An investigation into the associations of physical activity and
electronic media use with cognitive and psychosocial health in
preschool children

Jade McNeill

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An investigation into the associations of physical activity and electronic media use with cognitive and psychosocial health in preschool children.

A thesis submitted in fulfilment of the requirements for the award of the degree.

Doctor of Philosophy
from the
University of Wollongong

By
Jade McNeill
BSc. Sport Science
M.Sc Sport and Health Science

School of Education
Faculty of Social Science
Early Start
2019
I, Jade McNeill, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Social Sciences, University of Wollongong, is my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualification at any other academic institution.

Jade McNeill

Date: 7/05/2019
Abstract

Title: An investigation into the associations of physical activity, and electronic media use with cognitive and psychosocial health in preschool children.

Physical inactivity and electronic media use have been shown to be detrimentally associated with several health and developmental outcomes in the early years, however investigations into cognitive and psychosocial health outcomes are limited. The aim of this Doctoral thesis was to cross-sectionally and longitudinally investigate associations between physical activity (intensity and type) and electronic media use (type) with cognitive and psychosocial health in preschool children (3- to 5-years). This thesis aimed to provide evidence to better understand and improve the health and well-being of children, and to help inform policies and practices related to physical activity and electronic media use in young children. This Doctorate is comprised of a literature review, five original research papers using data from a prospective observational study – the Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition (PATH-ABC) study – and an overall discussion and conclusion chapter discussing the implications of the findings.

Chapter 1 introduces the topic and provides the aims and research questions outlined for this thesis. This chapter then discusses the significance of the research, its delimitations, limitations and definitions of key terms.

Chapter 2 provides a literature review of the topic area. It provides definitions of physical activity and electronic media use, and then discusses the measurement of these behaviours. The chapter discusses current physical activity and electronic media guidelines, and
prevalence rates in early childhood. This is then followed by a review of the evidence on associations of physical activity and electronic media use with cognitive and psychosocial health outcomes in early childhood, including a discussion of possible mechanisms. Lastly, this chapter discusses the translation of research into practice and reconciles the available evidence, highlighting gaps for further research.

Chapter 3 examines the cross-sectional associations of objectively-measured physical activity and modified organised sport participation with executive functions (i.e., cognitive control abilities that are central to thinking and learning, including working memory, inhibition and shifting) and psychosocial health in preschool children. Light intensity physical activity was negatively associated with children's visual-spatial working memory, while the positive association between vigorous intensity physical activity and visual-spatial working memory approached significance. Similarly, higher levels of vigorous intensity physical activity were associated with fewer internalising behaviour problems. However, vigorous and moderate-to-vigorous intensity physical activity were positively associated with externalising behaviour problems. In addition, modified organised sport participants displayed higher shifting performance compared to those who did not participate in sport.

Chapter 4 examines the longitudinal associations of objectively measured physical activity and modified organised sport participation at 3- to 5-years with executive functions and psychosocial health 12 months later. Vigorous intensity physical activity at baseline was positively associated with children’s shifting performance at follow-up, while this association for moderate-to-vigorous intensity physical activity approached statistical
significance. Children who did not participate in modified organised sport at baseline demonstrated better inhibition scores 12 months later compared to sports participants. No longitudinal associations were evident between physical activity or modified organised sport participation and psychosocial health.

Chapter 5 examines the cross-sectional associations of electronic media use with executive functions and psychosocial health in preschool children. Negative associations were observed for total electronic media use and TV/program viewing with children’s visual-spatial working memory. However, high-dose app users (≥30 min/day) displayed higher phonological working memory compared to non-users. Similarly, compared to non-users, low dose app users (1 - 29 min/day) displayed fewer total psychosocial difficulties.

Chapter 6 examines longitudinal associations of electronic media use at 3- to 5-years with executive functions and psychosocial health 12 months later. Higher levels of program viewing at baseline were significantly associated with more externalising behaviours and total psychosocial difficulties at follow-up. Likewise, high-dose app users (≥30 min/day) at baseline displayed significantly lower inhibition capabilities 12 months later, compared to low-dose app users (1 - 29 min/day), although neither group significantly differed from non-users.

Chapter 7 examines cross-sectional and longitudinal associations of compliance with the Australian 24-Hour Movement Guidelines for the Early Years with executive functions and psychosocial health in preschool children. Associations were examined for meeting: i) individual recommendations; ii) combinations of recommendations; iii) the number of
recommendations; and iv) the overall guidelines. Cross-sectionally, children who met both the physical activity and sleep guidelines combined displayed better phonological working memory and shifting performance, compared to those who did not. Compared to children who met one/no guidelines, children who met two guidelines displayed better phonological working memory, whereas the difference in phonological working memory between children who meet three guidelines, and those who met one/no guidelines approached significance. Children who met three guidelines demonstrated better shifting ability compared to children who met one/no guidelines. The difference in shifting ability between children who met two guidelines compared to those who met one/no guidelines approached significance. Longitudinally, children who met the physical activity guideline at 3-5 years displayed better shifting performance 12 months later compared to those who did not. However, children who met the overall integrated 24-h movement behaviour guidelines did not display better executive functions or psychosocial health outcomes, compared to those who did not, cross-sectionally or longitudinally. No significant cross-sectional or longitudinal associations were observed for psychosocial health outcomes.

Chapter 8 concludes by reconciling this evidence, and discussing its implications for the community, researchers and policy makers in relation to supporting young children’s cognitive and psychosocial health, and how these outcomes might be influenced by participation in physical activity and engagement with electronic media. Specifically, this thesis integrates these findings with other available evidence to suggest the most beneficial intensities and types of physical activity, and types and doses of electronic media use in the early years, to assist in placing children on the best pathway to optimal health and give them the best start to life.
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Firstly, a huge thank you to my supervisory team, Dr Dylan Cliff, Dr Steven Howard, and Dr Stewart Vella. Not only for providing me the opportunity to undertake this degree, but for always providing continuous support over the roller coaster of this journey. Dylan, thank you for always having an open-door policy, when a one-minute question always turns into a lengthy discussion. This usually led me to ask myself more questions, undoubtedly making me a better researcher and academic. Your support has always been positive and constructive, and you have always strived to make the story of my thesis come to life. Steven, thank you for your professional and academic advice, and always being willing to share your time and knowledge. Stewart, thank you for your academic advice and guidance. I have learned a lot from all of you.

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Lastly, I would like to thank all the families and children, and their preschools and primary schools who volunteered their time to participate in this study, as without them this thesis would have not been possible. I am forever grateful for the opportunity that this PhD will provide me in the near and distant future.
Statement of the thesis style

In agreement with my supervisors, this thesis has been prepared in journal article compilation style format. This style format was chosen to be appropriate for this thesis because the outcomes of this work will provide important evidence in respect to associations of physical activity and electronic media use with cognitive and psychosocial health in preschool children. Each chapter will help to expand on the gaps within the evidence base in relation to associations of physical activity and electronic media use with developmental outcomes. This thesis has been formatted to the APA 6th Edition.
List of publications from the thesis

Chapter 3

https://doi.org/10.1016/j.mhpa.2018.07.001

Chapter 6

List of papers under review

Chapter 5

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Chapter 7


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The greater part of the work involved in this thesis is directly attributed to me as a PhD candidate. Supervisors and co-authors have been involved in securing the funding and conceiving and designing the studies. All authors revised and approved the published, submitted and presented work. The studies, data analysis, and reporting have been performed solely by me in keeping with the requirements of my candidature. Documentation of the statement of contribution for each chapter in this thesis can be found in Appendix O: Author contribution forms.
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<th>Description</th>
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<tbody>
<tr>
<td>ABS</td>
<td>Australian Bureau of Statistics</td>
</tr>
<tr>
<td>ECEC</td>
<td>Early Childhood Education and Care</td>
</tr>
<tr>
<td>EYT</td>
<td>Early Years Toolbox</td>
</tr>
<tr>
<td>IRSAD</td>
<td>Index of Relative Socio-economic Advantage and Disadvantage</td>
</tr>
<tr>
<td>LPA</td>
<td>Light-Intensity Physical Activity</td>
</tr>
<tr>
<td>LMVPA</td>
<td>Light-to-Vigorous Intensity Physical Activity</td>
</tr>
<tr>
<td>MET</td>
<td>Metabolic Equivalent</td>
</tr>
<tr>
<td>MPA</td>
<td>Moderate-Intensity Physical Activity</td>
</tr>
<tr>
<td>MVPA</td>
<td>Moderate-to-Vigorous Intensity Physical Activity</td>
</tr>
<tr>
<td>Min/day</td>
<td>Minutes Per Day</td>
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<tr>
<td>SDQ</td>
<td>Strengths and Difficulties Questionnaire</td>
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<tr>
<td>SEIFA</td>
<td>Socio-Economic Indices for Areas</td>
</tr>
<tr>
<td>SES</td>
<td>Socio-Economic Status</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for Social Sciences</td>
</tr>
<tr>
<td>STATA</td>
<td>Software for Statistics and Data Science</td>
</tr>
<tr>
<td>STROBE</td>
<td>Strengthening the Reporting of Observational studies in Epidemiology</td>
</tr>
<tr>
<td>TPA</td>
<td>Total Physical Activity</td>
</tr>
<tr>
<td>VPA</td>
<td>Vigorous-Intensity Physical Activity</td>
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Chapter 1: Introduction and Aims
1.1 General introduction

Early childhood, defined as ages 0- to 5-years and encompassing the preschool years (3- to 5-years), is characterised by rapid brain development (Khan & Hillman, 2014; Lenroot & Giedd, 2006). During this time the brain is malleable, and undergoes dynamic production and pruning of synapses in regions that are responsible for higher-order processing (Huttenlocher & Dabholkar, 1997). Consequently, the preschool period involves significant changes to children’s physical, social, and emotional development (Denham, 1986).

Susceptible to these changes, but also seemingly instrumental to the development of further abilities, are cognitive control capacities and aspects of mental well-being. Higher-order cognitive process, known as executive functions, are responsible for activating and manipulating information in mind (working memory); flexibly switching attention due to the demands of a situation (shifting); and resisting urges, impulses and distractions (inhibition). Executive functions are essential for cognitive, mental, physical, and social health across the lifespan (Diamond, 2013; Moffitt et al., 2011), and are intimately linked with psychosocial health and behaviour (Benavides-Nieto, Romero-López, Quesada-Conde, & Corredor, 2017). Psychosocial health includes social, emotional, and behavioural functioning, and includes the presence of positive (and absence of negative) affect (Diener & Ryan, 2008), and positive psychosocial health has been associated with later academic achievement, and lower risk of adverse mental health outcomes (Jones, Brown, & Lawrence Aber, 2011; Meagher, Arnold, Doctoroff, Dobbs, & Fisher, 2009). Facilitating healthy cognitive and psychosocial health by understanding how modifiable factors can influence these outcomes during the preschool years is crucial.
While a considerable body of evidence expounds the health benefits of participating in physical activity in childhood (Poitras, Gray, Borghese, Carson, Chaput, & Katzmarzyk, 2016), physical activity is increasingly being speculated also as an important modifiable determinant for cognition and psychosocial health in children and adolescents (Biddle & Asare, 2011; Hillman, Erickson, & Kramer, 2008; Sibley & Etnier, 2003). For physical health outcomes, systematic reviews in the early years (0-4) suggest that physical activity is favourably associated with healthy bone development, motor skill development and aspects of cardio-metabolic health (Carson, Lee, et al., 2017). Evidence of associations with cognitive and psychosocial health is emerging, but remains inconsistent and limited (Carson, Lee, et al., 2017; Timmons et al., 2012), despite the fact that physical activity experts rank cognitive and psychosocial health as critical outcomes when attempting to determine appropriate physical activity guidelines for early childhood.

Indeed, few studies using objective measures of habitual physical activity or sport have investigated associations with foundational cognitive abilities (executive functions) or key domains of psychosocial health (e.g., internalising, externalising, prosocial behaviours; Carson, Hunter, et al., 2016; Carson, Lee, et al., 2017; Hinkley, Teychenne, et al., 2014). Further, the evidence base examining these outcomes is largely based on cross-sectional studies, which are limited in determining whether behaviours are the cause or consequence of cognitive or psychosocial outcomes. Additionally, it is unclear whether/which aspects of physical activity, such as the intensity or type, could be targeted to promote cognitive and psychosocial development during early childhood (Carson, Hunter, et al., 2016; Carson, Lee, et al., 2017; Hinkley, Teychenne, et al., 2014; Timmons et al., 2012). Thus, stronger designs, such as prospective longitudinal studies, are needed to provide more robust evidence.
At the same time, rapid technological advancements in electronic media have made screen-based forms of entertainment for young children ubiquitous, potentially influencing physical, cognitive and psychosocial trajectories. Yet research lags behind the adoption of these technologies (Radesky, Schumacher, & Zuckerman, 2015). There is a large body of evidence linking greater screen time with adverse health outcomes in school-aged children and youth (Carson et al., 2016). A recent review by Poitras and colleagues (2016) of sedentary behaviour and associations with health outcomes in the early years indicated primarily detrimental or null associations between screen time and health indicators of adiposity and motor development. Similarly, associations between screen time and health with indicators of psychosocial health and cognitive development were largely detrimental. However, many foundational aspects of cognitive and psychosocial development remain under-investigated in relation to electronic media use, thus limiting the ability to draw clear and actionable conclusions.

Further, the available evidence is comprised largely of cross-sectional studies that examined TV/DVD viewing, or adopted aggregated measures of screen time that include predominantly TV/DVD viewing and computer use (Poitras et al., 2017). Evidence of the associations for contemporary forms of electronic media use, such as mobile/handheld touch screen technologies is scarce (Poitras et al., 2017). As such it is unclear if traditional and typically passive electronic media behaviours such as TV/DVD or program viewing, and contemporary media behaviours that are often more active such as applications/games (apps) have similar associations with preschool children’s cognitive and psychosocial health. Also unclear is whether electronic media use is likely to be a cause or consequence of cognitive or psychosocial health outcomes. Determining if different types of electronic media influence early childhood development in different ways is of great importance,
because experts have proposed that touch-screen based interactive content such as apps may exert different influences on health and development compared to passive content such as program viewing (Christakis, 2014). Investigations considering modern electronic media use and using stronger designs, such as prospective longitudinal studies, is thus required to evaluate these possibilities.

Such evidence could inform initiatives, programs and policies designed to support child development. The implications of this thesis may contribute to the evidence in support, or to suggest refinement of the current guidelines for physical activity and electronic media use. In addition, the findings may help to indicate viable targets for education, prevention or intervention with broad benefits (e.g., targeting specific types of physical activity to achieve not only health, but also cognitive and psychosocial benefits) for children in the early years. Furthermore, the results may inform theorising about the mechanisms through which physical activity and/or electronic media might influence development more broadly, to be able to account for unique patterns of associations found. Lastly, the results may help to identify areas of research for further investigation, such as unexpected findings or those that do not conform to previous findings or recommendations. As such, studies that adopt objective measures to investigate different intensities of physical activity, examine different types of physical activity, and examine contemporary forms of electronic media are needed to help further our understanding (Carson et al., 2015; Carson, Lee, et al., 2017; Hinkley, Teychenne, et al., 2014; Poitras et al., 2017).
1.2 Aims and research questions

This thesis aims to investigate if physical activity and electronic media use are associated with cognitive and psychosocial health in preschool children aged 3- to 5-years, and if associations differ by the intensity or type of physical activity, or the type of electronic media. To address this over-arching aim, the thesis investigates the following aims and research questions:

**Aim 1:** To examine the associations of objectively measured physical activity and modified organised sport with executive functions and psychosocial health in preschool children cross-sectionally and longitudinally.

**Research Question 1:** Do the associations of physical activity with executive functions or psychosocial health differ by the intensity (i.e., light-intensity physical activity, moderate-intensity physical activity, vigorous-intensity physical activity, moderate-to-vigorous intensity physical activity, and light-to-vigorous intensity physical activity) or type (i.e., modified organised sports) of physical activity in preschool children? (Chapters 3 & 4).

**Aim 2:** To examine the associations of electronic media use with executive functions and psychosocial health in preschool children cross-sectionally and longitudinally.

**Research Question 2:** Do the associations of total electronic media use with executive functions or psychosocial health differ by the type of electronic media (i.e., program viewing or use of electronic apps) in preschool children? (Chapter 5 & 6).
**Aim 3:** To examine if compliance to the Australian 24-h Movement Guidelines for the Early years is associated with executive functions and psychosocial health cross-sectionally and longitudinally in preschool children.

**Research Question 3:** Is compliance with the 24-Hour Movement Guidelines for the Early Years associated with executive functions and psychosocial health in preschool children? Do associations differ for children meeting: i) individual guidelines (i.e., physical activity, screen time or sleep); ii) combinations of any two guidelines (i.e., sleep and physical activity, sleep and screen time or screen time and physical activity); or iii) meeting an increasing number of guidelines (i.e., 0/1 vs. 2 vs. 3)? (Chapter 7).

**1.3 Significance of research**

A large body of evidence demonstrates the associated health benefits of physical activity and health consequences of excessive electronic media use among school-aged children and youth (Carson et al., 2016; Poitras, Gray, Borghese, Carson, Chaput, & Katzmarzyk, 2016), however, these relationships are less well established in the early years (Carson, Lee, et al., 2017; Poitras et al., 2017). Moreover, the preschool years represent a period of rapid and formative change in cognitive and psychosocial development (Berk, 2007; Denham, 1986) – aspects of development that physical activity has also been speculated to influence. Yet a better understanding is required of the nature and extent to which physical activity intensity and type, and electronic media use, might influence broader domains of development. This evidence is important for informing practices and policies designed to support children's physical, cognitive and psychosocial health. Further, evaluating if guideline compliance is associated with cognitive and psychosocial health
outcomes can provide additional evidence, when considered in conjunction with all health indicators to further support these new guidelines, or suggest that alternative recommendations may be needed.

1.4 Delimitations

The study was delimited in the following manner.

1. Children aged 3- to 5-years attending early childhood education and care (ECEC) centres in the Illawarra region of NSW, Australia.

2. Physical activity was assessed objectively using accelerometry (Actigraph GT3X), worn for at least three valid days (Cliff, Reilly, & Okely, 2009).


4. Participation in modified organised sport was assessed subjectively using parent-report (Vella, Cliff, Magee, & Okely, 2015).

5. Executive functions were assessed using a validated battery of iPad-based measures (Early Years Toolbox; Howard & Melhuish, 2017).

6. Psychosocial health was assessed subjectively using a survey completed by educators that has established psychometrics and is used widely and internationally (Strengths and Difficulties Questionnaire; Goodman, 1997).

1.5 Definition of key terms

- Accelerometer: An instrument designed to measure differences in force or accelerations, across three planes of movement, across time to assess physical activity (Cliff et al., 2009).
• **Early childhood**: Children aged between 0 and 5 years

• **Electronic media use**: all of the time an individual engages with electronic media (Tremblay et al., 2017)

• **Executive function**: Higher-order cognitive process involved in goal-directed behaviour, responsible for paying attention and concentration, formulating goals, planning on how to achieve them, and carrying out these plans effectively (Miyake et al., 2000). In the context of this thesis, core executive functions consist of: (i) activating and working with information in mind (working memory); ii) changing our attention from one stimulus to the next, whilst ignoring irrelevant information (shifting); and, iii) resisting impulses toward goal-irrelevant stimuli and behaviours, as well as distractions (inhibition; Diamond, 2013).

• **Modified organized sport**: Modified organized sport is a modified version of the activities and games in organized sport (i.e., changes to the rules, equipment, and/or physical space) to match the developmental capabilities of children. The key focus of modified organised sport is on learning and development, with aspects of appropriate competition but not on competition per se, while trying to support inclusion and maximise participation (Eime et al., 2012).

• **Physical Activity**: Bodily movement that is produced by the contraction of skeletal muscles that results in increases in energy expenditure (Bouchard, Shephard, & Stephens, 1994).

