand how children and adolescents perceive green space quality would form an important next step.

Findings from this thesis can be influenced by residential self-selection bias. Caregivers who want their children to be healthier and experience better social and cognitive development might tend to choose to live in neighbourhoods perceived as safe and friendly for children. However, controlling for socioeconomic status can potentially adjust for selection bias, since access to favourable neighbourhood is strongly associated with socioeconomic position (Mitchell & Popham, 2008). Green space quantity (Astell-Burt et al., 2014) and quality (Feng & Astell-Burt, 2017d) were also found to be disproportionately distributed to more affluent neighbourhoods within the Australian context. In addition, using a longitudinal design as this thesis did can potentially address residential self-selection bias by controlling for unmeasured characteristics and establishing causality (Boone-Heinonen et al., 2010). However, it is important to acknowledge that this study is observational in design and issues of exchangeability and omitted variables bias still make causal inference difficult (Nichols, 2007).

In mediation studies (studies 4 and 5 presented in Chapters 6 and 7, respectively), time spent in physical activity was extracted from TUD data. The changes in informant reporting TUDs (caregiver or child) and the number of allocated days impacted the data analysis strategy. Only one day (weekday or weekend) was recorded in TUDs for Waves 4 to 6 which resulted in a smaller sample size when analyses were separated by weekday and weekend physical activity. In addition, data on the choice for free time and physical activity enjoyment were not collected for all waves due to a change in the approach to physical activity data collection, which in turn, impacted the incompleteness of mediation models. These studies also only used single mediation models where combined indirect effects of mediators through either serial or parallel models were not tested. This is due to the shortcoming of STATA macro that was unable to test multiple mediation models. Investigation on multiple mediation in series or parallel also needs further theorising.

Finally, the generalisability of the findings from this thesis should be taken into consideration. Even though LSAC was designed to be representative of Australian children, this was not strictly achieved. There were some documented dropping out and non-responses; and analytical samples had slightly higher socioeconomic position as presented in Chapter 5. Nonetheless, it is likely that the findings approximated the Australian population. However, due to cultural diversity in Australia, further studies with adequate sample sizes are needed to understand the extent to which the findings can be generalised to different non-Australian ethnicities based on the child's country of birth or self-identification (such as, Chinese, Vietnamese, Italian, Greek, English, etc.). Moreover, the findings of this thesis might not be widely applicable to populations in other settings or countries with different socioeconomic status and distribution, climate, and historical influences on urban planning. Findings from similar studies conducted in high-income countries and closely related settings (e.g., climate, population structure, urban landscape), such as in European countries, the US, Canada, New Zealand, etc. are more likely to be comparable with findings from this study.

8.4 Implications for future research

Findings from a series of five studies in this thesis suggest some implications for future research. It is clear from the findings that a complementary objective measure of green space quality is warranted to augment the caregiver reported one used in this thesis. While the objective measure of green space quality (e.g., expert assessments through audits or physical observations) can portray the actual situation of and changes in neighbourhood green space quality, a better subjective measure should be developed to take into account the assessments of different types or elements of green space viewed as important for boys and girls and as children age. Subjective preference-type measures are important for direct policy-relevance, particularly in provisioning and improving the quality of green space suitable for different genders and age groups. Future research that assesses the influence of green space quality on adolescent health and behaviour can consider using adolescent-reported rather than caregiver-reported green space quality since adolescents start assessing their surrounding environments more autonomously.

To better understand mechanistic pathways linking green space quality to prosocial behaviour, researchers should consider the consistency in collecting data for physical activity for both weekday and weekend day across the study period, as well as the completeness of other physical activity variables, such as choice for free time and physical activity enjoyment. These would allow a more comprehensive assessment of candidate mediators. In addition, distinguishing organised physical activity vs. unstructured active play can provide an avenue to disentangle the effect wherein physical activity is closely related to prosocial behaviour. A better measure of social interactions depicting children's interactions specifically with peers is warranted to adequately assess the mediation by social interactions. Besides, assessing mediators by taking into account all candidate mediators in the same mediation model using a serial or parallel technique (multiple mediation) is suggested for future studies. Doing so can provide new insight on how simultaneous effects of candidate mediators work on the pathway from green space quality to prosocial behaviour.

Findings from this thesis might have limited generalisability to different populations. Therefore, future studies will also benefit from evaluating the association between green space quality and prosocial behaviour among children and adolescents from different ethnic minorities and from different study settings (e.g., developing countries) in order to develop more in-depth knowledge and inform relevant policies. Furthermore, longitudinal studies with long-term follow-up examining how the availability of quality green space during childhood influences prosocial behaviour into adulthood and as a mediator of adult health are warranted.

8.5 Implications for policy

Findings presented in this thesis potentially contribute to inform public health and urban planning policies and practices to improve the quality of neighbourhood green space in order to support the development of prosocial behaviour across childhood and adolescence. Findings from identifying effect modifiers suggest that the provision and maintenance of quality green space should be prioritised in more deprived and remote areas. This would also align with addressing inequalities in the distribution of quality green space. Families living in more disadvantaged areas are more likely to be dependent on collective materials and social resources available in the neighbourhood to support their healthy life and wellbeing. The presence of quality green space potentially buffers the negative effects of living and growing up in unfavourable family and neighbourhood circumstances, which is paramount for the development of prosocial behaviour and other health-related outcomes.

There is a need for policy makers and researchers to collaborate on identifying characteristics of green space suitable for both boys and girls, and children from different age groups. Doing so can help develop green spaces that meet the needs of all and maximise the benefits of green space for the development of prosocial behaviour across childhood and adolescence. Findings from mediation analyses also suggest that investments in the provision of green space should also take into account characteristics of green space that encourages social interactions, physical activity, and mental health, which, in turn, can foster the development of prosocial behaviour, and vice versa. This also indicates that improving the quality of green space can yield co-benefits for various child health and behavioural outcomes.

In addition to the establishment and maintenance of quality green space in a targeted manner, increasing the access to, and promoting the use of, green space is also essential. Ensuring neighbourhoods are safe and friendly for ethnic minorities is vital to reduce external impediments to accessing quality green space. Furthermore, interventions such as conducting communication programmes promoting the availability and informing the benefits of quality green space to residents might enhance positive perceptions and use of green space.

8.6 Conclusion

This thesis presents important findings that contribute to the literature on green space and child health and behaviour. There is clear evidence that green space quality is associated with child prosocial behaviour. This association was found to not be consistent across age groups and gender. Boys were more likely to benefit more from the availability of quality green space in the neighbourhood than did girls. The effect of quality green space appeared to decline in adolescence. However, an association between green space quality and prosocial behaviour was evident irrespective of history of neighbourhood relocation.

Children had different trajectories of caregiver-reported green space quality across the study period. The accumulative effect of quality green space overtime could bring greater benefits for the development of prosocial behaviour across childhood and adolescence. The likelihood of being in trajectory groups with better green space quality was not equal across children from different neighbourhood circumstances. The findings indicated that the effect of accumulated quality green space potentially attenuates socioeconomic inequalities in prosocial behaviour. Furthermore, stronger associations between green space quality and prosocial behaviour were found among boys, children speaking only English at home, those living in more affluent, and those in remote areas. These findings have important implications for policy makers desiring to improve the quality of green space in unfavourable neighbourhoods, and in regard to designing green space to be appealing both to boys and girls and to be suitable for different age groups.

Some pathways linking green space quality to child prosocial behaviour have been identified that included physical activity enjoyment, social interaction, and mental health. Meanwhile, prosocial behaviour was also found as an intervening variable of the associations between green space quality and child health-related outcomes. Therefore, improving the availability of quality green space that supports the development of prosocial behaviour might yield positive impacts on child health and vice versa.

Overall, the evidence from this thesis emphasises the importance of quality green space for the development of prosocial behaviour. Neighbourhood green space which is well-designed for boys and girls and bears characteristics that support its utilisation across childhood and adolescence could potentially foster better child health and behavioural outcomes.

References

Abbasi, B., Pourmirzaei, M., Hariri, S., Heshmat, R., Qorbani, M., Dadvand, P., & Kelishadi, R. (2020). Subjective Proximity to Green Spaces and Blood Pressure in Children and Adolescents: The CASPIAN-V Study. *Journal of Environmental and Public Health*, *2020*, 8886241. https://doi.org/10.1155/2020/8886241

Abdi, B. (2010). Gender differences in social skills, problem behaviours and academic competence of Iranian kindergarten children based on their parent and teacher ratings. *Procedia - Social and Behavioral Sciences*, *5*, 1175-1179. https://doi.org/https://doi.org/10.1016/j.sbspro.2010.07.256

Abrams, D., Van de Vyver, J., Pelletier, J., & Cameron, L. (2015). Children's prosocial behavioural intentions towards outgroup members. *British Journal of Developmental Psychology*, *33*(3), 277-294. https://doi.org/10.1111/bjdp.12085

Acar, I., & Torquati, J. (2015). The power of nature: Developing prosocial behavior toward nature and peers through nature-based activities. *Young children*, *70*(5), 62-71. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1121&context=famconfacpub

Aggio, D., Smith, L., Fisher, A., & Hamer, M. (2015). Mothers' perceived proximity to green space is associated with TV viewing time in children: The Growing Up in Scotland study. *Preventive Medicine*, *70*, 46-49. https://doi.org/https://doi.org/10.1016/j.ypmed.2014.11.018

Aknin, L. B., Broesch, T., Hamlin, J. K., & Van de Vondervoort, J. W. (2015). Prosocial behavior leads to happiness in a small-scale rural society. *Journal of Experimental Psychology: General*, *144*(4), 788-795. https://doi.org/10.1037/xge0000082

Aknin, L. B., Hamlin, J. K., & Dunn, E. W. (2012). Giving leads to happiness in young children. *PloS one*, *7*(6), e39211-e39211. https://doi.org/10.1371/journal.pone.0039211

Aknin, L. B., Van de Vondervoort, J. W., & Hamlin, J. K. (2018). Positive feelings reward and promote prosocial behavior. *Current Opinion in Psychology*, *20*, 55-59. https://doi.org/https://doi.org/10.1016/j.copsyc.2017.08.017

Akpinar, A. (2017). Urban green spaces for children: A cross-sectional study of associations with distance, physical activity, screen time, general health, and overweight. *Urban Forestry & Urban Greening*, *25*, 66-73. https://doi.org/https://doi.org/10.1016/j.ufug.2017.05.006

Akpınar, A. (2020). Investigating the barriers preventing adolescents from physical activities in urban green spaces. *Urban Forestry & Urban Greening*, *53*, 126724. https://doi.org/https://doi.org/10.1016/j.ufug.2020.126724

Alcock, I., White, M. P., Wheeler, B. W., Fleming, L. E., & Depledge, M. H. (2014). Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas. *Environmental Science & Technology*, *48*(2), 1247-1255. https://doi.org/10.1021/es403688w

Allport, G. W., Clark, K., & Pettigrew, T. (1954). *The nature of prejudice*. Addison-Wesley. https://faculty.washington.edu/caporaso/courses/203/readings/allport_Nature_of_prejudice.pdf

Almquist, Y. B., Landstedt, E., & Hammarström, A. (2016). Associations between social support and depressive symptoms: social causation or social selection—or both? *European Journal of Public Health*, *27*(1), 84-89. https://doi.org/10.1093/eurpub/ckw120

American Academy of Child and Adolescent Psychiatry. (2012). *Fact for Families: The Anxious Children*. https://www.aacap.org/App_Themes/AACAP/docs/facts_for_families/47_the_anxious_child.pdf

Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., Alvarez-Pedrerol, M., Nieuwenhuijsen, M. J., & Sunyer, J. (2014). Green and Blue Spaces and Behavioral Development in Barcelona Schoolchildren: The BREATHE Project. *Environmental Health Perspectives*, *122*(12), 1351-1358. https://doi.org/10.1289/ehp.1408215

Andrusaityte, S., Grazuleviciene, R., Dedele, A., & Balseviciene, B. (2019). The effect of residential greenness and city park visiting habits on preschool Children's mental and general health in Lithuania: A cross-sectional study. *International Journal of Hygiene and Environmental Health*, *223*(1), 142-150. https://doi.org/https://doi.org/10.1016/j.ijheh.2019.09.009

Aram, F., Solgi, E., & Holden, G. (2019). The role of green spaces in increasing social interactions in neighborhoods with periodic markets. *Habitat International*, *84*, 24-32. https://doi.org/10.1016/j.habitatint.2018.12.004

Astell-Burt, T., Feng, X., Mavoa, S., Badland, H. M., & Giles-Corti, B. (2014). Do low-income neighbourhoods have the least green space? A cross-sectional study of Australia's most populous cities. *BMC Public Health*, *14*(1), 292. https://doi.org/10.1186/1471-2458-14-292

Australian Bureau of Statistics. (2006). *Socio-Economic Indexes for Areas (SEIFA)–Technical Paper*. https://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/72283F45CB86E5FECA2574170011B271/$File/2039055001_socio-economic%20indexes%20for%20areas%20(seifa)%20-%20technical%20paper_2006.pdf

Australian Bureau of Statistics. (2011). *Australian statistical geography standard (ASGS): Volume 1 - Main structure and greater capital city statistical areas*.

Australian Government. (2018). *Definition of a 'park' for the purposes of the Carbon Farming Initiative*. http://www.cleanenergyregulator.gov.au/ERF/Pages/Forms%20and%20resources/Regulatory%20Guidance/Sequestration%20guidance/Definition-of-a-park-for-the-purposes-of-the-Carbon-Farming-Initiative.aspx

Australian Institute of Family Studies. (2002). *Introducing the Longitudinal Study of Australian Children*. https://growingupinaustralia.gov.au/sites/default/files/discussionpaper1.pdf

Australian Institute of Family Studies. (2004). *The Longitudinal Study of Australian Children: 2004 Annual Report*. https://growingupinaustralia.gov.au/sites/default/files/annualreport2004.pdf

Australian Institute of Family Studies. (2005). *The Longitudinal Study of Australian Children: An Australian Government Initiative: Sample Design* (LSAC Technical Paper No. 1, Issue. https://growingupinaustralia.gov.au/sites/default/files/tp1.pdf

Australian Institute of Family Studies. (2007). *Children's time use in the Longitudinal Study of Australian Children: Data quality and analytical issues in the 4-year cohort* (LSAC Technical Paper No. 4, Issue. https://growingupinaustralia.gov.au/sites/default/files/tp4.pdf

Australian Institute of Family Studies. (2014). *Longitudinal analysis of LSAC time diary data: considerations for data users* (LSAC Technical Paper No. 11, Issue. https://growingupinaustralia.gov.au/sites/default/files/tp11.pdf

Australian Institute of Family Studies. (2018). *The Longitudinal Study of Australian Children: An Australian Government Initiative. Data User Guide*. Australian Goverment. https://growingupinaustralia.gov.au/data-and-documentation/data-user-guide

Australian Institute of Family Studies. (2020). *Data Dictionary*. https://growingupinaustralia.gov.au/data-and-documentation/data-dictionary/downloads

Bakas, T., McLennon, S. M., Carpenter, J. S., Buelow, J. M., Otte, J. L., Hanna, K. M., Ellett, M. L., Hadler, K. A., & Welch, J. L. (2012). Systematic review of health-related quality of life models. *Health and Quality of Life Outcomes*, *10*(1), 134. https://doi.org/10.1186/1477-7525-10-134

Balseviciene, B., Sinkariova, L., Grazuleviciene, R., Andrusaityte, S., Uzdanaviciute, I., Dedele, A., & Nieuwenhuijsen, M. J. (2014). Impact of Residential Greenness on Preschool Children's Emotional and Behavioral Problems. *Int J Environ Res Public Health*, *11*(7), 6757-6770. https://dx.doi.org/10.3390%2Fijerph110706757

Bandy, R., & Ottoni-Wilhelm, M. (2012). Family structure and income during the stages of childhood and subsequent prosocial behavior in young adulthood. *Journal of Adolescence*, *35*(4), 1023-1034. https://doi.org/10.1016/j.adolescence.2012.02.010

Bar-on, M. E. (2000). The effects of television on child health: implications and recommendations. *Archives of Disease in Childhood*, *83*(4), 289. https://doi.org/10.1136/adc.83.4.289

Bar-Tal, D. (1982). Sequential development of helping behavior: A cognitive-learning approach. *Developmental Review*, *2*(2), 101-124. https://doi.org/https://doi.org/10.1016/0273-2297(82)90006-5

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *J Pers Soc Psychol*, *51*(6), 1173-1182. https://doi.org/10.1037/0022-3514.51.6.1173

Bates, C. R., Bohnert, A. M., & Gerstein, D. E. (2018). Green schoolyards in low-income urban neighborhoods: Natural spaces for positive youth development outcomes. *Frontiers in psychology*, *9*, Article 805. https://doi.org/10.3389/fpsyg.2018.00805

Beets, M. W., Vogel, R., Forlaw, L., Pitetti, K. H., & Cardinal, B. J. (2006). Social support and youth physical activity: the role of provider and type. *Am J Health Behav*, *30*(3), 278-289. https://doi.org/https://doi.org/10.5555/ajhb.2006.30.3.278

Ben-Shlomo, Y., Mishra, G., & Kuh, D. (2014). Life Course Epidemiology. In W. Ahrens & I. Pigeot (Eds.), *Handbook of Epidemiology*. Springer. https://link.springer.com/referenceworkentry/10.1007%2F978-0-387-09834-0_56

Beutel, A. M., & Johnson, M. K. (2004). Gender and Prosocial Values during Adolescence: A Research Note. *The Sociological Quarterly*, *45*(2), 379-393. http://www.jstor.org/stable/4121177

Bingenheimer, J. B., & Raudenbush, S. W. (2004). Statistical and Substantive Inferences in Public Health: Issues in the Application of Multilevel Models. *Annual Review of Public Health*, *25*(1), 53-77. https://doi.org/10.1146/annurev.publhealth.25.050503.153925

Björk, J., Albin, M., Grahn, P., Jacobsson, H., Ardö, J., Wadbro, J., Östergren, P.-O., & Skärbäck, E. (2008). Recreational values of the natural environment in relation to neighbourhood satisfaction, physical activity, obesity and wellbeing. *Journal of Epidemiology and Community Health*, *62*(4), e2-e2. https://doi.org/10.1136/jech.2007.062414

Blakemore, T., Gibbings, J., & Strazdins, L. (2006). Measuring the socio-economic position of families in HILDA and LSAC. ACSPRI Social Science Methodology Conference, University of Sydney,

Bloemsma Lizan, D., Gehring, U., Klompmaker Jochem, O., Hoek, G., Janssen Nicole, A. H., Smit Henriëtte, A., Vonk Judith, M., Brunekreef, B., Lebret, E., & Wijga Alet, H. Green Space Visits among Adolescents: Frequency and Predictors in the PIAMA Birth Cohort Study. *Environmental Health Perspectives*, *126*(4), 047016. https://doi.org/10.1289/EHP2429

Boone-Heinonen, J., Guilkey, D. K., Evenson, K. R., & Gordon-Larsen, P. (2010). Residential self-selection bias in the estimation of built environment effects on physical activity between adolescence and young adulthood. *International Journal of Behavioral Nutrition and Physical Activity*, *7*(1), 70. https://doi.org/10.1186/1479-5868-7-70

Børve, H. E., & Børve, E. (2017). Rooms with gender: physical environment and play culture in kindergarten. *Early Child Development and Care*, *187*(5-6), 1069-1081. https://doi.org/10.1080/03004430.2016.1223072

Boxberger, K., & Reimers, A. K. (2019). Parental Correlates of Outdoor Play in Boys and Girls Aged 0 to 12-A Systematic Review. *Int J Environ Res Public Health*, *16*(2), 190. https://doi.org/10.3390/ijerph16020190

Bronfenbrenner, U. (1979). *The ecology of human development*. Harvard university press.

Browne, W. J., Goldstein, H., & Rasbash, J. (2001). Multiple membership multiple classification (MMMC) models. *Statistical Modelling*, *1*(2), 103-124. https://doi.org/10.1177/1471082X0100100202

Brownell, C. A. (2013). Early Development of Prosocial Behavior: Current Perspectives. *Infancy : the official journal of the International Society on Infant Studies*, *18*(1), 1-9. https://doi.org/10.1111/infa.12004

Brownell, C. A., Svetlova, M., & Nichols, S. (2009). To share or not to share: When do toddlers respond to another's needs? *Infancy : the official journal of the International Society on Infant Studies*, *14*(1), 117-130. https://doi.org/10.1080/15250000802569868

Buck, C., Tkaczick, T., Pitsiladis, Y., De Bourdehaudhuij, I., Reisch, L., Ahrens, W., & Pigeot, I. (2015). Objective Measures of the Built Environment and Physical Activity in Children: From Walkability to Moveability. *Journal of Urban Health*, *92*(1), 24-38. https://doi.org/10.1007/s11524-014-9915-2

Cai, D., Zhu, M., Lin, M., Zhang, X. C., & Margraf, J. (2017). The Bidirectional Relationship between Positive Mental Health and Social Rhythm in College Students:A Three-Year Longitudinal Study. *Frontiers in psychology*, *8*, 1119-1119. https://doi.org/10.3389/fpsyg.2017.01119

Campbell, S. B., Shaw, D. S., & Gilliom, M. (2000). Early externalizing behavior problems: toddlers and preschoolers at risk for later maladjustment. *Dev Psychopathol*, *12*(3), 467-488. https://doi.org/https://doi.org/10.1017/S0954579400003114

Caprara, G. V., Kanacri, B. P. L., Gerbino, M., Zuffianò, A., Alessandri, G., Vecchio, G., Caprara, E., Pastorelli, C., & Bridglall, B. (2014). Positive effects of promoting prosocial behavior in early adolescence: Evidence from a school-based intervention. *International Journal of Behavioral Development*, *38*(4), 386-396. https://doi.org/10.1177/0165025414531464

Caputi, M., Lecce, S., Pagnin, A., & Banerjee, R. (2012). Longitudinal effects of theory of mind on later peer relations: the role of prosocial behavior. *Developmental Psychology*, *48*(1), 257-270. https://doi.org/10.1037/a0025402

Carlo, G. (2014). The development and correlates of prosocial moral behaviors. In *Handbook of moral development, 2nd ed.* (pp. 208-234). Psychology Press. https://doi.org/10.4324/9780203581957.ch10

Carlo, G., Crockett, L. J., Randall, B. A., & Roesch, S. C. (2007). A latent growth curve analysis of prosocial behavior among rural adolescents. *Journal of Research on Adolescence*, *17*(2), 301-324. https://doi.org/10.1111/j.1532-7795.2007.00524.x

Carlo, G., Koller, S. H., Eisenberg, N., Da Silva, M. S., & Frohlich, C. B. (1996). A cross-national study on the relations among prosocial moral reasoning, gender role orientations, and prosocial behaviors. *Developmental Psychology*, *32*(2), 231-240. https://doi.org/10.1037/0012-1649.32.2.231

Carlo, G., Mestre, M. V., McGinley, M. M., Samper, P., Tur, A., & Sandman, D. (2012). The interplay of emotional instability, empathy, and coping on prosocial and aggressive behaviors. *Personality and Individual Differences*, *53*(5), 675-680. https://doi.org/https://doi.org/10.1016/j.paid.2012.05.022

Carlo, G., Mestre, M. V., Samper, P., Tur, A., & Armenta, B. E. (2010). The longitudinal relations among dimensions of parenting styles, sympathy, prosocial moral reasoning, and prosocial behaviors. *International Journal of Behavioral Development*, *35*(2), 116-124. https://doi.org/10.1177/0165025410375921

Carona, C., Vitorino, C., Alves-Nogueira, A. C., Moreira, H., Canavarro, M. C., & Silva, N. (2020). Nice Kids, Healthy Kids? Prosocial Behavior, Psychological Problems and Quality of Life in Children, Preadolescents, and Adolescents with and without Chronic Health Conditions. *Central European Journal of Pediatrics*, *16*(2). https://doi.org/http://dx.doi.org/10.5457/p2005-114.276

Carpendale, J. I., & Lewis, C. (2004). Constructing an understanding of mind: the development of children's social understanding within social interaction. *Behavioral and Brain Sciences*, *27*(1), 79-151. https://doi.org/https://doi.org/10.1017/s0140525x04000032

Carrus, G., Passiatore, Y., Pirchio, S., & Scopelliti, M. (2015). Contact with nature in educational settings might help cognitive functioning and promote positive social behaviour / El contacto con la naturaleza en los contextos educativos podría mejorar el funcionamiento cognitivo y fomentar el comportamiento social positivo. *Psyecology*, *6*(2), 191-212. https://doi.org/10.1080/21711976.2015.1026079

Carson, V., Spence, J. C., Cutumisu, N., & Cargill, L. (2010). Association between neighborhood socioeconomic status and screen time among pre-school children: a cross-sectional study. *BMC Public Health*, *10*(1), 367. https://doi.org/10.1186/1471-2458-10-367

Cauley, K., & Tyler, B. (1989). The relationship of self-concept to prosocial behavior in children. *Early Childhood Research Quarterly*, *4*(1), 51-60. https://doi.org/https://doi.org/10.1016/S0885-2006(89)90064-1

Cecil-Karb, R., & Grogan-Kaylor, A. (2009). Childhood body mass index in community context: neighborhood safety, television viewing, and growth trajectories of BMI. *Health & Social Work*, *34*(3), 169-177. https://doi.org/https://doi.org/10.1093/hsw/34.3.169

Chen, H., Sun, H., & Dai, J. (2017). Peer Support and Adolescents' Physical Activity: The Mediating Roles of Self-Efficacy and Enjoyment. *Journal of Pediatric Psychology*, *42*(5), 569-577. https://doi.org/10.1093/jpepsy/jsw103

Chen, X., Tian, L., & Huebner, E. S. (2019). Bidirectional Relations Between Subjective Well-Being in School and Prosocial Behavior Among Elementary School-Aged Children: A Longitudinal Study. *Child & Youth Care Forum*. https://doi.org/10.1007/s10566-019-09518-4

Choudhury, S., Blakemore, S.-J., & Charman, T. (2006). Social cognitive development during adolescence. *Social cognitive and affective neuroscience*, *1*(3), 165-174. https://doi.org/10.1093/scan/nsl024

Chung, A., Peeters, A., Gearon, E., & Backholer, K. (2018). Contribution of discretionary food and drink consumption to socio-economic inequalities in children's weight: prospective study of Australian children. *International Journal of Epidemiology*, *47*(3), 820-828. https://doi.org/10.1093/ije/dyy020

Clark, H. J., Camiré, M., Wade, T. J., & Cairney, J. (2015). Sport participation and its association with social and psychological factors known to predict substance use and abuse among youth: A scoping review of the literature. *International Review of Sport and Exercise Psychology*, *8*(1), 224-250. https://doi.org/10.1080/1750984X.2015.1068829

Clark, K. E., & Ladd, G. W. (2000). Connectedness and autonomy support in parent-child relationships: links to children's socioemotional orientation and peer relationships. *Developmental Psychology*, *36*(4), 485-498. https://doi.org/https://psycnet.apa.org/doi/10.1037/0012-1649.36.4.485

Collie, R. J., Martin, A. J., Roberts, C. L., & Nassar, N. (2018). The roles of anxious and prosocial behavior in early academic performance: A population-based study examining unique and moderated effects. *Learning and Individual Differences*, *62*, 141-152. https://doi.org/https://doi.org/10.1016/j.lindif.2018.02.004

Crane, J., & Temple, V. (2015). A systematic review of dropout from organized sport among children and youth. *European Physical Education Review*, *21*(1), 114-131. https://doi.org/10.1177/1356336x14555294

Crawford, D., Timperio, A., Giles-Corti, B., Ball, K., Hume, C., Roberts, R., Andrianopoulos, N., & Salmon, J. (2008). Do features of public open spaces vary according to neighbourhood socio-economic status? *Health Place*, *14*(4), 889-893. https://doi.org/https://doi.org/10.1016/j.healthplace.2007.11.002

Croft, S., Stride, C., Maughan, B., & Rowe, R. (2015). Validity of the Strengths and Difficulties Questionnaire in Preschool-Aged Children. *Pediatrics*, *135*(5), e1210-e1219. https://doi.org/https://doi.org/10.1542/peds.2014-2920

Crust, L., McKenna, J., Spence, J., Thomas, C., Evans, D., & Bishop, D. (2014). The effects of playground markings on the physical self-perceptions of 10–11-year-old school children. *Physical Education and Sport Pedagogy*, *19*(2), 179-190. https://doi.org/10.1080/17408989.2012.732565

Dadvand, P., Nazelle, A. d., Triguero-Mas, M., Schembari, A., Cirach, M., Amoly, E., Figueras, F., Basagaña, X., Ostro, B., & Nieuwenhuijsen, M. (2012). Surrounding Greenness and Exposure to Air Pollution During Pregnancy: An Analysis of Personal Monitoring Data. *Environmental Health Perspectives*, *120*(9), 1286-1290. https://doi.org/doi:10.1289/ehp.1104609

Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., Rivas, I., López-Vicente, M., De Castro Pascual, M., Su, J., Jerrett, M., Querol, X., & Sunyer, J. (2015). Green spaces and cognitive development in primary schoolchildren. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(26), 7937-7942. https://doi.org/10.1073/pnas.1503402112

Dadvand, P., Sunyer, J., Basagaña, X., Ballester, F., Lertxundi, A., Fernández-Somoano, A., Estarlich, M., García-Esteban, R., Mendez, M. A., & Nieuwenhuijsen, M. J. (2012). Surrounding Greenness and Pregnancy Outcomes in Four Spanish Birth Cohorts. *Environmental Health Perspectives*, *120*(10), 1481-1487. https://doi.org/doi:10.1289/ehp.1205244

Dadvand, P., Wright, J., Martinez, D., Basagaña, X., McEachan, R. R. C., Cirach, M., Gidlow, C. J., de Hoogh, K., Gražulevičienė, R., & Nieuwenhuijsen, M. J. (2014).