• **Preschool children**: Children aged between 3 and 5 years

• **Psychosocial health**: The presence of higher levels of positive, and lower levels of adverse psychological behaviours; such as lower levels of negative traits, such as
internalising problems (i.e., emotional problems and peer problems) and
externalising problems (i.e., conduct disorders and hyperactivity-inattention; Diener & Ryan, 2008).
1.6 Overview of thesis

This thesis is comprised of five original research studies, two of which have been accepted for publication in peer-reviewed journals (Chapters 3 and 6), and three of which are under review in peer-reviewed journals (Chapters 4, 5 and 7). The studies described in Chapters 3 and 4 address Research Question 1, by examining the cross-sectional and longitudinal associations of different physical activity intensities and modified organised sport with executive functions and sub-domains of psychosocial health in preschool children, respectively. Chapters 5 and 6 address Research Question 2, by examining the cross-sectional and longitudinal associations of overall electronic media use as well as different types of electronic media with executive functions and sub-domains of psychosocial health in preschool children. Chapter 7 address Aim 3, by examining whether compliance with Australian 24-h Movement Guidelines for the Early Years is associated with executive functions and psychosocial health in preschool children cross-sectionally and longitudinally. Chapter 8 provides a reconciliation of the main findings of this thesis, considers the strengths and limitations of the research, and provides recommendations for future research and discusses the practice and policy implications of these findings.
Chapter 2: Literature Review
2.1 Introduction

This chapter is structured according to the Behavioural Epidemiology Framework (Sallis, Owen, & Fotheringham, 2002) to review and evaluate the evidence on associations of physical activity and electronic media use with cognition and psychosocial health in the early years. This chapter will describe relevant background literature in order to provide a rationale for the research undertaken as part of this thesis. First, physical activity, electronic media use, and cognitive and psychosocial health will be defined. This is followed by a description and evaluation of the methods used to measure these exposures and outcomes. The literature review will then discuss physical activity and electronic media use guidelines for the early years and examine current prevalence rates. Evidence of associations between physical activity or electronic media use and cognitive and psychosocial health outcomes will then be reviewed, followed by a comparison of the evidence base in school-aged children and the early years, and a discussion of plausible mechanisms to explain potential associations. Lastly, this literature review will discuss the translational of research in this area into practice and policy and highlight the gaps in the evidence base that need to be addressed.

2.2 Definition of early childhood

Early childhood, defined as ages 0- to- 5 years and encompassing the preschool years (3- to 5-years). The developmental stage of early childhood, and particularly the preschool period, is a critical time when foundations are laid for the development of longitudinally persistent and influential health behaviours, such as physical activity and electronic media use (Jones, Hinkley, Okely, & Salmon, 2013).
2.3 Definition and measurement of physical activity

Physical activity is defined as any bodily movement produced by contraction of skeletal muscles that requires energy expenditure above resting levels (Caspersen, Powell, & Christenson, 1985). Physical activity is categorised by intensity, using ranges of metabolic equivalents (METs) – one MET is equivalent to resting energy expenditure – as a reference. These categories include sedentary behaviour (≤ 1.5 METs), light intensity physical activity (LPA: 1.6 – 2.9 METs), moderate intensity physical activity (MPA: 3.0 – 5.9 METs) and vigorous physical activity (VPA: ≥ 6.0 METs). While physical activity in adults is often planned, structured and habitual, physical activity in children is often sporadic, unstructured and short in duration (Obeid, Nguyen, Gabel, & Timmons, 2011).

2.3.1 Subjective measures of physical activity

Subjective methods to assess physical activity include self-reports, parent-reports, questionnaires, diaries or interviews. Although these methods are inexpensive, they are inappropriate for children in the early years (Atkin et al., 2012). For self-reports, the age of participants and their lack of ability to conceptualise physical activity, including memory of these activities, may impede their ability to recall such events. For this reason, parent-proxy reports are often used, but these also have inherent biases, and tend to overestimate physical activity (Cliff et al., 2009). Alternatively, direct observation offers a more objective approach, however this method is only appropriate for confined settings, such as child care centres/preschools, and can be costly and time consuming (Sylvia, Bernstein, Hubbard, Keating, & Anderson, 2015).
2.3.2 Objective measures of physical activity

Due to the sporadic and intermittent nature of young children’s physical activity, accelerometry has become the method of choice for assessing this behaviour in early childhood (Cliff et al., 2009; Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006). Accelerometers are a small, light and robust device that can be worn on the body. Accelerometers are instruments designed to measure time varying differences in force or acceleration. When applied to the measurement of physical activity, an accelerometer can assess the magnitude and total volume of movement as a function of time (Cliff et al., 2009). The Actigraph activity monitor is one of the most widely used accelerometers among paediatric populations (Cain, Sallis, Conway, Dyck, & Calhoon, n.d.). Age-appropriate and validated cut points can be applied to accelerometer data to establish varying intensities of physical activity. For pre-schoolers, cross-validation evidence (Janssen et al., 2013) supports the use of the Pate et al. (2006) cut-points: ≥25 - 419 counts per 15s for LPA; ≥420 - 841 counts per 15s for MPA; ≥842 counts per 15s for VPA; ≥420 counts per 15s for Moderate-to-Vigorous Physical intensity Activity (MVPA); and ≥25 counts per 15s for Total Physical Activity (TPA). It is important to distinguish between physical activity intensities for early childhood for several reasons. For instance, in addition to the health benefits of MVPA, emerging evidence in older children suggests that engagement in LPA may elicit health benefits (Carson et al., 2013). Likewise, there is also evidence in older children that supporting engagement in VPA might be beneficial for health, as Poitras and colleagues (2016) concluded that higher intensities of physical activity (i.e., MVPA and VPA) were more frequently examined and had both more consistent associations and larger effect sizes than lower intensity physical activity (i.e., LPA and MPA).
While accelerometers can be advantageous in minimising researcher or participant-reporting bias, they are not without limitations. Accelerometers only accurately assess movement of the body segment where the device is attached. Therefore, movement of the arms and legs will not be accurately measured if the monitor is placed on the waist (Cliff et al., 2009). Moreover, accelerometers cannot distinguish between different types of physical activities or sedentary behaviours, therefore limiting our understanding of the context in which the behaviour occurs. Most accelerometers are now water resistant, but some are not water-proof, thus water-based activities will not be captured and recorded by such devices.

2.4 Definition and measurement of electronic media use

Electronic media use includes all of the time an individual engages with electronic media (Tremblay et al., 2017). In the interest of clarity, electronic media use will be used as an umbrella term that encompasses all electronic media behaviours that children engage in, including watching TV or DVDs, or viewing programs on any device (thereby combining viewing programs on traditional and non-traditional devices, herein referred to as program viewing); playing games or apps on an electronic tablet, hand-held device or computer; or playing video games on a console system. Passive electronic media activities would include those in which there is typically limited interaction between a child and the media (i.e., program viewing), while interactive electronic media activities include those in which a child actively responds to stimuli on the screen (i.e., electronic apps or games). For young children, electronic media use behaviours have traditionally been limited to TV/DVD viewing and/or computer use (Common Sense Media, 2017). However, touch-screen technology has led to the development of new platforms for engagement, such as electronic tablets and smart phones, resulting in an increase in availability of contemporary electronic
apps and games. It is important to consider all electronic media behaviours present in today’s society, as technological advancements now mean that mobile devices can provide preschoolers with unprecedented access to electronic media. Thus, preschool children can engage with traditional or contemporary forms of electronic media in almost any context and at any time of the day. This may include meal times, during transportation, during daily activities in or out of the home, or in their bed (Tremblay et al., 2017). Interestingly, Australian parents recently identified excessive “screen time” as the number one issue facing children’s health (Rhodes, 2015).

2.4.1 Subjective measures of electronic media use

Subjective measures, including parent-report questionnaires, diaries or interviews are the most common methods used to assess young children’s electronic media use (Hardy et al., 2013; Lubans et al., 2011). Similar to subjective measures of physical activity, although these methods are inexpensive, they are inappropriate for preschool children to complete themselves due to issues of recall and lack of clarity around the concept of reporting their media use. For this reason, parent-proxy reports are typically used, although there is the potential for estimates to be biased by over- or under-reporting (Colley et al., 2012; Robinson, Winiewicz, Fuerch, Roemmich, & Epstein, 2006).

2.4.2 Objective measures of electronic media use

Objective measures, including screen monitoring devices, wearable cameras, or screen monitoring software have also been used to assess children’s electronic media use (Hardy et al., 2013; Lubans et al., 2011). These emerging methods of data collection may help to objectively measure and analyse an individual child’s behaviour that is constantly
changing with intermittent use of contemporary electronic devices. Screen monitoring devices requires a unit to be attached to each screen (e.g., TV, computer), and individuals need to log-in using unique codes or tokens. This may be suitable for traditional devices such as TV viewing, but not for contemporary devices such as handheld devices. Although screen monitoring software could overcome these limitations, capturing habitual total media use would still require data to be captured and combined from all possible devices thus making this process lengthy and complicated. Wearable cameras is another option, by capturing images using momentary time sampling (Doherty et al., 2013). However, at present there a number of ethical dilemmas of privacy and confidentiality, as well as each method remains expensive, difficult to achieve a large sample size and involves a lengthy process to analyse (i.e., processing a large number of photos). Although these methods provide objective assessments of electronic media use, they are still in their infancy and require further development and validation for use in early childhood, making their use problematic. Because of these challenges, parent-proxy reports remain the most common measures of electronic media use in young children.

2.5 Guidelines for physical activity and electronic media use in the early years

In recognition of the potential developmental benefits for young children of engaging in sufficient physical activity and limiting electronic media use, several countries including Australia (Department of Health and Aging, 2010), the United Kingdom (Department of Health Physical Activity Health Improvement and Protection, 2011), and Canada (Tremblay et al., 2012) developed physical activity and electronic media use guidelines for the early years (0-to 4 years) between 2010 and 2012. More recently, there has been a shift towards a more holistic approach to these behaviours across the day,
acknowledging the potential importance for children’s health and development in relation to the full spectrum of “movement behaviours” including physical activity, sedentary behaviour (including electronic media use) and sleep. Systematic reviews indicate that sleep (Chaput et al., 2017), sedentary behaviour (Poitras et al., 2017), and physical activity (Carson, Lee, et al., 2017) are individually associated with health and developmental outcomes across the early years. In light of this, the Canadian 24-Hour Movement Guidelines for the Early Years (Tremblay, Chaput, et al., 2017), and the adolopment of these guidelines in Australia (Okely et al., 2017) were released in 2017. These guidelines recommend that for pre-schoolers, a healthy 24 hours should include: i) at least 180 min of physical activity, of which at least 60 min is energetic play (i.e., MVPA); ii) no more than 1 h of sedentary screen time; and iii) 10 to 13 h of good quality sleep (Okely et al., 2017).

2.5.1 Prevalence of physical activity and electronic media use in the early years

National data from the Australian Health Survey using parent-reported physical activity indicated that in 2011-2012, 84% of 2- to 4-year-olds averaged more than 3 hours of physical activity per day, and 43% engaged in no more than 1 hour of electronic media per day (Australian Bureau of Statistics., 2013). Further, although the total daily duration of electronic media use has remained relatively stable in the past years among young children, the types of devices have changed significantly, with interactive devices becoming more common (Common Sense Media, 2017). However, some evidence suggests that when children use interactive devices, a high proportion of time is spent using them for passive content such a viewing programs, and exposure to playing apps and electronic games is less common (Kilic et al., 2019).
Since the release of the 24-Hour Movement Guidelines for the Early Years in Australia, compliance studies in toddlers (Santos et al., 2017) and pre-schoolers (Cliff, McNeill, Vella, Howard, Santos, et al., 2017) using smaller samples indicate high proportions of children met the physical activity guidelines (97% and 93% respectively), however, fewer (11% and 17% respectively) met the screen time guideline. Efforts to maintain the high prevalence rates for physical activity and increase adherence to the screen time guidelines are thus needed.

2.6 Relationship of physical activity and electronic media use with health indicators in early childhood

Although it is well established that physical inactivity and high levels of electronic media use are associated with adverse health outcomes in older children (Carson, Hunter, et al., 2016; Poitras, Gray, Borghese, Carson, Chaput, & Katzmarzyk, 2016), there are several gaps and limitations in the literature pertaining to early childhood (Carson, Lee, et al., 2017; Poitras et al., 2017). A systematic review conducted by Carson and colleagues (2017) on physical activity and health indicators synthesised 96 studies in early childhood. Their main conclusion was that higher levels of physical activity, in frequency or duration of MVPA, VPA and TPA, were consistently associated with improvements in adiposity, healthy bone development, motor skill development, and aspects of cardio-metabolic health in experimental studies. However, associations for LPA and MPA were not consistently associated with any health indicators (Carson, Lee, et al., 2017). In contrast, a recent systematic review that synthesised data from 96 studies concluded that electronic media use was detrimentally associated with adiposity, motor development, cognitive development, and psychosocial health in the early years (Poitras et al., 2017).
Despite evidence of associations between physical activity and electronic media use with multiple indicators of health, the authors identified several key evidence gaps. For instance, most studies included parental-reported measures of physical activity, which are prone to biases (Carson, Lee, et al., 2017). Furthermore, mixed associations are evident between physical activity and cognitive and psychosocial health in the literature. Consistent positive associations were demonstrated in experimental studies for cognitive and psychosocial health outcomes, but associations across observational studies were not consistent (Carson et al., 2017).

Likewise, a large number of studies focused on TV viewing as the primary measures of children’s electronic media use, but few studies investigated more recent types of contemporary electronic media behaviours such as apps (Poitras et al., 2017). As such, more studies using objective measures of physical activity and considering contemporary electronic media use are needed, particularly in the domains of cognitive and psycho-social development. Given previous findings, it could be expected that patterns of association may not be uniformly positive, negative, or even present across the physical activity and screen time predictors of cognitive and psychosocial health in early childhood.

2.7 Health indicators: cognitive and psychosocial development

While the term cognitive development is necessarily broad, research has tended to focus on aspects of early cognition that are important for adaptive functioning in the here-and-now, as well as for influencing trajectories toward positive outcomes. Core cognitive capacities that appear foundational to development include attention, executive functions, intelligence, and learning (Tomporowski et al., 2009). There also appear to be reciprocal links between cognitive and psychosocial development, with both seeming to influence a broad range of developmental trajectories throughout childhood and beyond.
2.7.1 Cognitive Development

Executive functions in particular are considered a key component of early cognitive development (Diamond, 2013). They consist of multiple inter-related, top-down processes responsible for assisting humans to focus and sustain attention, formulate goals, plan how to achieve them, and carry out these plans (Diamond, 2013; Miyake et al., 2000). There is general consensus that there are three ‘core’ executive functions responsible for effortful control of our attention, namely: i) activating, maintaining and working with information in mind (working memory); ii) flexibly switching our attention from one stimulus to the next, toward goal-relevant stimuli or processing and away from task-irrelevant aspects (shifting); and, iii) resisting temptations, impulses and distractions (inhibition; Diamond. 2013).

Although an individual’s executive functioning appears to develop gradually through to at least adolescence, this change occurs more rapidly across early childhood (Best & Miller, 2010).

Executive functions are a strong indicator of school readiness, and a better predictor of academic achievement in childhood than even one’s Intelligence Quotient (Blair & Razza, 2007). Specifically, research indicates that executive functions are associated with early literacy and numeracy skills (Blair & Razza, 2007), perhaps as a consequence of its role in learning throughout childhood (Bull, Espy, & Wiebe, 2008). Executive functions are also implicated in mental, physical and prosocial outcomes longitudinally. For instance, a study conducted by Moffitt et al. (2011) found children who displayed better self-control (which is under-pinned by executive functions; Hofmann, Schmeichel, & Baddeley, 2012) in childhood had better physical and mental health outcomes 30 years later than those with poorer self-regulation.
2.7.2 Plausible mechanisms through which physical activity might influence cognition

Studies in animals and older adults have investigated physiological and neurological mechanisms at the cellular and behavioural level to understand possible reasons for the relationship between physical activity and cognition (Voss, Vivar, Kramer, & van Praag, 2013). Proposed physiological and neurological mechanisms that are proposed to justify the exercise-cognition relationship suggest that physical activity leads to changes in the structural and functional composition of the brain. These include three broad categories: (1) cells, molecules, and circuits that at present are only detectable in animal studies (e.g., neurogenesis and synaptogenesis); (2) biomarkers (e.g., grey matter volume, cerebral blood flow), and; (3) peripheral biomarkers (e.g., circulating growth factors, neurotransmitters, neurotrophic factors, oxygen availability, glucose regulation and oxidative stress; Voss, Carr, Clark, & Weng, 2014).

To support these mechanisms, several hypotheses have been used to explain the ways through which physical activity might influence cognition. The most widely recognised is the physiological hypothesis (also known as the cardiovascular fitness or cerebral hypothesis; Chodzko-Zajko & Moore, 1994), which seizes on the fact that physical activity at increasing intensities induces oxygen and glucose to transport to the brain via an increase in blood flow (Dustman & White, 2006; Marmeleira, 2013). As oxygen and glucose are not stored in the brain, the vascular system must quickly respond to environmental demands on the central nervous system by resupplying activated brain areas with these substances. This increase in resources is speculated to account for the finding of positive associations for physical activity with cognition (Dustman & White,
2006), although this hypothesis would be challenged by findings that only some forms of physical activity relate to only particular aspects of cognition.

Another plausible alternative to explain this relationship is the neurotrophic stimulation hypothesis. This explanation implicates the increased plasma brain-derived neurotrophic factor as a result of physical activity. Plasma brain-derived neurotrophic factor is a protein that supports health and functioning of neuronal activity, synaptic structure, and neuronal plasticity (Dustman & White, 2006; Voss et al., 2014). Therefore, it is plausible that high intensity physical activity, particularly MVPA and VPA, might hold stronger associations with executive functions than LPA in early childhood through these mechanisms. Evidence of associations for different physical activity intensities in the early years is needed to be able to evaluate this hypothesis, given that guidelines for the early years have historically promoted all intensities of physical activity (i.e., TPA) – although evidence on the health benefits of MVPA in early years is emerging (Carson, Lee, et al., 2017) and recent guideline updates have also highlighted the importance of "energetic play", which is operationalised as MVPA (Okely et al., 2017; Tremblay, Chaput, et al., 2017). Although experimental studies are increasingly reporting the cognitive benefits of participating in physical activity in children and adolescents, the mechanisms of these associations have not been fully elucidated – with especial gaps in the early years (Voss et al., 2013).

2.7.3 Psychosocial Development

Psychosocial health includes the presence of higher levels of positive and lower levels of adverse psychological behaviours, such as lower levels of negative traits, including internalising problems and externalising problems (Diener & Ryan, 2008).
Internalising behaviours are those that centrally affect a child’s internal psychological environment. These include: anxiety; withdrawn, inhibited and depressive symptoms; and emotional problems (Cumberland et al., 2003). Externalising behaviours are problem behaviours that negatively act on the external environment. These include disruptive, hyperactive, aggressive and anti-social behaviours (Cumberland et al., 2003). Prosocial behaviours are a broad range of actions intended to benefit one or more people other than oneself—behaviours such as helping, comforting, sharing and cooperation (Cumberland et al., 2003). Fewer internalising and externalising problems, and better prosocial behaviour reflect better psychosocial health (Goodman, Lamping, & Ploubidis, 2010).

In Australia, approximately 10% of 4- to 5-year-olds display consistent behavioural problems in these areas (Smart, 2010). Further, it has been estimated that almost one in seven Australian children aged 4- to 17-years has suffered from a mental disorder within the previous 12 months, equivalent to ~560,000 children nationally (Smart, 2010). These high prevalence rates of psychiatric symptoms and disorders have high continuity into adolescence and adulthood, thereby placing children at risk of problematic developmental trajectories (Fergusson, Horwood, & Ridder, 2005). More than just affecting mental health, childhood externalising and internalising psychopathologies are additionally associated with adverse health behaviours, and health outcomes in adulthood (Jokela, Power, & Kivimäki, 2009). Conversely, research indicates that positive psychosocial health in early childhood is associated with better academic achievement and lower risk of adverse mental health outcomes (i.e., lower levels of depression and aggressive interpersonal behaviours) on entry to formal schooling (Jones, Brown, & Lawrence Aber, 2011; Meagher, Arnold, Doctoroff, Dobbs, & Fisher, 2009).
2.7.4 Plausible mechanisms through which physical activity might influence psychosocial health

Self-Determination Theory suggests that physical activity could influence an individual’s psychosocial health through satisfying their basic psychological need for connectedness, autonomy, self-acceptance, environmental mastery and purpose in life (Deci & Ryan, 2002). Lubans et al. (2016) further extended upon the work of Deci and Ryan (2002) to present a conceptual model to explain how physical activity might influence cognitive and mental health outcomes in young people. The model proposes three potential mechanisms: i) neurobiological; ii) psychosocial; and, iii) behavioural. In neurobiological mechanisms, physical activity leads to changes in the structural and functional composition of the brain (Voss, Carr, Clark, & Weng, 2014), as aerobic exercise leads to an increase in oxygen and glucose to be transported to the brain via an increase in blood flow (Dustman & White, 2006; Marmeleira, 2013). This increase in resources may enhance aspects of psychosocial health, in the same manner as for cognition (Dustman & White, 2006). Similarly, physical activity at increasing intensities induces plasma brain-derived neurotrophic factor, which also might have positive effects on psychosocial health.