Inequality, green spaces, and pregnant women: Roles of ethnicity and individual and neighbourhood socioeconomic status. *Environment International*, *71*, 101-108. https://doi.org/https://doi.org/10.1016/j.envint.2014.06.010

Datar, A., Nicosia, N., & Shier, V. (2013). Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: evidence from a national longitudinal study. *American journal of epidemiology*, *177*(10), 1065-1073. https://doi.org/10.1093/aje/kws353

David, M. W., George, D. P., Melissa, A. N., Beth, A. L., Jessica, A. W., & Bess, H. M. (2006). Perceived Enjoyment Moderates the Efficacy of an Individually Tailored Physical Activity Intervention. *Journal of Sport and Exercise Psychology*, *28*(3), 300-309. https://doi.org/10.1123/jsep.28.3.300 10.1123/jsep.28.3.300

Davies, K., Tropp, L. R., Aron, A., Pettigrew, T. F., & Wright, S. C. (2011). Cross-Group Friendships and Intergroup Attitudes: A Meta-Analytic Review. *Personality and Social Psychology Review*, *15*(4), 332-351. https://doi.org/10.1177/1088868311411103

de Jong, K., Albin, M., Skarback, E., Grahn, P., & Bjork, J. (2012). Perceived green qualities were associated with neighborhood satisfaction, physical activity, and general health: results from a cross-sectional study in suburban and rural Scania, southern Sweden. *Health Place*, *18*(6), 1374-1380. https://doi.org/10.1016/j.healthplace.2012.07.001

de Leeuw, R. N. H., Kleemans, M., Rozendaal, E., Anschütz, D. J., & Buijzen, M. (2015). The Impact of Prosocial Television News on Children’s Prosocial Behavior: An Experimental Study in the Netherlands. *Journal of Children and Media*, *9*(4), 419-434. https://doi.org/10.1080/17482798.2015.1089297

de Vries, S., van Dillen, S. M. E., Groenewegen, P. P., & Spreeuwenberg, P. (2013). Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. *Social Science & Medicine*, *94*, 26-33. https://doi.org/https://doi.org/10.1016/j.socscimed.2013.06.030

Dendup, T., Feng, X., O’Shaughnessy, P. Y., & Astell-Burt, T. (2021). Role of perceived neighbourhood crime in the longitudinal association between perceived built environment and type 2 diabetes mellitus: a moderated mediation analysis. *Journal of Epidemiology and Community Health*, *75*(2), 120-127. https://doi.org/https://doi.org/10.1136/jech-2020-214175

Dennis, M., & James, P. (2016). User participation in urban green commons: Exploring the links between access, voluntarism, biodiversity and well being. *Urban Forestry & Urban Greening*, *15*, 22-31. https://doi.org/https://doi.org/10.1016/j.ufug.2015.11.009

Department of Health and Aged Care. (2001). *Measuring remoteness: accessibility/remoteness index of Australia (ARIA)* (New Series Number 14, Issue. https://www1.health.gov.au/internet/main/publishing.nsf/Content/E2EE19FE831F26BFCA257BF0001F3DFA/$File/ocpanew14.pdf

Department of Social Services, Australian Institute of Family Studies, & Australian Bureau of Statistics. (2020). *Growing Up in Australia: Longitudinal Study of Australian Children (LSAC) Release 7.2 (Waves 1-7)* https://doi.org/doi/10.26193/F2YRL5

Di Bartolomeo, G., & Papa, S. (2017). The Effects of Physical Activity on Social Interactions: The Case of Trust and Trustworthiness. *Journal of Sports Economics*, *20*(1), 50-71. https://doi.org/10.1177/1527002517717299

Diderichsen, F., Hallqvist, J., & Whitehead, M. (2018). Differential vulnerability and susceptibility: how to make use of recent development in our understanding of mediation and interaction to tackle health inequalities. *International Journal of Epidemiology*, *48*(1), 268-274. https://doi.org/10.1093/ije/dyy167

Diez-Roux, A. V. (2000). Multilevel Analysis in Public Health Research. *Annual Review of Public Health*, *21*(1), 171-192. https://doi.org/10.1146/annurev.publhealth.21.1.171

Diez Roux, A. V. (2002). A glossary for multilevel analysis. *Journal of Epidemiology and Community Health*, *56*(8), 588-594. https://doi.org/10.1136/jech.56.8.588

Dinnie, E., Brown, K. M., & Morris, S. (2013). Community, cooperation and conflict: Negotiating the social well-being benefits of urban greenspace experiences. *Landscape and Urban Planning*, *112*, 1-9. https://doi.org/https://doi.org/10.1016/j.landurbplan.2012.12.012

Dopko, R. L., Capaldi, C. A., & Zelenski, J. M. (2019). The psychological and social benefits of a nature experience for children: A preliminary investigation. *Journal of Environmental Psychology*, *63*, 134-138. https://doi.org/10.1016/j.jenvp.2019.05.002

Dray, J., Bowman, J., Freund, M., Campbell, E., Hodder, R. K., Lecathelinais, C., & Wiggers, J. (2016). Mental health problems in a regional population of Australian adolescents: association with socio-demographic characteristics. *Child and adolescent psychiatry and mental health*, *10*(1), 32. https://doi.org/10.1186/s13034-016-0120-9

Dunfield, K. A. (2014). A construct divided: prosocial behavior as helping, sharing, and comforting subtypes. *Frontiers in psychology*, *5*, 958-958. https://doi.org/10.3389/fpsyg.2014.00958

Durlak, J. A., Weissberg, R. P., Dymnicki, A. B., Taylor, R. D., & Schellinger, K. B. (2011). The Impact of Enhancing Students' Social and Emotional Learning: A Meta-Analysis of School-Based Universal Interventions [https://doi.org/10.1111/j.1467-8624.2010.01564.x]. *Child Development*, *82*(1), 405-432. https://doi.org/https://doi.org/10.1111/j.1467-8624.2010.01564.x

Dzhambov, A., Hartig, T., Markevych, I., Tilov, B., & Dimitrova, D. (2018). Urban residential greenspace and mental health in youth: Different approaches to testing multiple pathways yield different conclusions. *Environ Res*, *160*, 47-59. https://doi.org/https://doi.org/10.1016/j.envres.2017.09.015

Edwards, B. (2012). Growing up in Australia: The longitudinal study of Australian children: The first decade of life. *Family Matters*, *91*, 7-17. https://aifs.gov.au/sites/default/files/fm91a.pdf

Edwards, C. P., Knoche, L., & Kumru, A. (2001). Play patterns and gender. In J. Worrell (Ed.), *Encyclopedia of Women and Gender* (Vol. 2, pp. 809-815). Academic Press. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1610&context=psychfacpub

Eigenschenk, B., Thomann, A., McClure, M., Davies, L., Gregory, M., Dettweiler, U., & Inglés, E. (2019). Benefits of Outdoor Sports for Society. A Systematic Literature Review and Reflections on Evidence. *Int J Environ Res Public Health*, *16*(6), 937. https://doi.org/10.3390/ijerph16060937

Eime, R. M., Young, J. A., Harvey, J. T., Charity, M. J., & Payne, W. R. (2013). A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *International Journal of Behavioral Nutrition and Physical Activity*, *10*(1), 98. https://doi.org/10.1186/1479-5868-10-98

Eisenberg, N., Spinrad, T. L., & Knafo-Noam, A. (2015). Prosocial Development. In R. M. Lerner (Ed.), *Handbook of Child Psychology and Developmental Science* (pp. 1-47). https://doi.org/10.1002/9781118963418.childpsy315

Eldeirawi, K., Kunzweiler, C., Zenk, S., Finn, P., Nyenhuis, S., Rosenberg, N., & Persky, V. (2019). Associations of urban greenness with asthma and respiratory symptoms in Mexican American children. *Annals of Allergy, Asthma & Immunology*, *122*(3), 289-295. https://doi.org/https://doi.org/10.1016/j.anai.2018.12.009

Eriksson, M., Lindgren, U., Ivarsson, A., & Ng, N. (2019). The effect of neighbourhood social capital on child injuries: A gender-stratified analysis. *Health Place*, *60*, 102205. https://doi.org/https://doi.org/10.1016/j.healthplace.2019.102205

Fabes, R. A., Hanish, L. D., Martin, C. L., Moss, A., & Reesing, A. (2012). The effects of young children's affiliations with prosocial peers on subsequent emotionality in peer interactions. *Br J Dev Psychol*, *30*(Pt 4), 569-585. https://doi.org/10.1111/j.2044-835X.2011.02073.x

Feng, X., & Astell-Burt, T. (2017a). Do greener areas promote more equitable child health? *Health Place*, *46*, 267-273. https://doi.org/10.1016/j.healthplace.2017.05.006

Feng, X., & Astell-Burt, T. (2017b). Is Neighborhood Green Space Protective Against Associations Between Child Asthma, Neighborhood Traffic Volume and Area Safety? Multilevel Analysis of 4,447 Australian Children. *Journal of Transport & Health*, *5*, S40-S41. https://doi.org/https://doi.org/10.1016/j.jth.2017.05.328

Feng, X., & Astell-Burt, T. (2017c). The Relationship between Neighbourhood Green Space and Child Mental Wellbeing Depends upon Whom You Ask: Multilevel Evidence from 3083 Children Aged 12-13 Years. *Int J Environ Res Public Health*, *14*(3). https://doi.org/10.3390/ijerph14030235

Feng, X., & Astell-Burt, T. (2017d). Residential Green Space Quantity and Quality and Child Well-being: A Longitudinal Study. *American Journal of Preventive Medicine*, *53*(5), 616-624. https://doi.org/https://doi.org/10.1016/j.amepre.2017.06.035

Feng, X., & Astell-Burt, T. (2018). Residential green space quantity and quality and symptoms of psychological distress: a 15-year longitudinal study of 3897 women in postpartum. *BMC Psychiatry*, *18*(1), 348. https://doi.org/10.1186/s12888-018-1926-1

Feng, X., & Astell-Burt, T. (2019). Can green space quantity and quality help prevent postpartum weight gain? A longitudinal study. *Journal of Epidemiology and Community Health*, *73*(4), 295-302. https://doi.org/10.1136/jech-2018-211133

Ferreira, T., Cadima, J., Matias, M., Vieira, J. M., Leal, T., & Matos, P. M. (2016). Preschool Children's Prosocial Behavior: The Role of Mother–Child, Father–Child and Teacher–Child Relationships. *Journal of Child and Family Studies*, *25*(6), 1829-1839. https://doi.org/10.1007/s10826-016-0369-x

Finch, J. E., Yousafzai, A. K., Rasheed, M., & Obradovic, J. (2018). Measuring and understanding social-emotional behaviors in preschoolers from rural Pakistan. *PloS one*, *13*(11), e0207807. https://doi.org/10.1371/journal.pone.0207807

Fitzgerald, A., Fitzgerald, N., & Aherne, C. (2012). Do peers matter? A review of peer and/or friends' influence on physical activity among American adolescents. *Journal of Adolescence*, *35*(4), 941-958. https://doi.org/https://doi.org/10.1016/j.adolescence.2012.01.002

Fletcher, R. J., Feeman, E., Garfield, C., & Vimpani, G. (2011). The effects of early paternal depression on children's development. *The Medical Journal of Australia*, *195*(11-12), 685-689. https://doi.org/10.5694/mja11.10192

Flouri, E., Midouhas, E., & Joshi, H. (2014). The role of urban neighbourhood green space in children's emotional and behavioural resilience. *Journal of Environmental Psychology*, *40*, 179-186. https://doi.org/https://doi.org/10.1016/j.jenvp.2014.06.007

Flouri, E., & Sarmadi, Z. (2016). Prosocial behavior and childhood trajectories of internalizing and externalizing problems: The role of neighborhood and school contexts. *Developmental Psychology*, *52*(2), 253-258. https://doi.org/10.1037/dev0000076

Flynn, E., Ehrenreich, S. E., Beron, K. J., & Underwood, M. K. (2015). Prosocial Behavior: Long-Term Trajectories and Psychosocial Outcomes. *Social Development*, *24*(3), 462-482. https://doi.org/10.1111/sode.12100

Fongar, C., Aamodt, G., Randrup, T. B., & Solfjeld, I. (2019). Does Perceived Green Space Quality Matter? Linking Norwegian Adult Perspectives on Perceived Quality to Motivation and Frequency of Visits. *Int J Environ Res Public Health*, *16*(13), 2327. https://doi.org/10.3390/ijerph16132327

Fortuna, K., & Knafo, A. (2014). Parental and genetic contributions to prosocial behavior during childhood. In *Prosocial development: A multidimensional approach.* (pp. 70-89). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199964772.003.0004

Francis, J., Wood, L. J., Knuiman, M., & Giles-Corti, B. (2012). Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia. *Social Science & Medicine*, *74*(10), 1570-1577. https://doi.org/https://doi.org/10.1016/j.socscimed.2012.01.032

Fraser, M., Munoz, S.-A., & MacRury, S. (2019). What Motivates Participants to Adhere to Green Exercise? *Int J Environ Res Public Health*, *16*(10), 1832. https://doi.org/10.3390/ijerph16101832

Frontini, R., Crespo, C., Carona, C., & Canavarro, M. C. (2012). Health-Related Quality of Life and its Correlates in Children with Cerebral Palsy: An Exploratory Study. *Journal of Developmental and Physical Disabilities*, *24*(2), 181-196. https://doi.org/10.1007/s10882-011-9265-x

Fujisawa, K. K., Kutsukake, N., & Hasegawa, T. (2008). Reciprocity of prosocial behavior in Japanese preschool children. *International Journal of Behavioral Development*, *32*(2), 89-97. https://doi.org/10.1177/0165025407084055

Furukawa, T. A., Kessler, R. C., Slade, T., & Andrews, G. (2003). The performance of the K6 and K10 screening scales for psychological distress in the Australian National Survey of Mental Health and Well-Being. *Psychol Med*, *33*(2), 357-362. https://doi.org/10.1017/S0033291702006700

Gallitto, E., & Leth-Steensen, C. (2019). Moderating effect of trait emotional intelligence on the relationship between parental nurturance and prosocial behaviour. *Journal of Adolescence*, *74*, 113-119. https://doi.org/https://doi.org/10.1016/j.adolescence.2019.04.008

Garaigordobil, M. (2009). A comparative analysis of empathy in childhood and adolescence: Gender differences and associated socio-emotional variables. *International Journal of Psychology & Psychological Therapy*, *9*(2), 217-235. https://www.ijpsy.com/volumen9/num2/233/a-comparative-analysis-of-empathy-in-childhood-EN.pdf

García-Carrión, R., Villarejo-Carballido, B., & Villardón-Gallego, L. (2019). Children and Adolescents Mental Health: A Systematic Review of Interaction-Based Interventions in Schools and Communities. *Frontiers in psychology*, *10*(918). https://doi.org/10.3389/fpsyg.2019.00918

Garcia, J. M., Sirard, J. R., Deutsch, N. L., & Weltman, A. (2016). The influence of friends and psychosocial factors on physical activity and screen time behavior in adolescents: a mixed-methods analysis. *J Behav Med*, *39*(4), 610-623. https://doi.org/10.1007/s10865-016-9738-6

Gerbino, M., Zuffiano, A., Eisenberg, N., Castellani, V., Luengo Kanacri, B. P., Pastorelli, C., & Caprara, G. V. (2018). Adolescents' Prosocial Behavior Predicts Good Grades Beyond Intelligence and Personality Traits. *J Pers*, *86*(2), 247-260. https://doi.org/10.1111/jopy.12309

Goldstein, H. (2011). *Multilevel statistical models* (Vol. 922). John Wiley & Sons.

Goldy, S. P., & Piff, P. K. (2020). Toward a social ecology of prosociality: why, when, and where nature enhances social connection. *Current Opinion in Psychology*, *32*, 27-31. https://doi.org/https://doi.org/10.1016/j.copsyc.2019.06.016

Goodman. (1997). The Strengths and Difficulties Questionnaire: a research note. *Journal of Child Psychology and Psychiatry*, *38*(5), 581-586. https://doi.org/https://doi.org/10.1111/j.1469-7610.1997.tb01545.x

Goodman, A., & Goodman, R. (2009). Strengths and difficulties questionnaire as a dimensional measure of child mental health. *Journal of the American Academy of Child & Adolescent Psychiatry*, *48*(4), 400-403. https://doi.org/10.1097/CHI.0b013e3181985068

Greitemeyer, T. (2011). Effects of Prosocial Media on Social Behavior:When and Why Does Media Exposure Affect Helping and Aggression? *Current Directions in Psychological Science*, *20*(4), 251-255. https://doi.org/10.1177/0963721411415229

Grzywacz, J. G., Almeida, D. M., Neupert, S. D., & Ettner, S. L. (2004). Socioeconomic Status and Health: A Micro-level Analysis o Exposure and Vulnerability to Daily Stressors. *Journal of Health and Social Behavior*, *45*(1), 1-16. https://doi.org/10.1177/002214650404500101

Gupta, K., Kumar, P., Pathan, S. K., & Sharma, K. P. (2012). Urban Neighborhood Green Index – A measure of green spaces in urban areas. *Landscape and Urban Planning*, *105*(3), 325-335. https://doi.org/https://doi.org/10.1016/j.landurbplan.2012.01.003

Gustin, K., Tofail, F., Vahter, M., & Kippler, M. (2018). Cadmium exposure and cognitive abilities and behavior at 10 years of age: A prospective cohort study. *Environment International*, *113*, 259-268. https://doi.org/https://doi.org/10.1016/j.envint.2018.02.020

Hair Jr., J. F., & Fávero, L. P. (2019). Multilevel modeling for longitudinal data: concepts and applications. *RAUSP Management Journal*, *54*(4), 459-489. https://doi.org/10.1108/RAUSP-04-2019-0059

Hall, C. L., Guo, B., Valentine, A. Z., Groom, M. J., Daley, D., Sayal, K., & Hollis, C. (2019). The validity of the Strengths and Difficulties Questionnaire (SDQ) for children with ADHD symptoms. *PloS one*, *14*(6), e0218518-e0218518. https://doi.org/10.1371/journal.pone.0218518

Hammond, S. I., & Brownell, C. A. (2015). Prosocial Development Across the Lifespan. In R. Tremblay, M. Boivin, & R. Peters (Eds.), *Encyclopedia on Early Childhood Development*. http://www.child-encyclopedia.com/prosocial-behaviour/according-experts/prosocial-development-across-lifespan

Hammond, S. I., Waugh, W., Satlof-Bedrick, E., & Brownell, C. A. (2015). Prosocial Behavior during Childhood and Cultural Variations. In J. D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences (Second Edition)* (pp. 228-232). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-08-097086-8.23182-6

Hartig, T., Mitchell, R., Vries, S. d., & Frumkin, H. (2014). Nature and Health. *Annual Review of Public Health*, *35*(1), 207-228. https://doi.org/10.1146/annurev-publhealth-032013-182443

Hartley, K., Ryan, P., Brokamp, C., & Gillespie, G. L. (2020). Effect of greenness on asthma in children: A systematic review. *Public Health Nursing*, *37*(3), 453-460. https://doi.org/10.1111/phn.12701

Hay, D. F. (1994). Prosocial Development. *Journal of Child Psychology and Psychiatry*, *35*(1), 29-71. https://doi.org/10.1111/j.1469-7610.1994.tb01132.x

Hay, D. F., & Cook, K. V. (2007). The transformation of prosocial behavior from infancy to childhood. In *Socioemotional development in the toddler years: Transitions and transformations.* (pp. 100-131). Guilford Press. https://psycnet.apa.org/record/2007-15136-004

Hay, D. F., & Pawlby, S. (2003). Prosocial Development in Relation to Children's and Mothers' Psychological Problems. *Child Development*, *74*(5), 1314-1327. http://www.jstor.org/stable/3696180

Hay, D. F., Payne, A., & Chadwick, A. (2004). Peer relations in childhood. *Journal of Child Psychology and Psychiatry*, *45*(1), 84-108. https://doi.org/10.1046/j.0021-9630.2003.00308.x

Hayes, A. F. (2009). Beyond Baron and Kenny: Statistical Mediation Analysis in the New Millennium. *Communication Monographs*, *76*(4), 408-420. https://doi.org/10.1080/03637750903310360

Hoffimann, E., Barros, H., & Ribeiro, A. I. (2017). Socioeconomic inequalities in green space quality and accessibility—Evidence from a Southern European city. *Int J Environ Res Public Health*, *14*(8), 916. https://doi.org/https://dx.doi.org/10.3390%2Fijerph14080916

Holt, E. W., Lombard, Q. K., Best, N., Smiley-Smith, S., & Quinn, J. E. (2019). Active and Passive Use of Green Space, Health, and Well-Being amongst University Students. *Int J Environ Res Public Health*, *16*(3), 424. https://doi.org/10.3390/ijerph16030424

Hong, A., Sallis, J. F., King, A. C., Conway, T. L., Saelens, B., Cain, K. L., Fox, E. H., & Frank, L. D. (2018). Linking green space to neighborhood social capital in older adults: The role of perceived safety. *Social Science & Medicine*, *207*, 38-45. https://doi.org/10.1016/j.socscimed.2018.04.051

Hossin, M. Z., Koupil, I., & Falkstedt, D. (2019). Early life socioeconomic position and mortality from cardiovascular diseases: an application of causal mediation analysis in the Stockholm Public Health Cohort. *BMJ Open*, *9*(6), e026258-e026258. https://doi.org/10.1136/bmjopen-2018-026258

Houlden, V., Weich, S., Porto de Albuquerque, J., Jarvis, S., & Rees, K. (2018). The relationship between greenspace and the mental wellbeing of adults: A systematic review. *PloS one*, *13*(9), e0203000. https://doi.org/10.1371/journal.pone.0203000

Hughes, C., McHarg, G., & White, N. (2018). Sibling influences on prosocial behavior. *Current Opinion in Psychology*, *20*, 96-101. https://doi.org/10.1016/j.copsyc.2017.08.015

Hur, M., Nasar, J. L., & Chun, B. (2010). Neighborhood satisfaction, physical and perceived naturalness and openness. *Journal of Environmental Psychology*, *30*(1), 52-59. https://doi.org/https://doi.org/10.1016/j.jenvp.2009.05.005

Hyndman, B., & Chancellor, B. (2015). Engaging children in activities beyond the classroom walls: a social–ecological exploration of Australian primary school children's enjoyment of school play activities. *Journal of Playwork Practice*, *2*(2), 117-141. https://doi.org/10.1332/205316215X14454218579212

Israel, S., Hasenfratz, L., & Knafo-Noam, A. (2015). The genetics of morality and prosociality. *Current Opinion in Psychology*, *6*, 55-59. https://doi.org/https://doi.org/10.1016/j.copsyc.2015.03.027

Jennings, V., & Bamkole, O. (2019). The Relationship between Social Cohesion and Urban Green Space: An Avenue for Health Promotion. *Int J Environ Res Public Health*, *16*(3). https://doi.org/10.3390/ijerph16030452

Jones, D. E., Greenberg, M., & Crowley, M. (2015). Early Social-Emotional Functioning and Public Health: The Relationship Between Kindergarten Social Competence and Future Wellness. *Am J Public Health*, *105*(11), 2283-2290. https://doi.org/10.2105/AJPH.2015.302630

Kalish, M., Banco, L., Burke, G., & Lapidus, G. (2010). Outdoor play: A survey of parent's perceptions of their child's safety. *The Journal of trauma*, *69*(4 Suppl), S218-222. https://doi.org/10.1097/ta.0b013e3181f1eaf0

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169-182. https://doi.org/https://doi.org/10.1016/0272-4944(95)90001-2

Karmakar, R., & Ghosh, A. (2012). Altruistic behaviour of adolescents of different regions of India. *Journal of the Indian Academy of Applied Psychology*, *38*(1), 44-53. http://www.jiaap.org.in/Listing_Detail/Logo/ef3a0d9a-325b-4541-ab82-ccaa9dcf1481.pdf

Kaymaz, I., Oguz, D., & Cengiz-Hergul, O. C. (2017). Factors influencing children's use of urban green spaces. *Indoor and Built Environment*, *28*(4), 520-532. https://doi.org/10.1177/1420326X17705943

Kaźmierczak, A. (2013). The contribution of local parks to neighbourhood social ties [Article]. *Landscape and Urban Planning*, *109*(1), 31-44. https://doi.org/10.1016/j.landurbplan.2012.05.007

Kessler, R. C., Andrews, G., Colpe, L. J., Hiripi, E., Mroczek, D. K., Normand, S. L. T., Walters, E. E., & Zaslavsky, A. M. (2002). Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol Med*, *32*(6), 959-976. https://doi.org/10.1017/S0033291702006074

Kim-Cohen, J., Moffitt, T. E., Taylor, A., Pawlby, S. J., & Caspi, A. (2005). Maternal Depression and Children's Antisocial Behavior: Nature and Nurture Effects. *Archives of General Psychiatry*, *62*(2), 173-181. https://doi.org/10.1001/archpsyc.62.2.173

Kim, J.-H., Lee, C., & Sohn, W. (2016). Urban Natural Environments, Obesity, and Health-Related Quality of Life among Hispanic Children Living in Inner-City Neighborhoods. *Int J Environ Res Public Health*, *13*(1), 121. https://doi.org/10.3390/ijerph13010121

Kingsbury, M., Kirkbride, J. B., McMartin, S. E., Wickham, M. E., Weeks, M., & Colman, I. (2015). Trajectories of childhood neighbourhood cohesion and adolescent mental health: evidence from a national Canadian cohort. *Psychol Med*, *45*(15), 3239-3248. https://doi.org/10.1017/S0033291715001245

Knafo-Noam, A., Uzefovsky, F., Israel, S., Davidov, M., & Zahn-Waxler, C. (2015). The prosocial personality and its facets: genetic and environmental architecture of mother-reported behavior of 7-year-old twins. *Frontiers in psychology*, *6*, 112. https://doi.org/10.3389/fpsyg.2015.00112

Knafo, A., Zahn-Waxler, C., Van Hulle, C., Robinson, J. L., & Rhee, S. H. (2008). The developmental origins of a disposition toward empathy: Genetic and environmental contributions. *Emotion*, *8*(6), 737-752. https://doi.org/10.1037/a0014179

Kok, R., Prinzie, P., Bakermans-Kranenburg, M. J., Verhulst, F. C., White, T., Tiemeier, H., & van Ijzendoorn, M. H. (2018). Socialization of prosocial behavior: Gender differences in the mediating role of child brain volume. *Child Neuropsychology*, *24*(6), 723-733. https://doi.org/10.1080/09297049.2017.1338340

Kondo, M. C., Fluehr, J. M., McKeon, T., & Branas, C. C. (2018). Urban Green Space and Its Impact on Human Health. *Int J Environ Res Public Health*, *15*(3). https://doi.org/10.3390/ijerph15030445

Kongsted, A., & Nielsen, A. M. (2017). Latent Class Analysis in health research. *Journal of Physiotherapy*, *63*(1), 55-58. https://doi.org/https://doi.org/10.1016/j.jphys.2016.05.018

Koning, M., de Jong, A., de Jong, E., Visscher, T. L. S., Seidell, J. C., & Renders, C. M. (2018). Agreement between parent and child report of physical activity, sedentary and dietary behaviours in 9-12-year-old children and associations with children's weight status. *BMC psychology*, *6*(1), 14. https://doi.org/10.1186/s40359-018-0227-2

Kuh, D., Ben-Shlomo, Y., Lynch, J., Hallqvist, J., & Power, C. (2003). Life course epidemiology. *Journal of Epidemiology and Community Health*, *57*(10), 778-783. https://doi.org/10.1136/jech.57.10.778

Kwok, O.-M., Underhill, A. T., Berry, J. W., Luo, W., Elliott, T. R., & Yoon, M. (2008). Analyzing longitudinal data with multilevel models: An example with individuals living with lower extremity intra-articular fractures. *Rehabilitation Psychology*, *53*(3), 370-386. https://doi.org/10.1037/a0012765

Lai, F. H. Y., Siu, A. M. H., & Shek, D. T. L. (2015). Individual and Social Predictors of Prosocial Behavior among Chinese Adolescents in Hong Kong [Original Research]. *Frontiers in pediatrics*, *3*(39). https://doi.org/10.3389/fped.2015.00039

Lambert, K. A., Bowatte, G., Tham, R., Lodge, C., Prendergast, L., Heinrich, J., Abramson, M. J., Dharmage, S. C., & Erbas, B. (2017). Residential greenness and allergic respiratory diseases in children and adolescents – A systematic review and meta-analysis. *Environ Res*, *159*, 212-221. https://doi.org/https://doi.org/10.1016/j.envres.2017.08.002

Lapointe-Shaw, L., Bouck, Z., Howell, N. A., Lange, T., Orchanian-Cheff, A., Austin, P. C., Ivers, N. M., Redelmeier, D. A., & Bell, C. M. (2018). Mediation analysis with a time-to-event outcome: a review of use and reporting in healthcare research. *BMC Medical Research Methodology*, *18*(1), 118. https://doi.org/10.1186/s12874-018-0578-7

Larsen, M., Goemans, A., Baste, V., Wilderjans, T. F., & Lehmann, S. (2020). Predictors of quality of life among youths in foster care — a 5-year prospective follow-up study. *Quality of Life Research*. https://doi.org/10.1007/s11136-020-02641-z

Laurens, K. R., Tzoumakis, S., Dean, K., Brinkman, S. A., Bore, M., Lenroot, R. K., Smith, M., Holbrook, A., Robinson, K. M., Stevens, R., Harris, F., Carr, V. J., & Green, M. J. (2017). The 2015 Middle Childhood Survey (MCS) of mental health and well-being at age 11 years in an Australian population cohort. *BMJ Open*, *7*(6), e016244. https://doi.org/10.1136/bmjopen-2017-016244

Lawrence, D., Johnson, S., Hafekost, J., Boterhoven De Haan, K., Sawyer, M., Ainley, J., & Zubrick, S. (2015). *The Mental Health of Children and Adolescents: Report on the Second Australian Child and Adolescent Survey of Mental Health and*

Wellbeing. https://www.health.gov.au/sites/default/files/documents/2020/11/the-mental-health-of-children-and-adolescents_0.pdf

Lee, A. C., & Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health*, *33*(2), 212-222. https://doi.org/10.1093/pubmed/fdq068

Lee, C.-T., Padilla-Walker, L. M., & Memmott-Elison, M. K. (2016). The role of parents and peers on adolescents' prosocial behavior and substance use. *Journal of Social and Personal Relationships*, *34*(7), 1053-1069. https://doi.org/10.1177/0265407516665928

Lee, H., Herbert, R. D., & McAuley, J. H. (2019). Mediation analysis. *JAMA*, *321*(7), 697-698. https://doi.org/10.1001/jama.2018.21973

Lenzi, M., Vieno, A., Perkins, D. D., Pastore, M., Santinello, M., & Mazzardis, S. (2012). Perceived Neighborhood Social Resources as Determinants of Prosocial Behavior in Early Adolescence. *American Journal of Community Psychology*, *50*(1-2), 37-49. https://doi.org/https://doi.org/10.1007/s10464-011-9470-x

Leventhal, K. S., Gillham, J., DeMaria, L., Andrew, G., Peabody, J., & Leventhal, S. (2015). Building psychosocial assets and wellbeing among adolescent girls: A randomized controlled trial. *Journal of Adolescence*, *45*, 284-295. https://doi.org/https://doi.org/10.1016/j.adolescence.2015.09.011

Li, Y., Yu, J., & Zeng, T. (2017). Deviance Information Criterion for Model Selection: Justification and Variation.

Liao, J., Zhang, B., Xia, W., Cao, Z., Zhang, Y., Liang, S., Hu, K., Xu, S., & Li, Y. (2019). Residential exposure to green space and early childhood neurodevelopment. *Environ Int*, *128*, 70-76. https://doi.org/10.1016/j.envint.2019.03.070

Liu, S.-H., Ulbricht, C. M., Chrysanthopoulou, S. A., & Lapane, K. L. (2016). Implementation and reporting of causal mediation analysis in 2015: a systematic review in epidemiological studies. *BMC research notes*, *9*(1), 354. https://doi.org/10.1186/s13104-016-2163-7

Lovasi, G. S., Schwartz-Soicher, O., Quinn, J. W., Berger, D. K., Neckerman, K. M., Jaslow, R., Lee, K. K., & Rundle, A. (2013). Neighborhood safety and green space as predictors of obesity among preschool children from low-income families in New York City. *Preventive Medicine*, *57*(3), 189-193. https://doi.org/https://doi.org/10.1016/j.ypmed.2013.05.012

Luengo Kanacri, B. P., Pastorelli, C., Eisenberg, N., Zuffianò, A., & Caprara, G. V. (2013). The Development of Prosociality from Adolescence to Early Adulthood: The Role of Effortful Control [https://doi.org/10.1111/jopy.12001]. *J Pers*, *81*(3), 302-312. https://doi.org/https://doi.org/10.1111/jopy.12001

MacDonald, K. (2018). Latent class analysis. London Stata Conference 2018,

Mackinnon, D. P. (2011). Integrating Mediators and Moderators in Research Design. *Research on social work practice*, *21*(6), 675-681. https://doi.org/10.1177/1049731511414148

MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation analysis. *Annual review of psychology*, *58*, 593-614. https://doi.org/10.1146/annurev.psych.58.110405.085542

Mäkinen, K., & Tyrväinen, L. (2008). Teenage experiences of public green spaces in suburban Helsinki. *Urban Forestry & Urban Greening*, *7*(4), 277-289. https://doi.org/https://doi.org/10.1016/j.ufug.2008.07.003

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A. M., de Vries, S., Triguero-Mas, M., Brauer, M., Nieuwenhuijsen, M. J., Lupp, G., Richardson, E. A., Astell-Burt, T., Dimitrova, D., Feng, X., Sadeh, M., Standl, M., Heinrich, J., & Fuertes, E. (2017). Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environ Res*, *158*, 301-317. https://doi.org/10.1016/j.envres.2017.06.028

Marmot, M. (2011). Social determinants and the health of Indigenous Australians. *The Medical Journal of Australia*, *194*(10), 512-513. https://doi.org/10.5694/j.1326-5377.2011.tb03086.x

Marselle, M. R., Irvine, K. N., Lorenzo-Arribas, A., & Warber, S. L. (2014). Moving beyond green: exploring the relationship of environment type and indicators of perceived environmental quality on emotional well-being following group walks. *Int J Environ Res Public Health*, *12*(1), 106-130. https://doi.org/10.3390/ijerph120100106

Martí-Vilar, M., Corell-García, L., & Merino-Soto, C. (2019). Systematic review of prosocial behavior measures. *Revista de Psicología*, *37*(1), 349-377. https://doi.org/https://psycnet.apa.org/doi/10.18800/psico.201901.012

Masten, C. L., Eisenberger, N. I., Pfeifer, J. H., Colich, N. L., & Dapretto, M. (2013). Associations among pubertal development, empathic ability, and neural responses while witnessing peer rejection in adolescence. *Child Development*, *84*(4), 1338-1354. https://doi.org/10.1111/cdev.12056

Mayfield, C. A., Child, S., Weaver, R. G., Zarrett, N., Beets, M. W., & Moore, J. B. (2017). Effectiveness of a Playground Intervention for Antisocial, Prosocial, and Physical Activity Behaviors. *Journal of School Health*, *87*(5), 338-345. https://doi.org/10.1111/josh.12506

McCormack, G. R., Rock, M., Toohey, A. M., & Hignell, D. (2010). Characteristics of urban parks associated with park use and physical activity: A review of qualitative research. *Health Place*, *16*(4), 712-726. https://doi.org/https://doi.org/10.1016/j.healthplace.2010.03.003

McCormick, R. (2017). Does Access to Green Space Impact the Mental Well-being of Children: A Systematic Review. *Journal of Pediatric Nursing*, *37*, 3-7. https://doi.org/https://doi.org/10.1016/j.pedn.2017.08.027

McCracken, D. S., Allen, D. A., & Gow, A. J. (2016). Associations between urban greenspace and health-related quality of life in children. *Preventive Medicine Reports*, *3*, 211-221. https://doi.org/https://doi.org/10.1016/j.pmedr.2016.01.013

McEachan, R. R. C., Prady, S. L., Smith, G., Fairley, L., Cabieses, B., Gidlow, C., Wright, J., Dadvand, P., van Gent, D., & Nieuwenhuijsen, M. J. (2016). The association between green space and depressive symptoms in pregnant women: moderating roles of socioeconomic status and physical activity. *Journal of Epidemiology and Community Health*, *70*(3), 253-259. https://doi.org/http://dx.doi.org/10.1136/jech-2015-205954

McEachan, R. R. C., Yang, T. C., Roberts, H., Pickett, K. E., Arseneau-Powell, D., Gidlow, C. J., Wright, J., & Nieuwenhuijsen, M. (2018). Availability, use of, and satisfaction with green space, and children's mental wellbeing at age 4 years in a multicultural, deprived, urban area: results from the Born in Bradford cohort study. *The Lancet Planetary Health*, *2*(6), e244-e254. https://doi.org/10.1016/s2542-5196(18)30119-0

McNamee, R. (2003). Confounding and confounders. *Occupational and Environmental Medicine*, *60*(3), 227-234. https://doi.org/10.1136/oem.60.3.227

Meleady, R., & Seger, C. R. (2016). Imagined contact encourages prosocial behavior towards outgroup members. *Group Processes & Intergroup Relations*, *20*(4), 447-464. https://doi.org/10.1177/1368430215612225

Mitchell, R., & Popham, F. (2008). Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet*, *372*(9650), 1655-1660. https://doi.org/10.1016/s0140-6736(08)61689-x

Mitchell, R., Richardson, E. A., Shortt, N. K., & Pearce, J. R. (2015). Neighborhood Environments and Socioeconomic Inequalities in Mental Well-Being. *American Journal of Preventive Medicine*, *49*(1), 80-84. https://doi.org/10.1016/j.amepre.2015.01.017

Moeijes, J., van Busschbach, J. T., Bosscher, R. J., & Twisk, J. W. R. (2018). Sports participation and psychosocial health: a longitudinal observational study in children. *BMC Public Health*, *18*(1), 702-702. https://doi.org/10.1186/s12889-018-5624-1

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The, P. G. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLOS Medicine*, *6*(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Moore, J. B., Yin, Z., Hanes, J., Duda, J., Gutin, B., & Barbeau, P. (2009). Measuring Enjoyment of Physical Activity in Children: Validation of the Physical Activity Enjoyment Scale. *Journal of Applied Sport Psychology*, *21*(S1), S116-S129. https://doi.org/10.1080/10413200802593612

Morrongiello, B. A., Zdzieborski, D., & Normand, J. (2010). Understanding gender differences in children's risk taking and injury: A comparison of mothers' and fathers' reactions to sons and daughters misbehaving in ways that lead to injury. *Journal of Applied Developmental Psychology*, *31*(4), 322-329. https://doi.org/https://doi.org/10.1016/j.appdev.2010.05.004

Morrow, V. (2006). *Conceptualising social capital in relation to children and young people: is it different for girls?* Routledge.

National Institutes of Health U.S. Department of Health & Human Services. (2019). *Study Quality Assessment Tools*. Retrieved 7 September from https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

National Research Council, & Institute of Medicine. (2004). Children’s Health: A New Conceptual Framework. In *Children's Health, The Nation's Wealth: Assessing and Improving Child Health*. National Academies Press (US). https://doi.org/10.17226/10886

Nichols, A. (2007). Causal Inference with Observational Data. *The Stata Journal*, *7*(4), 507-541. https://doi.org/10.1177/1536867X0800700403

Nicksic, N. E., Salahuddin, M., Butte, N. F., & Hoelscher, D. M. (2018). Associations Between Parent-Perceived Neighborhood Safety and Encouragement and Child Outdoor Physical Activity Among Low-Income Children. *Journal of Physical Activity and Health*, *15*(5), 317. https://doi.org/10.1123/jpah.2017-0224

Nicole, J. S.-M. (2004). Conceptualizing Social Capital among Young People: Towards a New Theory. *Children, Youth and Environments*, *14*(1), 153-172. www.jstor.org/stable/10.7721/chilyoutenvi.14.1.0153

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the Number of Classes in Latent Class Analysis and Growth Mixture Modeling: A Monte Carlo Simulation Study. *Structural Equation Modeling: A Multidisciplinary Journal*, *14*(4), 535-569. https://doi.org/10.1080/10705510701575396

Obsuth, I., Eisner, M. P., Malti, T., & Ribeaud, D. (2015). The developmental relation between aggressive behaviour and prosocial behaviour: A 5-year longitudinal study. *BMC psychology*, *3*(1), 16-16. https://doi.org/10.1186/s40359-015-0073-4

Odgers, C. L., Caspi, A., Bates, C. J., Sampson, R. J., & Moffitt, T. E. (2012). Systematic Social Observation of Children's Neighborhoods Using Google Street View: A Reliable and Cost-Effective Method. *Journal of Child Psychology and Psychiatry*, *53*(10), 1009-1017. https://doi.org/http://dx.doi.org/10.1111/j.1469-7610.2012.02565.x

Oerlemans, A. M., Rommelse, N. N. J., Buitelaar, J. K., & Hartman, C. A. (2018). Examining the intertwined development of prosocial skills and ASD symptoms in adolescence. *European child & adolescent psychiatry*, *27*(8), 1033-1046. https://doi.org/10.1007/s00787-018-1114-3

Ogundele, M. O. (2018). Behavioural and emotional disorders in childhood: A brief overview for paediatricians. *World journal of clinical pediatrics*, *7*(1), 9-26. https://doi.org/10.5409/wjcp.v7.i1.9

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, *19*(7), 305-343. https://doi.org/10.1080/10937404.2016.1196155

Oldfield, J., Humphrey, N., & Hebron, J. (2016). The role of parental and peer attachment relationships and school connectedness in predicting adolescent mental health outcomes. *Child and Adolescent Mental Health*, *21*(1), 21-29. https://doi.org/10.1111/camh.12108

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. https://doi.org/10.1371/journal.pone.0237725

Ou, L., Chen, J., Hillman, K., & Eastwood, J. (2010). The comparison of health status and health services utilisation between Indigenous and non-Indigenous infants in Australia. *Australian and New Zealand Journal of Public Health*, *34*(1), 50-56. https://doi.org/10.1111/j.1753-6405.2010.00473.x

Oviedo, L. (2016). Religious attitudes and prosocial behavior: a systematic review of published research. *Religion, Brain & Behavior*, *6*(2), 169-184. https://doi.org/10.1080/2153599X.2014.992803

Padilla-Walker, L. M., Carlo, G., & Nielson, M. G. (2015). Does Helping Keep Teens Protected? Longitudinal Bidirectional Relations Between Prosocial Behavior and Problem Behavior. *Child Development*, *86*(6), 1759-1772. https://doi.org/10.1111/cdev.12411

Park, S. A., Cho, M. K., Yoo, M. H., Kim, S. Y., Im, E. A., Song, J. E., Lee, J. C., & Jun, I. G. (2016). Horticultural Activity Program for Improving Emotional Intelligence, Prosocial Behavior, and Scientific Investigation Abilities and Attitudes in Kindergarteners [Article]. *HortTechnology*, *26*(6), 754-761. https://doi.org/10.21273/HORTTECH03489-16

Pastorelli, C., Lansford, J. E., Luengo Kanacri, B. P., Malone, P. S., Di Giunta, L., Bacchini, D., Bombi, A. S., Zelli, A., Miranda, M. C., Bornstein, M. H., Tapanya, S., Uribe Tirado, L. M., Alampay, L. P., Al-Hassan, S. M., Chang, L., Deater-Deckard, K., Dodge, K. A., Oburu, P., Skinner, A. T., & Sorbring, E. (2016). Positive parenting and children's prosocial behavior in eight countries. *Journal of Child Psychology and Psychiatry*, *57*(7), 824-834. https://doi.org/10.1111/jcpp.12477

Pate, R. R., Dowda, M., Brown, W. H., Mitchell, J., & Addy, C. (2013). Physical activity in preschool children with the transition to outdoors. *Journal of physical activity & health*, *10*(2), 170-175. https://doi.org/10.1123/jpah.10.2.170

Pavlova, M. K., & Silbereisen, R. K. (2015). Leisure Activities Choices among Adolescents. In J. D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences (Second Edition)* (pp. 830-837). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-08-097086-8.26003-0

Pawlowski, T., Schüttoff, U., Downward, P., & Lechner, M. (2016). Can Sport Really Help to Meet the Millennium Development Goals? Evidence From Children in Peru. *Journal of Sports Economics*, *19*(4), 498-521. https://doi.org/10.1177/1527002516661601

Pettygrove, D. M., Hammond, S. I., Karahuta, E. L., Waugh, W. E., & Brownell, C. A. (2013). From cleaning up to helping out: parental socialization and children's early prosocial behavior. *Infant Behavior and Development*, *36*(4), 843-846. https://doi.org/10.1016/j.infbeh.2013.09.005

Piliavin, J. (2001). Altruism and Prosocial Behavior, Sociology of. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences* (1 ed., pp. 411-415). Elsevier Science Ltd. https://doi.org/10.1016/B0-08-043076-7/01826-X

Piotrowski, J. T., Vossen, H. G. M., & Valkenburg, P. M. (2015). Media and Child Development. In J. D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences (Second Edition)* (pp. 1-10). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-08-097086-8.92145-7

Plenty, S., Östberg, V., & Modin, B. (2015). The role of psychosocial school conditions in adolescent prosocial behaviour. *School Psychology International*, *36*(3), 283-300. https://doi.org/10.1177/0143034315573350

Pope, D., Tisdall, R., Middleton, J., Verma, A., van Ameijden, E., Birt, C., Macherianakis, A., & Bruce, N. G. (2015). Quality of and access to green space in relation to psychological distress: results from a population-based cross-sectional study as part of the EURO-URHIS 2 project. *European Journal of Public Health*, *28*(1), 35-38. https://doi.org/10.1093/eurpub/ckv094

Porcu, M., & Giambona, F. (2016). Introduction to Latent Class Analysis With Applications. *The Journal of Early Adolescence*, *37*(1), 129-158. https://doi.org/10.1177/0272431616648452

Proctor, C., & Linley, P. A. (2014). Life satisfaction in youth. In *Increasing psychological well-being in clinical and educational settings: Interventions and cultural contexts.* (pp. 199-215). Springer Science + Business Media. https://doi.org/10.1007/978-94-017-8669-0_13

Prot, S., Gentile, D. A., Anderson, C. A., Suzuki, K., Swing, E., Lim, K. M., Horiuchi, Y., Jelic, M., Krahé, B., Liuqing, W., Liau, A. K., Khoo, A., Petrescu, P. D., Sakamoto, A., Tajima, S., Toma, R. A., Warburton, W., Zhang, X., & Lam, B. C. P. (2014). Long-Term Relations Among Prosocial-Media Use, Empathy, and Prosocial Behavior. *Psychological Science*, *25*(2), 358-368. https://doi.org/10.1177/0956797613503854

Pursell, G. R., Laursen, B., Rubin, K. H., Booth-Laforce, C., & Rose-Krasnor, L. (2008). Gender Differences in Patterns of Association Between Prosocial Behavior, Personality, and Externalizing Problems. *Journal of Research in Personality*, *42*(2), 472-481. https://doi.org/10.1016/j.jrp.2007.06.003

Putra, I. G. N. E., Astell-Burt, T., Cliff, D. P., Vella, S. A., & Feng, X. (2021a). Association between caregiver perceived green space quality and the development of prosocial behaviour from childhood to adolescence: Latent class trajectory and multilevel longitudinal analyses of Australian children over 10 years. *Journal of Environmental Psychology*, *74*, Article 101579. https://doi.org/https://doi.org/10.1016/j.jenvp.2021.101579

Putra, I. G. N. E., Astell-Burt, T., Cliff, D. P., Vella, S. A., & Feng, X. (2021b). Association between green space quality and prosocial behaviour: A 10-year multilevel longitudinal analysis of Australian children. *Environ Res*, *196*, Article 110334. https://doi.org/https://doi.org/10.1016/j.envres.2020.110334

Putra, I. G. N. E., Astell-Burt, T., Cliff, D. P., Vella, S. A., & Feng, X. (2021c). Do physical activity, social interaction, and mental health mediate the association between green space quality and child prosocial behaviour? *Urban Forestry & Urban Greening*, *64*, Article 127264. https://doi.org/https://doi.org/10.1016/j.ufug.2021.127264

Putra, I. G. N. E., Astell-Burt, T., Cliff, D. P., Vella, S. A., John, E. E., & Feng, X. (2020). The relationship between green space and prosocial behaviour among children and adolescents: A systematic review. *Frontiers in psychology*, *11*, Article 859. https://doi.org/10.3389/fpsyg.2020.00859

Qureshi, F., Koenen, K. C., Tiemeier, H., Williams, M. A., Misra, S., & Kubzansky, L. D. (2019). Childhood assets and cardiometabolic health in adolescence. *Pediatrics*, *143*(3), e20182004. https://doi.org/https://doi.org/10.1542/peds.2018-2004

Rabaglietti, E., Vacirca, M. F., & Pakalniskiene, W. (2013). Social-emotional competence and friendships: prosocial behaviour and lack of behavioural self-regulation as predictors of quantity and quality of friendships in middle childhood. *European Journal of Child Development, Education and Psychopathology*, *1*(5-20). https://formacionasunivep.com/ejpad/index.php/journal/article/download/4/4

Rasbash, J., Stelle, F., Browne, W. J., & Goldstein, H. (2017). *A User's Guide to MLwiN: Version 3.01*. Centre for Multilevel Modelling, University of Bristol.