In relation to the psychosocial hypothesis, Luban and colleagues suggest that participating in physical activity provides opportunities for social interaction (relatedness), mastery in the physical domain (self-efficacy, self-esteem, and perceived competence), improvements in self-perceptions of appearance (body image), and independence (autonomy). The behavioural hypothesis proposes that potential changes in mental health outcomes that result from physical activity are mediated by changes in relevant and
associated behaviours. For example, physical activity may improve sleep onset latency (Lang et al., 2013) and reduce sleepiness (Gaina et al., 2007), which in turn may result in improved psychosocial health.

2.7.5 Associations of physical activity with executive functions and psychosocial health in school-aged children and youth

In a meta-analysis, Etnier and colleagues (1997) reported that acute exercise had a small but significant positive association (Hedge’s g = 0.36) on cognitive performance in children (6 to 13 years), based on 134 studies which were predominantly correlational. Similar positive effect sizes (Hedge’s g = 0.32) were reported by Sibley and Etnier (2003) in their meta-analysis of 44 studies examining associations between physical activity and cognition in 4- to 18-year-olds, with the largest effects seen in children aged 4 to 7 years (Hedge’s g = 0.40). This meta-analysis included acute and chronic exercise studies, as well as randomised control trials, cross-sectional studies. A recent review of the health benefits of objectively-measured physical activity in school-aged children and youth reported limited but favourable associations with cognition/academic achievement based on eight included studies (Poitras, Gray, Borghese, Carson, Chaput, & Katzmarzyk, 2016). Specifically, experimental evidence demonstrated that increases in MVPA lead to improvements in executive functions in young school children (Fisher et al., 2011). Similarly, beneficial improvements in executive function and mathematics achievement were demonstrated following an after-school exercise program (20 and 40 min/day) among 7- to 11-year-old overweight/obese children after 13 weeks, compared to a control condition (Davis et al., 2011).
With respect to psychosocial development, the review examining associations between objectively-measured physical activity and health indicators in 5- to 17-year-olds conducted by Poitras and colleagues (2016) identified only one study that examined relationships of physical activity with behavioural conduct and pro-social behaviours. Cross-sectionally, among boys, peer problems were negatively associated with MVPA, and positively associated with conduct problems. Prosocial behaviour was unrelated to physical activity in boys. Social functioning was not associated with physical activity among girls in 652 children aged 10-to 11-years (Sebire et al., 2011). Another study not included in this review also found that MVPA had a significant negative correlation with internalising difficulties, but was positively correlated with externalising difficulties and conduct problems in 1013 children aged 10-to 11-years (Page, Cooper, Griew, & Jago, 2010). The review by Poitras and colleagues (2016) concluded that the available evidence was limited and insufficient to make sound conclusions about associations between physical activity and behavioural conduct or pro-social behaviours. However, a meta-analysis of data from 57 experimental studies conducted among 10- to 21-year-olds reported small-to-moderate effects of physical activity interventions on externalising problems ($d = 0.320$), internalising problems ($d = 0.316$) and self-concept ($d = 0.297$; Spruit, Assink, van Vugt, van der Put, & Stams, 2016).

In a review of experimental evidence conducted in any age group, Best (2010) concluded that cognitively-engaging exercise had a stronger effect on cognition than exercise that was not cognitively engaging. It is thus plausible that cognitively engaging physical activities such as participation in sports, which combine physiologically-enhancing physical activity with cognitive challenges associated with the goals, rules and tactics of game play, may be more strongly associated with cognition than any exercise or physical
activity without these cognitive challenges (e.g., running on a treadmill; Diamond, 2015). However, few studies have examined these associations in children and adolescents. From the available evidence, Chang, Tsai, Chen, and Hung, (2013) tested whether participation in a low- versus high-impact soccer training program (two 35-min sessions/week for 8 weeks, identified at 40–50% or 60–70% of maximal heart rate, respectively) influenced changes in executive functions during an experimental study involving 26 children aged 6- to 7-years. Interestingly, both groups demonstrated improvements in performance on an executive function task of inhibitory control. Unfortunately, the lack of a control group limited the interpretation of the study findings. Howard et al. (2018) observed that young children who participated in individual sports at 4- to 5-years demonstrated marginally but significantly higher self-regulation than those who did not participate two years later. However, participation in team sports at 4- to 5-years did not predict change in self-regulation at age 6 in a sample of 4385 children. Additionally, following a 3-month martial arts intervention (2 or 3 x 45-min sessions), results indicated that the martial arts group demonstrated greater improvements than the comparison group in self-regulation and affective self-regulation, and prosocial behaviour in 193 5- to 11-year old children.

In contrast to the limited evidence of associations between sport participation and executive functions in children, sports participation has been associated with the protection and enhancement of mental health (Fraser-Thomas, Côté, & Deakin, 2005). A systematic review (Eime, Young, Harvey, Charity, & Payne, 2013) and meta-analysis (Ahn & Fedewa, 2011) that synthesised 30 and 73 studies in children and adolescents, respectively, reported that participation in sport was beneficial to mental and psychosocial health above and beyond improvements attributable to participation in physical activity alone. Collectively, evidence on school-aged children and adolescents suggests that some positive associations
are apparent between physical activity or sport participation with domains of cognition and psychosocial health. As such, it is plausible to hypothesise that similar associations may exist during early childhood.

2.7.6 Associations of physical activity with executive functions in early childhood

Evidence of the presence, nature and degree of associations between physical activity and cognition in the early years is less substantial and consistent (Carson, Hunter, et al., 2016; Carson, Lee, et al., 2017). A review conducted by Carson and colleagues (2016) examining associations between physical activity and cognitive development in early childhood found four of seven studies that examined executive functions with preschool-aged children. These consisted of three cross-sectional (Becker, McClelland, Loprinzi, & Trost, 2014; Campbell, Eaton, & McKeen, 2002; Irwin, Johnson, Vanderloo, Burke, & Tucker, 2015) and one cross-over trial (Palmer, Miller, & Robinson, 2013). Of the four studies identified by Carson et al. (2016) that utilised objectively measures physical activity, acute changes in physical activity resulted improvements in sustained attention compared to a control group (Palmer et al., 2013). The remaining three observational studies found: positive associations with higher frequency of physical activity over a 24-hour monitoring period and behavioural control in children 4- to 6-years of age (Campbell et al., 2002); higher duration of active play during recess, quantified as MVPA and broader aspects of executive function (e.g., self-regulation; Becker et al., 2014); while total physical activity and MVPA were not associated with attention span in another study (Irwin et al., 2015). Similarly, another review of physical activity and health indicators that included; adiposity, motor development, psychosocial health, cognitive development, fitness, bone and skeletal health, cardiometabolic health in the early years found only 13
studies that investigated associations with aspects of cognitive development (Carson, Lee, et al., 2017). Of those 13, no additional studies examining the relationship between objectively measured physical activity and executive functions in preschoolers were identified in comparison to the review by Carson and colleagues (2016). From the four aforementioned studies it is difficult to understand if: i) chronic habitual physical activity that is less structured, or; ii) physical activity of different intensities (LPA, MPA, VPA or MVPA) is associated with executive functions in preschool children.

Following the review by Carson and colleagues (2017), two published cross-sectional studies examined associations between objectively-measured physical activity and executive functions in pre-schoolers. In one, null associations were observed for all intensities of physical activity with working memory and inhibition in a sample of 100 Canadian preschoolers (Carson, Rahman, & Wiebe, 2017). In the other, only the proportion of time spent in MVPA was negatively associated with executive functions in a sample of 85 preschoolers from the United States (Willoughby, Wylie, & Catellier, 2018). Thus, the two studies examining habitual activity in this area suggest that associations between physical activity and executive functions might be null (n = 1) or unfavourable (n = 1) in preschoolers.

In conclusion, the evidence of associations between objectively-measured physical activity intensity and executive functions in preschoolers is limited to two modestly-sized cross-sectional study’s with contrasting findings (Carson, Rahman, et al., 2017; Willoughby et al., 2018). The limited observational studies using objective measures of physical activity to examine associations with executive functions additionally highlights ongoing concerns about measurement accuracy. Further, the cross-sectional study designs prevent confident conclusions about the longer-term, chronic influence of habitual physical
activity at different intensities for children’s early cognitive development (e.g., executive functions).

2.7.7 Associations of physical activity with psychosocial health in early childhood

Although evidence in school-aged children indicates that physical activity is associated with psychosocial health (Spruit et al., 2016; Carson et al., 2016), evidence in the early years is inconsistent, albeit growing. As identified in Carson and colleagues’ review (2017), 11 studies were identified examining associations of physical activity with psychosocial health, however only four studies examined associations between objectively-measured physical activity and domains of psychosocial health: one longitudinal (Hinkley, Timperio, Salmon, & Hesketh, 2017), two cross-sectional (Ebenegger et al., 2012; Irwin et al., 2015), and one experimental (Bonvin et al., 2013). One longitudinal study (Hinkley et al., 2017), one cross-sectional study (Irwin et al., 2015), and one experimental study (Bonvin et al., 2013) reported null associations between physical activity and psychosocial health, while one cross-sectional study reported an unfavourable association between physical activity and psychosocial health (Ebenegger et al., 2012). No associations were observed between objectively measured habitual physical activity intensity with social or emotional health (n=108), examined by the Emotional Quotient Inventory (Hinkley et al., 2017). In contrast, higher levels of TPA and more time spent in MVPA were associated with higher levels of hyperactivity/inattention assessed using the SDQ, among 450 children aged 4 to 6 years (Ebenegger et al., 2012). Thus, findings from these two studies examining associations of objectively measured physical activity with psychosocial difficulties suggest that associations may be null (n = 1) or unfavourable (n = 1). Drawing conclusions in
regard to associations between physical activity and psychosocial health is difficult due to this limited evidence.

2.7.8 Plausible mechanisms through which sport might influence cognition and psychosocial health

In addition to the potential influence of the intensity of physical activity on executive functions, field leaders have hypothesised that activities that combine physical activity with cognitive challenges may hold stronger associations with executive functioning than simple aerobic movements (e.g., walking and running; Best, 2010; Diamond, 2015; Diamond & Ling, 2016). According to Diamond (2015), sport may be a type of physical activity that might be particularly beneficial for developing and enhancing executive functions, due to its integration of cognitive challenges and physical activity (see also Best, 2010). Modified organised sport involves an environment that demands a constant and rapid shift in attention, in that children may have to shift their attention between a variety of players, rules, and strategies, which requires an engagement of one’s executive functions (Howard, Vella, & Cliff, 2018). This hypothesis may suggest a plausible mechanism explaining the effects of physical activity on executive functions, and thus associations for other important areas of health such as academic achievement, might also depend on the duration or type (aerobic vs cognitively engaging) – instead of and/or in addition to the intensity – of physical activity.
2.7.9 Associations of sport with executive functions and psychosocial health in early childhood

For preschool-aged children, one of their first experiences of cognitively engaging physical activities might come in the form of modified organised sport, such as football, developmental gymnastics or swimming. Consistent with the proportion of studies examining associations between physical activity and executive functions, studies examining associations for modified organised sport and executive functions are also limited. One cross-sectional study in preschool children (n = 100) observed null associations between participation in organised physical activity (i.e., modified organised sports) and executive functions (Carson, Rahman, et al., 2017).

Consistent with the evidence base for executive functions and participation and modified organised sport, limited evidence exists examining associations between modified organised sport participation with psychosocial health in the preschool years (Carson, Lee, et al., 2017; Venetsanou, Kambas, & Giannakidou, 2015). One cross-sectional study (n = 13,470) of 5 year-old children from the UK found that those who participated in sport had fewer total difficulties (emotional, conduct, hyperactivity-inattention and peer relationship problems), and displayed more positive prosocial behaviours than those who did not (Griffiths, Dowda, Dezateux, & Pate, 2010). Similarly, one experimental study (n = 40) demonstrated that preschoolers who participated in a creative dance program improved their social competence, and internalising and externalising behaviours, more than those who did not participate (Lobo & Winsler, 2006). In summary, the findings from the one study examining associations between participation in modified organised sport and executive function suggests associations maybe null (n = 1). However, the findings from the two studies examining participation in modified organised sport and psychosocial
health suggests associations maybe favourable (n = 2). Longitudinal designs would allow researchers to understand if potential associations, persist over time. Similarly, of the aforementioned studies examining associations of modified organised sport participation with executive functions and psychosocial health, no studies adjusted for physical activity. It is therefore unknown whether the observed benefits are due to sport participation and its associated context, or to the physiological effects of physical activity that is inherent in sports.

2.7.10 Plausible mechanisms through which electronic media use might influence cognition

A growing body of literature is associating excessive and addictive use of electronic media with adverse physical, psychological, social and neurological consequences (Lissak, 2018). As hypothesised by Christakis (2014), one plausible mechanism through which electronic media use might influence cognition may be through overstimulation of the developing brain, due to the rapid, fast and changing pace, and frequent cuts and edits in electronic media content. This was demonstrated using a controlled experimental design, in which preschool-aged children’s executive functions were significantly impaired immediately after watching just nine minutes of a popular fast-paced television show relative to watching educational content (Lillard & Peterson, 2011). Christakis (2014) further suggests the displacement of time that could otherwise be spent in developmentally beneficial activities as another potential mechanism through which exposure to electronic media may indirectly affect cognition. The displacement hypothesis proposes that time spent engaging in electronic media may displace time away from other developmentally rich exploratory activities that may enhance aspects of cognition (e.g., puzzles, block play,
or card games). Another plausible mechanism is related to the role of dopamine and its implication to attentional problems. Dopamine is produced in response to screen novelty within the striatum, and has been found to occur quickly in young adult brains while playing computer games (Weinstein, 2010). Some researchers suggest that extensive electronic media use, particularly electronic gaming, may lead to long-term changes in the reward circuitry that may resemble the effects of substance dependence (Sigman, 2012).

In addition to the hypothesised adverse health effects of these media behaviours, it is also important to consider differences between the devices available to children, and how these may exert different effects on health. Christakis (2014) summarizes these, comparing traditional features of toys such as block play, with contemporary interactive touch screen devices and passive, traditional devices such as the television. In his comparison Christakis suggested that interactive devices theoretically differ from traditional passive media use (TV viewing). For example, Christakis suggests that a touch screen is reactive, promotes joint attention, and is highly portable – all of which is consistent with the characteristics of playing with traditional toys. However, touch screens also have the additional advantage of being interactive, tailorable and progressive, while a television show provides none of these features. Although the American Academy of Paediatrics guidelines recommend children younger than 2 years do not use any electronic media (American Academy of Pediatrics, 2016), the potential developmental and educational benefits that may come from some electronic media activities through mobile touch screen technology have led some experts to reconsider this guideline. For example, Christakis (2014) proposes a pragmatic limit of <30min/day of developmentally-appropriate app use might be appropriate for children younger than 2-years-old. Yet the specific qualities, characteristics, doses, and patterns of contemporary electronic media use that may not be harmful, or may even be beneficial, for
young children’s development is largely unknown (Radesky & Christakis, 2016; Radesky et al., 2015). Further, the mechanisms might differ for passive and interactive media use, along with their effects on health and development.

### 2.7.11 Plausible mechanisms through which electronic media use might influence psychosocial health

One plausible explanation for potential detrimental relationships between electronic media use and psychosocial health is through the neurobiology of socialisation. That is, empathy and compassion are developed through reading the non-verbal nuances of others’ emotions (Sigman, 2012). Likewise, social meaning of others’ behaviours, and consequently the emotions of others, are thought to arise due to the multiple mirror neuron systems in the brain’s insular cortex (Dawes et al., 2012). This helps children carry out and understand the actions and intentions of others (Sigman, 2012). These fundamental social skills that facilitate interaction and communication with others, both verbally and non-verbally, are typically learnt through social interaction and face-to-face communication (Radesky et al., 2015). Consequently, it may be hypothesised that when children are engaging in electronic media use, this is displacing time and opportunity for social interaction, such as socialising face-to-face (i.e., engaging with peers, adults, or siblings that may support their psychosocial health and development).

The application of Luban and colleagues’ (2016) behavioural hypothesis may also be used to explain potential detrimental associations between electronic media use and psychosocial health. Engaging with electronic media can come at the expense of other behaviours such as sleep, which then acts as a mediator for health and development. Electronic media use has been shown to result in shorter sleep duration and quality in
infants and toddlers (Cheung, Bedford, Saez De Urabain, Karmiloff-Smith, & Smith, 2017). Furthermore, Beyens and Nathanson (2018) observed that total daily and evening television and tablet use were associated with later bedtimes and later wake times in preschoolers, but not with fewer hours of sleep. Additionally, they observed that heavier daily electronic media use was associated with poorer sleep consolidation in preschoolers. Thus, electronic media use may detract time away from behaviours that are needed for development during the critical developmental stage of the preschool period.

### 2.7.12 Associations of electronic media use with executive functions and psychosocial health in school-aged children and youth

Evidence in school-aged children and youth suggests that higher levels of habitual screen viewing are detrimentally associated with health outcomes (Carson, Hunter, et al., 2016). The systematic review conducted by Carson and colleagues’ (2016) reported on 235 studies, of which 16 investigated associations for cognitive outcomes. Interestingly, although some negative associations were identified in cross-sectional studies, associations were mainly null from TV viewing, computer use, and mobile phone use with academic achievement. However, based on evidence from longitudinal studies, higher levels of TV viewing were found to be associated with lower academic achievement (Carson, Hunter, et al., 2016).

In relation to psychosocial outcomes, a systematic review that synthesised 91 studies in school-aged children concluded that there was strong evidence that higher levels of screen time were detrimentally associated with mental health indicators, including hyperactivity/inattention problems, internalising problems, and perceived quality of life (Suchert, Hanewinkel, & Isensee, 2015). Additionally, the systematic review conducted by
Carson and colleagues (2016) identified 24 studies that examined associations between electronic media use and behavioural conduct and pro-social behaviours. The review concluded that higher levels of TV viewing and computer use were unfavourably associated with conduct and pro-social behaviours across observational studies. Further, computer and video game use were found to be negatively associated with emotional and social health indicators (self-esteem, behavioural conduct/pro-social behaviour; Carson et al., 2016). Collectively, the evidence in school-aged children suggests that electronic media use may be detrimentally associated with cognition and psychosocial health and so it is plausible to hypothesise that similar associations might be present during early childhood.

2.7.13 Associations of electronic media use with executive functions in early childhood

A recent systematic review conducted by Poitras and colleagues (2017) on the health consequences or benefits of electronic media use in the early years synthesised a total of 96 studies, of which 25 examined associations with cognition. However, only 1 cross-sectional study (Nathanson, Aladé, Sharp, Rasmussen, & Christy, 2014) and two longitudinal studies (Blankson, O’Brien, Leerkes, Calkins, & Marcovitch, 2015; Zimmerman, Glew, Christakis, & Katon, 2005) examined these associations with executive functions in preschoolers (Poitras et al., 2017). One additional cross-sectional study in preschool children that was published following this review was also retrieved (Carson et al., 2017). When examining associations for TV viewing, null associations were observed in one of two cross-sectional studies with executive functions (Carson et al., 2017), and in both longitudinal studies (Blankson et al., 2015, Zimmerman et al., 2005). Conversely, one cross-sectional study observed negative associations between TV viewing duration and a composite score of executive functioning (Nathanson et al., 2014). In addition, of these
studies, only one examined associations for total screen time, computer use and TV viewing separately, for which no associations were observed with executive functions (Carson et al., 2017). In summary, based on the four studies in this area, associations between screen time and executive functions appear to be predominantly null (3/4 studies). Yet previous studies have focused on TV viewing and few studies have investigated other types of contemporary media formats available to preschool children today. For instance, no study has examined associations between app use and executive functions in preschool children. Yet there is speculation that contemporary media such as apps may exert different effects than passive media behaviours (e.g., TV, program viewing), due to the potential for reactivity, interactivity, tailorable, progressiveness, promotion of joint attention, and portability of these interactive devices compared to the passive nature of TV viewing (Christakis, 2014). Aggregate measures of ‘electronic media use’ may therefore be conceptually problematic, as different types of electronic media behaviours might have different associations with cognitive outcomes. Furthermore, more longitudinal research is needed to understand if associations persist over time.