Rebholz, C. E., Chinapaw, M. J. M., van Stralen, M. M., Bere, E., Bringolf, B., De Bourdeaudhuij, I., Jan, N., Kovacs, E., Maes, L., Manios, Y., Moreno, L., Singh, A. S., Brug, J., & te Velde, S. J. (2014). Agreement between parent and child report on parental practices regarding dietary, physical activity and sedentary behaviours: the ENERGY cross-sectional survey. *BMC Public Health*, *14*(1), 918. https://doi.org/10.1186/1471-2458-14-918

Reimers, A. K., Schoeppe, S., Demetriou, Y., & Knapp, G. (2018). Physical Activity and Outdoor Play of Children in Public Playgrounds-Do Gender and Social Environment Matter? *Int J Environ Res Public Health*, *15*(7), 1356. https://doi.org/10.3390/ijerph15071356

Reinfjell, T., Hjemdal, O., Aune, T., Vikan, A., & Diseth, T. H. (2008). The Pediatric Quality of Life Inventory (PedsQL) 4.0 as an assessment measure for depressive symptoms: a correlational study with young adolescents. *Nord J Psychiatry*, *62*(4), 279-286. https://doi.org/10.1080/08039480801983950

Reise, S. P., & Duan, N. (1999). Multilevel Modeling and its Application in Counseling Psychology Research. *The Counseling Psychologist*, *27*(4), 528-551. https://doi.org/10.1177/0011000099274003

Ren, Y., Yao, X., Liu, Y., Liu, S., Li, X., Huang, Q., Liu, F., Li, N., Lu, Y., Yuan, Z., Li, S., & Xiang, H. (2019). Outdoor air pollution pregnancy exposures are associated with behavioral problems in China's preschoolers. *Environmental Science and Pollution Research*, *26*(3), 2397-2408. https://doi.org/10.1007/s11356-018-3715-2

Reuben, A., Rutherford, G. W., James, J., & Razani, N. (2020). Association of neighborhood parks with child health in the United States. *Preventive Medicine*, *141*, 106265. https://doi.org/https://doi.org/10.1016/j.ypmed.2020.106265

Richardson, E. A., Pearce, J., Shortt, N. K., & Mitchell, R. (2017). The role of public and private natural space in children's social, emotional and behavioural development in Scotland: A longitudinal study. *Environ Res*, *158*, 729-736. https://doi.org/https://doi.org/10.1016/j.envres.2017.07.038

Richiardi, L., Bellocco, R., & Zugna, D. (2013). Mediation analysis in epidemiology: methods, interpretation and bias. *International Journal of Epidemiology*, *42*(5), 1511-1519. https://doi.org/10.1093/ije/dyt127

Richman, C. L., Berry, C., Bittle, M., & Himan, K. (1988). Factors related to helping behavior in preschool-age children. *Journal of Applied Developmental Psychology*, *9*(2), 151-165. https://doi.org/https://doi.org/10.1016/0193-3973(88)90020-2

Rijnhart, J. J. M., Valente, M. J., MacKinnon, D. P., Twisk, J. W. R., & Heymans, M. W. (2021). The Use of Traditional and Causal Estimators for Mediation Models with a Binary Outcome and Exposure-Mediator Interaction. *Structural Equation Modeling: A Multidisciplinary Journal*, *28*(3), 345-355. https://doi.org/10.1080/10705511.2020.1811709

Roe, J., Aspinall, P. A., & Ward Thompson, C. (2016). Understanding Relationships between Health, Ethnicity, Place and the Role of Urban Green Space in Deprived Urban Communities. *Int J Environ Res Public Health*, *13*(7). https://doi.org/10.3390/ijerph13070681

Roemmich, J. N., Epstein, L. H., Raja, S., Yin, L., Robinson, J., & Winiewicz, D. (2006). Association of access to parks and recreational facilities with the physical activity of young children. *Preventive Medicine*, *43*(6), 437-441. https://doi.org/https://doi.org/10.1016/j.ypmed.2006.07.007

Roth-Hanania, R., Davidov, M., & Zahn-Waxler, C. (2011). Empathy development from 8 to 16 months: early signs of concern for others. *Infant Behavior and Development*, *34*(3), 447-458. https://doi.org/10.1016/j.infbeh.2011.04.007

Saeri, A. K., Cruwys, T., Barlow, F. K., Stronge, S., & Sibley, C. G. (2017). Social connectedness improves public mental health: Investigating bidirectional relationships in the New Zealand attitudes and values survey. *Australian & New Zealand Journal of Psychiatry*, *52*(4), 365-374. https://doi.org/10.1177/0004867417723990

Safra, L., Tecu, T., Lambert, S., Sheskin, M., Baumard, N., & Chevallier, C. (2016). Neighborhood Deprivation Negatively Impacts Children's Prosocial Behavior. *Frontiers in psychology*, *7*(1760). https://doi.org/10.3389/fpsyg.2016.01760

Sallis, J. F., Taylor, W. C., Dowda, M., Freedson, P. S., & Pate, R. R. (2002). Correlates of vigorous physical activity for children in grades 1 through 12: Comparing parent-reported and objectively measured physical activity. *Pediatric Exercise Science*, *14*, 30-44. https://doi.org/10.1123/pes.14.1.30

Salvy, S.-J., Roemmich, J. N., Bowker, J. C., Romero, N. D., Stadler, P. J., & Epstein, L. H. (2008). Effect of Peers and Friends on Youth Physical Activity and Motivation to be Physically Active. *Journal of Pediatric Psychology*, *34*(2), 217-225. https://doi.org/10.1093/jpepsy/jsn071

Sanders, R. A. (2013). Adolescent Psychosocial, Social, and Cognitive Development. *Pediatrics in Review*, *34*(8), 354. https://doi.org/10.1542/pir.34-8-354

Sanders, T. (2016). *Investigating Associations between Neighbourhood Green Space and Weight Status: A Longitudinal Study of Australian Children Aged 4 to 13 Years Old* Western Sydney University (Australia)]. https://researchdirect.westernsydney.edu.au/islandora/object/uws:38124

Sanders, T., Feng, X., Fahey, P. P., Lonsdale, C., & Astell-Burt, T. (2015). The influence of neighbourhood green space on children's physical activity and screen time: findings from the longitudinal study of Australian children. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 126. https://doi.org/10.1186/s12966-015-0288-z

Sawka, K. J., McCormack, G. R., Nettel-Aguirre, A., Hawe, P., & Doyle-Baker, P. K. (2013). Friendship networks and physical activity and sedentary behavior among youth: a systematized review. *International Journal of Behavioral Nutrition and Physical Activity*, *10*, 130. https://doi.org/10.1186/1479-5868-10-130

Schisterman, E. F., Cole, S. R., & Platt, R. W. (2009). Overadjustment bias and unnecessary adjustment in epidemiologic studies. *Epidemiology*, *20*(4), 488-495. https://doi.org/https://doi.org/10.1097/ede.0b013e3181a819a1

Schüle, S. A., Hilz, L. K., Dreger, S., & Bolte, G. (2019). Social Inequalities in Environmental Resources of Green and Blue Spaces: A Review of Evidence in the WHO European Region. *Int J Environ Res Public Health*, *16*(7), 1216. https://doi.org/https://doi.org/10.3390/ijerph16071216

Schwartz, A. J., Dodds, P. S., O'Neil-Dunne, J. P. M., Danforth, C. M., & Ricketts, T. H. (2019). Visitors to urban greenspace have higher sentiment and lower negativity on Twitter. *People and Nature*, *0*(0). https://doi.org/10.1002/pan3.10045

Schwartz, J., Bellinger, D., & Glass, T. (2011). Expanding the Scope of Environmental Risk Assessment to Better Include Differential Vulnerability and Susceptibility. *101*(S1), S88-S93. https://doi.org/10.2105/ajph.2011.300268

Sefcik, J. S., Kondo, M. C., Klusaritz, H., Sarantschin, E., Solomon, S., Roepke, A., South, E. C., & Jacoby, S. F. (2019). Perceptions of Nature and Access to Green Space in Four Urban Neighborhoods. *Int J Environ Res Public Health*, *16*(13), 2313. https://doi.org/10.3390/ijerph16132313

Silke, C., Brady, B., Boylan, C., & Dolan, P. (2018). Factors influencing the development of empathy and pro-social behaviour among adolescents: A systematic review. *Children and Youth Services Review*, *94*, 421-436. https://doi.org/https://doi.org/10.1016/j.childyouth.2018.07.027

Singer, D. G., Singer, J. L., D'Agnostino, H., & DeLong, R. (2009). Children's Pastimes and Play in Sixteen Nations: Is Free-Play Declining? *American journal of play*, *1*(3), 283-312. https://doi.org/https://www.journalofplay.org/sites/www.journalofplay.org/files/pdf-articles/1-3-article-childrens-pastimes-play-in-sixteen-nations.pdf

Sithole, F., & Veugelers, P. J. (2008). Parent and child reports of children's activity. *Health Reports*, *19*(3), 19-24. https://www150.statcan.gc.ca/n1/en/pub/82-003-x/2008003/article/10662-eng.pdf?st=zWcEwy8g

Skelly, A. C., Dettori, J. R., & Brodt, E. D. (2012). Assessing bias: the importance of considering confounding. *Evidence-based spine-care journal*, *3*(1), 9-12. https://doi.org/10.1055/s-0031-1298595

Smith, E. P., Witherspoon, D. P., Bhargava, S., & Bermudez, J. M. (2019). Cultural Values and Behavior among African American and European American Children [journal article]. *Journal of Child and Family Studies*, *28*(5), 1236-1249. https://doi.org/10.1007/s10826-019-01367-y

Sobko, T., Jia, Z., & Brown, G. (2018). Measuring connectedness to nature in preschool children in an urban setting and its relation to psychological functioning [Journal: Article]. *PloS one*, *13*(11). https://doi.org/10.1371/journal.pone.0207057

Soori, H., & Bhopal, R. S. (2002). Parental permission for children's independent outdoor activities: Implications for injury prevention. *European Journal of Public Health*, *12*(2), 104-109. https://doi.org/10.1093/eurpub/12.2.104

Stafford, M., & Marmot, M. (2003). Neighbourhood deprivation and health: does it affect us all equally? *International Journal of Epidemiology*, *32*(3), 357-366. https://doi.org/10.1093/ije/dyg084

Straatmann, V. S., Lai, E., Law, C., Whitehead, M., Strandberg-Larsen, K., & Taylor-Robinson, D. (2020). How do early-life adverse childhood experiences mediate the relationship between childhood socioeconomic conditions and adolescent health outcomes in the UK? *Journal of Epidemiology and Community Health*, *74*(11), 969-975. https://doi.org/10.1136/jech-2020-213817

Strife, S., & Downey, L. (2009). Childhood Development and Access to Nature: A New Direction for Environmental Inequality Research. *Organization & Environment*, *22*(1), 99-122. https://doi.org/10.1177/1086026609333340

Su, J. G., Jerrett, M., de Nazelle, A., & Wolch, J. (2011). Does exposure to air pollution in urban parks have socioeconomic, racial or ethnic gradients? *Environ Res*, *111*(3), 319-328. https://doi.org/https://doi.org/10.1016/j.envres.2011.01.002

Subramanian, S., Jones, K., & Duncan, C. (2003). *Multilevel methods for public health research*. Neighborhoods and health. New York: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195138382.003.0004

Swit, C. (2012). Relational aggression and prosocial behaviours in Australian preschool children. *Australasian Journal of Early Childhood*, *37*(3), 30-34. https://doi.org/https://doi.org/10.1177%2F183693911203700305

Taylor, L., & Hochuli, D. F. (2017). Defining greenspace: Multiple uses across multiple disciplines. *Landscape and Urban Planning*, *158*, 25-38. https://doi.org/https://doi.org/10.1016/j.landurbplan.2016.09.024

Theunissen, M. H., Vogels, A. G., de Wolff, M. S., Crone, M. R., & Reijneveld, S. A. (2015). Comparing three short questionnaires to detect psychosocial problems among 3 to 4-year olds. *BMC Pediatr*, *15*, 84. https://doi.org/10.1186/s12887-015-0391-y

Timperio, A., Giles-Corti, B., Crawford, D., Andrianopoulos, N., Ball, K., Salmon, J., & Hume, C. (2008). Features of public open spaces and physical activity among children: findings from the CLAN study. *Preventive Medicine*, *47*(5), 514-518. https://doi.org/10.1016/j.ypmed.2008.07.015

Tischer, C., Gascon, M., Fernández-Somoano, A., Tardón, A., Lertxundi Materola, A., Ibarluzea, J., Ferrero, A., Estarlich, M., Cirach, M., Vrijheid, M., Fuertes, E., Dalmau-Bueno, A., Nieuwenhuijsen, M. J., Antó, J. M., Sunyer, J., & Dadvand, P. (2017). Urban green and grey space in relation to respiratory health in children. *European Respiratory Journal*, *49*(6), 1502112. https://doi.org/10.1183/13993003.02112-2015

Tom, A., Bosker, T. A. S. R. J., & Bosker, R. J. (1999). *Multilevel analysis: an introduction to basic and advanced multilevel modeling*. Sage. https://au.sagepub.com/en-gb/oce/multilevel-analysis/book234191

Torkar, G., & Rejc, A. (2015). Children's Play and Physical Activity in Traditional and Forest (Natural) Playgrounds. *International Journal of Educational Methodology*, *3*(1), 25-30. https://doi.org/https://doi.org/10.12973/ijem.3.1.25

Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ Res*, *166*, 628-637. https://doi.org/10.1016/j.envres.2018.06.030

Ulrich, R. S. (1983). Aesthetic and Affective Response to Natural Environment. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the Natural Environment* (pp. 85-125). Springer US. https://doi.org/10.1007/978-1-4613-3539-9_4

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201-230. https://doi.org/https://doi.org/10.1016/S0272-4944(05)80184-7

Valente, M. J., Rijnhart, J. J. M., Smyth, H. L., Muniz, F. B., & MacKinnon, D. P. (2020). Causal Mediation Programs in R, Mplus, SAS, SPSS, and Stata. *Structural Equation Modeling: A Multidisciplinary Journal*, 1-10. https://doi.org/10.1080/10705511.2020.1777133

Valeri, L., & Vanderweele, T. J. (2013). Mediation analysis allowing for exposure-mediator interactions and causal interpretation: theoretical assumptions and implementation with SAS and SPSS macros. *Psychological Methods*, *18*(2), 137-150. https://doi.org/10.1037/a0031034

Van Aart, C. J. C., Michels, N., Sioen, I., De Decker, A., Bijnens, E. M., Janssen, B. G., De Henauw, S., & Nawrot, T. S. (2018). Residential landscape as a predictor of psychosocial stress in the life course from childhood to adolescence. *Environment International*, *120*, 456-463. https://doi.org/https://doi.org/10.1016/j.envint.2018.08.028

van den Berg, M., Wendel-Vos, W., van Poppel, M., Kemper, H., van Mechelen, W., & Maas, J. (2015). Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. *Urban Forestry & Urban Greening*, *14*(4), 806-816. https://doi.org/https://doi.org/10.1016/j.ufug.2015.07.008

Van Der Leeden, R. (1998). Multilevel analysis of repeated measures data. *Quality and Quantity*, *32*(1), 15-29.

van der Waerden, J., Galéra, C., Larroque, B., Saurel-Cubizolles, M.-J., Sutter-Dallay, A.-L., & Melchior, M. (2015). Maternal Depression Trajectories and Children's Behavior at Age 5 Years. *The Journal of Pediatrics*, *166*(6), 1440-1448.e1441. https://doi.org/10.1016/j.jpeds.2015.03.002

van Dijk-Wesselius, J. E., Maas, J., Hovinga, D., van Vugt, M., & van den Berg, A. E. (2018). The impact of greening schoolyards on the appreciation, and physical, cognitive and social-emotional well-being of schoolchildren: A prospective intervention study. *Landscape and Urban Planning*, *180*, 15-26. https://doi.org/https://doi.org/10.1016/j.landurbplan.2018.08.003

van Dillen, S. M. E., de Vries, S., Groenewegen, P. P., & Spreeuwenberg, P. (2012). Greenspace in urban neighbourhoods and residents' health: adding quality to quantity. *Journal of Epidemiology and Community Health*, *66*(6), e8-e8. https://doi.org/10.1136/jech.2009.104695

Van Roy, B., Groholt, B., Heyerdahl, S., & Clench-Aas, J. (2010). Understanding discrepancies in parent-child reporting of emotional and behavioural problems:

Effects of relational and socio-demographic factors. *BMC Psychiatry*, *10*(1), 56. https://doi.org/10.1186/1471-244X-10-56

Vanaken, G. J., & Danckaerts, M. (2018). Impact of Green Space Exposure on Children's and Adolescents' Mental Health: A Systematic Review. *Int J Environ Res Public Health*, *15*(12). https://doi.org/10.3390/ijerph15122668

VanderWeele, T. J., & Robins, J. M. (2007). Four Types of Effect Modification: A Classification Based on Directed Acyclic Graphs. *Epidemiology*, *18*(5), 561-568. http://www.jstor.org/stable/20486427

Vargas-Hernández, J. G., Pallagst, K., & Zdunek-Wielgołaska, J. (2018). Urban Green Spaces as a Component of an Ecosystem. In J. Marques (Ed.), *Handbook of Engaged Sustainability* (pp. 885-916). Springer International Publishing. https://doi.org/10.1007/978-3-319-71312-0_49

Varni, J. W., Burwinkle, T. M., & Seid, M. (2006). The PedsQLTM 4.0 as a School Population Health Measure: Feasibility, Reliability, and Validity. *Quality of Life Research*, *15*(2), 203-215. https://doi.org/https://doi.org/10.1367/1539-4409(2003)003<0329:TPAAPP>2.0.CO;2

Varni, J. W., Burwinkle, T. M., Seid, M., & Skarr, D. (2003). The PedsQL™* 4.0 as a Pediatric Population Health Measure: Feasibility, Reliability, and Validity. *Ambulatory Pediatrics*, *3*(6), 329-341. https://doi.org/https://doi.org/10.1367/1539-4409(2003)003<0329:TPAAPP>2.0.CO;2

Varni, J. W., Seid, M., Knight, T. S., Uzark, K., & Szer, I. S. (2002). The PedsQLTM 4.0 Generic Core Scales: Sensitivity, Responsiveness, and Impact on Clinical Decision-Making. *J Behav Med*, *25*(2), 175-193. https://doi.org/10.1023/A:1014836921812

Vella, S. A., Gardner, L. A., Kemp, B., & Swann, C. (2018). Health-related quality of life as a longitudinal mediator of the relationship between participation in organised sports and adiposity among young people. *Preventive Medicine Reports*, *12*, 66-70. https://doi.org/https://doi.org/10.1016/j.pmedr.2018.07.006

Vella, S. A., Swann, C., Allen, M. S., Schweickle, M. J., & Magee, C. A. (2017). Bidirectional Associations between Sport Involvement and Mental Health in Adolescence. *Med Sci Sports Exerc*, *49*(4), 687-694. https://doi.org/10.1249/mss.0000000000001142

Villeneuve, P. J., Ysseldyk, R. L., Root, A., Ambrose, S., DiMuzio, J., Kumar, N., Shehata, M., Xi, M., Seed, E., Li, X., Shooshtari, M., & Rainham, D. (2018). Comparing the Normalized Difference Vegetation Index with the Google Street View Measure of Vegetation to Assess Associations between Greenness, Walkability, Recreational Physical Activity, and Health in Ottawa, Canada. *Int J Environ Res Public Health*, *15*(8). https://doi.org/10.3390/ijerph15081719

Voorhees, C. C., Murray, D., Welk, G., Birnbaum, A., Ribisl, K. M., Johnson, C. C., Pfeiffer, K. A., Saksvig, B., & Jobe, J. B. (2005). The role of peer social network factors and physical activity in adolescent girls. *Am J Health Behav*, *29*(2), 183-190. https://doi.org/https://doi.org/10.5993/AJHB.29.2.9

Walters, G. D. (2020). Positive Peers—The Neglected Stepchildren of Social Influence Theories of Crime. *J Abnorm Child Psychol*, *48*(5), 719-732. https://doi.org/10.1007/s10802-020-00630-x

Wang, P., Meng, Y.-Y., Lam, V., & Ponce, N. (2019). Green space and serious psychological distress among adults and teens: A population-based study in California. *Health Place*, *56*, 184-190. https://doi.org/https://doi.org/10.1016/j.healthplace.2019.02.002

Wang, Q., & Lan, Z. (2019). Park green spaces, public health and social inequalities: Understanding the interrelationships for policy implications. *Land Use Policy*, *83*, 66-74. https://doi.org/https://doi.org/10.1016/j.landusepol.2019.01.026

Warash, B. G., Root, A. E., & Devito Doris, M. (2017). Parents' perceptions of play: a comparative study of spousal perspectives. *Early Child Development and Care*, *187*(5-6), 958-966. https://doi.org/10.1080/03004430.2016.1237511

Ward, J. S., Duncan, J. S., Jarden, A., & Stewart, T. (2016). The impact of children's exposure to greenspace on physical activity, cognitive development, emotional wellbeing, and ability to appraise risk. *Health Place*, *40*, 44-50. https://doi.org/https://doi.org/10.1016/j.healthplace.2016.04.015

Weinstein, B. D., & Bearison, D. J. (1985). Social interaction, social observation, and cognitive development in young children. *European Journal of Social Psychology*, *15*(3), 333-343. https://doi.org/https://doi.org/10.1002/ejsp.2420150307

Wentzel, K. (2015). Prosocial Behaviour and Schooling. In R. Tremblay, M. Boivin, & R. Peters (Eds.), *Encyclopedia on Early Childhood Development*. http://www.child-encyclopedia.com/prosocial-behaviour/according-experts/prosocial-behaviour-and-schooling

Whitten, T., Stevens, R., Ructtinger, L., Tzoumakis, S., Green, M. J., Laurens, K. R., Holbrook, A., & Carr, V. J. (2018). Connection to the natural environment and well-being in middle childhood. *Ecopsychology*, *10*(4), 270-279. https://doi.org/10.1089/eco.2018.0010

WHO. (2005). *Child and adolescent mental health policies and plans*. World Health Organization. https://www.who.int/mental_health/policy/services/9_child%20ado_WEB_07.pdf?ua=1

WHO. (2012). *Urban green spaces*. Retrieved 7 July from https://www.who.int/sustainable-development/cities/health-risks/urban-green-space/en/

WHO Regional Office for Europe. (2016). *Urban green spaces and health: a review of evidence*. https://www.euro.who.int/__data/assets/pdf_file/0005/321971/Urban-green-spaces-and-health-review-evidence.pdf

WHO Regional Office for Europe. (2017). *Urban green spaces: a brief for action*. WHO Regional Office for Europe. https://www.euro.who.int/__data/assets/pdf_file/0010/342289/Urban-Green-Spaces_EN_WHO_web3.pdf

Williams, A., O'Driscoll, K., & Moore, C. (2014). The influence of empathic concern on prosocial behavior in children. *Frontiers in psychology*, *5*(425). https://doi.org/10.3389/fpsyg.2014.00425

Williams, J., Wake, M., Hesketh, K., Maher, E., & Waters, E. (2005). Health-Related Quality of Life of Overweight and Obese Children. *JAMA*, *293*(1), 70-76. https://doi.org/10.1001/jama.293.1.70

Williamson, A., Redman, S., Dadds, M., Daniels, J., D'Este, C., Raphael, B., Eades, S., & Skinner, T. (2010). Acceptability of an Emotional and Behavioural Screening Tool for Children in Aboriginal Community Controlled Health Services in Urban NSW. *Australian & New Zealand Journal of Psychiatry*, *44*(10), 894-900. https://doi.org/10.3109/00048674.2010.489505

Wilson, D. K., Kirtland, K. A., Ainsworth, B. E., & Addy, C. L. (2004). Socioeconomic status and perceptions of access and safety for physical activity. *Annals of Behavioral Medicine*, *28*(1), 20-28. https://doi.org/10.1207/s15324796abm2801_4

Wittek, R., & Bekkers, R. (2015). Altruism and Prosocial Behavior, Sociology of. In J. D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences (Second Edition)* (pp. 579-583). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-08-097086-8.32158-4

Wong, M., Olds, T., Gold, L., Lycett, K., Dumuid, D., Muller, J., Mensah, F. K., Burgner, D., Carlin, J. B., Edwards, B., Dwyer, T., Azzopardi, P., & Wake, M. (2017). Time-Use Patterns and Health-Related Quality of Life in Adolescents. *Pediatrics*, *140*(1), e20163656. https://doi.org/https://doi.org/10.1542/peds.2016-3656

Yang, Y., Li, W., Sheldon, K. M., & Kou, Y. (2019). Chinese adolescents with higher social dominance orientation are less prosocial and less happy: A value-environment fit analysis. *International Journal of Psychology*, *54*(3), 325-332. https://doi.org/10.1002/ijop.12474

Zach, A., Meyer, N., Hendrowarsito, L., Kolb, S., Bolte, G., Nennstiel-Ratzel, U., Stilianakis, N. I., & Herr, C. (2016). Association of sociodemographic and environmental factors with the mental health status among preschool children—Results from a cross-sectional study in Bavaria, Germany. *International Journal of Hygiene and Environmental Health*, *219*(4), 458-467. https://doi.org/https://doi.org/10.1016/j.ijheh.2016.04.012

Zahn-Waxler, C., Radke-Yarrow, M., Wagner, E., & Chapman, M. (1992). Development of concern for others. *Developmental Psychology*, *28*(1), 126-136. https://doi.org/10.1037/0012-1649.28.1.126

Zhang, J. W., Piff, P. K., Iyer, R., Koleva, S., & Keltner, D. (2014). An occasion for unselfing: Beautiful nature leads to prosociality. *Journal of Environmental Psychology*, *37*, 61-72. https://doi.org/https://doi.org/10.1016/j.jenvp.2013.11.008

Zhang, T., Solmon, M. A., Gao, Z., & Kosma, M. (2012). Promoting School Students' Physical Activity: A Social Ecological Perspective. *Journal of Applied Sport Psychology*, *24*(1), 92-105. https://doi.org/10.1080/10413200.2011.627083

Zhang, Y., Van den Berg, A. E., Van Dijk, T., & Weitkamp, G. (2017). Quality over Quantity: Contribution of Urban Green Space to Neighborhood Satisfaction. *Int J Environ Res Public Health*, *14*(5). https://doi.org/10.3390/ijerph14050535

Zhao, X., Lynch, J., xa, G, Chen, Q., John Deighton served as, e., & Gavan Fitzsimons served as associate editor for this, a. (2010). Reconsidering Baron and Kenny: Myths and Truths about Mediation Analysis. *Journal of Consumer Research*, *37*(2), 197-206. https://doi.org/10.1086/651257

Zimmerman, B. J., & Levy, G. D. (2000). Social cognitive predictors of prosocial behavior toward same and alternate race children among white pre-schoolers. *Current Psychology*, *19*(3), 175-193. https://doi.org/10.1007/s12144-000-1014-8

Appendix A. Ethics approval

11/28/2019 Mail - I Putra - Outlook

HREC Approval of Application 2019/433

irma-support@uow.edu.au

Thu 28/11/2019 13:04

To: Thomas Astell-Burt <thomasab@uow.edu.au>
Cc: Dylan Cliff <dylanc@uow.edu.au>; I Putra <ignep718@uowmail.edu.au>; Stewart Vella <stvella@uow.edu.au>; Thomas Astell-Burt <thomasab@uow.edu.au>; rso-ethics@uow.edu.au <rso-ethics@uow.edu.au>

Dear Professor Astell-Burt,

I am pleased to advise that the application detailed below has been **approved**.

Ethics Number:	2019/433
Approval Date:	26/11/2019
Expiry Date:	25/11/2020
Project Title:	Understanding the potential role of prosocial behaviour in mediating the relationship between green space quality and child health-related outcomes
Researcher/s:	Cliff Dylan; Putra I Gusti Ngurah Edi; Vella Stewart; Astell-Burt Thomas
Documents Approved:	• Ethics Application V1 05112019 • Ethics Training Certificate – Thomas Astell-Burt • Ethics Training Certificate – Dylan Cliff • Ethics Training Certificate – Stewart Vella • Ethics Training Certificate – I Gusti Ngurah Edi Putra

Sites:

Site	Principal Investigator for Site
Data Analysis - Australia	All Investigators

The HREC has reviewed the research proposal for compliance with the *National Statement on Ethical Conduct in Human Research* and approval of this project is conditional upon your continuing compliance with this document. Compliance is monitored through progress reports; the HREC may also undertake physical monitoring of research.

Approval is granted for a twelve month period; extension of this approval will be considered on receipt of a progress report **prior to the expiry date**. Extension of approval requires:

- The submission of an annual progress report and a final report on completion of your project.
- Approval by the HREC of any proposed changes to the protocol or investigators.
- Immediate report of serious or unexpected adverse effects on participants.

https://outlook.office.com/mail/inbox/id/AAQkADJjYWViNTImLTYxODAtNDQxZS04MmIxLWE1OTIlN2ZiN2Q5MAAQACLo41PItUHJuFFz6YWSI4... 1/2

- Immediate report of unforeseen events that might affect the continued acceptability of the project.

If you have any queries regarding the HREC review process or your ongoing approval please contact the Ethics Unit on 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely,

Susan Thomas

Dr Susan Thomas,
Chair, UOW & ISLHD Health and Medical Human Research Ethics Committee

The University of Wollongong and Illawarra and Shoalhaven Local Health District Health and Medical HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The processes used by this HREC to review multi-centre research proposals have been certified by the National Health and Medical Research Council.

Renewal Approval for Application 2019/433

rso-ethics@uow.edu.au <rso-ethics@uow.edu.au>
Wed 25/11/2020 14:27

To: Thomas Astell-Burt <thomasab@uow.edu.au>
Cc: Dylan Cliff <dylanc@uow.edu.au>; Stewart Vella <stvella@uow.edu.au>; Thomas Astell-Burt <thomasab@uow.edu.au>; I Putra <ignep718@uowmail.edu.au>; RSO Ethics <rso-ethics@uow.edu.au>

Dear Professor Astell-Burt,

Thank you for submitting the progress report. I am pleased to advise that renewal of the following Human Research Ethics application has been approved.

Please be aware that prior to conducting any part of this research face-to-face, the current UOW requirement is that all researchers must complete a COVID-19 Safe Work Plan and have the document signed off by an appropriate WHS signatory. This plan is a mandatory requirement and was introduced by University Management on 2 July. The COVID-19 Safe Work Plan document is accessible from the Intranet here https://intranet.uow.edu.au/coronavirus/returning-to-campus/index.html, and should be submitted to whs-admin@uow.edu.au. Please add your HREC reference number to the document. Once endorsed, WHS will forward the plan onto the Ethics Office for final approval.

Please note, as COVID-19 is an ever evolving health crisis, there may be times when it is necessary to cease face-to-face research activities again in the future. With this in mind, we ask that you regularly refer to the UOW COVID-19 webpage for up to date information regarding UOW research activities.

Ethics Number:	2019/433
Project Title:	Understanding the potential role of prosocial behaviour in mediating the relationship between green space quality and child health-related outcomes
Researchers:	Cliff Dylan; Vella Stewart; Astell-Burt Thomas; Putra I Gusti Ngurah Edi
Renewed From:	26/11/2020
New Project Expiry Date:	25/11/2021

Please note that approvals are granted for a twelve month period. Further extension will be considered on receipt of a progress report **prior to the expiry date**.

This certificate relates to the research protocol submitted in your original application and all approved amendments to date. Please remember that in addition to completing an annual report, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforeseen events that might affect continued ethical acceptability of the project

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. This progress report must be submitted by accessing the IRMA system prior to the expiry date.

Yours sincerely,

Susan Thomas

Dr Susan Thomas,
Chair, UOW & ISLHD Health and Medical Human Research Ethics Committee

The University of Wollongong and Illawarra and Shoalhaven Local Health District Health and Medical HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The processes used by this HREC to review multi-centre research proposals have been certified by the National Health and Medical Research Council.

HREC Approval of Amendment to Application 2019/433

rso-ethics@uow.edu.au <rso-ethics@uow.edu.au>
Thu 03/12/2020 08:20

To: Thomas Astell-Burt <thomasab@uow.edu.au>
Cc: Dylan Cliff <dylanc@uow.edu.au>; I Putra <ignep718@uowmail.edu.au>; Thomas Astell-Burt <thomasab@uow.edu.au>; Stewart Vella <stvella@uow.edu.au>; RSO Ethics <rso-ethics@uow.edu.au>

Dear Professor Astell-Burt,

I am pleased to advise that the amendment request submitted to the application detailed below has been **approved.**

Please be aware that prior to conducting any part of this research face-to-face, the current UOW requirement is that all researchers must complete a COVID-19 Safe Work Plan and have the document signed off by an appropriate WHS signatory. This plan is a mandatory requirement and was introduced by University Management on 2 July. The COVID-19 Safe Work Plan document is accessible from the Intranet here https://intranet.uow.edu.au/coronavirus/returning-to-campus/index.html, and should be submitted to whs-admin@uow.edu.au. Please add your HREC reference number to the document. Once endorsed, WHS will forward the plan onto the Ethics Office for final approval.

Please note, as COVID-19 is an ever evolving health crisis, there may be times when it is necessary to cease face-to-face research activities again in the future. With this in mind, we ask that you regularly refer to the UOW COVID-19 webpage for up to date information regarding UOW research activities.

Ethics Number:	2019/433
Amendment Approval Date:	01/12/2020
Expiry Date:	25/11/2021
Project Title:	Understanding the association between neighbourhood green space quality and child prosocial behaviour
Researchers:	Cliff Dylan; Putra I Gusti Ngurah Edi; Astell-Burt Thomas; Vella Stewart
Documents Approved:	• Revised Study Protocol (doc) rec. 23/11/2020
Amendments Approved:	• Project title change • Re-organised variables involved in analysis

The HREC has reviewed the research proposal for compliance with the *National Statement on Ethical Conduct in Human Research* and approval of this project is conditional upon your continuing compliance with this document. Compliance is monitored through progress reports; the HREC may also undertake physical monitoring of research.

Please remember that in addition to submitting proposed changes to the project to the HREC prior to implementing them the HREC requires:

- Immediate report of serious or unexpected adverse effects on participants.
- Immediate report of unforeseen events that might affect the continued acceptability of the project.
- The submission of an annual progress report and a final report on completion of your project.

If you have any queries regarding the HREC review process or your ongoing approval please contact the Ethics Unit on 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely,

Susan Thomas

Dr Susan Thomas,
Chair, UOW & ISLHD Health and Medical Human Research Ethics Committee

The University of Wollongong and Illawarra and Shoalhaven Local Health District Health and Medical HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The processes used by this HREC to review multi-centre research proposals have been certified by the National Health and Medical Research Council.

Appendix B. Approval to use the dataset

25/05/2020 Email - I Putra - Outlook

ADA Dataverse: You have been granted access to dataset: "Growing Up in Australia: Longitudinal Study of Australian Children (LSAC) Release 7.2 (Waves 1-7)>"

ada@anu.edu.au <ada@anu.edu.au>
Fri 20/12/2019 11:54
To: I Putra <ignep718@uowmail.edu.au>

Hello,

You recently applied for access to controlled access files in dataset: Growing Up in Australia: Longitudinal Study of Australian Children (LSAC) Release 7.2 (Waves 1-7). We are pleased to advise that your application for access has been approved.

Your obligations as an Authorised Data User are contained in the Terms and Conditions of Use.

You can now view and download files from the dataset at this link:
https://dataverse.ada.edu.au/dataset

(Please note that you will need to login to Dataverse to see your updated access, and to download controlled access files.)

If you have any queries in relation to the data please refer to the supporting documentation for Growing Up in Australia: Longitudinal Study of Australian Children (LSAC) Release 7.2 (Waves 1-7), or click on the email icon from anywhere in Dataverse to submit a query.

Thank you,
The Australian Data Archive
on behalf of the data owner(s): Department of Social Services (Australian Government); Australian Institute of Family Studies (Australian Government); Australian Bureau of Statistics (Australian Government).

https://outlook.office.com/mail/search/id/AAQkADJjYWViNTlmLTYxODAtNDQxZS04MmIxLWE1OTllN2ZiN2Q5MAAQAOUz55FUhvFEpcGTj2MS... 1/1

Appendix C. Published systematic review (1st study)

frontiers in Psychology

SYSTEMATIC REVIEW
published: 30 April 2020
doi: 10.3389/fpsyg.2020.00859

The Relationship Between Green Space and Prosocial Behaviour Among Children and Adolescents: A Systematic Review

I Gusti Ngurah Edi Putra[1], *Thomas Astell-Burt*[1,2,3,4]*, *Dylan P. Cliff*[5,6], *Stewart A. Vella*[6,7], *Eme Eseme John*[1] and *Xiaoqi Feng*[1,2,3,8]

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The plausible role of nearby green space in influencing prosocial behaviour among children and adolescents has been studied recently. However, no review has been conducted of the evidence testing the association between green space and prosocial behaviour. This systematic review addresses this gap among children and adolescents. Within this review, we propose a conceptual framework describing potential pathways linking green space to prosocial behaviour, discuss the direction, magnitude, moderators, and mediators of the association, and develop a narrative synthesis of future study directions. Out of 63 extracted associations from 15 studies, 44 were in the positive or expected direction, of which 18 were reported to be statistically significant ($p < 0.05$). Overall, the current evidence shows that exposure to green space may potentially increase prosocial behaviour among children and adolescents, with some contingencies (e.g., child's sex and ethnic background). However, the volume and quality of this evidence is not yet sufficient to draw conclusions on causality. Further, heterogeneity in the indicators of green space exposure could lead to mixed findings. In addition, none of the included studies investigated potential mediators. Nevertheless, this review provides preliminary evidence and a basis for further investigation with rigorous study methodology capable of drawing causal inferences and testing potential effect modifiers, linking pathways, and relevant green space measures.

Keywords: prosociality, altruism, nature, environment, green space quantity, green space quality, children, adolescents

INTRODUCTION

Prosocial behaviour is increasingly recognised as an important part of child development (Dunfield, 2014). It includes a range of behaviours that "benefit others or at very least promote harmonious relations with others" (Hay, 1994, p. 33). Prosociality among children is characterised by the presence of positive interactions, such as sharing, helping, cooperating, and comforting (Hay, 1994; Dunfield, 2014; Hammond et al., 2015; Piotrowski et al., 2015; Wittek and Bekkers, 2015). Prosocial behaviour emerges in early childhood and can progressively increase in variety, frequency, and complexity as children get older (Hay et al., 2004; Knafo et al., 2008; Brownell, 2013). In addition, newly established social networks (e.g., friendship) and the growth of socio-cognitive capabilities potentially lead to more opportunities for older children to behave prosocially (Hay and Cook, 2007; Abrams et al., 2015; Eisenberg et al., 2015). However, the evidence suggests that prosocial behaviour might decline in early- and middle-adolescence, but may start to rebound in late adolescence or early adulthood (Eisenberg et al., 2015).

A current body of literature highlights the importance of prosocial behaviour in positively contributing to aspects of youth development. Positive outcomes include greater academic success (Collie et al., 2018; Gerbino et al., 2018), social competence (Bar-Tal, 1982), and problem-solving skills (Carlo et al., 2012; Eisenberg et al., 2015). Prosocial behaviour is considered a psychosocial asset (Leventhal et al., 2015), that contributes to better quality peer relationships (Caputi et al., 2012), lower reported aggression (Swit, 2012; Obsuth et al., 2015), and favourable subjective well-being (Aknin et al., 2012, 2015; Proctor and Linley, 2014; Yang et al., 2019). Previous work also suggests that prosocial behaviour was associated with child health-related outcomes and behaviours including fewer externalising and internalising behavioural problems (Flynn et al., 2015; Flouri and Sarmadi, 2016), lower screen time (Healy and Garcia, 2019), and optimal cardiometabolic health (Qureshi et al., 2019). Given these potential benefits for positive health, psychological, and social aspects, promoting prosocial behaviour development beginning in early childhood is important.

The development of prosocial behaviours is jointly determined by factors that can be broadly described as personal and environmental characteristics (Piliavin, 2001). Genetic factors (Fortuna and Knafo, 2014; Israel et al., 2015; Knafo-Noam et al., 2015), gender (Abdi, 2010; Kok et al., 2018), personality traits or self-concepts (Cauley and Tyler, 1989; Gallitto and Leth-Steensen, 2019), and empathy (Garaigordobil, 2009; Williams et al., 2014) are the factors that contribute to prosocial behaviour differences between individuals. In addition, published literature has also suggested that cultural background and values are correlates of prosocial behaviour (Richman et al., 1988; Smith et al., 2019). Socio-environmental factors such as parental influences (parental nurturing, parent-child relationship, parental warmth, parental socialisation; Carlo et al., 2010; Pettygrove et al., 2013; Ferreira et al., 2016; Pastorelli et al., 2016) and peer influences (Fujisawa et al., 2008; Fabes et al., 2012; Lai et al., 2015; Lee et al., 2016; Oldfield et al., 2016; Silke et al., 2018) are important predictors for the development of prosocial skills among children and adolescents. Moreover, the exposures to prosocial content from media positively influence prosocial acts, whereas the use of violent media exhibits negative associations (Bar-on, 2000; Greitemeyer, 2011; Prot et al., 2014; de Leeuw et al., 2015). Aspects of the physical environment such as schools are also important to promote prosocial behaviour since schools enable social interactions among children and adolescents through organised cooperative learning activities in class, and through opportunities for play (Wentzel, 2015). The presence of other physical environments that facilitate social contacts and interactions such as green space in urban environments potentially serves as an additional space for children to develop and practice prosocial acts.

Green spaces are public areas that include natural vegetation components, such as grass, trees, and/or shrubs that people commonly utilise as gathering places for recreation, sport, relaxation, and other social activities (Dinnie et al., 2013; Dennis and James, 2016; Jennings and Bamkole, 2019). Those areas can be naturally created, such as forests, other landscapes with natural entities or human-made or built environments that contain natural vegetation, such as gardens and parks (Hartig et al., 2014; Taylor and Hochuli, 2017). While children in urban areas tend to spend less time in outdoor activities and have less social contact with other children (Singer et al., 2009), the presence of nearby green space might promote positive social interactions that lead to prosocial behaviour development. The plausible influence of urban green space on child prosocial acts is increasingly being studied in recent years (Amoly et al., 2014; Balseviciene et al., 2014; Richardson et al., 2017; McEachan et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019). However, no systematic review of these studies is available so far.

This systematic review aimed to evaluate the available literature on the association between urban green space and prosocial behaviour among children (0–12 years) and adolescents (13–18 years). These age ranges were selected based on a previous systematic review on prosocial behaviour among adolescents (Silke et al., 2018). Further, we propose a conceptual framework and provide discussion of the potential mechanisms linking green space and prosociality. In addition, a narrative synthesis of the existing published literature on green space and prosocial behaviour nexus is presented, followed by the discussion of our findings and future study directions.

POTENTIAL MECHANISMS LINKING GREEN SPACE AND PROSOCIAL BEHAVIOUR

Health benefits due to neighbourhood green space exposures in urban environments have been well-documented among children that include better mental health and well-being (Flouri et al., 2014; Feng and Astell-Burt, 2017c,d; McCormick, 2017; Vanaken and Danckaerts, 2018), more physically active and/or less screen time (Roemmich et al., 2006; Sanders et al., 2015; Akpinar, 2017), and reduced odds of respiratory health problems (Feng and Astell-Burt, 2017b; Tischer et al., 2017; Eldeirawi et al., 2019). Moreover, favourable health outcomes due to green space

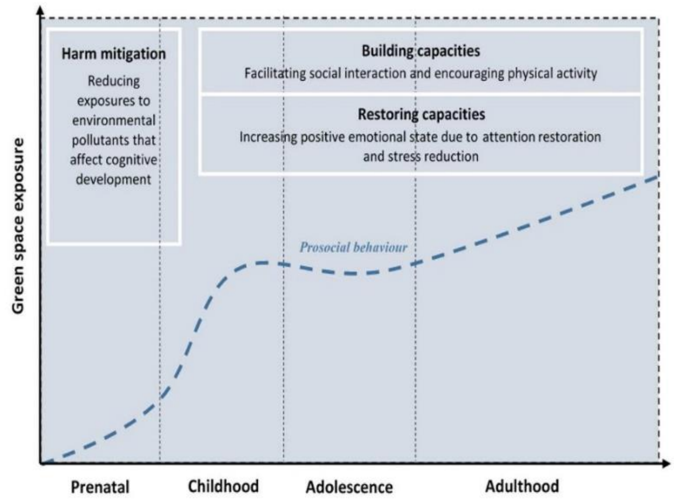

FIGURE 1 | Potential pathways linking green space to prosocial behaviour. Adapted from Markevych et al. (2017) and Ben-Shlomo et al. (2014).

exposure across the lifespan have been reported in some recent systematic reviews (Lee and Maheswaran, 2011; van den Berg et al., 2015; Kondo et al., 2018; Twohig-Bennett and Jones, 2018). However, the potential association between greenness and prosocial behaviour and its underlying mechanisms have not been widely reported.

Scholars in multidisciplinary fields suggested a conceptual model to help understand the mechanisms linking urban green space to health outcomes. Three domain pathways are proposed and these include (i) harm mitigation (e.g., reducing harmful environmental exposures—air pollution, noise, heat), (ii) restoring capacities (e.g., restorative effects, stress recovery), and (iii) building capacities (e.g., promoting physical activity, facilitating social cohesion; Markevych et al., 2017). Under the frame of this theoretical model, we elaborated potential mechanisms linking urban green space to prosocial behaviour. In addition, we also adopted the concept of life course epidemiology which suggests that exposures to physical or social factors during the life course might have long term effects on later disease risk or health outcomes (Kuh et al., 2003; Ben-Shlomo et al., 2014). Based on this concept, we identified potential critical and sensitive periods for the influence of green space on the development of prosocial behaviour. Our combined model is shown in **Figure 1** and discussed below.

Harm mitigation may be the first pathway linking green space to child prosocial behaviour. Exposures to environmental pollutants during vulnerable windows, such as prenatal or early postnatal periods might have adverse impacts on child cognitive development (Dadvand et al., 2015), which in turn, influences prosocial behaviour. Ren et al. (2019) conducted a cross-sectional study to examine the associations of prenatal exposure to outdoor air pollution on prosocial behaviour among China's preschoolers. Exposures to PM_{10} (particulate matter $<10\,\mu m$ in diameter) and $PM_{2.5}$ (particulate matter $<2.5\,\mu m$ in diameter) during the full gestation period were reported to be associated with increased odds of abnormal range of prosocial behaviour after controlling for child-related factors, maternal factors, and socio-economic status. Meanwhile, past work suggested that air-related pollution can be reduced by the presence of green space (Su et al., 2011; Dadvand et al., 2012a,b). Previous studies also found the association between urban greenness and cognitive development among children was partly explained by reduction in air-related pollution (Dadvand et al., 2015; Liao et al., 2019). Therefore, early and frequent exposures to nearby greenness can positively affect later prosocial behaviour by mitigating harmful environmental stressors during windows of susceptibility such as during the prenatal period. Furthermore, negative effects of prenatal exposure to air pollution on prosociality can be attenuated by factors driving cognitive development, such as learning activities and social interactions that can occur in other settings (e.g., schools; Weinstein and Bearison, 1985; Gustin et al., 2018).

Childhood could be one of the critical periods for the green space-prosociality association. Critical period refers to a specific time window in which exposure has effects on the development and subsequent outcome (Kuh et al., 2003). While prosocial behaviour can progressively increase with age during childhood, exposures to green space might help to elevate prosocial behaviour development through mechanisms of building and restoring capacities. Moreover, late childhood can be considered as the sensitive period for the association between green space and prosociality due to exposures to green space might have a greater effect than it would be at other childhood periods. Older children widen their friendships and develop socio-cognitive skills (Hay and Cook, 2007; Abrams et al., 2015; Eisenberg et al., 2015). They tend to have more social interactions and behave more prosocially than their younger counterparts and the presence of nearby green space might multiply these opportunities. According to the building capacities pathway, green space provides attractive places for children to foster social interactions and then facilitate prosocial behaviour development. This is supported by the social network theory which posits that repeated and frequent interaction among individuals brings opportunities for cooperation and helps to build trustworthiness, which in turn, stimulates individuals to perform prosocial behaviour toward others (Wittek and Bekkers, 2015). In addition, the intergroup contact hypothesis contends that time spent interacting with people from different backgrounds can promote positive intergroup attitudes and decrease prejudice (Allport et al., 1954; Davies et al., 2011). A study conducted by Meleady and Seger (2016) showed that imagining social interactions with outgroup members can encourage prosocial behaviour and the association is mediated by increased trust. Furthermore, some previous studies suggested that green space potentially facilitates social interactions among adults (Kazmierczak, 2013; Hong et al., 2018; Aram et al., 2019; Jennings and Bamkole, 2019). These studies indicate that green space can possibly influence prosocial behaviour through increased social interactions that align with the nature of prosociality which is developed and practised through frequent interaction (Oerlemans et al., 2018). Neighbourhood green space also can attract children to engage in outdoor physical activity with peers (Sanders et al., 2015; Ward et al., 2016), which in turn brings opportunities to foster prosocial behaviour (Di Bartolomeo and Papa, 2017).

Other theoretical perspectives help explain the possible roles of green space for restoring capacities in relation to prosocial behaviour. According to Ulrich's psycho-evolutionary theory (PET), natural environments are best suited for humans as places where we initially evolved and humankind's survival was reliant on nature before the agricultural revolution. Emotional responses upon natural environments are viewed as part of feeling connected to nature and as being "central to the psychological components of stress and restoration" (Ulrich et al., 1991, p. 207). PET is more commonly known as stress reduction theory (SRT) which suggests that contact with natural environments can reduce the levels of stress (Ulrich, 1983). Another complementary theory, attention restoration theory (ART) contends that taking time in natural environments reduces attention-demanding tasks and allows to restore attention thereby building more positive emotional and psychological responses (Kaplan, 1995; Ohly et al., 2016). Zhang et al. (2014) reported that positive emotions mediate the association between exposures to greenery perceived as beautiful and prosocial behaviour among adults. Positive emotional states due to exposures to nature can lead to greater prosocial tendencies by changing from an individual to collective mental frame (Schwartz et al., 2019). In addition, Goldy and Piff (2020) argued that contact with natural environment can increase attention to others and enhance prosocial behaviour through psychological processes of positive feelings that include feelings of awe and perception of beauty.

Building and restoring capacities might interact to link green space and prosocial behaviour among children and adolescents. For example, children who spend time in green space for having friendly talks and plays with friends may also experience attention restoration due to viewing natural vegetation. Frequent exposure to green space may be required to enable repeated and increased social interactions, as well as to build positive emotionality, that in turn facilitate prosocial behaviour development. Early and longer accumulation of exposure to green space may generate greater levels of benefit for prosocial behaviour, particularly in childhood as critical periods and late childhood as the sensitive period. However, the increase of prosocial behaviour associated with accumulated green space exposures in adolescence might not be as high as in childhood since the natural decline of prosociality is reported in this period (Eisenberg et al., 2015). Another possible scenario is that accumulated exposures are insufficient to lessen or moderate the intrinsically-caused decline in prosocial behaviour. Later, prosocial behaviour may start to rebound in early adulthood (Eisenberg et al., 2015) and the accumulation of exposure to green space may help to increase the levels of prosocial behaviour.

Having outlined a model by which green space may influence the development of prosocial behaviour across childhood and adolescence, the remainder of this paper is dedicated to a systematic review of existing literature to examine how the published evidence addresses the hypothesised direction and magnitude of association, potential mediators, moderators, and temporal nature.

METHODS

Search Strategy and Selection Criteria

This review was conducted following the guidelines from the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA; Moher et al., 2009). The literature search was carried out in 5–6 October 2019 using nine frequently used databases, including PubMED (US National Library of Medicine, Maryland, U.S.), Scopus, ScienceDirect (Elsevier, Amsterdam, Netherlands), Web of Science (Clarivate Analytics, Philadelphia, U.S.), PsycINFO, PsyschARTICLES (American Psychologist Association, Washington D.C., U.S.), CINAHL (EBSCO Publishing, Massachusetts, U.S.), Cochrane Library (John Wiley & Sons, New Jersey, U.S.), and ProQuest (ProQuest LLC, Michigan, U.S.). Guidance on the search terms selected was obtained from recently published systematic reviews on green space (Houlden et al., 2018; Vanaken and Danckaerts, 2018) and prosocial behaviour (Oviedo, 2016; Silke et al., 2018; Vilar et al., 2019). The terms as presented in **Table 1** were searched in the titles, abstracts, and/or keywords of the articles. In addition, references from eligible articles were also searched.

Eligibility Criteria

The inclusion criteria consisted of studies that; (1) were peer-reviewed research articles, (2) had quantitative observational or experimental design; (3) investigated association between green

TABLE 1 | Search terms and strategy used to search relevant literature.

Main keywords	Search terms
Green space	"green space" OR greenspace OR greenness OR greenery OR green OR "green area" OR landscape OR wilderness OR wild OR natur* OR park OR garden OR playground OR playspace OR "play space" OR "open space" OR recreation OR vegetation OR wood OR woodland OR tree OR plant OR grass OR forest OR shinrin-yoku
Prosocial behaviour	prosocial* OR pro-social* OR altruis*

*Truncation symbol used to enable search all possible variations of the word.

space as an exposure that includes objective and/or subjective measures (quantity, quality, or both) and prosocial behaviour as either an outcome or as a mediator of a health outcome; (4) were published in English; and (5) included participants ≤18 years of age. No restriction on publication date was applied. Published articles that only contained an abstract (e.g., conference proceedings) were excluded.

Prosocial behaviour among children and adolescents was the outcome of interest. In this review, prosociality was defined as a range of positive behaviours that include offering help, sharing, cooperating, and comforting. The outcome focuses on the behavioural aspect rather than cognitive or affective responses (e.g., kindness, love, etc.). Meanwhile, green space refers to naturally-created areas or built environments that bear natural vegetation. Green space exposure in this review considered all characteristics of green space in accordance with the keywords provided (presented in **Table 1**). Green space characteristics measured using land cover maps, remote sensing data, physical observation, and audits were categorised as objective measures, whilst green space exposure data collected through interviews and questionnaires were assigned as subjective measures (Houlden et al., 2018; Vanaken and Danckaerts, 2018). Green space measures can also be classified as assessing quantity which refers to amount of green space available locally within a particular administrative area (e.g., average greenness, percentage of green space), while quality of green space is evaluated by some aspects that influence the usability (e.g., cosiness, safety, amenities, facilities, attractiveness, etc.; McCormack et al., 2010; Marselle et al., 2014; Feng and Astell-Burt, 2017d, 2018). In addition, studies examining subjective connectedness to nature were also taken into account following a previous systematic review on green space (Houlden et al., 2018).

Selection Strategy and Data Collection

All articles retrieved using the search terms in the selected databases were downloaded into EndNote. Duplicate articles were removed either using the EndNote function or manually. Two reviewers (IP and EJ) independently assessed the title and abstract of the published articles using the same inclusion criteria, followed by the full-text assessment. Further, any discrepancies between the two reviewers were discussed and consulted with a third reviewer (TA). Information about publication details, study design, sample size, participant characteristics, exposure concept and measurement, measure instrument of prosocial behaviour, and the results were extracted into **Table 2**.

Data Analysis

Quality and risk of bias of the articles were assessed using the quality assessment tools developed by the National Institutes of Health (2019) for observational and experimental studies. Similar to the process of article screening and data extraction, two reviewers independently performed the quality assessment and any discrepancies were discussed with the third reviewer. The extracted data from all eligible articles were summarised along with study quality assessment outcomes, followed by the narrative synthesis of the evidence on direction, magnitude, effect modifiers, and mediators of the association. The findings were then discussed and future study directions were proposed.

RESULTS

Literature Search Results

Figure 2 presents the search results based on the PRISMA guidelines. Out of 15,267 articles retrieved from nine databases, 5,686 duplicates were removed. Screening based on title and abstract resulted in the selection of 35 articles for the full review. After the full-text assessment, 14 studies met the eligibility criteria. During this process, one paper (Carrus et al., 2015) was identified through references, resulting in a total of 15 papers for review.

Study Characteristics and Methods

Table 2 presents a summary for studies included in this review. All studies were from high-income countries. The majority were carried out in European countries (9; 60%), and followed by the US (3; 20%). Even though there was no restriction for publication date applied, all eligible studies were published between 2012–2019 and more than half (66.7%) were published in the last 3 years (2017–2019). There was an equal number (six studies) of cross-sectional (Odgers et al., 2012; Amoly et al., 2014; Balseviciene et al., 2014; Sobko et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019) and experimental studies (Carrus et al., 2015; Park et al., 2016; Mayfield et al., 2017; Bates et al., 2018; van Dijk-Wesselius et al., 2018; Dopko et al., 2019). The remaining studies were of a longitudinal design (Richardson et al., 2017; McEachan et al., 2018; Van Aart et al., 2018). The design of experimental studies varied with regards to the inclusion of a control group and measurement of the outcome before the intervention (pre-test). Out of two single group experimental studies, one study was a single group post-test only experiment (Bates et al., 2018), whereas another used a single group pre-post design (Park et al., 2016). The other four experimental studies reported using a control group, including two studies with—(Mayfield et al., 2017; van Dijk-Wesselius et al., 2018) and two without pre-test (Carrus et al., 2015; Dopko et al., 2019), respectively. Moreover, two (Richardson et al., 2017; McEachan et al., 2018), eight (Amoly et al., 2014; Balseviciene et al., 2014; Park et al., 2016; Mayfield et al., 2017; Van Aart et al., 2018; van Dijk-Wesselius et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019), and five (Odgers et al., 2012; Carrus et al., 2015; Bates et al., 2018; Sobko et al., 2018;

TABLE 2 | Summary of study characteristics and results.