**2.7.14 Associations of electronic media use with psychosocial health in early childhood**

A systematic review conducted by Hinkley and colleagues (2014), on associations between sedentary behaviour, including studies of electronic media use, and psychosocial well-being in early childhood reported on 15 studies. Of these studies, only two cross-sectional studies (Ebenegger et al., 2012; Griffiths et al., 2010) examined associations for specific domains of internalising, externalising and prosocial behaviours. Subsequently, Poitras and colleagues (2017) conducted a review on sedentary behaviour, including studies of electronic media use and health indicators in early childhood. The review synthesised a total of 96 studies, of which 15 examined associations for broad domains of psychosocial
health. Of those, one longitudinal (Hinkley et al., 2014) and two cross-sectional studies (Linebarger, 2015; Teramoto, Soeda, Hayashi, Saito, & Urashima, 2005) examined associations for internalising, externalising and prosocial behaviours in preschoolers. In addition, one cross-sectional (Lee & Carson, 2017) and one longitudinal study (Hinkley et al., 2017) that examined associations between electronic media use and internalising, externalising and prosocial behaviours were published following these reviews. Five studies that examined associations for TV viewing reported a mix of negative and null associations. Teramoto et al. (2005) observed higher levels of habitual TV viewing were associated with increased total behaviour problems and internalising behaviour problems, but null associations were observed for externalising behaviour problems cross-sectionally. Similarly, higher levels of habitual TV viewing were associated with higher levels of hyperactivity and inattention cross-sectionally (Ebenegger et al., 2012). In contrast, Lee and Carson (2017) reported a mix of positive and null associations, in that more TV viewing was associated with higher emotional skills but not associated with social or interactive skills. Further, the two longitudinal studies reported that early TV viewing was not associated with being at risk of poorer psychosocial outcomes after 2 (Hinkley, Verbestel, et al., 2014) or 3 years (Hinkley et al., 2017). In summary, the five studies in this area suggest that associations between TV viewing and psychosocial health are predominately null (n = 3) or unfavourable (n = 2).

When examining associations of electronic media behaviours other than TV with psychosocial health amongst preschool children, findings are similarly mixed. Two cross-sectional studies observed predominately null associations between total electronic media use (i.e., TV/videos/DVD viewing and computer or electronic game use; Griffiths et al., 2010), and habitual video game use (Linebarger, 2015) with psychosocial health. Yet, using
screen entertainment for more than two hours per day was associated with higher emotional and conduct problems in girls only in one study (Griffiths et al., 2010). Of the two longitudinally studies, weekday e-game/computer use at age 4 years was associated with increased risk of emotional problems, but not peer problems, 2 years later (Hinkley, Verbestel, et al., 2014). Sedentary electronic console game use at 3-5 years was positively associated emotion-related factors (i.e., intrapersonal skills, stress management, emotional quotient; Hinkley et al., 2017) 3 years later. However, this study also found that early computer/internet use was negatively associated with interpersonal skills but positively associated with stress management skills 3 years later.

In summary, findings from the four studies that examined associations of electronic media behaviours other than TV viewing with psychosocial health are inconsistent (null: n = 2, unfavourable: n = 1, and mixed; positive and null: n = 1). No studies have reported on associations of app use with psychosocial development in preschool children. This may result in misleading conclusions if different forms of electronic media have different effects on children’s development. Given the profound developments in interactive technologies and available apps, combined with the changing nature of how preschoolers engage with and use such devices, research is needed to examine associations for different types of electronic media behaviours concurrently. This would help to explore the hypothesis that not all electronic media behaviours are equal (Przybylski & Weinstein, 2017). More robust longitudinal and experimental studies are also needed to provide evidence to understand whether associations, if any, persist over time and to overcome the possibility of reverse causality (i.e., children with adverse psychosocial outcomes have increased exposure to electronic media).
2.8 Translating research into policy and practice

The generation of a robust, reliable and consistent evidence base relating to the health and developmental benefits or consequences of physical activity and electronic media use in preschoolers can be used to inform parent and early childhood educator practices, policies and associated guidelines. For example, recent Movement Behaviour Guidelines for Early Years in Australia (Okely et al., 2017) and Canada (Tremblay, Chaput, et al., 2017) are founded on large systematic reviews from the available evidence (Carson et al., 2017; Poitras et al., 2018). There is, however, ongoing discussion surrounding physical activity (Okely, Tremblay, Reilly, Draper, & Robinson, 2019; Skouteris et al., 2012) and electronic media use recommendations (Straker, Zabatiero, Danby, Thorpe, & Edwards, 2018), since the intensity and type of physical activity, and the different types of electronic media that might influence areas of health and development in the early years, remain unclear (Carson et al., 2015; Carson et al., 2016; Carson et al., 2017; Hinkley et al., 2014; Poitras et al., 2017). Scholars have highlighted the importance and need for further evidence to examine the impact of physical activity and electronic media use on health and development (Carson et al., 2016; Carson et al., 2017; Hinkley et al., 2014; Poitras et al., 2017; Straker et al., 2018). Given the recognised importance of the early childhood period, and its implications for development (Straker et al., 2018), research in this area has the potential to inform programs and policies designed to optimise developmental outcomes in young children.

2.9 Conclusion

This literature review has provided an overview of the evidence and gaps in the literature relating to physical activity and electronic media use, and their associations with
executive function and psychosocial health in preschool children. It is plausible that health behaviours might also influence children’s cognitive and psychosocial health, yet there are a number of issues that limit our ability to draw such conclusions. Additional studies are needed that use objective measures to identify if the intensity of physical activity, as well as appraise the type of physical activity (e.g., modified organised sport), to examine the outcomes of physical activity on cognitive and psychosocial health in preschool-aged children. Similarly, studies are needed that assess children’s engagement with different types of electronic media – not only traditional and passive forms such as TV/program viewing, but also contemporary and interactive forms such as the use of electronic apps and games, and how these can influence children’s cognitive and psychosocial health.

It is important that we build on the current evidence base using longitudinal cohort studies to eliminate the possibility of reverse causality between behaviours and outcomes and to understand prospective associations, rather than just point-in-time associations that may be conflated or fleeting. This thesis aims to fill these gaps by comparing the cross-sectional and prospective associations of physical activity and electronic media use with cognitive and psychosocial health in preschool-aged children. Through investigating these associations, this thesis seeks to provide higher quality evidence to inform physical activity and electronic media guidelines for the early years and inform practices that promote healthy levels of physical activity and electronic media use.
Chapter 3: Physical activity and modified organised sport among preschool children: associations with cognitive and psychosocial health

This chapter has been published as:


Chapter 2 reviewed pertinent literature on physical activity as a modifiable factor that have been associated with executive functions and psychosocial health in preschool children and identified gaps in the evidence base that formed the aims and research questions for this thesis. This chapter address part of Aim 1: to examine the associations of objectively measured physical activity and modified organised sport with executive function and psychosocial health in preschool children cross-sectionally. In this chapter, the following research question is investigated:

Research Question 1: Do the associations between physical activity and executive functions or psychosocial health differ by the intensity (i.e., light- intensity physical activity, moderate- intensity physical activity, vigorous- intensity physical activity, moderate- to vigorous- intensity physical activity, and light- to vigorous intensity physical activity) or type (i.e., modified organised sports) of physical activity in preschool children?
3.1 Introduction

Executive functions are associated with many aspects of children's development including school readiness and academic achievement (Blair & Razza, 2007; Diamond & Ling, 2016). In the context of these investigations, executive functions are typically considered to be higher order cognitive processes that are essential for: activating and manipulating information in mind (working memory); flexibly switching attention due to the demands of a situation (shifting); and resisting urges, impulses and distractions (inhibition) (Diamond, 2013; Miyake et al., 2000).

The development of executive functions during the preschool period (3- to 5-years) is rapid (Best & Miller, 2010), and influential to later outcomes into adulthood (Moffitt et al., 2011). Further, executive functions are related to psychosocial health and development during the early years (Benavides-Nieto et al., 2017). Psychosocial health includes social, emotional, and behavioural functioning, and includes the presence of positive (and absence of negative) affect (Diener & Ryan, 2008). Positive psychosocial health in early childhood has been shown to be beneficially associated with later health outcomes, including lower levels of depression and aggressive interpersonal behaviour (Meagher et al., 2009; Toumbourou, Williams, Letcher, Sanson, & Smart, 2011). Understanding modifiable factors that are associated with executive functions and its correlates, such as psychosocial health, may suggest viable targets for early prevention, education and intervention (Khan & Hillman, 2014).

Physical activity may be one modifiable factor that has an impact on children's cognitive development (Best, 2010; Carson, Lee, et al., 2017). Research on neurobiological mechanisms suggests changes to brain composition can occur through increased cerebral blood flow, and this can be influenced by the duration and intensity of physical activity.
Experimental research in school aged children indicates that physical activity improved executive functions and altered brain activity in inactive overweight 7-11 year-old children (Davis et al., 2011). However, to the author's knowledge, only 3 studies have examined physical activity and core executive functions in preschoolers. Two studies found acute bouts of exercise was associated with better sustained attention (Palmer et al., 2013) and behavioural inhibition (Campbell et al., 2002) in preschoolers. From these studies it is difficult to understand if i) chronic habitual physical activity, or ii) physical activity intensity is associated with executive functions. Specifically, higher intensity physical activity, including moderate-to-vigorous intensity physical activity and vigorous physical activity, have been shown to be beneficially associated with other developmental outcomes in preschoolers (Carson, Lee, et al., 2017). However only one cross-sectional study has examined if physical activity intensity is associated with executive functions in a sample of 100 preschoolers. Carson, Rahman, & Wiebe (2017) reported that objectively measured physical activity of any intensity was not associated with executive functions.

Of the studies 8 that have examined associations between physical activity and domains of psychosocial health (e.g., quality of life, temperament, conduct problems, and social-emotional health) in preschool children, the majority of studies largely report no associations (Bonvin et al., 2013; Trina Hinkley et al., 2017; Irwin et al., 2015; Lindsey & Colwell, 2013; Wang, Sekine, Chen, Yamagami, & Kagamimori, 2008) or unfavourable associations (Ebenegger et al., 2012; M.-L. Yu, Ziviani, Baxter, & Haynes, 2012; M. L. Yu, Ziviani, Baxter, & Haynes, 2010). One study investigating associations of objectively-measured habitual physical activity intensity with social and emotional health in a small sub-sample of participants (n = 108) reported no longitudinal associations (Hinkley et al.,
Thus, the lack of studies using objective measures of physical activity prevents clear conclusions about how duration and intensity of physical activity might be associated with psychosocial development in the preschool years.

The cognitive effects of physical activity might be more likely to be maximized when complex cognitive skills and movements are combined (Best, 2010; Diamond, 2015; Diamond & Ling, 2016), such a participation in modified organised sports. When examining cognitively engaging activities such as sport in preschool children, only four studies has investigated this in cognitive and psychosocial health. A cross-sectional study reported no associations between participation in organised physical activity and executive functions (Carson, Rahman, et al., 2017). Conversely, one experimental evaluation of a creative dance program (Lobo & Winsler, 2006), one longitudinal study (Howard et al., 2018), and one cross-sectional study (Griffiths et al., 2010), have reported beneficial associations between participation in organised physical activities or modified sports and social-emotional health outcomes in young children. Of these studies, none have adjusted for physical activity, it is therefore unknown whether the benefits to executive functions or psychosocial health are due to sport participation, or to the physiological effects of physical activity that is inherent in sports.

In summary, evidence of associations between physical activity intensity or sport participation and executive functions in preschoolers is limited to one modestly-sized cross-sectional study with null findings (Carson, Rahman, et al., 2017). Likewise, evidence of associations between physical activity intensity and psychosocial health in preschoolers is limited to one modestly-sized longitudinal study with null findings (Hinkley et al., 2017). Furthermore, because the small number of studies that have investigated associations between sports participation and psychosocial health in preschoolers have not adjusted for
physical activity level, it is difficult to determine if positive outcomes are due to the inherent physical activity involved in sports or other contextual factors. As such, this study aims to strengthen the evidence base on associations of physical activity with executive functions and psychosocial health in preschoolers by investigating associations for objectively-measured physical activity intensity in a larger sample than previous studies, and by accounting for children's habitual physical activity when examining associations for sports participation. In line with previous research, it was hypothesized that higher intensity physical activity, specifically MVPA, and sport participation would be positively associated with domains of executive function, and that sport participation would be inversely associated with internalising and externalising behaviours, and positively associated with pro-social behaviours in preschool children.

3.2 Methods

Design, protocol and participants

The reporting of this paper followed the standards for reporting observational studies outlined in the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) statement (von Elm et al., 2008). Baseline data used in this study were drawn from the Preschool Activity, Technology and Health, Adiposity, Behaviour and Cognition (PATH-ABC) study (Cliff, McNeill, Vella, Howard, Kelly, et al., 2017). Ethical approval was obtained from the University of Wollongong Health & Medical Human Research Ethics Committee. Early childhood education and care (ECEC) centres were recruited based on a stratified sampling process from the Illawarra region of New South Wales. All ECECs (including long day cares and preschools) in the region were categorized as a low (deciles 1–4), medium (deciles 5–7) or high socio-economic area (deciles 8–10).
based on suburb, using the 2011 Socio-Economic Indices for Areas (SEIFA) Index of 
Relative Socio-economic Advantage and Disadvantage (IRSAD). SEIFA is developed by 
the Australian Bureau of Statistics, which ranks areas in Australia according to relative 
The number of ECECs invited to participate from each socio-economic group was 
proportional to the population distribution of centre type. Children in recruited ECECs were 
eligible to participate if they were 3–5 years of age, generally healthy, and were typically 
developing. Children were ineligible if they had a learning or physical disability, known 
motor delay, or a diagnosed medical or psychological condition (e.g., conduct disorder) that 
might influence the study findings. Data collection occurred in children's ECECs in 2015. 
A total of 24 ECEC’s were invited to participate in the PATH-ABC project, and 18 (75%) 
consented. This resulted in 503 children being recruited into the project, 13 children were 
not eligible, resulting in 490 eligible children. Following informed consent, children 
provided verbal assent, and data collection was conducted in a quiet area of the ECEC 
under supervision of the educators.

Physical activity and modified organised sport

ActiGraph GT3X + accelerometers (ActiGraph, Pensacola, FL) were 
used to assess physical activity due to the device's established accept- ability, validity and 
reliability in young children (Cliff, Reilly, & Okely, 2009). Monitors were fitted on an 
elastic belt at the right hip (e.g. anterior to the iliac crest). Parents were instructed that 
children should wear the monitor for 24 h over seven consecutive days, and to remove 
monitors during water or bathing activities. Raw data was sampled at 30 Hz and then 
reintegrated into 15s epochs using ActiLife (v6.12.1) software. Non-wear time was defined
as ≥20 min of consecutive “0” counts, and children's physical activity data were included in analyses if they had at least 3 days of valid data (either weekday and/or weekend) (i.e., ≥360 min of valid wear time, between 5 am and 11 pm; Bingham et al., 2016). Valid weekend day data were not a requirement for inclusion because evidence in preschoolers indicates that reliability of physical activity estimates is not increased by inclusions of a weekend day (Bingham et al., 2016; Hislop et al., 2014). Age-appropriate cut-points were applied to the data to define different intensities of physical activity with a cut off of ≥25–419 counts per 15s for Light intensity Physical Activity (LPA), ≥420–841 counts per 15s for Moderate intensity Physical Activity (MPA), ≥842 counts per 15s for Vigorous intensity Physical Activity (VPA), ≥420 counts per 15s for Moderate to-Vigorous intensity Physical Activity (MVPA), and ≥25 counts per 15s for Total Physical Activity (TPA). To adjust for wear time variance, percentage variables were calculated for all physical activity intensities and TPA. Associations were examined for all physical activity variables because all intensities are specified as influencing health and development in recent 24-Hour Movement Guidelines for the Early Years (Okely et al., 2017).

Participation in modified organised sports was assessed using a 7-item parent report survey from the Longitudinal Study of Australian Children (Vella et al., 2015). Parents were asked, in relation to a number of different activities: ‘Thinking about the last 12 months, has your child regularly attended any special cost activities that are not part of his/her normal child care, preschool or school activities’ (‘Regularly’ is defined as at least weekly or fortnightly activities, even if they lasted less than 6 months)’. Parents could answer “yes” or “no” for each item. Responses to the sports participation question identified children as: (1) participating in organised sports, which included team sports (e.g., football) or individual sports (e.g., kinder-gymnastics, swimming or dance); or (2) a
non-participant in organised sports. No psychometric properties have been reported for this variable.

**Cognitive development**

Executive function was assessed using measures drawn from the Early Years Toolbox, which has been psychometrically validated in preschool-aged children, in that it is developmentally appropriate, sensitivities enough to detect change, as well as being technologically dynamic (Howard & Melhuish, 2017). The measures have demonstrated validity (i.e., construct and convergent) and reliability (e.g., internal consistency). For instance, correlations of EYT measures with comparison measures selected from the NIH Toolbox were as follows: working memory, $r(79) = .46, p < .001$; Inhibition, $r(80) = .40, p < .001$; and Shifting, $r(80) = .45, p < .001$. Internal consistency analyses for Go/No-Go showed good reliability for both go (Cronbach’s $\alpha = .95$) and no-go trials (Cronbach’s $\alpha = .84$) in Australian pre-school samples (Howard & Melhuish, 2017).

Four tasks were used to assess: visual-spatial working memory (‘Mr Ant’), phonological working memory (‘Not This’), inhibition (‘Go/No-Go’), and shifting (‘Card Sort’). Measures are administered using an iPad, through which all instructions, practice, feedback and scoring are delivered and standardised. Still, all data were collected under the guidance of a data collector, who served to supplement initial instruction as needed and help keep the child on task.

During the Mr Ant (visual-spatial working memory) task, participants were asked to remember the spatial locations of “stickers” placed on a cartoon ant for 5 s. Prior to commencing, instruction and three practice trials serve to familiarize participants with task requirements. The task then proceeds as follows: Mr Ant presented with 1–8 stickers on parts of his body (the number of stickers corresponds to the difficulty level, which increases
across the task) for 5 s; a blank screen for 4 s; and then a blank Mr Ant on which they tap the locations that previously had stickers. The task continued until the earlier of completion (at Level 8) or failure on all three trials at the same level of difficulty. Visual-spatial working memory capacity was calculated using a point score: beginning from Level 1, one point for each consecutive level in which at least two of the three trials were performed accurately, plus 1/3 of a point for all correct trials thereafter.

During the Not This (phonological working memory) task, participants were asked to carry out auditory instructions of increasing complexity (e.g., point to a stimulus that is not of a particular colour, shape, or size – or some combination of these). Prior to commencing, participations were provided with auditory and visual demonstrations and a practice trial. The task progresses as follows: a blank screen, against which an auditory instruction plays (e.g., ‘Point to a shape that is not green’); a delay interval; and then an array of differently sized, coloured and shaped stimuli in a grid. Children respond by touching a stimulus that satisfies the auditory instruction. The task increases in complexity from Level 1 (one dimension to remember, such as shape, colour or size) to Level 8 (eight dimensions to remember, including a mix of colour, shape and size). Levels that require multiple directions (i.e., from Level 4) pertaining to multiple stimuli (e.g., 2 shapes) must be carried out in the specified order stated by auditory instructions. The task continues until the earlier of completion (at Level 8) or failure to accurately complete at least three of the five trials within a level. Performance was indexed by a point score: from Level 1, one point for each consecutive level in which at least three of the five trials were performed accurately, plus 1/5 of a point for all correct trials thereafter.

During the Go/No-Go (inhibition) task, participants were instructed to tap the screen on “go” trials (“catch the fish”) and not tap the screen on “no-go” trials (“avoid catching
sharks”). The majority of the stimuli are go trials (80% fish), which generates a prepotent tendency to respond. Participants need to inhibit this pre-potent response on no-go trials (20% sharks). Stimuli are presented in pseudo-random order, such that a block never begins with a no-go stimulus and no more than two successive trials are no-go stimuli. Each trial involves presentation of an animated stimulus (i.e., fish or shark swimming across the screen for 1500 ms), each separated by a 1000 ms inter-stimulus interval. Prior to commencing, participants were given instructions and practice as follows: go instructions, followed by five practice “go” trials; no-go instructions, followed by five practice “no-go” trials; combined go/no-go instructions, followed by a mixed block of 10 practice trials (80% go trials); and a recap of instructions to familiarise the with the procedure. An impulse control score indexed inhibition, calculated as the product of proportional “go” (to account for the strength of the prepotent response generated) and “no-go” accuracy (to index a participant's ability to overcome this prepotent response).

During the Card Sort (shifting) task, participants were required to sort cards (i.e., red rabbits, blue boats) by a sorting dimension (i.e., colour or shape) into one of two castles (identified by a blue rabbit or a red boat banner). Prior to commencing, participants watched a demonstration trial and took part in two practice trials. After a number of attempts at this sorting rule, the child is required to switch to the alternate sorting rule. If at least 5 of 6 trials are performed correctly in these first two phases, children are then presented with a post-switch phase. In this phase, participants are required to sort cards by colour if they are surrounded by a black border or by shape if there is no black border. Scores represent the number of correct sorts after the first sorting phase.

*Psychosocial development*
Psychosocial difficulties were assessed using the educator-reported version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). This scale has established validity and reliability in young Australian children (Hawes & Dadds, 2004), as well as internationally. Sufficient psychometric properties for internal consistency, test-retest reliability and inter-rater agreement have been reported across studies for the teacher version of the SDQ (Stone et al., 2010). The SDQ is comprised of 25-items assessing five psychosocial domains, namely: conduct problems, hyperactivity, emotional problems, peer problems and pro-social behaviour. Each item (i.e., child behaviour) is rated in frequency on a 3-point Likert scale (from 0=not true to 2=certainly true). In low risk and general populations, it is recommended that a three sub-scales model of the SDQ can be used, which assess: (1) internalising problems (sum of emotional symptoms and peer relationship problems subscales), (2) externalising problems (sum of conduct problems and hyperactivity subscales) and (3) pro-social behaviours (Goodman, Lamping, & Ploubidis, 2010). In addition, total psychological difficulties are calculated by summing the 20 items pertaining to behavioural difficulties (conduct problems, hyperactivity, emotional symptoms, and peer problems).

Covariates

Data on child and parent information, classified as covariates were collected via parent-report. Covariates were children's age, sex, and area-level socio-economic status (SEIFA and IRSAD, ABS, 2011). Parents also reported; average daily sleep (usual daily sleep duration, in hrs), average screen time per day (the total time children usually spent in screen-based behaviours on weekdays and weekends, which was averaged to derive
average daily screen time); and the quality of the home learning environment (frequency with which parents engaged their children in going to the library, reading, listening to the child read, practicing numbers, or teaching them songs (Sammons et al., 2015). These were also included as covariates given their established association with children's cognitive and psychosocial development. Lastly, parental education was categorized into three groups: (1) less than Year 12 High School; (2) Year 12 High School or Trade; or (3) Post Graduate Qualification

Statistical analysis

Analyses were conducted in STATA/IC (v13.1: Stata Corporation, College Station, TX). Initially, assumption of normality for linear regression was assessed by examining residuals for physical activity, executive functions and psychosocial variables. No variables needed to be transformed. Linear regression models were conducted for physical activity intensity (i.e., LPA, MPA, VPA, MVPA, or TPA) or sports participation (i.e., participant, non-participant) predicting individual executive function or psychosocial development outcomes. The models that evaluated physical activity intensity controlled for participation in modified organised sport, and the model testing participation in modified organised sport controlled for MVPA. Individual models adjusted for covariates and preschool-level clustering. Regression results are presented as beta coefficient (b) and 95% confidence intervals (95% CI) for the continuous variables (i.e., physical activity) and mean difference (MD) and 95% CI for the categorical variable (sports participation). Significance was set at p < 0.05.
3.3 Results

Participant characteristics are reported in Table 3.1. It was determined that the level of missing data was too high for confident imputation, as such complete case analysis was used, and the resultant sample was investigated for any evidence of bias. Children with missing data had lower phonological working memory scores (p=0.03) and lower IRSAD scores (p=0.02) compared to the analytic sample but did not differ on any other factors. Of the 490 eligible participants, 188 children were missing at least one parent-reported variable; 26 children did not return an activity monitor; and of those who did, 29 children had less than three days of accelerometry data. Therefore 247 children were included in the analytical sample; however, due to incomplete data for executive function and psychosocial variables, sample sizes for the individual analyses varied and is reported in Table 1. Average waking accelerometer wear time was 12.7 h/day over 6.8 days (Standard Deviation (SD) =1.7), of the sample 209 (85%) had at least 1 valid weekend day of data. Participants averaged more than 6 h/day in TPA, of which 1.7 h/day was MVPA. In the analytic sample, 83.4% of children participated in modified organised sports (Table 3.1). Mean scores across all executive function tasks were consistent with normative data in preschool children (Howard & Melhuish, 2017). Mean total difficulties and all subscales scores on the SDQ fell within the ‘normal’ range. Within the analytical sample girls were younger (p < 0.01), had higher home learning environment scores (p=0.04), were more sedentary (p=0.01), spent less time in MPA (p < 0.01), VPA (p < 0.01), MVPA (p < 0.01), and TPA (p=0.01), and experienced fewer externalising problems (p=0.02) than boys. There were no other statistically significant sex differences.
Table 3.1: Participant Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Male</th>
<th>Female</th>
<th>Total sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean (SD)</td>
<td>n</td>
</tr>
<tr>
<td>Age (y)*</td>
<td>148</td>
<td>4.3 (0.7)</td>
<td>99</td>
</tr>
<tr>
<td>SES (IRSAD)</td>
<td>148</td>
<td>1025.8 (60.2)</td>
<td>99</td>
</tr>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light- intensity PA (%)</td>
<td>148</td>
<td>36.3 (4.0)</td>
<td>99</td>
</tr>
<tr>
<td>Moderate- intensity PA (%)</td>
<td>148</td>
<td>10.4 (2.7)</td>
<td>99</td>
</tr>
<tr>
<td>Vigorous- intensity PA (%)</td>
<td>148</td>
<td>4.2 (2.2)</td>
<td>99</td>
</tr>
<tr>
<td>Moderate- to vigorous PA (%)</td>
<td>148</td>
<td>14.6 (4.5)</td>
<td>99</td>
</tr>
<tr>
<td>Total PA (%)</td>
<td>148</td>
<td>50.9 (6.7)</td>
<td>99</td>
</tr>
<tr>
<td>Total wear time (mins)</td>
<td>148</td>
<td>757.6 (105.0)</td>
<td>99</td>
</tr>
<tr>
<td>Average calendar days of wear</td>
<td>148</td>
<td>6.74 (1.8)</td>
<td>99</td>
</tr>
<tr>
<td>Executive Function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual-Spatial Working Memory, b</td>
<td>135</td>
<td>1.3 (1.1)</td>
<td>98</td>
</tr>
<tr>
<td>Phonological Working Memory, c</td>
<td>141</td>
<td>1.8 (0.8)</td>
<td>94</td>
</tr>
<tr>
<td>Shifting, d</td>
<td>137</td>
<td>4.5 (4.2)</td>
<td>95</td>
</tr>
<tr>
<td>Inhibition, e</td>
<td>133</td>
<td>0.5 (0.2)</td>
<td>92</td>
</tr>
<tr>
<td>Psychosocial Difficulties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems, f</td>
<td>136</td>
<td>3.2 (2.8)</td>
<td>87</td>
</tr>
<tr>
<td>Externalising problems, g</td>
<td>136</td>
<td>5.7 (4.8)</td>
<td>87</td>
</tr>
<tr>
<td>Pro-social behaviours, h</td>
<td>136</td>
<td>7.0 (2.6)</td>
<td>87</td>
</tr>
<tr>
<td>Total difficulties, i</td>
<td>136</td>
<td>8.9 (5.9)</td>
<td>87</td>
</tr>
<tr>
<td>Average Screen Time (min/day)</td>
<td>148</td>
<td>143.1 (83.8)</td>
<td>99</td>
</tr>
<tr>
<td>Home learning environment</td>
<td>148</td>
<td>25.9 (9.1)</td>
<td>99</td>
</tr>
<tr>
<td>Sleep (hrs/day)</td>
<td>148</td>
<td>10.50 (1.0)</td>
<td>99</td>
</tr>
<tr>
<td>Participation in modified organised sport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (%)</td>
<td>120</td>
<td>81.1</td>
<td>86</td>
</tr>
<tr>
<td>No (%)</td>
<td>28</td>
<td>18.9</td>
<td>13</td>
</tr>
<tr>
<td>Parental Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school or lower (%)</td>
<td>17</td>
<td>11.5</td>
<td>27</td>
</tr>
<tr>
<td>Trade or Diploma (%)</td>
<td>43</td>
<td>29.1</td>
<td>14</td>
</tr>
<tr>
<td>Degree/Postgraduate (%)</td>
<td>88</td>
<td>59.5</td>
<td>58</td>
</tr>
</tbody>
</table>

Notes: Characteristics of the participants are presented as mean ± SD, distributions of the sample are presented in percentages. Abbreviations: SD, standard deviation; SES, socioeconomic status; IRSAD, Index of Relative Socio-economic advantage and disadvantage. aAt enrolment into the study. bScore range: 0–8; cScore range: 0–8; dScore range: 0–12; eScore range: 0–1; fScore range: 0–20; gScore range: 0–20; hScore range: 0–10; iScore range: 0–40; *p <.05, **p <.01.
Linear regression results for the associations for objectively measured physical activity with the executive function and psychosocial variables are presented in Table 3.2. Time spent in LPA (b=−0.04; 95% CI: −0.07, −0.01, p=0.02) was negatively associated with children's visual-spatial working memory. A 30 min/day (0.97 SD) lower level of LPA was associated with a 0.15-unit higher visual-spatial working memory score (i.e., working memory capacity), which is equivalent to ~5 months of typical expected development (Howard & Melhuish, 2017). Minutes per day were calculated by taking the percentage of time for each physical activity intensity as an expression of the total wear time of the accelerometer (reported in minutes) Table 3.1. In contrast, the positive association between time spent in VPA and visual-spatial working memory approached statistical significance (b=0.04; 95% CI: −0.01, 0.09, p=0.08), although the association was relatively weak. A 15 min/day (0.97 SD) higher level of VPA was associated with a 0.07-unit higher visual-spatial working memory capacity, which is roughly equivalent to ~3 months of functional development (Howard & Melhuish, 2017). No other significant associations between physical activity and executive functions were observed.

Time spent in VPA was inversely associated with internalising (peer and emotional) problems, (b=−0.17; CI: −0.28, −0.06, p < 0.01). A 15 min/day (0.97 SD) increase in VPA was associated with a −0.33-unit decrease in internalising behavioural problems. Externalising problems were positively (detrimentally) associated with time spent in MPA (b=0.30; CI: 0.02, 0.58, p=0.03) and MVPA (b=0.18; CI: 0.00, 0.36, p=0.05) weakly positively, associated with externalising problems. A 15 min/day (0.46 SD) increase in MVPA was associated with a 0.35-unit increase in externalising problems. The association for VPA and externalising problems was non-significant but trended in the same direction as MPA and MVPA (b=0.31; CI: −0.05, 0.68, p=0.09), such that those higher in
externalising problems also descriptively, but non-significantly, engaged in more VPA. No other significant associations were observed for objectively measured physical activity and psychosocial domains.
Table 3:2 Unstandardised beta coefficients (95% Confidence Intervals) for associations between objectively-measured PA, executive function and SDQ subscales and total difficulties scores.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Light intensity physical activity</th>
<th>Moderate intensity physical activity</th>
<th>Vigorous intensity physical activity</th>
<th>Moderate-to-vigorous-intensity physical activity</th>
<th>Total physical activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b (95% CI)</td>
<td>p value</td>
<td>b (95% CI)</td>
<td>p value</td>
<td>b (95% CI)</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual spatial Working Memory</td>
<td>-0.04 (-0.07, -0.01)</td>
<td>0.02</td>
<td>0.00 (-0.03, 0.03)</td>
<td>0.98</td>
<td>0.04 (-0.01, 0.09)</td>
</tr>
<tr>
<td>(n = 241)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonological Working Memory</td>
<td>-0.05 (-0.01, 0.00)</td>
<td>0.16</td>
<td>-0.00 (-0.05, 0.03)</td>
<td>0.64</td>
<td>0.01 (-0.05, 0.07)</td>
</tr>
<tr>
<td>(n = 235)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhibition</td>
<td>-0.01 (-0.01, 0.00)</td>
<td>0.19</td>
<td>-0.00 (-0.01, 0.01)</td>
<td>0.86</td>
<td>0.01 (-0.00, 0.03)</td>
</tr>
<tr>
<td>(n = 224)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shifting</td>
<td>0.04 (-0.03, 0.12)</td>
<td>0.21</td>
<td>-0.10 (-0.22, 0.12)</td>
<td>0.35</td>
<td>-0.09 (-0.45, 0.27)</td>
</tr>
<tr>
<td>(n = 232)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Psychological Difficulties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems</td>
<td>-0.01 (-0.10, 0.07)</td>
<td>0.74</td>
<td>-0.06 (-0.22, 0.09)</td>
<td>0.43</td>
<td>-0.17 (-0.28, -0.06)</td>
</tr>
<tr>
<td>(n = 223)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalising problems</td>
<td>0.05 (-0.15, 0.26)</td>
<td>0.59</td>
<td>0.30 (0.02, 0.58)</td>
<td>0.03</td>
<td>0.31 (-0.05, 0.68)</td>
</tr>
<tr>
<td>(n = 223)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prosocial behaviours</td>
<td>0.01 (-0.09, 0.11)</td>
<td>0.80</td>
<td>0.00 (-0.18, 0.18)</td>
<td>0.97</td>
<td>-0.00 (-0.23, 0.23)</td>
</tr>
<tr>
<td>(n = 223)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Difficulties</td>
<td>0.04 (-0.23, 0.31)</td>
<td>0.76</td>
<td>0.23 (-0.16, 0.64)</td>
<td>0.23</td>
<td>0.15 (-0.30, 0.59)</td>
</tr>
<tr>
<td>(n = 223)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Notes: Linear regression models adjusted for age, sex, suburb-level socio-economic status, parental education, average screen time per day, participation in modified organised sport, The Home Learning Environment, average daily sleep and childcare-level clustering. p < 0.05
Associations between participation in sports, executive function and psychosocial variables are presented in Table 3.3. Modified organised sport participants demonstrated higher shifting scores compared to non-participants (MD 2.17; CI: 3.44, 0.91, p < 0.01), which was equivalent to approximately 1 year of normal development (Howard & Melhuish, 2017). No other significant associations were evident between participation in modified organised sports, executive function and SDQ domains.

Table 3.3 Mean, and marginal mean difference scores (95% Confidence Intervals) for associations between modified organised sports, executive function, SDQ subscales and total difficulties scores.

<table>
<thead>
<tr>
<th>Executive Function</th>
<th>Fully adjusted model</th>
<th>Mean (95%CI)</th>
<th>Mean group difference (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sport participants</td>
<td>Non-participants</td>
<td>Non-participants vs Sport participants</td>
</tr>
<tr>
<td>Working Memory</td>
<td></td>
<td>1.27 (1.13, 1.41)</td>
<td>1.15 (0.86, 1.44)</td>
<td>-0.11 (-0.34, 0.11)</td>
</tr>
<tr>
<td>Phonological Working Memory</td>
<td></td>
<td>1.82 (1.67, 1.98)</td>
<td>1.54 (1.25, 1.83)</td>
<td>-0.28 (-0.62, 0.06)</td>
</tr>
<tr>
<td>Inhibition</td>
<td></td>
<td>0.55 (0.50, 0.59)</td>
<td>0.50 (0.43, 0.56)</td>
<td>-0.05 (-0.11, 0.01)</td>
</tr>
<tr>
<td>Shifting</td>
<td></td>
<td>4.74 (3.87, 5.60)</td>
<td>2.56 (1.37, 3.75)</td>
<td>-2.17 (-3.44, -0.91)</td>
</tr>
</tbody>
</table>

Psychological Difficulties (n = 223)

| Internalising problems | 3.35 (2.73, 3.98)  | 3.00 (1.78, 4.23)  | -0.35 (-1.62, 0.91) | 0.56   |
| Externalising problems | 5.24 (4.47, 6.01)  | 5.00 (3.28, 6.71)  | -0.24 (-1.88, 1.39) | 0.75   |
| Prosocial behaviours  | 7.21 (6.61, 7.80)  | 7.45 (6.70, 8.20)  | 0.24 (-0.62, 1.11)  | 0.56   |
| Total Difficulties    | 8.60 (7.35, 9.85)  | 8.00 (5.88, 10.12) | -0.59 (-2.91, 1.71) | 0.59   |

Notes: Linear regression models adjusted for age, sex, suburb-level socio-economic status, parental education, average screen time per day, MVPA, The Home Learning Environment, average daily sleep and childcare-level clustering. p < 0.05.
3.4 Discussion

The findings from this study indicated that the intensity and type of physical activity were associated with some aspects of executive functions and psychosocial health in preschool children. Specifically, time spent in LPA was negatively associated with visual-spatial working memory, while the time spent in VPA was positively, but marginally and weakly associated. Likewise, time spent in VPA was negatively (beneficially) associated with a child's internalising behaviour, although associations were of small magnitude, such that children engaging in more VPA had fewer internalising problems. However, time spent in MPA, VPA and MVPA were positively (detrimentally) associated with externalising behaviour problems, such that children engaging in more of this moderate intensity physical activity showed more externalising problems. Finally, children participating in modified organised sports displayed higher shifting ability than children who did not participate in such activities. However, it is important to note that overall, the majority of associations observed for the intensity and type of physical activity with executive functions and psychosocial health were not significant.

The associations of VPA with visual-spatial working memory are inconsistent with those observed by Carson, Rahman, et al. (2017) who reported no significant cross-sectional associations between any intensity of objectively-measured habitual physical activity and working memory in a sample of 100 preschool children. It is noted, however, that the direction of associations in that study was similar to the present study (i.e., negative for LPA, positive for MVPA), and similar in that no associations were reported for physical activity and inhibition. As such, extending the study to a larger sample and narrower age range may have served to identify an association between higher intensity physical activity and working memory. Differences in the measures of executive function and covariates
may have also contributed to differences in the findings between these two studies. The current results are consistent with experimental research with older children, with whom physical activity has shown to be beneficial for working memory (Kamijo et al., 2011).

While it may initially appear that children who spent more of their physical activity time in VPA (e.g., running and jumping activities) spent less time in LPA (i.e. slowly walking or moving), this was not the case. Those children spending the greatest time in VPA did not appear to spend less time in LPA; that is, there was no correlation between time spent in VPA and LPA (r<.01, p>.05). A moderate increase in VPA (15min/day or 0.97 SD) was associated with a moderate improvement in children visual-spatial working memory scores that were about 3 months of normal of development. However, directionality cannot be conclusively determined. For instance, it may be that higher levels of VPA support the development of visual-spatial working memory – with potential mechanisms ranging from blood flow benefits in the brain (Voss et al., 2014) to improving attention. In such a case, it is likely that these benefits are functional (e.g., improved application of working memory resources) rather than structural (e.g., speeding the development of working memory), however it is unclear why a dose response association was not observed for MPA and MVPA. Alternatively, it may be that children with better visual-spatial working memory tend to engage in more VPA, although possible reasons for this are less clear. While further experimental research and longer-term follow-up is required to establish this directionality and degree of effect, the current results suggest increasing initially low levels of VPA as a potentially viable target for improving not only health and physical development, but also important aspects of cognitive development.

Consistent with the cross-sectional results observed by Page, Cooper, Griew, & Jago. (2010) with 10–11-year old's, our results of VPA showed a similarly beneficial
association with child internalising problems. In contrast, no associations between physical activity at 3–5 years and domains of social and emotional health in 6–8-year old's were demonstrated in an observational study (Hinkley et al., 2017). The discrepancy between findings may lie in varied measures of psychosocial health, as the current study found a beneficial association for only one area of psychosocial health investigated. Further, the current results are supported by parallel research showing that engaging in physical activity influences aspects related to broad areas of mental health (Biddle, 1993). Additional positive links between physical activity – particularly VPA – and psychosocial health (i.e. social integrations, self-mastery) have been found with older children (Deci & Ryan, 2002), yet it is unclear why higher intensities have a stronger association. Possible mechanisms surrounding associations of VPA with internalising behaviour problems may be via the body's systematic and cellular systems, or behavioural brain health outcomes (Voss et al., 2014). Evidence in both animal models and humans suggests that acute exercise induced improvements in mood, stress and cognitive function occur. These processes are via the HPA axis response of cortisol, neurotrophins including; brain derived neuro-trophic factor, neuro- transmitters including dopamine, serotonin norepinephrine and epinephrine (Basso & Suzuki, 2017). While suggestions of directionality in the current study can only be speculative, it is plausible that activity of higher intensities may be associated with neurochemical pathways that underpin psychosocial factors that may lead to fewer emotional and peer problems in the early years, yet it is unclear why VPA was the only intensity that was associated with internalising behaviour problems. More evidence is needed to further understand the possible mechanisms to explain these associations.

The other beneficial association of physical activity found in the current study was between sports participation and one aspect of executive functioning – the ability to
flexibly shift attention between rules, stimuli and mental sets. According to Diamond (2015), this may be due to sport's integration of cognitive challenge, which is essential to engage and extend executive functions, in the context of physical activity (see also Best, 2010). In contrast, however, the cross-sectional study conducted by Carson, Rahman, et al. (2017) found no associations between time spent in organised physical activity (e.g., swimming lessons, skating lessons, gymnastics etc.) and domains of executive functions. It is noted, however, that shifting was not measured in this study and thus specific associations with this factor could not have been detected. Modified organised sport involves a constantly and rapidly shifting environment, requiring children to shift attention between a variety of players, rules, and strategies, thereby engaging (and perhaps extending) aspects of executive function (Howard et al., 2018). Alternatively, and also in line with the longitudinal findings observed by Howard et al. (2018), it may be that children who are better in executive functions are those more likely to be enrolled in sports, as they are deemed more ‘ready’ or are more likely to succeed in sports. Given the lack of clarity on these issues, and that this has only been clarified across a narrow window of development (Howard et al., 2018), additional and more protracted longitudinal research is needed to understand the causal and temporal nature of these possible relationships.