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Arnoly et al. (2014), Spain	Cross-sectional study	2,111 (7–10 years)	a. Time spent playing in green spaces *(a total number of hours during the last school period and summer holidays)*; b. Residential surrounding greenness in buffers of 100, 250, and 500 m; c. School greenness in a buffer of 100 m; d. Home-school greenness *(average residential and school surrounding greenness in a buffer of 100 m, weighted by daily time spent at home and school)*; e. Residential proximity to a major green space *(a binary variable indicating whether the child's home within 300 m of a major green space)*.	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ *(a continuous variable)*.	Child's sex, school level, ethnicity, preterm birth, breastfeeding, exposure to environmental tobacco smoke, maternal smoking during pregnancy, responding person, parental educational achievement, parental employment status, and neighbourhood socioeconomic.	Quasi-Poisson mixed-effects models	No statistically significant association was found between all green space indicators and prosocial behaviour *(non-significant in expected direction)*.	Fair
Andrusaityte et al. (2019), Lithuania	Cross-sectional study.	1,489 (4–6 years)	a. Time spent in a city park *(hours per week)*; b. Residential surrounding greenness in buffers of 100 m.	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ *(a binary outcome: borderline/ abnormal vs. normal)*.	Child's sex, birth weight, wheeze, asthma, allergy, BMI, breastfeeding, siblings, paracetamol and antibiotic usage during the first year of life, maternal education, tobacco smoke, age at childbirth.	Logistic regression	Increased time spent in city parks per 1 h per week was associated with decreased odds of borderline/abnormal prosocial behaviour: aOR = 0.98 (0.96, 0.99) *(significant in expected direction)*. Non-significant association was found for residential surrounding greenness *(non-significant in expected direction)*.	Fair
Balseviciene et al. (2014), Lithuania	Cross-sectional study.	1,468 (4–6 years)	a. Residential surrounding greenness in a buffer of 300 m; b. Proximity to the nearest city parks *(transformed using the square root function in meters)*.	NDVI	Parent-reported prosocial scale from SDQ *(a continuous variable)*.	Child's age, sex, and parenting stress.	Linear regression	Analysis was stratified by mother's educational level. Increased distance to city parks was negatively associated with prosocial behaviour among lower education group: $\beta = -0.029$ ($p < 0.05$) *(significant in expected direction)*. Residential greenness was negatively associated with prosocial behaviour among higher education group: $\beta = -1.104$ ($p < 0.05$) *(significant in unexpected direction)*.	Fair

(Continued)

TABLE 2 | Continued

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Bates et al. (2018), USA	Experimental study (one-group post-test-only design)	3,345 and 3,710 observations at the first (T1) and second (T2) time, respectively (age ranges from pre-kindergarten to 8th grade)	Schoolyard renovation by increasing the presence of natural components (e.g., grass, trees) and also the quality (e.g., aesthetics; facilities).	In-person observation	Positive social interaction, measured by behavioural mapping using System for Observing Children's Activity and Relationship during Play (SOCARP). It was measured two times (T1, T2) after schoolyard renovation.	No confounders adjusted in the analysis	Chi-square test	The percentage of observed positive social interaction or prosocial behaviour increased from T1 (27.10%) to T2 (35.20%) ($p < 0.001$) *(significant in expected direction).*	Poor (no pretest, no randomisation)
Carrus et al. (2015), Italy	Experimental study (two-group post-test-only design)	39 (1.5–3 years)	Children's spending time in school green space vs. in internal space of school	In-person observation	Positive social interaction, measured by a behavioural checklist to record frequency of positive relational behaviours	No confounders adjusted in the analysis	ANOVA	After children were exposed to green space, more frequent positive relational behaviours were observed on days when children spent time in school green space compared to days when they did not ($p = 0.038$) *(significant in expected direction).*	Poor (no pretest, no randomisation)
Dopko et al. (2019), Canada	Experimental study (two-group post-test-only design)	80 (mean age = 10.49 years)	Children' spending time outdoors at the nature school vs. indoors at the museum	In-person observation	Using two tasks: a. A windfall task by asking children to imagine that they received money and what they decided on four available options (buy things they want, give to charity, spend on gifts for other people, and save for the future). Children who decided for charity and spending on gifts for other people represent higher prosociality. b. A tangram task by asking children to imagine that they assigned 11 tangrams from three categories: easy, medium, and hard to someone else in their class. Children who assigned more tangrams in easy and medium categories, and few in hard category represent higher prosociality.	No confounders adjusted in the analysis	Paired sample *t*-test	Windfall task: Mean score for spending money on charity was statistically higher among children visiting nature school than museum: $\beta = 3.66$ (0.06, 7.26) *(significant in expected direction).* Mean score for spending money on gift was lower among children visiting nature school than museum: $\beta = -4.15$ (-8.32, 0.03) *(non-significant in unexpected direction).* Tangram task: Mean score for assigning easy tangram was statistically higher among children visiting nature school than museum: $\beta = 0.74$ (0.01, 1.46) *(significant in expected direction).* Mean score for assigning hard tangram was statistically lower among children visiting nature school than museum: $\beta = -1.29$ (-2.15, -0.42) *(significant in expected direction).*	Poor (no pretest, no randomisation)

(Continued)

TABLE 2 | Continued

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Mayfield et al. (2017), USA	Experimental study (two-group pretest-post-test design)	Two elementary schools for each intervention and control groups. This study included 3,588 SOCARP scans representing 1,196 child recess days with 3 rotation conducted.	The intervention was carried out by improving the quality of playground through adding playground marking with colourful interactive games. In addition, intervention schools received equipment to use with the game and training sessions for teachers.	In-person observation	Positive social interaction, measured by behavioural mapping using System for Observing Children's Activity and Relationship during Play (SOCARP).	Scans nested within days nested with schools	Mixed-effects regression analysis	There was a non-significant decrease in prosocial behaviour in the verbal or physical manner before and after the intervention *(non-significant in unexpected direction)*.	Fair
McEachan et al. (2018), UK	Longitudinal study	2,594 (aged 0 at baseline, 4 years at follow up)	a. Satisfaction with green space *(asked among a sub-sample of 832 (32%) only)* b. Time spent playing outside *(minutes per week calculated for winter and summer months - asked among a sub-sample of 832 (32%) only)* c. Residential surrounding greenness in buffers of 100 m, 300 m, and 500 m	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ *(a continuous variable)*	Child's age, sex, maternal age, cohabitation status, maternal education, subjective poverty, household size, neighbourhood deprivation index, mother's smoking behaviour, and mother's treatment record of mental disorder	Linear regression	Analysis was stratified by ethnicity (white British vs. south Asian). Satisfaction with green space was significantly associated prosocial behaviour among south Asian children only: β = 0.20 (0.02, 0.38) *(significant in expected direction)*. Time spent playing outside was not associated with prosocial behaviour among both ethnicities *(non-significant in expected direction for south Asian children and non-significant in non-reported direction for white British children)*. Residential greenness in all buffer distances were not associated with prosocial behaviour among both ethnicities *(non-significant in expected direction)*.	Good
Odgers et al. (2012), UK	Cross-sectional study	2,024 (12 years)	Percentage of green space in a buffer of 0.5 mile *(measured only among a sub-sample of 200 neighbourhoods)*	A systematic social observation using Google Street view	A combined parent and teacher's reports of Revised Rutter Parent Scale for School-Age Children *(a continuous variable)*	No confounders adjusted in the analysis	Linear regression	No association was observed between percentage of green space and prosocial behaviour *(non-significant in unexpected direction)*.	Poor (no control for confounders)

(Continued)

TABLE 2 | Continued

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Park et al. (2016), South Korea	Experimental study (one-group pretest-post-test design)	336 (5–7 years)	Participation in 24-session horticultural activity program that included indoor and outdoor activities, such as transplanting, planting seeds, making and applying eco-friendly fertilizer, observing vegetable plants, harvesting, etc.	In-person observation	Teacher-reported of prosocial behaviour using the revised questionnaire with four subscales (helping, sharing, cooperation, kindness) *(a continuous variable)*	No confounders adjusted in the analysis	Paired sample *t*-test	All prosocial behaviour scales (helping, sharing, cooperation, kindness) increased from pretest to post-test *(significant in expected direction)*.	Fair
Richardson et al. (2017), UK	Longitudinal study	2,909 (aged 4 years at baseline, 6 years at follow-up)	a. Percentage of park space in a buffer of 500 m b. Percentage of total natural space in a buffer of 500 m c. Garden access *(indicating whether the child had access to a private garden)*	Land cover map; Questionnaire	Parent-reported prosocial scale from SDQ *(a continuous variable)*	Child's age, sex, screen time, household income, educational attainment, carer's mental health, and neighbourhood socio-economic status	Linear regression	Analysis was stratified by the child's sex and household educational level. Percentage of total natural space was significantly associated with prosocial behaviour among girls: $\beta = 0.14$ ($p < 0.01$) and among high education households: $\beta = 0.12$ ($p < 0.05$) *(significant in expected direction)*. Percentage of parks was not significantly associated with prosocial behaviour among all sub-sample groups *(non-significant in expected direction)*. Access to private garden was not significantly associated with prosocial behaviour among all sub-sample groups *(non-significant in unexpected direction)*.	Good
Sobko et al. (2018), Hong Kong	Cross-sectional study	299 (2–5 years)	Connectedness to nature (enjoyment of, empathy for, responsibility toward, and awareness of nature)	Questionnaire	Parent-reported prosocial scale from SDQ *(a continuous variable)*	No confounders adjusted in the analysis	Structural equation modelling	Greater responsibility toward nature was significantly associated with improved prosocial behaviour: $\beta = 0.77$ *(significant in expected direction)*.	Poor (no control for confounders)
Van Aart et al. (2018), Belgium	Longitudinal study	172 (6–12 years at baseline, 9–15 years at follow-up)	a. Percentage of semi-natural and forested area in a buffer of 2,000 m b. Percentage of agricultural area in a buffer of 300 m	Land cover map	Parent-reported prosocial scale from SDQ *(a continuous variable)*	Child's age, sex, and parental socio-economic status	Linear regression	Percentage semi-natural and forested area was not associated with prosocial behaviour *(non-significant in unexpected direction)*. Percentage of agricultural area was not associated with prosocial behaviour *(non-significant in expected direction)*.	Fair

(Continued)

TABLE 2 | Continued

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
van Dijk-Wesselius et al. (2018), Netherlands	Experimental study (two-group pretest-post-test design)	About 700 (7–11 years)	The intervention was carried out by increasing the presence of natural components (e.g., grass, trees) and also the quality of schoolyards (e.g., aesthetics; facilities).	In-person observation	a. Prosocial orientation assessed by self-administrated Social Orientation Choice Card (SOCC) *(a binary variable)* b. Self-reported prosocial scale from SDQ *(a continuous variable)*	Child's sex, grade level	Multi-level analysis	Analysis was stratified by grade levels (4, 5, and 6). Proportion of prosocial orientation in grades 4 and 5 in intervention compared to control group increased from baseline to the follow-up, but there was a significant decrease in grade 6 *(significant in expected and unexpected directions)*. There was no significant increase of self-reported prosocial behaviour *(non-significant in non-reported direction)*.	Fair
Whitten et al. (2018), Australia	Cross-sectional study	26,848 (mean age = 11.92 years)	Connectedness to nature	Questionnaire (self-report)	Self-reported prosocial scale from SDQ *(a continuous variable)*	Child's sex, social supports, empathy, attention, and neighbourhood socio-economic status	Linear regression	Increased connection to the nature was associated with higher prosocial behaviour: $\beta = 0.12$ ($p < 0.001$) *(significant in expected direction)*.	Fair

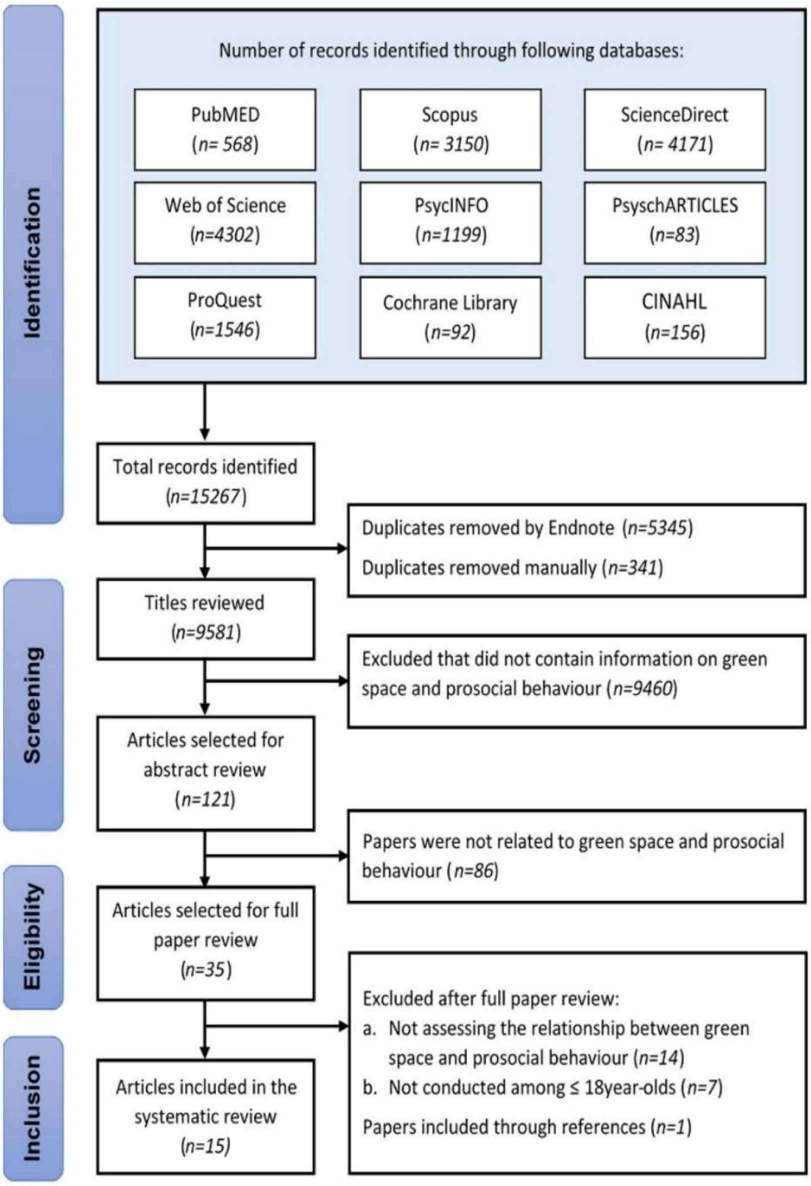

FIGURE 2 | Study selection process based on PRISMA guidelines.

Dopko et al., 2019) studies included in this review were judged to be of good, fair, and poor quality, respectively.

Sample size and age of participants differed by included study. Small sample sizes (<100) were reported in two experimental studies (Carrus et al., 2015; Dopko et al., 2019), whilst the largest sample size was observed in a cross-sectional study of 26,848 Australian children aged 11.9 years on average (Whitten et al., 2018). Two experimental studies recorded the number of person-observations as the unit of analysis instead of number of participants (Mayfield et al., 2017; Bates et al., 2018). Furthermore, age of participants differed across studies. One of the longitudinal studies collected the baseline data of exposure during pregnancy and then did the follow-up measurement of prosocial behaviour when children were aged 4 years old (McEachan et al., 2018). In cross-sectional studies, the age of participants ranged from 2 to 12 years-old (Odgers et al., 2012; Amoly et al., 2014; Balseviciene et al., 2014; Sobko et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019). Two experimental studies did not explicitly mention the age of participants (Mayfield et al., 2017; Bates et al., 2018). The youngest participants in experimental studies were aged 1.5 years, while 8th-grade students (aged 13–14 years depending on the country) were the oldest participant.

Green Space Measures

Green space measurements varied by study. Secondary data linked with objective measurements of area-level green space were used in seven observational studies mostly reported from European countries (Odgers et al., 2012; Amoly et al., 2014; Balseviciene et al., 2014; Richardson et al., 2017; McEachan et al., 2018; Van Aart et al., 2018; Andrusaityte et al., 2019). Green space quantity, such as residential nearby greenness, as well as the percentage of green space or other related characteristics (e.g., park space, semi-natural and forested, agricultural area) within specified distances from participants' homes were commonly used objective measurements of green space exposure. Only one study reported measuring school and combined home-school greenness in relation to prosocial behaviour (Amoly et al., 2014). In addition, residential proximity (e.g., distance to major or nearby green space) was assessed by two studies (Amoly et al., 2014; Balseviciene et al., 2014). Normalised Difference Vegetation Index (NDVI) was predominantly utilised (Amoly et al., 2014; Balseviciene et al., 2014; McEachan et al., 2018; Andrusaityte et al., 2019), followed by land cover map (Richardson et al., 2017; Van Aart et al., 2018), and Google Street View (Odgers et al., 2012).

Some studies (Amoly et al., 2014; Richardson et al., 2017; McEachan et al., 2018; Sobko et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019) also introduced subjective measures of green space and mostly relied on questionnaire-based parental-led approach. The indicator of children's time spent in green space was reported by three studies in Europe (Amoly et al., 2014; McEachan et al., 2018; Andrusaityte et al., 2019). Other studies from the UK also measured access to private gardens (Richardson et al., 2017) and satisfaction with green space (McEachan et al., 2018). Only two studies measured the contacts of green space as a perception of connectedness to nature, of which one measured connection to nature in general (Whitten et al., 2018) and the other (Sobko et al., 2018) employed multiple indicators (enjoyment of, empathy for, responsibility of, and awareness of nature).

For six experimental studies, exposure to green space was observed directly among participants. There were two main concepts of intervention model for green space exposures exhibited that included: (1) improving the appearance of frequently accessed green space by children and adolescents (e.g., schoolyards; playground markings) and (2) spending time in green space or participating in activities involving contacts with natural vegetation (e.g., horticultural programs). Improvements in the quality of schoolyards by increasing the presence of natural components and other facilities was evaluated in studies in the US (Bates et al., 2018) and the Netherlands (van Dijk-Wesselius et al., 2018), while another study in the US measured the change of prosocial behaviour due to improved playgrounds in schools (Mayfield et al., 2017). Moreover, studies in Italy (Carrus et al., 2015) and Canada (Dopko et al., 2019) compared differences in prosocial behaviour between children spending time outdoors in school green space compared to indoors within or outside a school setting. A study in South Korea observed change in prosocial behaviour after children participated in a horticultural program that facilitated contact with natural vegetation (Park et al., 2016).

Prosocial Behaviour Measures

Even though tools for assessing prosocial behaviour varied by study, the data were mostly documented based on parental report (7; 47%). However, measurements based on teacher-reports (1; 7%), combined parent- and teacher-report (1; 7%), and self-report (2; 13%) were also observed. In addition, prosociality was assessed through in-person observations in four experimental studies (27%). The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), which is a common tool for assessing prosocial behaviour, was employed in the majority of studies (9; 60%). This prosocial scale consists of five Likert-scale questions with a higher total score indicating more favourable prosocial behaviour. Only one study categorised a prosocial behaviour score into a binary variable using a validated cut-off point (normal with score >5; abnormal/borderline with score ≤ 5) (Andrusaityte et al., 2019). Meanwhile, experimental studies used different measures, such as the System for Observing Children's Activity and Relationship during Play (SOCARP; Mayfield et al., 2017; Bates et al., 2018), a behavioural checklist (Crust et al., 2014), assigned tasks (Dopko et al., 2019), the Social Orientation Choice Card (SOCC; van Dijk-Wesselius et al., 2018), and a questionnaire developed by previous researchers (Park et al., 2016). Three experimental studies used multiple measures of prosociality to disentangle which measure or component of prosocial behaviour is more relevant for green space exposure (Park et al., 2016; van Dijk-Wesselius et al., 2018; Dopko et al., 2019).

Association Between Green Space and Prosocial Behaviour Among Children and Adolescents

A total of 63 associations between green space and prosocial behaviour were observed from 15 articles, including all indicators of green space and prosocial behaviour analysed within individual studies, as well as multiple analyses disaggregated by moderators (see **Table 3**). Exposure to green space was objectively (Odgers et al., 2012; Amoly et al., 2014; Balseviciene et al., 2014; Carrus et al., 2015; Park et al., 2016; Mayfield et al., 2017; Richardson et al., 2017; Bates et al., 2018; McEachan et al., 2018; Van Aart et al., 2018; van Dijk-Wesselius et al., 2018;

TABLE 3 | Summary of associations extracted from 15 articles.

Green space measurements	n[a]	Association				
		Significant		Non-significant		
		E[b]	UE[c]	E[b]	UE[c]	NR[d]
OBJECTIVE						
Residential surrounding greenness in buffers of:						
- 100 m	4			4		
- 250 m	1			1		
- 300 m	4		1	2	1	
- 500 m	3			3		
School greenness in a buffer of 100 m	1			1		
Home-school greenness in a buffer of 100 m	1			1		
Percentage of green or natural space in a buffer of:						
- 500 m	4	2		2	1	
- 0.5 mile (≈804.672 m)	1					
Percentage of park space in a buffer of 500 m	4			3	1	
Percentage of semi-natural and forested area in a buffer 2,000 m	1				1	
Percentage of agricultural area in a buffer 300 m	1			1		
Residential proximity to green space	3	1		2		
Schoolyard renovation[e]	7	3	1			3
Spending time in school green space[e]	5	4			1	
Playground marking[e]	4			1	3	
Participation in horticultural program[e]	4	4				
Sub-total	48	14	2	21	8	3
SUBJECTIVE						
Time spent in green space	4	1		2		1
Access to private garden	4				4	
Satisfaction with green space	2	1				1
Connectedness to nature	1	1				
- [-] Enjoyment of nature	1			1		
- Empathy for nature	1			1		
- Awareness of nature	1			1		
- Responsibility of nature	1	1				
Sub-total	15	4	0	5	4	2
Total: *n* (%)	63	18 (28.6)	2 (3.2)	26 (41.3)	12 (19.0)	5 (7.9)

[a] *Number of associations examined between green space and prosocial behaviour that count multiple indicators of green space or prosocial behaviour, as well as, multiple analyses (e.g., analysis stratified by moderators).*
[b] *Association in expected direction.*
[c] *Association in unexpected direction.*
[d] *Association in non-reported direction.*
[e] *Green space exposures assessed by in-person observation in experimental studies.*

Andrusaityte et al., 2019; Dopko et al., 2019) or subjectively (Amoly et al., 2014; Richardson et al., 2017; McEachan et al., 2018; Sobko et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019) measured. Overall, 44 (69.9%) out of 63 associations were in the expected direction. However, only 18 associations were reported to be statistically significant in the expected direction (Balseviciene et al., 2014; Carrus et al., 2015; Park et al., 2016; Richardson et al., 2017; Bates et al., 2018; McEachan et al., 2018; Sobko et al., 2018; van Dijk-Wesselius et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019; Dopko et al., 2019).

Two studies reported statistically significant associations between objective area-level measures of green space and prosocial behaviour after socio-demographic characteristics were counted as moderating factors (Balseviciene et al., 2014; Richardson et al., 2017). A longitudinal study in the UK reported statistically significant confounder-adjusted associations between percentage of green space in a buffer of 500 m and prosocial behaviour among 2,909 children (Richardson et al., 2017). Analyses stratified by the child' sex (males vs. females = 51 vs. 49%) and household educational level (high vs. low = 38 vs. 62%) showed that positive associations was only found among samples of girls and participants in highly educated households (Richardson et al., 2017). By contrast, a cross-sectional study in Lithuania found that increased residential greenness within a distance of 300 m from home was associated with lower levels of prosocial behaviour among children from high-educated mothers (Balseviciene et al., 2014). This study also reported an expected direction association that lower distance to city parks increased prosocial behaviour among children from low-educated mothers.

In-person observations used to measure green space exposure in experimental studies tended to report statistically significant findings. Children and adolescents who had used the quality-improved schoolyards (Bates et al., 2018; van Dijk-Wesselius et al., 2018) or participated in activities involving contact with nature (Carrus et al., 2015; Park et al., 2016; Dopko et al., 2019) had higher prosociality. One study in the Netherlands suggested that grade levels as a proxy of children's age modified the effects of intervention (van Dijk-Wesselius et al., 2018). The effects of a schoolyard renovation on child prosocial orientation varied by grade level. Among younger students (grade 4 and 5), the proportion of prosocial orientation increased from baseline to the follow-up, but a negative association was observed among older students (grade 6).

Nine out of 15 associations between subjective measures of green space and prosociality were reported in positive direction, of which only four were statistically significant. One study reported that increased time spent in city parks by 1 h per week was associated with decreased odds of borderline or abnormal prosocial behaviour after controlling for covariates (Andrusaityte et al., 2019). By contrast, studies that measured either spending time in green space as annual total hours during the last school period and holidays (Amoly et al., 2014), or time spent playing outside (minutes per week during summer and winter months; McEachan et al., 2018) did not report statistically significant associations. Only one study from Bradford, UK assessed the green space quality by asking parents about their satisfaction with frequently visited green space (McEachan et al., 2018). Analysis was disaggregated by the child's ethnicity (white British vs. south Asian), which was defined by parental report of which ethnicity they belonged to. This study found a statistically significant positive association for south Asian children, but the direction of the non-significant association was not reported among white British children. In addition, analyses of the access to private green space stratified by child's sex (male vs. female) and household educational level (low vs. high) consistently found non-significant negative associations for all sub-group analyses (Richardson et al., 2017). Furthermore, studies in Australia (Whitten et al., 2018) and Hong Kong (Sobko et al., 2018) reported that increased feelings of connection to nature and responsibility for nature were statistically significant associated with greater prosocial behaviour, respectively.

DISCUSSION

This review aimed to provide an overview of existing evidence assessing potential links between green space and prosocial behaviour among children and adolescents. The balance of evidence suggests that the development of prosocial behaviour may be associated with exposure to higher levels of nearby green space. However, the quality of this evidence is not yet sufficient to draw firm conclusions around causality or to offer specific guidance around well-defined interventions. Moreover, potential effect modifiers of the relationship between green space and prosocial behaviour were evident in some study contexts. Plausible mechanisms linking green space to prosociality have not been explored so far that need further investigation.

Inconsistent Findings

Differences in methodological approaches, such as the measurement of green space, could have led to inconsistent findings. Measures of exposure to green space from included studies consisted of land cover-based metrics, distance to green space, and in-person observations, as well as subjective measurements of green space-related satisfaction, the amount of time spent outdoors, access to private gardens, and perceived connectedness to nature. There were 20 associations between green space quantity and prosocial behaviour in the expected direction, but only two associations were statistically significant. Meanwhile, five associations were reported in unexpected direction, of which one association was statistically significant. The small number of statistically significant associations in expected direction might be due to limitations in measurements. Specifically, NDVI as the common measure for area-level green space has some limitations, such as its inability to distinguish different types of green space (park, garden, etc.) and does not take into account the quality of green space including abandoned or unsafe areas (Villeneuve et al., 2018). Previous studies reported that parental concern on children's safety for playing outdoors might discourage green space use (Strife and Downey, 2009; Sefcik et al., 2019). Therefore, adequate quantity of neighbourhood green space available might not fully lead to its utilisation due to other characteristics are paid attention for children's use, such as green space quality.

Parental report on green space-related satisfaction measured in a study in Bradford, UK (McEachan et al., 2018) could be considered as a proxy of green space quality. While the higher parental satisfaction with green space was associated with greater prosocial behaviour among south Asian children, none of the green space quantity indicators was identified as a predictor of prosociality. Since children are reliant on their parents to chaperon them to green spaces, parental perceptions whether the aspects of green space quality (e.g., safety, physically attractive, etc.) meet their acceptable level might be a more reliable measurement for children's access to and use of green space. It can be an important factor for children's contact with green space than the amount of neighbourhood green space (Feng and Astell-Burt, 2017d). Three studies on child health in Australia confirmed that favourable green space quality—defined subjectively by asking parents to what extent they agreed that good parks, playgrounds, and play spaces were available in the neighbourhood—was associated with higher child well-being (Feng and Astell-Burt, 2017c,d) and general health (Feng and Astell-Burt, 2017a) independently of the green space quantity. One of those studies also reported that green space quality was a stronger determinant of children's externalising behaviours (conduct and hyperactive problems), as measured by the SDQ, than green space quantity (Feng and Astell-Burt, 2017c). It might suggest that parental report on green space quality matters in evaluating the relationship between green space and child health-related outcomes.

Out of three studies from Spain, Lithuania, UK assessing children's time spent in green space, studies that expressed time as annual total hours during the last school period and holidays in Spain (Amoly et al., 2014) and total minutes per week in summer and winter months in the UK (McEachan et al., 2018) might be prone to recall bias, leading to non-significant associations with prosocial behaviour. Meanwhile, having access to a private garden was negatively associated with prosociality in Scotland, UK, which may be because private gardens might promote less social interaction compared to public green space (Richardson et al., 2017). In addition, the use of different measurements (Connectedness to Nature Index for Parents of Preschool Children vs. combined Connection to Nature Index and Connectedness to Nature Scale) and to whom perceived connection to nature (parental report vs. self-report) was asked might generate different findings between studies in Hong Kong (Sobko et al., 2018) and Australia (Whitten et al., 2018).