Furthermore, it may be that alternate organised activities, that were not assessed in this study may provide important experiences that may support behaviours that underpin shifting abilities. Conceptually, participation in sport may also contribute to early social-emotional development through its demonstrated effects on psychosocial factors. Specifically, sport provides an opportunity for social interaction, self-esteem and connectedness (Biddle, 1993; Fraser-Thomas et al., 2005). Despite this, our study found sports participation was not associated with teacher-reported psychosocial difficulties.
Contrary to previous observational and experimental studies within the preschool years, Griffiths et al. (2010) reported sports participation was beneficially associated with psychosocial development, similarly Lobo & Winsler. (2006) reported improvements in social competence via a creative dance program. An alternative explanation as to why no associations were observed might be that preschool children may have engaged in alternative/additional extra-curricular activities that support psychosocial well-being (e.g., community or religious groups). Or perhaps the combination of sports types (i.e., individual, team) may obscure the possible associations for some sports and not others. Interestingly, Howard et al. (2018) reported marginal bi-directional associations for participation in individual sport and self-regulation, but not for team sport.

Contrastingly, time spent in higher intensities of physical activity appeared to be positively (detrimentally) associated with externalising problems in our sample. This finding is somewhat inconsistent with evidence from a systematic review of the health and developmental benefits of physical activity for young children (Carson et al., 2017), which found that physical activity interventions were consistently associated with improved psychosocial health. However, our findings are consistent with the only other observational study in young children that has examined associations between objectively-measured physical activity and psychosocial health using the SDQ (Ebenegger et al., 2012). Ebenegger et al. (2012) found that parent reported SDQ scores of hyperactivity/inattention problems was higher in preschool children who spent greater time in MVPA and VPA. These findings among preschool-aged children are also consistent with cross-sectional studies in school-aged children, where objectively measured MVPA has been shown to be associated with externalising behaviours measured using the SDQ (Page et al., 2010). Our findings and those of Ebenegger et al. (2012) highlight issues in assigning directionality, as
children who are highly active may also exhibit behaviours that are associated with externalising problems. Interestingly, the mechanisms previously described for the inverse associations of VPA with psychosocial health do not align or explain the detrimental associations observed for VPA and externalizing behaviours. More research is needed to explore possible mechanisms for how the intensity of physical activity might hold different associations with domains of psychosocial health.

A particular strength of this study was the objective measurement of children's habitual physical activity (Cliff et al., 2009), making it possible to investigate associations for different intensities of physical activity. Additionally, the complete range of executive functions were measured, through direct objective measures that have strong validity, reliability, and developmental sensitivity (Howard & Melhuish, 2017). Furthermore, the inclusion of further covariates than have previously been examined strengthens confidence in the findings. A limitation of this study is that the findings are based on cross-sectional data, therefore causality cannot be established. Longitudinal and experimental studies using objective measures (which is less common for physical activity, while important cognitive development components are often omitted) are needed to further explore possible relationships. Additionally, the small number (n = 41) of children who did not participate in organised sport may have limited the ability to detect significant associations. Furthermore, other potential confounders such as diet (Black, 2003) were not controlled for and may have implications for interpreting the results. Although the PATH-ABC study used a re-presentative sampling approach, a considerable proportion of participants could not be included in the analytic sample for the current analyses due to missing data (i.e., excluded participants had lower IRSAD scores and phonological working memory). This
may limit generalisability of our findings to the broader population, particularly children of low socioeconomic areas.

3.5 Conclusion

This study indicates that VPA was positively associated with domains of executive functions, while mixed, inverse (beneficial) and positive (detrimental) associations were observed with aspects of psychosocial development. Further, participation in modified organized sports was positively associated with domains of executive functions. However, predominately null associations were observed for physical activity intensity and type with cognitive and psychosocial health outcomes. Although these findings need replication in longitudinal and experimental studies, the current results suggest that targeting high intensity activity, or promoting participation in sport, may have the potential to positively influence executive functions and psychosocial development in the early year.
Chapter 4: Longitudinal associations of physical activity and modified organised sport participation with executive function and psychosocial health in preschoolers

This chapter is under review with the Journal of Sport Science.

Chapter 3 examined the associations of objectively measured physical activity and modified organised sport with executive function and psychosocial health in preschool children cross-sectionally. While cross-sectional study designs are important to establish associations, an understanding of the temporal nature of associations is needed. This chapter builds on chapter 3, and further address Aim 1: to examine the associations of objectively measured physical activity and modified organised sport with executive function and psychosocial health in preschool children longitudinally. In this chapter, the following research question is investigated:

Research Question 1: Do the associations between physical activity and executive functions or psychosocial health differ by the intensity (i.e., light-intensity physical activity, moderate-intensity physical activity, vigorous-intensity physical activity, moderate-to-vigorous-intensity physical activity, and light-to-vigorous intensity physical activity) or type (i.e., modified organised sports) of physical activity in preschool children?
4.1 Introduction

National guidelines in several countries including Australia and Canada recommend that preschool children should obtain at least 180min/day of physical activity, and 60 minutes of this should be energetic play (Okely et al., 2017; Mark S. Tremblay et al., 2017). These guidelines are derived from evidence that physical activity has a range of health benefits for young children (0-4 years), including motor development, cardiometabolic health, and bone and skeletal health (Carson, Lee, et al., 2017). Physical activity may also support children’s cognitive and psychosocial development though neurological (e.g., increased blood flow to the brain) (Voss et al., 2014) and psychological pathways (e.g., satisfying basic psychological needs for connectedness, autonomy, mastery, and purpose) (Lubans et al., 2016).

Research on the cognitive effects of physical activity have increasingly focused on Executive functions and aspects of psychological well-being. Executive functions are higher order cognitive processes responsible for reasoning, problem-solving, and goal-directed behaviors. These include: thinking before impulsively acting, and resisting temptations and distractions (inhibition); holding information in memory, and mentally working with it (working memory); and, shifting attention from one point of focus to the next, whilst ignoring irrelevant information (shifting; Miyake et al., 2000). Executive functions develop rapidly in preschoolers (3- to 5-years; Best & Miller, 2010), contribute to children’s school readiness and academic achievement (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006), and predict later socio-economic position and health outcomes in adulthood (Moffitt et al., 2011). Executive functions appear foundational to a broad range of outcomes, and as such there has been extensive effort to identify mechanisms through which positive change in executive functions can be achieved; and, it is hoped, thereby
positively shift its associated outcomes. Preliminary evidence suggests that physical activity may be one of those mechanisms (Voss et al., 2014), although the form, duration and frequency of activity required to achieve these benefits is unclear.

There is also evidence that physical activity may yield improvements in psychological health and well-being (Lubans et al., 2016). Psychosocial health encompasses social, emotional, and behavioural functioning, and includes the presence of positive (and absence of negative) affect (Diener & Ryan, 2008). Positive psychosocial health in early childhood has been shown to be beneficially associated with later health outcomes, including lower levels of depression (Meagher et al., 2009). Therefore, understanding how physical activity is associated with executive functions and psychosocial health in preschoolers may inform practices and policies designed to support child development. Cross-sectional evidence in school-aged children suggests that physical activity is associated with executive functions (Best, 2010), and psychosocial health (Poitras, Gray, Borghese, Carson, Chaput, Janssen, et al., 2016), yet limited evidence is available in preschool children (Carson, Lee, et al., 2017). Evidence examining acute changes in physical activity in preschool children has similarly reported positive effects of acute with cognition (Campbell et al., 2002; Palmer et al., 2013) however from these studies it is difficult to understand if i) chronic habitual physical activity or ii) physical activity intensity is associated with this improvement. While cross-sectional evidence indicates vigorous physical activity might be beneficially associated with executive functions in preschoolers which was obtained from the baseline cohort from this dataset (McNeill, Howard, Vella, Santos, & Cliff, 2018), no previous longitudinal studies have investigated the associations of objectively-measured physical activity with executive functions or psychosocial health in preschoolers (Carson, Lee, et al., 2017).
Modified organized sport (e.g., football, gymnastics, swimming) are common forms of physical activity for preschool children, and have been speculated as having particular potential for promoting cognitive development because of their combination of physical activity participation and cognitive challenge (Diamond, 2015). Sports’ benefits also include improved self-esteem, social skills and teamwork, which may also support children’s psychosocial development (Howard et al., 2018; Vella et al., 2015). Although some cross-sectional evidence from the baseline cohort of this sample suggests that modified organized sport may indeed have these effects (McNeill et al., 2018), no published studies have investigated these associations longitudinally (Carson, Lee, et al., 2017). The purpose of this study was to investigate if physical activity intensity and participation in modified organized sport at 3-to 5-years of age were associated with EF and psychosocial development 12 months later.

4.2 Methods

Longitudinal data used in this study were drawn from the Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition (PATH-ABC) cohort study (Cliff et al., 2017; McNeill et al., 2018). Ethical approval was obtained for this study (HE14/310). Preschool centers were recruited based on a stratified sampling process from a regional area of New South Wales, Australia. Preschool centers in the region were categorized according to the 2011 Socio-Economic Indices for Areas (SEIFA) Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) as a low (deciles 1-4), medium (deciles 5-7) or high socio-economic area (deciles 8-10; ABS, 2011). The number of preschools invited to participate from each socio-economic group was proportional to the population distribution of center type. A total of 24 ECEC’s were invited into the PATH-ABC project, and 18
(75%) consented. This resulted in 503 children being recruited into the project, 13 children were not eligible, resulting in 490 eligible children. Baseline data were collected in centers (n=18) between April and December 2015. Follow-up data were collected approximately the same time 12-months later, between April and December 2016, at the child’s preschool center (n=17) or primary school (n=51).

Children were eligible to participate if they were 3-to 5-years of age, healthy, and were typically developing, and ineligible if they had a learning or physical disability, known motor delay, or a diagnosed medical or psychological condition (e.g., conduct disorder). Following informed consent and verbal assent, measures were completed in a quiet area of the preschool. Children attending primary school at follow-up completed data collection with a researcher in a quiet classroom at their primary school. All children completed the same assessment procedure across timepoints.

ActiGraph GT3X+ accelerometers (ActiGraph, Pensacola, FL) were used to assess physical activity due to the device’s established acceptability, validity and reliability in young children. (Cliff et al., 2009) Monitors were fitted on an elastic belt at the right hip (e.g. anterior to the iliac crest). Parents were instructed that children should wear the monitor for 24-hours over seven consecutive days and removed during water or bathing activities. Raw data was sampled at 30 Hz and then reintegrated into 15s epochs using ActiLife (v6.12.1) software. Non-wear time was defined as ≥20 min of consecutive “0” counts, and children’s physical activity data were included in analyses if they had a least 3 days of valid data (i.e., ≥360 min of valid wear time; between 5 am and 11 pm). Valid weekend day data were not a requirement for inclusion because evidence in preschoolers indicates that reliability of physical activity estimates is not substantially increased by inclusion of a weekend day (Bingham et al., 2016). Age-appropriate cut-points were
applied to the data to define different intensities of physical activity with a cut off of $\geq 25 - 419$ counts per 15s for Light Physical Activity (LPA), $\geq 420 - 841$ counts per 15s for Moderate intensity Physical activity (MPA), $\geq 842$ counts per 15s for Vigorous Physical Activity (VPA), $\geq 420$ counts per 15s for Moderate to-Vigorous intensity Physical Activity (MVPA), and $\geq 25$ counts per 15s for Total Physical Activity (TPA; Pate et al., 2006). To adjust for wear time variance, percentage variables were calculated for all physical activity intensities and TPA. Associations were examined for all intensities because all are indicated as influencing health and development in Australian 24-Hour Movement Guidelines for the Early Years (Okely et al., 2017).

Participation in modified organized sports was assessed using a 7-item parent report survey drawn from the Longitudinal Study of Australian Children (Vella et al., 2015). No psychometric properties have been reported for this variable. Parents were asked about their child’s sport participation in the last 12 months, such as, ‘has your child regularly attended any special cost activities that are not part of his/her normal child care, preschool or school activities’. Parents answered “yes” or “no” for each item, with definitions of key terms provided to guide interpretation (e.g., regularly is defined as at least fortnightly activities, even if lasting < 6 months). Responses to the sports participation question categorized children as: (1) participating in organized team (e.g., football) or individual (e.g., swimming, dance) sports; or (2) a non-participant in organized sports.

Executive function was assessed using measures drawn from the Early Years Toolbox, which has been psychometrically validated in preschool-aged children, in that it is developmentally appropriate, sensitivities enough to detect change, as well as being technologically dynamic (Howard & Melhuish, 2017). The measures have demonstrated validity (i.e., construct and convergent) and reliability (e.g., internal consistency). For
instance, correlations of EYT measures with comparison measures selected from the NIH Toolbox were as follows: working memory, \( r(79) = .46, p < .001 \); Inhibition, \( r(80) = .40, p < .001 \); and Shifting, \( r(80) = .45, p < .001 \). Internal consistency analyses for Go/No-Go showed good reliability for both go (Cronbach’s \( \alpha = .95 \)) and no-go trials (Cronbach’s \( \alpha = .84 \)) in Australian pre-school samples (Howard & Melhuish, 2017).

Four tasks were used to assess: visual-spatial working memory (‘Mr. Ant’), phonological working memory (‘Not This’), inhibition (‘Go/No-Go’), and shifting (‘Card Sort’). Measures were administered by a trained researcher using an electronic tablet, through which all instructions, practice, familiarization, feedback and scoring are delivered and standardized, under the guidance of a data collector. Full details of the EYT methodology have been reported elsewhere (Howard & Melhuish, 2017).

Psychosocial development was assessed using the educator-reported version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), which has demonstrated validity and reliability in Australian children (Hawes & Dadds, 2004). Sufficient psychometric properties for internal consistency, test-retest reliability and inter-rater agreement have been reported across studies the teacher version of the SDQ (Stone et al., 2010). The SDQ consists of 25-items assessing five psychosocial domains: conduct problems, hyperactivity, emotional problems, peer problems and prosocial behavior. Educators rate typicality of each behaviour (i.e., item) on a 3-point Likert scale ranging from not true (0) to certainly true (2). In low risk and general populations, it is recommended that a three sub-scale model of the SDQ be used, which assesses: internalizing problems (sum of emotional and peer problems); externalizing problems (sum of conduct problems and hyperactivity); and prosocial behavior. Total psychological difficulties were indexed by summing the 20 ‘difficulties’ items.
Child and parent covariates were collected via parent-report. Covariates were: child age and sex; area-level socio-economic status (SEIFA; ABS, 2011), and primary caregiver education (coded as 1 = less that high school, 2 = high school or trade, or 3 = tertiary qualification). Parents also reported daily electronic media use (program viewing; computer use; app/electronic game use; and console use for weekday and weekend). Total time for each behaviour was summed and averaged to calculate total electronic media use). Established indices of quality of the home learning environment and average daily sleep duration were included as additional covariates given their potential associations with children’s cognitive and psychosocial development (Cliff, McNeill, Vella, Howard, Kelly, et al., 2017; Sammons et al., 2015)

Analyses were conducted in STATA/IC (v13.1: Stata Corporation, College Station, TX). Separate linear regression models were conducted to examine physical activity intensity (i.e., LPA, MPA, VPA, MVPA, or TPA) or modified organized sports participation (i.e., participant vs. non-participant) at baseline predicting executive functions or psychosocial development outcomes at 1-year follow-up, adjusting for all covariates. The models that evaluated physical activity intensity also controlled for participation in modified organized sport, and the model testing participation in modified organized sport controlled for MVPA. All models adjusted for participant education sector at follow-up (i.e., preschool or primary school), (pre-)school cluster, and baseline levels of the outcome variable. Assumptions of normality for linear regression were met for all analyses. As this study was an exploratory analysis of observational data, rather than a confirmatory analysis of a clinical trial, formal correction for multiple testing was not conducted (Ekelund et al., 2012). Regression analyses are presented as beta coefficient (b) and 95% confidence intervals (95% CI) for the continuous variables (i.e., physical activity) and mean difference
(MD) and 95% CI for the categorical variable (sports participation). Significance was set at $p < 0.05$.

### 4.3 Results

Of the 490 participants recruited at baseline, 188 children were missing at least one parent-reported variable, 12 only consented for baseline data, an additional 26 did not return their accelerometer, and of those who did return an accelerometer 29 has insufficient data therefore 235 were eligible for follow-up. Of those eligible at follow up, 15 participants did not agree to follow-up and 35 were not contactable. As such, 185 children comprised the analytical sample. It was determined that the level of missing data from baseline to follow-up was too high for reliable imputation, thus a complete case analysis was used, and the analytical sample was investigated for any evidence of bias. Children with missing data had lower IRSAD scores ($p = .003$) and a lower phonological working memory score ($p = .028$) at baseline compared to the analytical sample but did not differ on any other variables. Due to incomplete data for outcome variables, sample sizes for the individual analysis varied (Table 4.3).

At baseline, average waking accelerometry was 12.8 (1.7) h/day over 6.8 (1.6) days. Participants averaged more than 6.3 1.0 (Standard deviation: SD) h/day in TPA, which included 1.7 (0.5) h/day of MVPA. At baseline, 83.2% of the children regularly participated in modified organized sport over the last 12 months. When examining gender differences, girls were younger ($p <.001$), spent less time in MPA ($p < .001$), VPA ($p = .004$), and MVPA ($p = .002$), and experienced fewer externalizing behaviors ($p = .014$) than boys. At baseline, mean scores for total psychological difficulties and SDQ subscales fell within the ‘normal’ range. From 3-5 years to 4-6 years of age, significant improvements were found
for all executive function domains (p < .001) and for total difficulty scores (p = .033), but not for individual SDQ subscales (Table 4.2).
Table 4:1 Participant characteristics at 3- to 5-years

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Male n</th>
<th>Mean (SD)</th>
<th>Female n</th>
<th>Mean (SD)</th>
<th>Total Sample n</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)*</td>
<td>112</td>
<td>4.32 (0.66)</td>
<td>73</td>
<td>3.99 (0.57)</td>
<td>185</td>
<td>4.19 (0.64)**</td>
</tr>
<tr>
<td>SES (IRSAD)</td>
<td>112</td>
<td>1027.20 (60.00)</td>
<td>73</td>
<td>1020.33 (55.02)</td>
<td>185</td>
<td>1024.0 (57.35)</td>
</tr>
<tr>
<td>Physical Activity (PA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-intensity PA (%)</td>
<td>112</td>
<td>36.32 (3.8)</td>
<td>73</td>
<td>36.42 (3.99)</td>
<td>185</td>
<td>36.36 (3.87)</td>
</tr>
<tr>
<td>Moderate-intensity PA (%)</td>
<td>112</td>
<td>10.41 (2.67)</td>
<td>73</td>
<td>9.16 (1.67)</td>
<td>185</td>
<td>9.91 (249)**</td>
</tr>
<tr>
<td>Vigorous-intensity PA (%)</td>
<td>112</td>
<td>4.28 (2.35)</td>
<td>73</td>
<td>3.72 (1.43)</td>
<td>185</td>
<td>4.06 (2.05)*</td>
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<tr>
<td>Moderate-to vigorous PA (%)</td>
<td>112</td>
<td>14.69 (4.65)</td>
<td>73</td>
<td>12.88 (3.14)</td>
<td>185</td>
<td>13.98 (4.20)*</td>
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<tr>
<td>Total PA (%)</td>
<td>112</td>
<td>51.02 (6.67)</td>
<td>73</td>
<td>49.30 (5.73)</td>
<td>185</td>
<td>50.34 (6.36)</td>
</tr>
<tr>
<td>Total wear time (mins)</td>
<td>112</td>
<td>758.72 (103.71)</td>
<td>73</td>
<td>776.67 (92.44)</td>
<td>185</td>
<td>765.80 (99.55)</td>
</tr>
<tr>
<td>Average calendar days of wear</td>
<td>112</td>
<td>6.7 (1.76)</td>
<td>73</td>
<td>7.05 (1.32)</td>
<td>185</td>
<td>6.8 (1.60)</td>
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<td>Total Screen Time (Avg.min/d)</td>
<td>112</td>
<td>118.75 (64.83)</td>
<td>73</td>
<td>127.36 (74.30)</td>
<td>185</td>
<td>122.15 (68.65)</td>
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<td>Participation in modified organized sport</td>
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<td></td>
</tr>
<tr>
<td>Yes (%)</td>
<td>89</td>
<td>79.5</td>
<td>65</td>
<td>89.0</td>
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<td>No (%)</td>
<td>23</td>
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<td>8</td>
<td>11.0</td>
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<td>Parental Education</td>
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<td></td>
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<tr>
<td>less than High School (%)</td>
<td>10</td>
<td>8.9</td>
<td>21</td>
<td>28.8</td>
<td>31</td>
<td>16.8**</td>
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<td>High School or Trade/Diploma (%)</td>
<td>36</td>
<td>32.1</td>
<td>10</td>
<td>13.7</td>
<td>46</td>
<td>24.9**</td>
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<tr>
<td>Tertiary qualification (%)</td>
<td>66</td>
<td>58.9</td>
<td>42</td>
<td>57.5</td>
<td>108</td>
<td>58.4</td>
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<td>Participant education sector at follow-up</td>
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<td></td>
<td></td>
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<tr>
<td>Preschool</td>
<td>62</td>
<td>55.4</td>
<td>51</td>
<td>69.9</td>
<td>113</td>
<td>61.1</td>
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<td>Primary school</td>
<td>50</td>
<td>44.6</td>
<td>22</td>
<td>30.1</td>
<td>72</td>
<td>38.9</td>
</tr>
</tbody>
</table>

Note: Characteristics of the participants are presented as mean ± SD, distributions of the sample are presented in percentages. Abbreviations: SD, standard deviation; SES, socioeconomic status; IRSAD, Index of Relative Socio-economic advantage and disadvantage. aAt enrolment into the study. ascore range: 0 – 8; bscore range: 0 – 8; cscore range: 0 – 12; dscore range: 0 – 1; escore range: 0 – 20; fscore range: 0 – 20; gscore range: 0 – 10; hscore range: 0 – 40; *p <.05, **p <.01.
Table 4:2 Mean (SD) Executive functions and SDQ subscales scores at baseline (ages 3- to 5-years) and follow-up (ages 4-6).