The statistically significant associations between green space and prosocial behaviour were more apparent in experimental studies, which might be due to assessments of green space exposure. The more consistent association in experimental studies could be possibly due to the use of in-person observation. While cross-sectional and longitudinal studies commonly used area-level of, proximity to green space, or other subjective measurements as proxies of green space exposure, in-person observation in experimental was potentially a more accurate assessment of use and direct contact with green space among children. Indeed, having direct contact with green space may enable children to gain necessary benefits for prosocial development.

Moderators and Mediators of the Association

Findings from the studies in this review indicating that socio-demographic background moderates associations between green space and prosocial behaviour might suggest that green space inequalities exist in some settings. For example, ethnic background was found to moderate the association between green space-related satisfaction and prosociality among chidren in Bradford, UK (McEachan et al., 2018). Within the study context in Bradford, south Asian families were found with less green space quantity and they reported less time spent in green space by their children and lower green space-related satisfaction compared to those from white British communities. A study in Kaunas, Lithuania reported an association in the non-hypothesised direction among children whose mothers had high education (Balseviciene et al., 2014). High socio-economic families in Kaunas live in suburban areas (more expensive than residing in cities) with an adequate amount of residential greenness available, but it does not promote outdoor activities due to parental concern of children's safety. Inversely, in Scotland, UK, a positive association was observed among children from high-education households (Richardson et al., 2017). These families had more green space available in their neighbourhoods, where a lack of safety might be less of an issue. In addition, this study also found a statistically significant association between green space measured as total natural space and prosocial behaviour among girls only. The characteristics of natural spaces (e.g., amenity areas, playing fields) might be more important for mentally-stimulating play and prosocial development among girls (Richardson et al., 2017). Furthermore, a moderation effect of grade level (as proxy for children's age) may indicate short-term increase in prosocial behaviour among younger, but negative impact on older children (van Dijk-Wesselius et al., 2018). To conclude, depending on the study settings, moderating variables may work in different ways.

The conceptual model described earlier suggests different pathways linking green space to child prosocial behaviour. Unfortunately, none of the included studies analysed potential mediators to test plausible linking pathways. Current literature indicates that mediators may influence this association. A study conducted among adult samples by Zhang et al. (2014) confirmed that mental health and well-being aspects (e.g., positive emotions) mediated the association between green space exposure and prosocial behaviour. In addition, Chen et al. (2019) reported bidirectional relationships between subjective well-being and prosocial behaviour among elementary school-aged children, of which, well-being leads to greater prosociality. Given the well-established relationships between green space and child mental well-being (Flouri et al., 2014; Feng and Astell-Burt, 2017c,d; McCormick, 2017; Vanaken and Danckaerts, 2018), it is plausible that mental health may mediate the association between green space and prosocial behaviour. Moreover, physical activity may also influence the green space-prosociality relationship. Recent growing literature suggest that exposure to local greenness improved physical activity among children (Roemmich et al., 2006; Sanders et al., 2015; Akpinar, 2017). Physical activity performed with other children can encourage social interactions and promote prosocial behaviour. Studies among Peruvian (Pawlowski et al., 2016) and Dutch children (Moeijes et al., 2018) confirmed that participation in a sport group fostered prosocial behaviour. A systematic review among the general population also showed that outdoor sports, in particular, can help increase prosocial behaviour (Eigenschenk et al., 2019). Therefore, child mental health and physical activity may potentially explain the relationship between green space and prosocial behaviour that needs further investigation.

In general, this review summarises preliminary evidence on the positive association between green space exposure and prosocial behaviour with some reported potential effect modifiers. However, the current available evidence available is not sufficient to infer causal associations. The longitudinal studies had short periods of observation (2–4 years) and did not account for time-variant measures of green space and prosocial behaviour. This prevents the examination of possible variations in prosocial behaviour as a response to changes in green space exposure over time. According to the conceptual framework, the accumulation of exposure to green space might elevate the benefits for prosocial behaviour development and greater impact may be observed during the late childhood as the sensitive period. Therefore, testing this hypothesis in longitudinal studies will provide new insights that will be beneficial for policy recommendations. In addition, mediation analyses are needed to test mechanistic pathways that may underlie the documented associations between green space and prosocial behaviour.

Strengths and Limitations

To our knowledge, this is the first systematic review evaluating the relationship between green space and prosocial behaviour. The findings are presented and discussed by different measures of green space exposure with additional explanations on potential moderators. The use of nine databases with keywords adopted from current published systematic reviews, no restriction on publication date, and screening of references of included studies allowed a comprehensive search. The process of developing and reporting this review following the PRISMA guidelines lends credibility to the findings.

There are some limitations of the evidence reviewed and review method. Firstly, there was only a limited number of longitudinal studies which preclude drawing causal inferences. The findings from experimental studies without control groups are also prone to low internal validity. Secondly, area-level measures of green space varied by study and resulted in mixed-findings, making it difficult to define absolute amount of green space needed in the neighbourhood for positive development of prosocial behaviour. Thirdly, all studies were from high-income countries. Thus, findings can be applicable to these countries, including high-income countries with hot climates and rapidly growing populations where the presence of green space is substantial for mitigating harmful environmental stressors (e.g., heat) and bridging people to the community (e.g., social interactions). However, findings may not be widely applicable to middle- and low-income countries. A limitation of the review method is that some articles that were not published in English may not have been retrieved.

Future Research Directions

This review provides preliminary evidence of positive associations between green space exposure and prosociality. However, experimental studies are just as limited as observational studies, the exposure to green space can be randomly assigned, but individual compliance in reality is agentic. Therefore, it might lead to the question of what aspects or characteristics of green space might further influence the use of green space. It is conceivable that individuals might not use green space if it is not well-maintained, physically attractive, or generally of poor quality. Therefore, the quality of green space might be an important aspect that should be considered in understanding the potential benefits of green space on human health.

Green space quality has been associated with health outcomes independently of the green space quantity (van Dillen et al., 2012). In addition, green space quality was identified to be more strongly associated with mental health outcomes than green space quantity (Francis et al., 2012; de Vries et al., 2013; Feng and Astell-Burt, 2018). Comparing between objective and subjective measurements of quality, expert-determined quality of green space involving audit tools or checklist, physical observation, GIS analyses often do not take into account the appraisal of laypeople (e.g., residents) of their environment. Laypeople are more likely to know about their environment and more qualified to assess the green space quality (Hur et al., 2010). Since they have day-to-day experiences and live in the neighbourhood, their perceptions of nearby green space are likely to be consequential for successful policymaking. The importance of subjective quality compared to objective quality of green space was noted by a study in the Netherlands (Zhang et al., 2017). This study found that subjective quality mediated the association between objective quality of green space and neighbourhood satisfaction. It strongly indicates that the perceived quality of green space was a proximate determinant for neighbourhood satisfaction and might apply to other outcomes, such as prosocial behaviour. Green space quality might be an important determinant for further study in relation to prosocial behaviour since low evidence was found on green space quantity and green space quality is less studied in relation to prosociality.

New studies with greater methodological rigor (e.g., longitudinal studies that examine time-variant measures of green space quality and prosocial behaviour for change-on-change analyses) are required to edge closer to causal inferences and evidence-based policy recommendations. Based on a conceptual model described above, using a longitudinal approach may also help to understand to what extent the accumulation of green space exposure affects the levels of prosocial behaviour in different stages of development, particularly during critical and sensitive periods of the green space-prosociality association. Assessment of potential mediators could help to test plausible pathways linking green space with prosocial behaviour. Moreover, measuring green space exposure as perceived quality is needed due to a sensitive measurement in relation to child health and behaviour outcomes. Lastly, given reported effect modifiers from previous studies, analysis of green space and prosocial behaviour should be tested across strata of other variables (e.g., socio-economic status).

CONCLUSIONS

The current evidence shows that exposure to higher levels of green space may be associated with greater prosocial behaviour. Different measurements of green space exposure led to mixed findings. Area-level green space measures were less consistent in demonstrating statistically significant associations between green space and prosocial behaviour, whereas associations were more consistent when green space was measured using in-person observation. The number of studies was too few to draw conclusions on subjective green space measurements. Further investigation on the association between green space and prosociality is warranted, especially with studies employing longitudinal designs to confirm temporality and sensitive period, as well as, capable of testing potential effect modifiers, mediators, and measures of green space quality.

AUTHOR CONTRIBUTIONS

IP, TA-B, and XF conceptualised the review. IP conducted the systematic search, study quality assessment, summarised the findings, wrote, and revised the manuscript. EJ peer-reviewed the systematic search, performed full-paper assessment of the eligible articles, and reviewed the manuscript draft. TA-B, DC, SV, and XF provided critical inputs throughout the process and edited the manuscript. All authors approved the final version of the manuscript.

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REFERENCES

Abdi, B. (2010). Gender differences in social skills, problem behaviours and academic competence of Iranian kindergarten children based on their parent and teacher ratings. *Proc. Soc. Behav. Sci.* 5, 1175–1179. doi: 10.1016/j.sbspro.2010.07.256

Abrams, D., Van de Vyver, J., Pelletier, J., and Cameron, L. (2015). Children's prosocial behavioural intentions towards outgroup members. *Br. J. Dev. Psychol.* 33, 277–294. doi: 10.1111/bjdp.12085

Aknin, L. B., Broesch, T., Hamlin, J. K., and Van de Vondervoort, J. W. (2015). Prosocial behavior leads to happiness in a small-scale rural society. *J. Exp. Psychol.* 144, 788–795. doi: 10.1037/xge0000082

Aknin, L. B., Hamlin, J. K., and Dunn, E. W. (2012). Giving leads to happiness in young children. *PloS ONE* 7:e39211. doi: 10.1371/journal.pone.0039211

Akpinar, A. (2017). Urban green spaces for children: a cross-sectional study of associations with distance, physical activity, screen time, general health, and overweight. *Urban Forest. Urban Green.* 25, 66–73. doi: 10.1016/j.ufug.2017.05.006

Allport, G. W., Clark, K., and Pettigrew, T. (1954). *The Nature of Prejudice.* Cambridge, MA: Addison-Wesley.

Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., et al. (2014). Green and blue spaces and behavioral development in barcelona schoolchildren: the BREATHE Project. *Environ. Health Perspect.* 122, 1351–1358. doi: 10.1289/ehp.1408215

Andrusaityte, S., Grazuleviciene, R., Dedele, A., and Balseviciene, B. (2019). The effect of residential greenness and city park visiting habits on preschool children's mental and general health in lithuania: a cross-sectional study. *Int. J. Hyg. Environ. Health.* 223, 142–150. doi: 10.1016/j.ijheh.2019.09.009

Aram, F., Solgi, E., and Holden, G. (2019). The role of green spaces in increasing social interactions in neighborhoods with periodic markets. *Habit. Int.* 84, 24–32. doi: 10.1016/j.habitatint.2018.12.004

Balseviciene, B., Sinkariova, L., Grazuleviciene, R., Andrusaityte, S., Uzdanaviciute, I., Dedele, A., et al. (2014). Impact of residential greenness on preschool children's emotional and behavioral problems. *Int. J. Environ. Res. Public Health* 11, 6757–6770. doi: 10.3390/ijerph110706757

Bar-on, M. E. (2000). The effects of television on child health: implications and recommendations. *Arch. Dis. Child.* 83, 289–292. doi: 10.1136/adc.83.4.289

Bar-Tal, D. (1982). Sequential development of helping behavior: a cognitive-learning approach. *Dev. Rev.* 2, 101–124. doi: 10.1016/0273-2297(82)90006-5

Bates, C. R., Bohnert, A. M., and Gerstein, D. E. (2018). Green schoolyards in low-income urban neighborhoods: natural spaces for positive youth development outcomes. *Front. Psychol.* 9:805. doi: 10.3389/fpsyg.2018.00805

Ben-Shlomo, Y., Mishra, G., and Kuh, D. (2014). "*Life* course epidemiology," in *Handbook of Epidemiology*, eds W. Ahrens and I. Pigeot (New York, NY: Springer), 1521–1549.

Brownell, C. A. (2013). Early development of prosocial behavior: current perspectives. *Infancy* 18, 1–9. doi: 10.1111/infa.12004

Caputi, M., Lecce, S., Pagnin, A., and Banerjee, R. (2012). Longitudinal effects of theory of mind on later peer relations: the role of prosocial behavior. *Dev. Psychol.* 48, 257–270. doi: 10.1037/a0025402

Carlo, G., Mestre, M. V., McGinley, M. M., Samper, P., Tur, A., and Sandman, D. (2012). The interplay of emotional instability, empathy, and coping on prosocial and aggressive behaviors. *Pers. Individ. Differ.* 53, 675–680. doi: 10.1016/j.paid.2012.05.022

Carlo, G., Mestre, M. V., Samper, P., Tur, A., and Armenta, B. E. (2010). The longitudinal relations among dimensions of parenting styles, sympathy, prosocial moral reasoning, and prosocial behaviors. *Int. J. Behav. Dev.* 35, 116–124. doi: 10.1177/0165025410375921

Carrus, G., Passiatore, Y., Pirchio, S., and Scopelliti, M. (2015). Contact with nature in educational settings might help cognitive functioning and promote positive social behaviour / El contacto con la naturaleza en los contextos educativos podría mejorar el funcionamiento cognitivo y fomentar el comportamiento social positivo. *Psyecology* 6, 191–212. doi: 10.1080/21711976.2015.1026079

Cauley, K., and Tyler, B. (1989). The relationship of self-concept to prosocial behavior in children. *Early Child. Res. Q.* 4, 51–60. doi: 10.1016/S0885-2006(89)90064-1

Chen, X., Tian, L., and Huebner, E. S. (2019). Bidirectional relations between subjective well-being in school and prosocial behavior among elementary school-aged children: a longitudinal study. *Child Youth Care Forum.* 49, 77–95. doi: 10.1007/s10566-019-09518-4

Collie, R. J., Martin, A. J., Roberts, C. L., and Nassar, N. (2018). The roles of anxious and prosocial behavior in early academic performance: a population-based study examining unique and moderated effects. *Learn. Individ. Differ.* 62, 141–152. doi: 10.1016/j.lindif.2018.02.004

Crust, L., McKenna, J., Spence, J., Thomas, C., Evans, D., and Bishop, D. (2014). The effects of playground markings on the physical self-perceptions of 10–11-year-old school children. *Phys. Educ. Sport Pedag.* 19, 179–190. doi: 10.1080/17408989.2012.732565

Dadvand, P., Nazelle, A. D., Triguero-Mas, M., Schembari, A., Cirach, M., et al. (2012a). Surrounding greenness and exposure to air pollution during pregnancy: an analysis of personal monitoring data. *Environ. Health Perspect.* 120, 1286–1290. doi: 10.1289/ehp.1104609

Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., et al. (2015). Green spaces and cognitive development in primary school children. *Proc. Natl. Acad. Sci. U.S.A.* 112, 7937–7942. doi: 10.1073/pnas.1503402112

Dadvand, P., Sunyer, J., Basagaña, X., Ballester, F., Lertxundi, A., Fernández-Somoano, A., et al. (2012b). Surrounding greenness and pregnancy outcomes in four Spanish birth cohorts. *Environ. Health Perspect.* 120, 1481–1487. doi: 10.1289/ehp.1205244

Davies, K., Tropp, L. R., Aron, A., Pettigrew, T. F., and Wright, S. C. (2011). Cross-group friendships and intergroup attitudes: a meta-analytic review. *Pers. Soc. Psychol. Rev.* 15, 332–351. doi: 10.1177/1088868311411103

de Leeuw, R. N. H., Kleemans, M., Rozendaal, E., Anschütz, D. J., and Buijzen, M. (2015). The impact of prosocial television news on children's prosocial behavior: an experimental study in the netherlands. *J. Child. Med.* 9, 419–434. doi: 10.1080/17482798.2015.1089297

de Vries, S., van Dillen, S. M. E., Groenewegen, P. P., and Spreeuwenberg, P. (2013). Streetscape greenery and health: stress, social cohesion and physical activity as mediators. *Soc. Sci. Med.* 94, 26–33. doi: 10.1016/j.socscimed.2013.06.030

Dennis, M., and James, P. (2016). User participation in urban green commons: exploring the links between access, voluntarism, biodiversity and well being. *Urban Forest. Urban Green.* 15, 22–31. doi: 10.1016/j.ufug.2015.11.009

Di Bartolomeo, G., and Papa, S. (2017). The effects of physical activity on social interactions: the case of trust and trustworthiness. *J. Sports Econ.* 20, 50–71. doi: 10.1177/1527002517717299

Dinnie, E., Brown, K. M., and Morris, S. (2013). Community, cooperation and conflict: negotiating the social well-being benefits of urban greenspace experiences. *Landsc. Urban Plan.* 112, 1–9. doi: 10.1016/j.landurbplan.2012.12.012

Dopko, R. L., Capaldi, C. A., and Zelenski, J. M. (2019). The psychological and social benefits of a nature experience for children: a preliminary investigation. *J. Environ. Psychol.* 63, 134–138. doi: 10.1016/j.jenvp.2019.05.002

Dunfield, K. A. (2014). A construct divided: prosocial behavior as helping, sharing, and comforting subtypes. *Front. Psychol.* 5:958. doi: 10.3389/fpsyg.2014.00958

Eigenschenk, B., Thomann, A., McClure, M., Davies, L., Gregory, M., Dettweiler, U., et al. (2019). Benefits of outdoor sports for society. a systematic literature review and reflections on evidence. *Int. J. Environ. Res. Public Health* 16:937. doi: 10.3390/ijerph16060937

Eisenberg, N., Spinrad, T. L., and Knafo-Noam, A. (2015). "Prosocial development," in *Handbook of Child Psychology and Developmental Science,* ed *R. M. Lerner* (John Wiley & Sons), 1—47.

Eldeirawi, K., Kunzweiler, C., Zenk, S., Finn, P., Nyenhuis, S., Rosenberg, N., et al. (2019). Associations of urban greenness with asthma and respiratory symptoms in Mexican American children. *Ann. Allergy Asthma Immunol.* 122, 289–295. doi: 10.1016/j.anai.2018.12.009

Fabes, R. A., Hanish, L. D., Martin, C. L., Moss, A., and Reesing, A. (2012). The effects of young children's affiliations with prosocial peers on subsequent emotionality in peer interactions. *Br. J. Dev. Psychol.* 30, 569–585. doi: 10.1111/j.2044-835X.2011.02073.x

Feng, X., and Astell-Burt, T. (2017a). Do greener areas promote more equitable child health? *Health Place* 46, 267–273. doi: 10.1016/j.healthplace.2017.05.006

Feng, X., and Astell-Burt, T. (2017b). Is neighborhood green space protective against associations between child asthma, neighborhood traffic volume and area safety? Multilevel analysis of 4,447 Australian Children. *J. Transport. Health* 5, S40–S41. doi: 10.1016/j.jth.2017.05.328

Feng, X., and Astell-Burt, T. (2017c). The relationship between neighbourhood green space and child mental wellbeing depends upon whom you ask: multilevel evidence from 3083 children aged 12-13 years. *Int. J. Environ. Res. Public Health* 14:235. doi: 10.3390/ijerph14030235

Feng, X., and Astell-Burt, T. (2017d). Residential green space quantity and quality and child well-being: a longitudinal study. *Am. J. Prev. Med.* 53, 616–624. doi: 10.1016/j.amepre.2017.06.035

Feng, X., and Astell-Burt, T. (2018). Residential green space quantity and quality and symptoms of psychological distress: a 15-year longitudinal study of 3897 women in postpartum. *BMC Psychiatry* 18:348. doi: 10.1186/s12888-018-1926-1

Ferreira, T., Cadima, J., Matias, M., Vieira, J. M., Leal, T., and Matos, P. M. (2016). Preschool Children's prosocial behavior: the role of mother–child, father–child and teacher–child relationships. *J. Child Family Stud.* 25, 1829–1839. doi: 10.1007/s10826-016-0369-x

Flouri, E., Midouhas, E., and Joshi, H. (2014). The role of urban neighbourhood green space in children's emotional and behavioural resilience. *J. Environ. Psychol.* 40, 179–186. doi: 10.1016/j.jenvp.2014.06.007

Flouri, E., and Sarmadi, Z. (2016). Prosocial behavior and childhood trajectories of internalizing and externalizing problems: the role of neighborhood and school contexts. *Dev. Psychol.* 52, 253–258. doi: 10.1037/dev0000076

Flynn, E., Ehrenreich, S. E., Beron, K. J., and Underwood, M. K. (2015). Prosocial behavior: long-term trajectories and psychosocial outcomes. *Soc. Dev.* 24, 462–482. doi: 10.1111/sode.12100

Fortuna, K., and Knafo, A. (2014). "Parental and genetic contributions to prosocial behavior during childhood," in *Prosocial Development: A Multidimensional Approach*, eds L. M. Padilla-Walker and G. Carlo (New York, NY: Oxford University Press), 70–89.

Francis, J., Wood, L. J., Knuiman, M., and Giles-Corti, B. (2012). Quality or quantity? *Exploring the relationship between public open space attributes and mental health in perth, western Australia. Soc. Sci. Med.* 74, 1570–1577. doi: 10.1016/j.socscimed.2012.01.032

Fujisawa, K. K., Kutsukake, N., and Hasegawa, T. (2008). Reciprocity of prosocial behavior in Japanese preschool children. *Int. J. Behav. Dev.* 32, 89–97. doi: 10.1177/0165025407084055

Gallitto, E., and Leth-Steensen, C. (2019). Moderating effect of trait emotional intelligence on the relationship between parental nurturance and prosocial behaviour. *J. Adolesc.* 74, 113–119. doi: 10.1016/j.adolescence.2019.04.008

Garaigordobil, M. (2009). A comparative analysis of empathy in childhood and adolescence: gender differences and associated socio-emotional variables. *Int. J. Psychol. Psychol. Ther.* 9, 217–235. Available online at: https://psycnet.apa.org/record/2009-09327-006

Gerbino, M., Zuffiano, A., Eisenberg, N., Castellani, V., Luengo Kanacri, B. P., Pastorelli, C., et al. (2018). Adolescents' prosocial behavior predicts good grades beyond intelligence and personality traits. *J. Pers.* 86, 247–260. doi: 10.1111/jopy.12309

Goldy, S. P., and Piff, P. K. (2020). Toward a social ecology of prosociality: why, when, and where nature enhances social connection. *Curr. Opin. Psychol.* 32, 27–31. doi: 10.1016/j.copsyc.2019.06.016

Goodman, R. (1997). The strengths and difficulties questionnaire: a research note. *J. Child Psychol. Psychiatry* 38, 581–586.

Greitemeyer, T. (2011). Effects of prosocial media on social behavior:when and why does media exposure affect helping and aggression? *Curr. Direct. Psychol. Sci.* 20, 251–255. doi: 10.1177/0963721411415229

Gustin, K., Tofail, F., Vahter, M., and Kippler, M. (2018). Cadmium exposure and cognitive abilities and behavior at 10 years of age: a prospective cohort study. *Environ. Int.* 113, 259–268. doi: 10.1016/j.envint.2018.02.020

Hammond, S. I., Waugh, W., Satlof-Bedrick, E., and Brownell, C. A. (2015). "Prosocial behavior during childhood and cultural variations," in *International Encyclopedia of the Social and Behavioral Sciences, 2nd Edn,* ed J. D. Wright (Oxford: Elsevier), 228–232.

Hartig, T., Mitchell, R., Vries, S.,d., and Frumkin, H. (2014). Nature and health. *Annu. Rev. Public Health* 35, 207–228. doi: 10.1146/annurev-publhealth-032013-182443

Hay, D. F. (1994). Prosocial development. *J. Child Psychol. Psychiatry* 35, 29–71. doi: 10.1111/j.1469-7610.1994.tb01132.x

Hay, D. F., and Cook, K. V. (2007). "The transformation of prosocial behavior from infancy to childhood," in *Socioemotional Development in the Toddler Years: Transitions and Transformations*, eds. C. A. Brownell and C. B. Kopp (New York, NY: Guilford Press), 100–131.

Hay, D. F., Payne, A., and Chadwick, A. (2004). Peer relations in childhood. *J. Child Psychol. Psychiatry* 45, 84–108. doi: 10.1046/j.0021-9630.2003.00308.x

Healy, S., and Garcia, J. M. (2019). Psychosocial correlates of physical activity participation and screen-time in typically developing children and children on the autism spectrum. *J. Dev. Phys. Disab.* 31, 313–328. doi: 10.1007/s10882-018-9642-9

Hong, A., Sallis, J. F., King, A. C., Conway, T. L., Saelens, B., Cain, K. L., et al. (2018). Linking green space to neighborhood social capital in older adults: the role of perceived safety. *Soc. Sci. Med.* 207, 38–45. doi: 10.1016/j.socscimed.2018.04.051

Houlden, V., Weich, S., Porto de Albuquerque, J., Jarvis, S., and Rees, K. (2018). The relationship between greenspace and the mental wellbeing of adults: a systematic review. *PLoS ONE* 13:e0203000. doi: 10.1371/journal.pone.0203000

Hur, M., Nasar, J. L., and Chun, B. (2010). Neighborhood satisfaction, physical and perceived naturalness and openness. *J. Environ. Psychol.* 30, 52–59. doi: 10.1016/j.jenvp.2009.05.005

Israel, S., Hasenfratz, L., and Knafo-Noam, A. (2015). The genetics of morality and prosociality. *Curr. Opin. Psychol.* 6, 55–59. doi: 10.1016/j.copsyc.2015.03.027

Jennings, V., and Bamkole, O. (2019). The relationship between social cohesion and urban green space: an avenue for health promotion. *Int. J. Environ. Res. Public Health* 16:452. doi: 10.3390/ijerph16030452

Kaplan, S. (1995). The restorative benefits of nature: toward an integrative framework. *J. Environ. Psychol.* 15, 169–182. doi: 10.1016/0272-4944(95)90001-2

Kazmierczak, A. (2013). The contribution of local parks to neighbourhood social ties. *Landsc. Urban Plan.* 109, 31–44. doi: 10.1016/j.landurbplan.2012.05.007

Knafo, A., Zahn-Waxler, C., Van Hulle, C., Robinson, J. L., and Rhee, S. H. (2008). The developmental origins of a disposition toward empathy: genetic and environmental contributions. *Emotion* 8, 737–752. doi: 10.1037/a0014179

Knafo-Noam, A., Uzefovsky, F., Israel, S., Davidov, M., and Zahn-Waxler, C. (2015). The prosocial personality and its facets: genetic and environmental architecture of mother-reported behavior of 7-year-old twins. *Front. Psychol.* 6:112. doi: 10.3389/fpsyg.2015.00112

Kok, R., Prinzie, P., Bakermans-Kranenburg, M. J., Verhulst, F. C., White, T., Tiemeier, H., et al. (2018). Socialization of prosocial behavior: gender differences in the mediating role of child brain volume. *Child Neuropsychol.* 24, 723–733. doi: 10.1080/09297049.2017.1338340

Kondo, M. C., Fluehr, J. M., McKeon, T., and Branas, C. C. (2018). Urban green space and its impact on human health. *Int. J. Environ. Res. Public Health* 15:445. doi: 10.3390/ijerph15030445

Kuh, D., Ben-Shlomo, Y., Lynch, J., Hallqvist, J., and Power, C. (2003). Life course epidemiology. *J. Epidemiol. Commun. Health* 57, 778–783. doi: 10.1136/jech.57.10.778

Lai, F. H, Siu, A. M, and Shek, D. T. (2015). Individual and social predictors of prosocial behavior among Chinese adolescents in Hong Kong. *Front. Pediatr.* 3:39. doi: 10.3389/fped.2015.00039

Lee, A. C., and Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *J. Public Health* 33, 212–222. doi: 10.1093/pubmed/fdq068

Lee, C.-T., Padilla-Walker, L. M., and Memmott-Elison, M. K. (2016). The role of parents and peers on adolescents' prosocial behavior and substance use. *J. Soc. Pers. Relat.* 34, 1053–1069. doi: 10.1177/0265407516665928

Leventhal, K. S., Gillham, J., DeMaria, L., Andrew, G., Peabody, J., and Leventhal, S. (2015). Building psychosocial assets and wellbeing among adolescent girls: a randomized controlled trial. *J. Adolesc.* 45, 284–295. doi: 10.1016/j.adolescence.2015.09.011

Liao, J., Zhang, B., Xia, W., Cao, Z., Zhang, Y., Liang, S., et al. (2019). Residential exposure to green space and early childhood neuro development. *Environ. Int.* 128, 70–76. doi: 10.1016/j.envint.2019.03.070

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A. M., et al. (2017). Exploring pathways linking greenspace to health: theoretical and methodological guidance. *Environ. Res.* 158, 301–317. doi: 10.1016/j.envres.2017.06.028

Marselle, M. R., Irvine, K. N., Lorenzo-Arribas, A., and Warber, S. L. (2014). Moving beyond green: exploring the relationship of environment type and indicators of perceived environmental quality on emotional well-being following group walks. *Int. J. Environ. Res. Public Health* 12, 106–130. doi: 10.3390/ijerph120100106

Mayfield, C. A., Child, S., Weaver, R. G., Zarrett, N., Beets, M. W., and Moore, J. B. (2017). Effectiveness of a playground intervention for antisocial, prosocial, and physical activity behaviors. *J. School Health* 87, 338–345. doi: 10.1111/josh.12506

McCormack, G. R., Rock, M., Toohey, A. M., and Hignell, D. (2010). Characteristics of urban parks associated with park use and physical activity: a review of qualitative research. *Health Place* 16, 712–726. doi: 10.1016/j.healthplace.2010.03.003

McCormick, R. (2017). Does access to green space impact the mental well-being of children: a systematic review. *J. Pediatr. Nurs.* 37, 3–7. doi: 10.1016/j.pedn.2017.08.027

McEachan, R. R. C., Yang, T. C., Roberts, H., Pickett, K. E., Arseneau-Powell, D., Gidlow, C. J., et al. (2018). Availability, use of, and satisfaction with green space, and children's mental wellbeing at age 4 years in a multicultural, deprived, urban area: results from the Born in Bradford cohort study. *Lancet. Planet Health* 2, e244–e254. doi: 10.1016/s2542-5196(18)30119-0

Meleady, R., and Seger, C. R. (2016). Imagined contact encourages prosocial behavior towards outgroup members. *Group Process. Intergr. Relations* 20, 447–464. doi: 10.1177/1368430215612225

Moeijes, J., van Busschbach, J. T., Bosscher, R. J., and Twisk, J. W. R. (2018). Sports participation and psychosocial health: a longitudinal observational study in children. *BMC Public Health* 18:702. doi: 10.1186/s12889-018-5624-1

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., and The, P. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 6:e1000097. doi: 10.1371/journal.pmed.1000097

National Institutes of Health (2019). *Study Quality Assessment Tools.* US Department of Health and Human Services. Available online at: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools (accessed September 7, 2019).