<table>
<thead>
<tr>
<th>Developmental outcomes</th>
<th>Baseline Mean (SD)</th>
<th>Follow-up Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive Function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual spatial working memory&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.29 (1.02)</td>
<td>2.25 (0.92)&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>Phonological working memory&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.80 (0.79)</td>
<td>2.17 (0.71)&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>Inhibition&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.56 (0.21)</td>
<td>0.73 (0.16)&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>Shifting&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.51 (4.35)</td>
<td>7.64 (3.64)&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>Psychosocial Health</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalizing problems&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.22 (2.85)</td>
<td>2.83 (3.17)</td>
</tr>
<tr>
<td>Externalizing problems&lt;sup&gt;f&lt;/sup&gt;</td>
<td>5.27 (4.54)</td>
<td>4.41 (4.44)</td>
</tr>
<tr>
<td>Pro-social behaviors&lt;sup&gt;g&lt;/sup&gt;</td>
<td>7.23 (2.61)</td>
<td>7.49 (2.35)</td>
</tr>
<tr>
<td>Total difficulties&lt;sup&gt;h&lt;/sup&gt;</td>
<td>8.50 (5.78)</td>
<td>7.24 (6.22)&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: Characteristics of the participants are presented as mean ± SD. <sup>a</sup>score range: 0 – 8; <sup>b</sup>score range: 0 – 8; <sup>c</sup>score range: 0 – 12; <sup>d</sup>score range: 0 – 1; <sup>e</sup>score range: 0 – 20; <sup>f</sup>score range: 0 – 20; <sup>g</sup>score range: 0 – 10; <sup>h</sup>score range: 0 – 40; <sup>*</sup>p < .05, <sup>**</sup>p < .001.

Levels of VPA at baseline were positively associated with shifting at follow-up (b = 0.245; 95% CI: 0.006, 0.485, p = .045), while a positive association between MVPA and shifting approached significance (b = 0.119; 95% CI: -0.001, 0.0239, p = .051). Specifically, a 16 min/day (1 SD) increase in VPA was associated with an additional 0.50-unit (0.14 SD) increase in shifting scores beyond that expected with increasing age (equivalent to an extra ~3 months of development over and above age-related change) (Howard & Melhuish, 2017). Likewise, a 32 min/day (1 SD) increase in MVPA was associated with an additional
0.50-unit (0.14 SD) increase in shifting over and above typical age-related change (equivalent to an extra ~3 months of development; Howard & Melhuish, 2017). No other significant associations were observed for objectively measured physical activity, executive functions or psychosocial development (Table 4.3).
Table 4.3 Unstandardised beta coefficients (95% Confidence Intervals) for objectively measured physical activity at baseline and associations between executive functions, SDQ subscales and total difficulties scores at follow-up, controlling for executive functions, SDQ subscales and total difficulties scores at baseline and adjusted for covariates.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Light intensity physical activity</th>
<th>Moderate intensity physical activity</th>
<th>Vigorous intensity physical activity</th>
<th>Moderate-to-vigorous-intensity physical activity</th>
<th>Total physical activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n$</td>
<td>$b$ (95% CI)</td>
<td>$p$ value</td>
<td>$b$ (95% CI)</td>
<td>$p$ value</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual spatial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working Memory</td>
<td>182</td>
<td>-0.009 (-0.032, 0.013)</td>
<td>0.395</td>
<td>-0.007 (-0.069, 0.056)</td>
<td>0.825</td>
</tr>
<tr>
<td>Phonological</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working Memory</td>
<td>175</td>
<td>0.010 (-0.015, 0.035)</td>
<td>0.410</td>
<td>-0.020 (-0.057, 0.017)</td>
<td>0.269</td>
</tr>
<tr>
<td>Inhibition</td>
<td>167</td>
<td>-0.002 (-0.007, 0.004)</td>
<td>0.494</td>
<td>0.004 (-0.007, 0.014)</td>
<td>0.456</td>
</tr>
<tr>
<td>Shifting</td>
<td>179</td>
<td>-0.071 (-0.188, 0.047)</td>
<td>0.222</td>
<td>0.166 (-0.027, 0.360)</td>
<td>0.087</td>
</tr>
<tr>
<td><strong>Psychosocial Health</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems</td>
<td>156</td>
<td>-0.013 (-0.154, 0.127)</td>
<td>0.843</td>
<td>0.113 (-0.105, 0.331)</td>
<td>0.290</td>
</tr>
<tr>
<td>Externalising problems</td>
<td>156</td>
<td>0.040 (0.517, 0.175)</td>
<td>0.309</td>
<td>0.175 (0.301, 0.673)</td>
<td>0.039</td>
</tr>
<tr>
<td>Prosocial behaviours</td>
<td>156</td>
<td>-0.022 (-0.086, 0.042)</td>
<td>0.483</td>
<td>-0.032 (-0.210, 0.146)</td>
<td>0.710</td>
</tr>
<tr>
<td>Total Difficulties</td>
<td>156</td>
<td>0.032 (0.206, 0.270)</td>
<td>0.779</td>
<td>0.283 (0.384, 1.056)</td>
<td>0.164</td>
</tr>
</tbody>
</table>

*Note:* Linear regression models adjusted for age, sex, SES, parental education, average screen time per day, participation in modified sport, the Home Learning Environment, average daily sleep, Participant education sector at follow-up, and preschool level clustering. $p < .05$. 
Children who did not participate in modified organized sport at baseline had better inhibition at follow-up compared to those children that participated in organized sport ($MD = 0.06; CI: 0.00, 0.13, p = .046$). This difference equates to an additional ~4 months of development over and above typical age-related change (Howard & Melhuish, 2017). No other significant associations were evident between participation in modified organized sports and outcome variables (Table 4.4).
Table 4: Mean, and marginal mean difference scores (95% Confidence Intervals) for associations between modified organised sports, executive function, SDQ subscales and total difficulties scores.

<table>
<thead>
<tr>
<th>Executive Function</th>
<th>Mean (95%CI)</th>
<th>Mean group difference (95% CI) vs Sport participants</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sport participants</td>
<td>Non-participants</td>
<td>Non-participants</td>
</tr>
<tr>
<td>Visual spatial Working Memory</td>
<td>182</td>
<td>2.28 (2.05, 2.51)</td>
<td>2.13 (1.91, 2.36)</td>
</tr>
<tr>
<td>Phonological Working Memory</td>
<td>175</td>
<td>2.20 (2.03, 2.37)</td>
<td>2.16 (1.93, 2.38)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>167</td>
<td>0.73 (0.71, 0.75)</td>
<td>0.79 (0.74, 0.85)</td>
</tr>
<tr>
<td>Shifting</td>
<td>179</td>
<td>7.64 (6.97, 8.32)</td>
<td>7.89 (6.40, 9.37)</td>
</tr>
<tr>
<td>Strengths Difficulties Questionnaire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems</td>
<td>156</td>
<td>2.88 (2.16, 3.61)</td>
<td>2.72 (1.45, 3.98)</td>
</tr>
<tr>
<td>Externalising problems</td>
<td>156</td>
<td>4.48 (3.46, 5.50)</td>
<td>4.56 (2.87, 6.26)</td>
</tr>
<tr>
<td>Prosocial behaviours</td>
<td>156</td>
<td>7.53 (6.98, 8.09)</td>
<td>7.39 (6.63, 8.14)</td>
</tr>
<tr>
<td>Total Difficulties</td>
<td>156</td>
<td>7.35 (5.79, 8.91)</td>
<td>7.34 (4.75, 9.93)</td>
</tr>
</tbody>
</table>

Note: Linear regression models adjusted for age, sex, SES, parental education, average screen time per day, MVPA, the Home Learning Environment, average daily sleep, Participant education sector at follow-up, and preschool level clustering. p < .05.
4.4 Discussion

This study examined longitudinal associations of early organized sport participation and objectively measured physical activity 12 months later, with cognitive and psychological development. After adjusting for executive functions at baseline and relevant covariates, time spent in VPA and MVPA at 3-to 5-years was positively, meaningfully, and uniquely associated with change in shifting scores (which was not found for LPA, MPA or TPA). Unexpectedly, children who did not participate in modified organized sport at baseline displayed significantly better inhibition scores at follow-up than children who participated in sport. Neither physical activity intensity nor participation in modified organized sport at baseline were associated with changes in psychosocial development a year later.

Health benefits of higher intensity activity is well documented in children and adolescents (Poitras, Gray, Borghese, Carson, Chaput, Janssen, et al., 2016), along with emerging evidence in the early years (Carson, Lee, et al., 2017). Mixed associations were observed for intensity of physical activity and executive functions from this study, in that VPA and MVPA was significantly associated with one domain of executive function, which was inconsistent with the cross-sectional associations observed from the same data set (McNeill et al., 2018), and remaining associations were null. The current results extend these plausible benefits that have been observed in children and adolescents, by showing for the first time the longitudinal associations between objectively-measured habitual physical activity and aspects of cognitive development (i.e., shifting). To this point, evidence for these associations have derived almost exclusively from cross-sectional evidence, which show inconsistent associations with executive functions (Carson, Rahman, et al., 2017; McNeill et al., 2018; Willoughby et al., 2018). Indeed, of the three cross-
sectional studies examining physical activity and executive functions in early childhood (Carson, Rahman, et al., 2017; McNeill et al., 2018; Willoughby et al., 2018), only one study reported a positive association with one domain of executive function, from the baseline cohort used in this study (McNeill et al., 2018).

Further, while a recent review (Carson, Lee, et al., 2017) observed that physical activity interventions were consistently (>60% of studies) associated with improvements in cognitive development in the early years, none of these studies have examined executive functions. The current results suggest that these associations do indeed exist – accounting for improvements in the order of ~3 months of additional developmental change – but uniquely for more vigorous forms of activity and only for specific aspects of cognitive development. That is, children in the current study who spent more time in VPA had better shifting ability one year later. Associations of higher intensity physical activity with enhanced cognitive function may be attributable to the increased cerebral blood flow during and following high intensity activity (Voss et al., 2014), although the processes that link physical activity to changes in neural structure and function are not fully elucidated. For instance, given that these blood flow effects are transitory and short-lived after exercise, it is unclear what the mechanisms for sustained improvement may be. One possibility is that these periods of increased attention and blood flow may create opportunities for particularly effective acquisition of cognitive resources (sustained structural improvements). In contrast, it may be that habitual physical activity levels are stable, such that those engaging in more vigorous physical activity continue to do so over time and thus continue to experience more frequent incidence of temporary cognitive ‘boosts’ (temporary functional improvements). The current results serve as a stimulus for further research to elaborate the functional and structural effects of these mechanisms.
The addition of cognitive-challenge to physical activities is speculated to enhance the effect of physical activity on cognitive development (Best, 2010). Despite this, our study observed predominantly null associations between modified organized sports participation at 3- to 5-years of age with cognitive and psychosocial development one year later. Interestingly, it was observed that non-sport participants at baseline had better inhibition at follow-up compared to sports participants. The null findings are largely consistent with cross-sectional studies in preschoolers which have mostly observed null associations (Carson, Rahman, et al., 2017; McNeill et al., 2018), and only one study observed a significant positive association for one of four executive functions domains (McNeill et al., 2018). However, no previous longitudinal studies have examined these associations. Research in school-aged children suggests beneficial associations between sports participation and psychological difficulties after 2 years (Vella et al., 2015). While the predominantly null results were unexpected, it may be due to the ubiquity of sports participation (only 31 children did not participate in organized sport), potentially limiting the ability to detect significant differences between groups. Similarly, the combination of sports types (i.e., individual, team, or sports with more rules might provide more challenge) may obscure possible associations for some sports and not others, as marginal bi-directional associations for participation in individual sport, but not for team sport at 4-5 years was associated with self-regulation two years later (Howard et al., 2018). One explanation for the significant association observed for non-sport participants and inhibition is that children with less ability to remain still, more impulsive and great proclivity to remain active may be those who are more commonly enrolled in early sports. As the current data are unable to evaluate this proposition, further research is required to evaluate this possibility, and possible bi-directional associations.
Similar to that of cognitively engaging activities, this study predominantly observed null associations between physical activity intensity at 3- to 5-years of age with psychosocial development one year later. Limited evidence exists examining the longitudinal associations of physical activity with psychosocial health outcomes in preschool children (Carson et al., 2017). However, the null results observed for physical activity intensity and psychosocial health are consistence with the only other longitudinal study (Hinkley et al., 2017), and consistent with cross-sectional studies and broad psychosocial outcomes identified in a review by Carson and colleagues (2017).

A strength of this study was the objective measurement of habitual physical activity (Cliff et al., 2009), and executive functions (Howard & Melhuish, 2017). Furthermore, the inclusion of additional covariates that have previously been associated with outcome variables strengthens confidence in the findings. Our findings extend cross-sectional associations and demonstrate the temporal nature of associations – that is, time spent in VPA and MVPA preceded later shifting improvement. Still, repeated measurements over additional and/or longer follow-up periods would provide further information on these associations. Also, the amount of missing data could have biased the findings, and as such, the findings may not be generalizable to children of low socioeconomic areas. Given the multiple associations examined in this study, and the unexpected associations for non-sports participants, further research is needed to confirm or refute these findings. Lastly, although evaluation of the sport context was not within the scope of this project, future research could consider the types of physical activity or sport (e.g., team vs. individual) and possible associations with health and development.
4.5 Conclusion

Children who spent more time in VPA and MVPA at 3-to 5-years of age had meaningfully improved ability to shift their attention one year later. Few other associations were statistically or meaningfully significant for physical activity or sports participation on cognitive and psychological outcomes. However, predominately null associations were observed for physical activity intensity at baseline with changes in psychosocial development a year later. The current study nevertheless suggests the possible additional benefits of targeting and promoting high-intensity activity for aspects of cognitive development.
Chapter 5: Associations of application use and media program viewing with cognitive and psychosocial health in preschoolers.

This chapter is under review with *Journal of BMC Pediatrics*.

Chapter 2 reviewed pertinent literature on electronic media use as a modifiable factor that have been associated with executive functions and psychosocial health in preschool children and identified gaps in the evidence base that formed the aims and research questions for this thesis. This chapter address part of Aim 2: to examine the associations of electronic media use with executive functions and psychosocial health in preschool children cross-sectionally. In this chapter, the following research question is investigated:

Research Question 2: Do the associations between total electronic media use and executive functions or psychosocial health differ by the type of electronic media (i.e., program viewing or use of electronic apps) in preschool children?
5.1 Introduction

Healthy brain development prominently includes growth and maturation of one’s executive functions, which develop rapidly across the preschool years (e.g., Best & Miller, 2010). Executive functions are higher-order cognitive process that are responsible for: activating and manipulating information in mind (working memory); resisting urges, impulses, and distractions (inhibition); and flexibly shifting attention with the demands of a situation (shifting; Diamond, 2013; Miyake et al., 2000). The importance of one’s executive function is demonstrated by its associations with school readiness and academic achievement (e.g., Blair & Razza, 2007), risky life choices, employment and psychosocial development (Benavides-Nieto et al., 2017; Moffitt et al., 2011; Riggs, Greenberg, Kusché, & Pentz, 2006). These associations may be further compounded by the flow-on effects of negative trajectories in areas influenced by executive functions, such as the health outcomes of poorer psychosocial development and well-being (e.g., higher levels of depression and aggressive interpersonal behavior; Jones, Brown, & Lawrence Aber, 2011; Meagher, Arnold, Doctoroff, Dobbs, & Fisher, 2009). Given these broad, robust, and longitudinal associations, considerable research has sought to identify malleable factors that can shift early trajectories of executive functions and psychosocial development.

Electronic media use – including watching programs on television (TV) or other devices, and playing on apps or console computer games – is one modifiable behavior that has been shown to have a detrimental impact on a child’s health and development (Carson et al., 2015; Hinkley, Teychenne, et al., 2014; Lissak, 2018; Poitras et al., 2017). For this reason, guidelines in the United States of America (USA) and Australia are consistent in recommending that electronic media use of high quality programs for children aged 2-5 years should be limited to no more than 1 hour per day (American Academy of Pediatrics,
Likewise, Canadian guidelines recommend no more than 1 hour per day of high quality screen time for children aged 2-4 years, and 2 hours per day for children aged ≥5 years (Tremblay et al., 2017). Yet estimates from the USA suggest that children aged 2-to 4-years routinely exceed these levels, and engage in on average 2.5 hours of electronic media use per day (Common Sense Media [CSM], 2017).

Although young children’s daily time spent using electronic media appears to have remained relatively constant in the USA over recent years, the types of devices that children use has shifted considerably (CSM, 2017). TV/program viewing and DVD viewing still remain the most prominent forms of media exposure in the early years of life, at approximately 1.5 hours/day. However, the use of mobile devices (including smartphones, tablets, or similar devices) has tripled from 2011- 2017 among 0-8 year old’s in the USA. This accounts for ~1 hour/day of their electronic media use, while a very small percentage is spent playing on a computer or video game (CSM, 2017).

Research examining habitual electronic media use and executive functions in preschoolers are limited to two cross-sectional (Carson, Rahman, et al., 2017; Nathanson et al., 2014) and two longitudinal studies (Blankson, O’Brien, Leerkes, Calkins, & Marcovitch, 2015; Zimmerman & Christakis, 2005) – all of which examined associations primarily for TV viewing. Null associations were reported in one cross-sectional (Carson, Rahman, et al., 2017) and both of the longitudinal studies (Blankson et al., 2015; Zimmerman & Christakis, 2005). Conversely, one cross-sectional study reported negative associations between TV viewing and a composite score of executive function (Nathanson et al., 2014). Given the changing nature of preschoolers’ electronic media use, and that
existing studies have focused on a declining (albeit still important) format, it is unclear
whether these patterns might hold for interactive electronic media as well.

In relation to psychosocial development, inconsistent associations are reported for
early habitual electronic media use in preschoolers across the four cross-sectional and two
longitudinal studies. In the context of TV viewing again being the primary focus, one cross-
sectional study reported a mix of negative and null associations (i.e., longer hours of
watching TV increased total behaviour problems and internalizing behaviour problems but
was not associated with externalizing behaviour problems; Teramoto, Soeda, Hayashi,
Saito, & Urashima, 2005), while another reported a mix of null and positive associations
(i.e., more TV viewing was associated with high emotional skills; Lee & Carson, 2017).
Both longitudinal studies, in contrast, reported that TV viewing was not associated with
being at risk of poorer psychosocial outcomes after 2 years (Hinkley, Verbestel, et al.,
2014) or psychosocial health after 3 years (Hinkley, Timperio, Salmon, & Hesketh., 2017).

When examining associations of using other electronic media use and psychosocial
health amongst young children, findings are similarly mixed. For instance, one cross-
sectional study examined associations after aggregating all electronic media use (i.e.,
television/videos/DVDs and used a computer or played electronic games) and reported
predominately null associations (Griffiths et al., 2010). Likewise, one cross-sectional study
reported null associations for video game use (Linebarger, 2015). In contrast, a longitudinal
study found that weekday e-game/computer use at age 4 years was associated with
increased risk of emotional problems, but not peer problems, 2 years later (Hinkley,
Verbestel, et al., 2014). Hinkley et al. (2017) found the reverse, however, in that sedentary
electronic games use at 3- to 5-years of age was positively associated with a range of
emotion-related factors 3 years later (intrapersonal skills, stress management, emotional
quotient). They also found that early computer/internet use was negatively associated with interpersonal skills, and positively associated with stress management skills 3 years later.