Obsuth, I., Eisner, M. P., Malti, T., and Ribeaud, D. (2015). The developmental relation between aggressive behaviour and prosocial behaviour: a 5-year longitudinal study. *BMC Psychol.* 3:16. doi: 10.1186/s40359-015-0073-4

Odgers, C. L., Caspi, A., Bates, C. J., Sampson, R. J., and Moffitt, T. E. (2012). Systematic social observation of children's neighborhoods using google street view: a reliable and cost-effective method. *J. Child Psychol. Psychiatry* 53, 1009–1017. doi: 10.1111/j.1469-7610.2012.02565.x

Oerlemans, A. M., Rommelse, N. N. J., Buitelaar, J. K., and Hartman, C. A. (2018). Examining the intertwined development of prosocial skills and ASD symptoms in adolescence. *Eur. Child Adolesc. Psychiatry* 27, 1033–1046. doi: 10.1007/s00787-018-1114-3

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., et al. (2016). Attention restoration theory: a systematic review of the attention restoration potential of exposure to natural environments. *J. Toxicol. Environ. Health Part B* 19, 305–343. doi: 10.1080/10937404.2016.1196155

Oldfield, J., Humphrey, N., and Hebron, J. (2016). The role of parental and peer attachment relationships and school connectedness in predicting adolescent mental health outcomes. *Child Adolesc. Mental Health* 21, 21–29. doi: 10.1111/camh.12108

Oviedo, L. (2016). Religious attitudes and prosocial behavior: a systematic review of published research. *Religion Brain Behav.* 6, 169–184. doi: 10.1080/2153599X.2014.992803

Park, S. A., Cho, M. K., Yoo, M. H., Kim, S. Y., Im, E. A., Song, J. E., et al. (2016). Horticultural activity program for improving emotional intelligence, prosocial behavior, and scientific investigation abilities and attitudes in kindergarteners. *Hort Technol.* 26, 754–761. doi: 10.21273/HORTTECH03489-16

Pastorelli, C., Lansford, J. E., Luengo Kanacri, B. P., Malone, P. S., Di Giunta, L., Bacchini, D., et al. (2016). Positive parenting and children's prosocial behavior in eight countries. *J. Child Psychol. Psychiatry Allied Dis.* 57, 824–834. doi: 10.1111/jcpp.12477

Pawlowski, T., Schüttoff, U., Downward, P., and Lechner, M. (2016). Can sport really help to meet the millennium development goals? *Evidence from children in Peru. J. Sports Econ.* 19, 498–521. doi: 10.1177/1527002516661601

Pettygrove, D. M., Hammond, S. I., Karahuta, E. L., Waugh, W. E., and Brownell, C. A. (2013). From cleaning up to helping out: parental socialization and children's early prosocial behavior. *Infant. Behav. Dev.* 36, 843–846. doi: 10.1016/j.infbeh.2013.09.005

Piliavin, J. (2001). "Altruism and prosocial behavior, sociology of," in *International Encyclopedia of the Social and Behavioral Sciences,* eds N. J. Smelser and P. B. Baltes *(Oxford: Elsevier Science Ltd).* 411–415.

Piotrowski, J. T., Vossen, H. G. M., and Valkenburg, P. M. (2015). "Media and child development," in *International Encyclopedia of the Social & Behavioral Sciences, 2nd Edn,* ed *J. D. Wright (Oxford: Elsevier),* 1–10.

Proctor, C., and Linley, P. A. (2014). "Life satisfaction in youth," in *Increasing Psychological well-being in Clinical and Educational Settings: Interventions and Cultural Contexts,* eds G. A. Fava and C. Ruini (New York, NY: Springer Science + Business Media), 199–215.

Prot, S., Gentile, D. A., Anderson, C. A., Suzuki, K., Swing, E., Lim, K. M., et al. (2014). Long-term relations among prosocial-media use, empathy, and prosocial behavior. *Psychol. Sci.* 25, 358–368. doi: 10.1177/0956797613503854

Qureshi, F., Koenen, K. C., Tiemeier, H., Williams, M. A., Misra, S., and Kubzansky, L. D. (2019). Childhood assets and cardiometabolic health in adolescence. *Pediatrics* 143:e20182004. doi: 10.1542/peds.2018-2004

Ren, Y., Yao, X., Liu, Y., Liu, S., Li, X., Huang, Q., et al. (2019). Outdoor air pollution pregnancy exposures are associated with behavioral problems in China's preschoolers. *Environ. Sci. Pollut. Res. Int.* 26, 2397–2408. doi: 10.1007/s11356-018-3715-2

Richardson, E. A., Pearce, J., Shortt, N. K., and Mitchell, R. (2017). The role of public and private natural space in children's social, emotional and behavioural development in Scotland: a longitudinal study. *Environ. Res.* 158, 729–736. doi: 10.1016/j.envres.2017.07.038

Richman, C. L., Berry, C., Bittle, M., and Himan, K. (1988). Factors related to helping behavior in preschool-age children. *J. Appl. Dev. Psychol.* 9, 151–165. doi: 10.1016/0193-3973(88)90020-2

Roemmich, J. N., Epstein, L. H., Raja, S., Yin, L., Robinson, J., and Winiewicz, D. (2006). Association of access to parks and recreational facilities with the physical activity of young children. *Prev. Med.* 43, 437–441. doi: 10.1016/j.ypmed.2006.07.007

Sanders, T., Feng, X., Fahey, P. P., Lonsdale, C., and Astell-Burt, T. (2015). The influence of neighbourhood green space on children's physical activity and screen time: findings from the longitudinal study of Australian children. *Int. J. Behav. Nutr. Phys. Act.* 12:126. doi: 10.1186/s12966-015-0288-z

Schwartz, A. J., Dodds, P. S., O'Neil-Dunne, J. P. M., Danforth, C. M., and Ricketts, T. H. (2019). Visitors to urban greenspace have higher sentiment and lower negativity on Twitter. *People Nat.* 1, 476–485. doi: 10.1002/pan3.10045

Sefcik, J. S., Kondo, M. C., Klusaritz, H., Sarantschin, E., Solomon, S., Roepke, A., et al. (2019). Perceptions of nature and access to green space in four urban neighborhoods. *Int. J. Environ. Res. Public Health* 16:2313. doi: 10.3390/ijerph16132313

Silke, C., Brady, B., Boylan, C., and Dolan, P. (2018). Factors influencing the development of empathy and pro-social behaviour among adolescents: a systematic review. *Child. Youth Serv. Rev.* 94, 421–436. doi: 10.1016/j.childyouth.2018.07.027

Singer, D. G., Singer, J. L., D'Agnostino, H., and DeLong, R. (2009). Children's pastimes and play in sixteen nations: is free-play declining? *Am. J. Play* 1, 283–312. Available online at: https://eric.ed.gov/?id=EJ1069041

Smith, E. P., Witherspoon, D. P., Bhargava, S., and Bermudez, J. M. (2019). Cultural values and behavior among African American and European American children. *J. Child Family Stud.* 28, 1236–1249. doi: 10.1007/s10826-019-01367-y

Sobko, T., Jia, Z., and Brown, G. (2018). Measuring connectedness to nature in preschool children in an urban setting and its relation to psychological functioning. *PLoS ONE* 13:e0207057. doi: 10.1371/journal.pone.0207057

Strife, S., and Downey, L. (2009). Childhood development and access to nature: a new direction for environmental inequality research. *Organ. Environ.* 22, 99–122. doi: 10.1177/1086026609333340

Su, J. G., Jerrett, M., de Nazelle, A., and Wolch, J. (2011). Does exposure to air pollution in urban parks have socioeconomic, racial or ethnic gradients? *Environ. Res.* 111, 319–328. doi: 10.1016/j.envres.2011.01.002

Swit, C. (2012). *Relational aggression and prosocial behaviours in Australian preschool* children. *Aust. J. Early. Child.* 37, 30–34. doi: 10.1177/183693911203700305

Taylor, L., and Hochuli, D. F. (2017). Defining greenspace: multiple uses across multiple disciplines. *Landsc. Urban Plan.* 158, 25–38. doi: 10.1016/j.landurbplan.2016.09.024

Tischer, C., Gascon, M., Fernández-Somoano, A., Tardón, A., Lertxundi Materola, A., Ibarluzea, J., et al. (2017). Urban green and grey space in relation to respiratory health in children. *Eur. Respir. J.* 49:1502112. doi: 10.1183/13993003.02112-2015

Twohig-Bennett, C., and Jones, A. (2018). The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ. Res.* 166, 628–637. doi: 10.1016/j.envres.2018.06.030

Ulrich, R. S. (1983). "Aesthetic and affective response to natural environment," in *Behavior and the Natural Environment*, eds I. *Altman and J. F. Wohlwill (Boston, MA: Springer US)*, 85–125.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., and Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* 11, 201–230. doi: 10.1016/S0272-4944(05)80184-7

Van Aart, C. J. C., Michels, N., Sioen, I., De Decker, A., Bijnens, E. M., Janssen, B. G., et al. (2018). Residential landscape as a predictor of psychosocial stress in the life course from childhood to adolescence. *Environ. Int.* 120, 456–463. doi: 10.1016/j.envint.2018.08.028

van den Berg, M., Wendel-Vos, W., van Poppel, M., Kemper, H., van Mechelen, W., and Maas, J. (2015). Health benefits of green spaces in the living environment: a systematic review of epidemiological studies. *Urban Forest.Urban Green.* 14, 806–816. doi: 10.1016/j.ufug.2015.07.008

van Dijk-Wesselius, J. E., Maas, J., Hovinga, D., van Vugt, M., and van den Berg, A. E. (2018). The impact of greening schoolyards on the appreciation, and physical, cognitive and social-emotional well-being of schoolchildren: a prospective intervention study. *Landsc. Urban Plan.* 180, 15–26. doi: 10.1016/j.landurbplan.2018.08.003

van Dillen, S. M. E., de Vries, S., Groenewegen, P. P., and Spreeuwenberg, P. (2012). Greenspace in urban neighbourhoods and residents' health: adding quality to quantity. *J. Epidemiol. Commun. Health* 66:e8. doi: 10.1136/jech.2009.104695

Vanaken, G. J., and Danckaerts, M. (2018). Impact of green space exposure on children's and adolescents' mental health: a systematic review. *Int. J. Environ. Res. Public Health* 15:2668. doi: 10.3390/ijerph15122668

Vilar, M. M., Corell, L., and Merino, C. (2019). Systematic review of prosocial behavior *measures* 37, 349–377. doi: 10.18800/psico.201901.012

Villeneuve, P. J., Ysseldyk, R. L., Root, A., Ambrose, S., DiMuzio, J., Kumar, N., et al. (2018). Comparing the normalized difference vegetation index with the google street view measure of vegetation to assess associations between greenness, walkability, recreational physical activity, and health in Ottawa, Canada. *Int. J. Environ. Res. Public Health* 15:1719. doi: 10.3390/ijerph15081719

Ward, J. S., Duncan, J. S., Jarden, A., and Stewart, T. (2016). The impact of children's exposure to greenspace on physical activity, cognitive development, emotional wellbeing, and ability to appraise risk. *Health Place* 40, 44–50. doi: 10.1016/j.healthplace.2016.04.015

Weinstein, B. D., and Bearison, D. J. (1985). Social interaction, social observation, and cognitive development in young children. *Eur. J. Soc. Psychol.* 15, 333–343.

Wentzel, K. (2015). "Prosocial behaviour and schooling," in *Encyclopedia on Early Childhood Development*, eds R. Tremblay, M. Boivin, and R. Peters. (The Centre of Excellence for Early Childhood Development (CEECD)). Available online at: http://www.child-encyclopedia.com/prosocial-behaviour/according-experts/prosocial-behaviour-and-schooling

Whitten, T., Stevens, R., Ructtinger, L., Tzoumakis, S., Green, M. J., Laurens, K. R., et al. (2018). Connection to the natural environment and well-being in middle childhood. *Ecopsychology* 10, 270–279. doi: 10.1089/eco.2018.0010

Williams, A., O'Driscoll, K., and Moore, C. (2014). The influence of empathic concern on prosocial behavior in children. *Front. Psychol.* 5:425. doi: 10.3389/fpsyg.2014.00425

Wittek, R., and Bekkers, R. (2015). "Altruism and prosocial behavior, sociology of," in *International Encyclopedia of the Social & Behavioral Sciences, 2nd Edn*, ed *J. D. Wright (Oxford: Elsevier)*, 579–583.

Yang, Y., Li, W., Sheldon, K. M., and Kou, Y. (2019). Chinese adolescents with higher social dominance orientation are less prosocial and less happy: a value-environment fit analysis. *Int. J. Psychol.* 54, 325–332. doi: 10.1002/ijop.12474

Zhang, J. W., Piff, P. K., Iyer, R., Koleva, S., and Keltner, D. (2014). An occasion for unselfing: Beautiful nature leads to prosociality. *J. Environ. Psychol.* 37, 61–72. doi: 10.1016/j.jenvp.2013.11.008

Zhang, Y., Van den Berg, A. E., Van Dijk, T., and Weitkamp, G. (2017). Quality over quantity: contribution of urban green space to neighborhood satisfaction. *Int. J. Environ. Res. Public Health* 14:535. doi: 10.3390/ijerph14050535

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix D. Published research article (2nd study)

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Association between green space quality and prosocial behaviour: A 10-year multilevel longitudinal analysis of Australian children

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ABSTRACT

Background: Current evidence from studies on green space and child prosocial behaviour suggests a paucity of studies investigating the plausible role of green space quality in shaping the development of prosocial behaviour. This study aimed to examine longitudinal association between green space quality and prosocial behaviour among children.

Methods: We analysed 10-year longitudinal data (2004–2014) from the Longitudinal Study of Australian Children (LSAC), a nationally representative cohort study. Prosocial behaviour that covers positive behaviours (e.g. sharing, helping) was measured using a prosocial scale from Goodman's Strengths and Difficulties Questionnaire (SDQ). Parents' perceptions on the availability of "good" parks, playgrounds, and play space in the neighbourhood assessed green space quality. Multilevel linear regression models were used to examine potential changes in prosocial behaviour across childhood in relation to green space quality. A two-way interaction term between green space and age was fitted to assess potential differences in the effect of green space quality by age. Sensitivity analyses by child's sex and history of residential movement were also performed.

Results: From the analysis of 24,418 observations nested in 4969 children, prosocial behaviour was relatively high (mean = 8.13 out of 10; SD = 1.79) and about balanced proportions between girls (48.74%) and boys (51.26%) were included. Prosocial behaviour was higher among children whose parents agreed ($\beta = 0.10$; 95% CI = 0.04, 0.16) and strongly agreed ($\beta = 0.20$; 95%CI = 0.13, 0.27) to having quality green space in their neighbourhood. The benefit of exposure to favourable green space on prosocial behaviour was similar among both children who changed and did not change neighbourhood, but reported higher among boys than girls. Younger compared with older children or adolescents tended to benefit more by the presence of quality green space.

Conclusion: Green space quality was positively associated with child prosocial behaviour. Boys and younger children tended to benefit more from quality green space. Future research might seek to identify preferred characteristics of quality green spaces, and to understand how these preferences vary by gender and age, to best support the development of prosocial behaviour across childhood and adolescence.

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Appendix E. Published research article (3rd study)

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Association between caregiver perceived green space quality and the development of prosocial behaviour from childhood to adolescence: Latent class trajectory and multilevel longitudinal analyses of Australian children over 10 years

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A R T I C L E I N F O

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Keywords:
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Environment
Prosociality
Child behaviour
Subjective measure
Latent class analysis

A B S T R A C T

Background: Studies investigating the potential role of neighbourhood green space quality on the development of prosocial behaviour among children are sparse. This study aimed to investigate the longitudinal association between caregiver perceived green space quality and child prosocial behaviour, and identify potential effect modifiers of the association.

Methods: This was a longitudinal study using data from the Longitudinal Study of Australian Children, involving 4,969 children aged 4–5 years that were biannually followed-up from 2004 to 2014. Prosocial behaviour was assessed using a prosocial scale from Goodman's Strengths and Difficulties Questionnaire. Green space quality was measured based on caregiver perception of the availability of neighbourhood parks, playgrounds, and play spaces of good quality. Latent class analysis was used to partition children into groups denoting different levels of caregiver perceptions of green space quality accumulated over 10 years. Multinomial logistic regression was used to examine the likelihood of being in groups with favourable perception of green space quality. Multilevel linear regression was used to examine associations between trajectory groups and prosocial behaviour. Separate multivariate models were developed to assess the potential role of quality green space in reducing prosocial behaviour related inequalities. Furthermore, two-way interaction terms were added into the models to identify potential effect moderation.

Results: There were six trajectory classes of green space quality perceived by caregivers. The likelihood of being in groups with better green space quality varied by neighbourhood circumstances. Children with consistently very good quality green space had higher prosocial behaviour ($\beta = 0.35$; 95%CI = 0.23, 0.47) than those with low quality green space. Better prosocial behaviour was also observed among children whose caregiver perception of green space quality trended from good to very good ($\beta = 0.23$; 95%CI = 0.11, 0.35) and from very good to good ($\beta = 0.31$; 95%CI = 0.20, 0.42) compared to children with consistently low quality green space. Very good quality green space perceived by caregivers over time potentially reduces socioeconomic inequalities in prosocial behaviour. Green space quality-prosocial behaviour association was stronger among boys, children speaking only English at home, those living in more affluent areas, and remote areas.

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Appendix F. Published research article (4th study)

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Do physical activity, social interaction, and mental health mediate the association between green space quality and child prosocial behaviour?

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ABSTRACT

Potential pathways linking green space quality to prosocial behaviour have not been investigated so far. This study aimed to examine 15 candidate mediators of the association between green space quality and prosocial behaviour across physical activity, social interaction, health-related quality of life (HRQOL), child and caregiver mental health. This study analysed data of 4969 children aged 4–5 years that were observed for 10 years (2004–2014), retrieved from the Longitudinal Study of Australian Children. Caregiver perceptions of the availability of good neighbourhood parks, play spaces, and playgrounds were used to evaluate green space quality. Prosocial behaviour was measured based on caregiver reports of the prosocial subscale from the Strengths and Difficulties Questionnaire. Causal mediation analysis was used to fit each candidate mediator in a single mediation model. Additional analyses were conducted to strengthen the findings by modelling green space quality, candidate mediators with child-reported prosocial behaviour. Findings from this study suggest weak evidence of physical activity mediation, with only physical activity enjoyment displaying moderate mediation consistency. Child social interaction and caregiver mental health showed low mediation consistency. In addition, moderate-to-high and low-to-high mediation consistency was found for child mental health and HRQOL indicators, respectively. Mediation by candidate mediators appeared to manifest more in late childhood. Mediation models using child-reported prosocial behaviour tended to show weaker mediation compared to caregiver-reported prosocial behaviour models. To conclude, green space quality may indirectly influence prosocial behaviour among children via several pathways. Improving the quality of neighbourhood green space may support physical activity enjoyment, social interaction, mental health among children, which in turn, may potentially foster the development of prosocial behaviour.

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Appendix G. Published research article (5th study)

Social Psychiatry and Psychiatric Epidemiology
https://doi.org/10.1007/s00127-021-02186-7

ORIGINAL PAPER

Is prosocial behaviour a missing link between green space quality and child health-related outcomes?

I Gusti Ngurah Edi Putra[1] · Thomas Astell-Burt[1,2,3,4] · Dylan P. Cliff[5,6] · Stewart A. Vella[6,7] · Xiaoqi Feng[1,2,3,8]

Received: 18 March 2021 / Accepted: 31 October 2021

Abstract

Background This study aimed to investigate prosocial behaviour—those behaviours that benefit others or enhance relationships with others—as a mediator of the associations between green space quality and child health-related outcomes (physical activity, mental health, and health-related quality of life (HRQOL)).

Methods This study involved data from 4983 children with 10-year follow-up (2004–2014) retrieved from the Longitudinal Study of Australian Children. Green space quality (the exposure), prosocial behaviour (the candidate mediator), and child health-related outcomes were assessed biennially based on caregiver reports. Causal mediation analysis was used, with four mediation models developed for each outcome.

Results Mediation by prosocial behaviour appeared in the late childhood mediation model with higher mediation proportions reported compared to models of earlier and middle childhood. Prosocial behaviour had moderate mediation consistency for the association between green space quality and physical activity enjoyment, but no mediation was evident for other physical activity variables. Prosocial behaviour had low mediation consistency for child mental health (internalising and externalising subscales). Similarly, low mediation consistency of prosocial behaviour was also evident for all HRQOL variables, such as physical, emotional, social, school functioning, psychosocial health, and total quality of life (QOL).

Conclusion Prosocial behaviour partially mediated the association between green space quality and child health-related outcomes (physical activity enjoyment, mental health, and HRQOL). Improving the quality of neighbourhood green space that supports the development of prosocial behaviour may result in better child health-related outcomes. Other physical activity variables might not specifically relate to social interactions, and therefore, no mediation by prosocial behaviour was apparent.

Keywords Environment · Prosociality · Physical activity · Mental health · Health-related quality of life (HRQOL)

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Appendix H. Powerful Ideas Symposium

PowerLab
Population Wellbeing and Environment Research Lab

UNIVERSITY OF WOLLONGONG AUSTRALIA

POWERful Ideas!

A symposium to celebrate PowerLab PhD research

FRIDAY 13th December 2019

233-G12 ITAMS Bld, Innovation Campus, North Wollongong

9:30am – 11:30am | Lunch 12:00 – 2:00pm

U O W

Introduction:
Prof Thomas Astell-Burt (PowerLab, UOW): *Parklife – Our Green Space Research and Impacts*

Keynote talk:
Prof Richard Fuller (University of Queensland): *Nature Orientation and Biodiversity in Cities*

PhD Presentations:
Selin Akaraci: *Exploring Potential Influence of Green Spaces on Birth Weight*

Shumirai Mushangwe: *Ethnicity and Urban Greenspace: Is the difference in greenspace availability contributing to ethnic inequalities in health?*

Tashi Dendup: *The role of the neighbourhood built environment in type 2 diabetes prevention*

Eme John: *Greenspace and Healthy Ageing: Does Nature Relatedness Explain The Relationship?*

Gideon Meyerowitz-Katz: *How to make sure diabetes apps aren't a waste of time.*

Faysal Shuvo: *Role of urban green spaces (UGS) on social and active ageing in contrasting geographical settings?*

Edi Putra: *Prosocial behaviour: A missing piece to the puzzle of green space and child health-related outcomes?*

Lunch will be held at 12:00pm following the Powerful Ideas symposium at North Beach Pavilion Restaurant, North Beach, Wollongong.

By Invitation Only.
For any enquiries please contact traso@uow.edu.au

UNIVERSITY OF WOLLONGONG AUSTRALIA

PowerLab
Population Wellbeing and Environment Research Lab

Population Wellbeing and Environment Research Lab (PowerLab)
School of Health and Society | Faculty of Social Sciences

Appendix I. School of Health and Society Research Seminar

Appendix J. ISEE Young 2021

ISEE Young
2021

Certificate of Participation

This certificate confirms that

I Gusti Ngurah Edi Putra

joined the Swiss TPH / ISEE Europe Chapter Event:

ISEE Young 2021 Virtual Conference –
18-19 February

PD. Dr. Danielle Vienneau
Epidemiology and Public Health
Swiss Tropical and Public Health Institute
Socinstrasse 57, PO Box, 4002 Basel, Switzerland

This certificate has been downloaded via the ISEE Young 2021 conference app, accessible only by registered participants.

Swiss TPH

Swiss Tropical and Public Health Institute
Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse

Associated Institute of the University of Basel

INTERNATIONAL SOCIETY FOR ENVIRONMENTAL EPIDEMIOLOGY
ISEE
STUDYING HUMAN HEALTH AND THE ENVIRONMENT

Appendix K. The 14th Biennial Conference of the Asian Association of Social Psychology (AASP) 2021

ASIAN ASSOCIATION OF SOCIAL PSYCHOLOGY

Certification

Paper Presentation

Author/s

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Thomas Astell-Burt (University of Wollongong, University of Sydney, Chinese Center for Disease Control and Prevention, The Chinese Academy for Medical Sciences and Tsinghua University),

Dylan P. Cliff (University of Wollongong),

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Xiaoqi Feng (University of Wollongong, University of Sydney, Chinese Center for Disease Control and Prevention, University of New South Wales)

Title

Better Green Space Quality, More Prosocial? Evidence from Australia

2021. 07. 31.

Hoonseok Choi

HOON-SEOK CHOI, Ph.D.

President