The evidence base around the implications of electronic media use is mixed and contentious. Differences between studies may account for the discrepancies observed. For example, the majority of previous evidence has combined all forms of electronic media use (i.e., TV viewing/video game/computer use) as one media behavior. Further, indices of electronic media use precede the proliferation of electronic tablets (and thus, app use), and as such, results have predominantly reported on passive viewing behaviours such as TV viewing. Currently no studies have investigated independent associations of contemporary patterns of electronic media use with young children’s executive function and psychosocial development. This limits conclusions about how use of contemporary and, now, ubiquitous forms of interactive electronic media may be associated with young children’s cognitive and psychosocial development.

While the associations between electronic media use and child development remain under-researched and under-explained, there are a number of hypothesized mechanisms through which electronic media use might adversely affect young children. These include overstimulation of the developing brain (i.e., due to its rapid, fast and changing pace, frequent cuts and edits) or displacement of time from social interactions or other developmentally beneficial activities (Radesky & Christakis, 2016; Radesky et al., 2015). However, there is also speculation that interactive media, such as apps used on mobile hand-held devices with touch-screen technologies may have different effects than passive media, such as TV or program viewing, due to the potential for reactivity, interactivity, tailorability, progressiveness, promotion of joint attentions, and portability (Christakis, 2014). Further research is needed to understand if different types of media, particularly app
use, may have different associations with young children’s development differently (Poitras et al., 2018).

The aim of the current study was to investigate if different types of electronic media use, such as TV/media program viewing compared to app and electronic game use hold different associations with domains of executive functions and psychosocial development in preschool children. This study aims were to build on the existing literature that has reported inconsistent findings, with an additional focus on contemporary electronic media use. In line with previous research (Poitras et al., 2018), it was hypothesized that both total electronic media use and program viewing would be negatively associated with executive function and psychosocial development, while interactive app use will be positively associated with executive function, and positively associated with psychosocial development.

5.2 Methods

Centre Recruitment

A total of 24 ECEC’s were invited into the PATH-ABC project, and 18 (75%) consented from the Illawarra region - a coastal region situated immediately south of Sydney, New South Wales, Australia using a stratified sampling process on the basis of their suburb. Using the area-level SES index of the Australian Bureau of Statistics (Socio-Economic Indices for Areas, or SEIFA, Index of Relative Socio-economic Advantage and Disadvantage; ABS, 2011), ECECs in the region were categorized as in low (deciles 1-4), medium (deciles 5-7), or high SES areas (deciles 8-10). The number of ECECs invited to participate from each socio-economic group was proportional to the population distribution.
Participants

Children in recruited ECECs were eligible to participate if they were 3-to 5-years of age, generally healthy, and typically developing. Children were ineligible if they had a learning or physical disability, known motor delay, or a diagnosed medical or psychological condition (e.g., conduct disorder) that might influence the study findings. A total of 503 children were recruited into the project, 13 children were not eligible, which resulted in 490 eligible participants. Of the 490 eligible participants, 188 children were missing at least one parent-reported variable. An additional 26 children did not return an activity monitor, and of those who did, 29 children had insufficient data. It was determined that the level of missing data from baseline to follow-up was too high for confident imputation, thus a complete case analysis was used, and the analytical sample was investigated for any evidence of bias. Therefore, 247 children were included in the analytical sample, however, due to incomplete data for executive function and psychosocial variables, sample sizes for the individual analyses varied (Table 1). Children with missing data had lower phonological working memory scores ($p = .028$), and lower IRSAD scores ($p = .016$) than those without missing data but did not differ on other cognitive or psychosocial variables.

Ethical approval was obtained from the university’s Health & Medical Human Research Ethics Committee.

Measures

Electronic media use. Parents reported the total number of electronic media devices in the house, and those that were available to the child. Children’s time spent engaging in different electronic media behaviours during a typical week, separately for weekdays (Monday – Friday) and weekends (Saturday – Sunday), was reported by their
parent/caregiver (Hinkley, Salmon, Okely, Crawford, & Hesketh, 2012). Original electronic media items had established acceptable test-retest reliability (ICC = 0.68–0.69; Hinkley et al., 2012). Electronic media behaviours included: i) program viewing on traditional devices, “e.g., TV/DVD”; ii) program viewing on non-traditional devices, “e.g., tablet, DVD in car, computer, laptop, mobile phone”; iii) use of applications/electronic games on portable handheld devices or laptop/computer, “e.g., tablet, mobile phone, handheld game system (hereafter referred to as apps)”; iv) non-active console games, “e.g., PlayStation or Xbox”; and v) active console games, “e.g., Wii or Xbox Kinect”. The time in each behavior for weekdays and weekend days was summed and averaged to calculate children’s average daily screen time as on variable. Similarly, individual electronic media use variables were: (1) average daily minutes in program viewing (combining viewing programs on traditional and non-traditional devices); and (2) level of app use – because a large proportion of children (30%) in the analytical sample did not engage in this at all, participants were categorized as non-users (i.e., 0 min/day), low dose users (1 - 29 min/day), or high dose users (≥30 min/day).

Cognitive development. Executive function was assessed using measures drawn from the Early Years Toolbox, which has been psychometrically validated in preschool-aged children, in that it is developmentally appropriate, sensitivities enough to detect change, as well as being technologically dynamic (Howard & Melhuish, 2017). The measures have demonstrated validity (i.e., construct and convergent) and reliability (e.g., internal consistency). For instance, correlations of EYT measures with comparison measures selected from the NIH Toolbox were as follows: working memory, $r(79) = .46$, $p < .001$; Inhibition, $r(80) = .40$, $p < .001$; and Shifting, $r(80) = .45$, $p < .001$. Internal consistency analyses for Go/No-Go showed good reliability for both go (Cronbach’s $\alpha$
and no-go trials (Cronbach’s $\alpha = .84$) in Australian pre-school samples (Howard & Melhuish, 2017). Four tasks were used to assess: visual-spatial working memory (‘Mr Ant’), phonological working memory (‘Not This’), inhibition (‘Go/No-Go’), and shifting (‘Card Sort’). These measures are administered using an electronic tablet, through which all instructions, practice, familiarization, feedback and scoring are delivered and standardized. All four executive function tasks were administered collectively, under the guidance of a data collector, who served to supplement initial instructions as needed and keep the child on task.

In Mr Ant (visual-spatial working memory), participants were asked to remember the spatial locations of “stickers” placed on a cartoon ant for 5 s. The task proceeds as follows: Mr Ant presented with 1-8 stickers on parts of his body (the number of stickers corresponds to the difficulty level, which increases across the task) for 5 s; a blank screen for 4 s; and then a blank Mr Ant on which they tap the locations that previously had stickers. The task continued until the earlier of completion (at Level 8) or failure on all three trials at the same level of difficulty. Visual-spatial working memory capacity was calculated using a point score: beginning from Level 1, one point for each consecutive level in which at least two of the three trials were performed accurately, plus 1/3 of a point for all correct trials thereafter.

In Not This (phonological working memory), participants were asked to carry out auditory instructions of increasing complexity (e.g., point to a stimulus that is not of a particular colour, shape, or size – or some combination of these). The task progressed as follows: a blank screen, against which an auditory instruction plays (e.g., ‘Point to a shape that is not green’); a delay interval; and then an array of different sizes and colors of shapes in a grid. Children responded by touching a stimulus that satisfied the auditory instruction.
The task increased in complexity from Level 1 (one dimension to remember, such as shape, colour, or size) to Level 8 (eight dimensions to remember, including a mix of colour, shape, and size). Levels that required multiple directions (i.e., from Level 4) pertaining to multiple stimuli (e.g., 2 shapes), had to be carried out in the order specified by the instructions. The task continued until the earlier of completion (at Level 8) or failure to accurately complete at least three of the five trials within a level. Performance was indexed by a point score: from Level 1, one point for each consecutive level in which at least three trials were performed accurately, plus 1/5 of a point for all correct trials thereafter.

In Go/No-Go (inhibition), participants were instructed to tap the screen on “go” fish trials (“catch the fish”) and not tap the screen on “no-go” shark trials (“avoid catching sharks”). The majority of the stimuli were go trials (80% fish), which generated a pre-potent tendency to respond. Participants needed to inhibit this pre-potent response on no-go trials (20% sharks). Stimuli were presented in pseudo-random order, such that a block never began with a no-go stimulus and no more than two successive trials were no-go stimuli. Each trial involved presentation of an animated stimulus (i.e., fish or shark swimming across the screen for 1,500 ms), each separated by a 1,000 ms inter-stimulus interval. An impulse control score indexed inhibition, calculated as the product of proportional “go” (to account for the strength of the prepotent response generated) and “no-go” accuracy (to index a participant’s ability to overcome this prepotent response).

In Card Sort (shifting), participants were required to sort cards (i.e., red rabbits, blue boats) by a sorting dimension (i.e., colour or shape) into one of two castles (identified by a blue rabbit or a red boat banner). After a number of attempts at this sorting rule, the child was required to switch to the alternate sorting rule. If at least 5 of 6 trials were performed correctly in these first two phases, children were then presented with a post-switch phase.
In this phase, participants were required to sort cards by colour if they were surrounded by a black border or by shape if there was no black border. Scores represent the number of correct sorts after the first sorting phase.

_Psychosocial development._ Psychosocial development was assessed using an educator-report version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). The SDQ is comprised of 25-items assessing five psychosocial domains, namely: conduct problems; hyperactivity; emotional problems; peer problems; and pro-social behavior. Each item (i.e., child behavior) is scored on a 3-point Likert scale (from 0 = not true to 2 = certainly true). In low risk populations, it is recommended that a three sub-scales model of the SDQ be used, comprising: (1) internalizing problems (sum of emotional symptoms and peer relationship problems subscales); (2) externalizing problems (sum of conduct problems and hyperactivity subscales); and (3) pro-social behaviours (Goodman, Lamping, & Ploubidis, 2010). In addition, total psychological difficulties were calculated by summing the 20 items pertaining to behavioral difficulties (conduct problems, hyperactivity, emotional symptoms, and peer problems). This scale has demonstrated good validity and reliability in young Australian children (Hawes & Dadds, 2004), as well as internationally, and sufficient psychometric properties for internal consistency, test-retest reliability and inter-rater agreement have been reported across studies for the teacher version of the SDQ (Stone et al., 2010).

_Child and Parent Covariates._ Data on children and parents were collected via parent-report. Covariates included children’s age, sex, and area-level socio-economic status (SEIFA; ABS, 2011), and parental education (of the primary caregiver). Parental education was categorized into three groups: (1) less than high school completion; (2) high school completion or trade; or (3) tertiary qualification. In addition, due to evidence of their
associations with children’s cognitive and psychosocial development, further covariates controlled for were parent-reported: sleep time (Chaput et al., 2017); sports participation (Cliff, McNeill, Vella, Howard, Kelly, et al., 2017; McNeill et al., 2018); educational and extra-curricular experiences as an index for quality of the home learning environment (frequency with which parents engaged their children in going to the library, reading, listening to the child read, practicing numbers, or teaching them songs (Sammons et al., 2015) and accelerometer-measured moderate-to-vigorous intensity physical activity (McNeill et al., 2018; Poitras et al., 2017).

Procedure

Baseline data used in this study were drawn from the Preschool Activity, Technology and Health, Adiposity, Behavior and Cognition (PATH-ABC) study (Cliff et al., 2017). Data collection occurred in children’s ECECs in 2015. Parents provided written informed consent, and children gave verbal assent, as a condition of participation in the study. Following informed consent, parents/carers provided demographic information and other data via surveys. Following verbal assent, trained data collectors completed assessments with children in a quiet area of the ECEC centre, away from the main group of children but within the supervision of the educators. Measures were completed in assessment sessions grouped by outcomes (cognitive development, and physical health), with assessors being flexible and sensitive to children’s need to take breaks between assessments.

Statistical Analysis
Analyses were conducted in STATA/IC (v13.1: Stata Corporation, College Station, TX). Differences by child sex, and between the analytical sample and those excluded due to missing data, were tested using independent samples t-tests. Separate linear regression models were conducted to examine whether any of the following; (1) total electronic media use; (2) total program viewing; and (3) level of app use predicted executive function or psychosocial development variables. All models controlled for age, sex, SEIFA, parental education, sleep, participation in sport, MVPA, the home learning environment and preschool-level clustering. The model examining app use also controlled for total program viewing, due to this being the predominant form of electronic media use. Regression models were not conducted for console use, due to only 15% (n = 37) of children engaging with such forms of electronic media. Linear regression assumptions were assessed by examining model residuals. No variable needed to be transformed. Regression results are presented as unstandardized beta coefficients (b) and 95% confidence intervals (95% CI) for continuous variables, or for categorical variables as mean difference (MD) and 95% CIs.
5.3 Results

Initial Data exploration: When examining sex differences in the analytical sample (n = 247), girls were younger (p < .001), were reported by parents as having a higher-quality home learning environment (p = .040), spent less time in MVPA (p < .001), and experienced fewer externalizing problems (p = .022) (Table 1). Based upon parental education, girls had a greater number of parents educated to less than Year 12 high school, but fewer parents with a trade specific education (p = .001), than boys. Fewer girls spent ≥30 min/day engaging in apps compared to boys (p = .028). No other sex differences were evident.

On average, there were 10 electronic media devices in a child’s home, with half of these ($M = 5.0 \pm SD 3.4$) available to the preschool child. Children spent, on average, ~2.4 h/day in electronic media use, with the majority of this time (120min/day) 84% spent in program viewing, and 14% (20min/day) and 2% (3min/day) of the total time spent using apps and console devices, respectively. All children engaged in program viewing, while 173 (70%) used apps, and 37 (15%) used console devices. Children’s mean executive function scores were in line with preliminary norms derived from Early Years Toolbox validation studies (Howard & Melhuish, 2017). Mean scores for internalizing and externalizing subscales, pro-social scores and total difficulties scores for the SDQ fell within the ‘normal’ ranges (as opposed to borderline or abnormal ranges; Goodman & Goodman, 2009).
Table 5:1 Participant characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Male</th>
<th>Female</th>
<th>Total sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean (SD)</td>
<td>n</td>
</tr>
<tr>
<td>Age (y)a</td>
<td>148</td>
<td>4.3 (0.7)</td>
<td>99</td>
</tr>
<tr>
<td>SES (IRSAD)</td>
<td>148</td>
<td>1025.8 (60.2)</td>
<td>99</td>
</tr>
<tr>
<td><strong>Parental Education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>less than Year 12 High School (%)</td>
<td>17</td>
<td>11.5</td>
<td>27</td>
</tr>
<tr>
<td>High School or Trade/Diploma (%)</td>
<td>43</td>
<td>29.1</td>
<td>14</td>
</tr>
<tr>
<td>Tertiary qualification (%)</td>
<td>88</td>
<td>59.5</td>
<td>58</td>
</tr>
<tr>
<td><strong>Electronic media use (min/d)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total electronic media use</td>
<td>148</td>
<td>143.7 (83.8)</td>
<td>99</td>
</tr>
<tr>
<td>Program viewing (traditional devices)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program viewing (non-traditional devices)</td>
<td>148</td>
<td>92.3 (49.4)</td>
<td>99</td>
</tr>
<tr>
<td>App use</td>
<td>148</td>
<td>23.4 (30.7)</td>
<td>99</td>
</tr>
<tr>
<td>Console use (combined)</td>
<td>148</td>
<td>4.0 (12.5)</td>
<td>99</td>
</tr>
<tr>
<td>Active console use</td>
<td>148</td>
<td>2.8 (10.2)</td>
<td>99</td>
</tr>
<tr>
<td>Non-active console use</td>
<td>148</td>
<td>1.2 (5.8)</td>
<td>99</td>
</tr>
<tr>
<td><strong>App use</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-users (0 min/day) (%)</td>
<td>37</td>
<td>25</td>
<td>37</td>
</tr>
<tr>
<td>Low-dose users (&gt;1 – 29 min/day)</td>
<td>68</td>
<td>45.9</td>
<td>46</td>
</tr>
<tr>
<td>High-dose users (&gt;30 min/day)</td>
<td>43</td>
<td>29.1</td>
<td>16</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual-Spatial WMb</td>
<td>135</td>
<td>1.3 (1.1)</td>
<td>98</td>
</tr>
<tr>
<td>Phonological WMc</td>
<td>141</td>
<td>1.8 (0.8)</td>
<td>94</td>
</tr>
<tr>
<td>Inhibitiond</td>
<td>133</td>
<td>0.5 (0.2)</td>
<td>91</td>
</tr>
<tr>
<td>Shiftinge</td>
<td>137</td>
<td>4.5 (4.2)</td>
<td>95</td>
</tr>
<tr>
<td><strong>Psychosocial Development</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalisingf</td>
<td>136</td>
<td>3.2 (2.8)</td>
<td>87</td>
</tr>
<tr>
<td>Externalisingg</td>
<td>136</td>
<td>5.7 (4.8)</td>
<td>87</td>
</tr>
<tr>
<td>Pro-socialhb</td>
<td>136</td>
<td>7.0 (2.6)</td>
<td>87</td>
</tr>
<tr>
<td>Total difficultiesi</td>
<td>136</td>
<td>8.9 (5.9)</td>
<td>87</td>
</tr>
</tbody>
</table>

Note. Data presented as mean (standard deviation) for continuous variables, and percentages for categorical variable aAt enrolment into the study. Abbreviations: SD, standard deviation; SES, socioeconomic status; IRSAD, Index of Relative Socio-economic advantage and disadvantage. 
bScore range: 0 – 8, cScore range: 0 – 8, dScore range: 0 – 1, eScore range: 0 – 12, fScore range: 0 – 20, gScore range: 0 – 20, hScore range: 0 – 10, iScore range: 0 – 4; *p <.05, ** <.01
Total electronic media: Linear regression results for associations of total electronic media use and program viewing with executive functions and psychosocial outcomes are reported in Table 2. Visual-spatial working memory, but not phonological working memory (p > .05), showed small but significantly negative associations with total electronic media use (b = -0.001; 95% CI: -0.003, -0.000, p = .026). A 83 min/day (1 SD) decrease in total electronic media use may be associated with a 0.08-point (0.08 SD) increase in VSWM. On the basis of established developmental sequences (Howard & Melhuish, 2017), this would suggest an improvement that would equate to approximately 2.8 months more of typical expected development. No other significant associations were observed for total electronic media use executive functions or psychosocial development variables.

Program viewing: Visual-spatial working memory, but not phonological working memory (p > .05), showed small but significantly negative associations with program viewing (b = -0.002; 95% CI: -0.003, -0.000, p = .033). A 69 min/day (1 SD) decrease in program viewing, may be associated with a 0.14-point (0.14 SD) increase in VSWM. On the basis of established developmental sequences (Howard & Melhuish, 2017), this would suggest an improvement that would equate to approximately 4.9 months more of typical expected development. No other significant associations were observed for program viewing use, with executive functions or psychosocial development variables.
Table 5:2 Unstandardised beta coefficients and 95% confidence intervals for associations of media use and program viewing, with executive functions and psychosocial health subdomains.

<table>
<thead>
<tr>
<th></th>
<th>Total electronic media use</th>
<th>Program viewing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>b (95% CI)</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual-spatial working memory</td>
<td>241</td>
<td>-0.001 (-0.003, -0.000)</td>
</tr>
<tr>
<td>Phonological working memory</td>
<td>235</td>
<td>0.000 (-0.001, 0.002)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>224</td>
<td>-0.000 (-0.000, 0.000)</td>
</tr>
<tr>
<td>Shifting</td>
<td>232</td>
<td>-0.005 (-0.015, 0.004)</td>
</tr>
<tr>
<td><strong>Psychosocial Development</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prosocial behaviours</td>
<td>223</td>
<td>0.001 (-0.003, 0.004)</td>
</tr>
<tr>
<td>Internalising problems</td>
<td>223</td>
<td>0.000 (-0.003, 0.006)</td>
</tr>
<tr>
<td>Externalising problems</td>
<td>223</td>
<td>-0.000 (-0.007, 0.007)</td>
</tr>
<tr>
<td>Total Difficulties</td>
<td>223</td>
<td>0.001 (-0.007, 0.001)</td>
</tr>
</tbody>
</table>

*Note.* Linear regression models adjusted for age, sex, suburb-level socio-economic status, parental education, participation in sport, MVPA, The Home Learning Environment, average daily sleep, and childcare-level clustering. p < .05
Application use: Associations of app use with executive functions and psychosocial development are reported in Table 3. Phonological working memory was uniquely higher for high-dose app users (≥30 min/day), MD = 0.31; CI: 0.04, 0.58, p = .025, compared to non-users (low-dose users showed descriptively but non-significantly higher scores than non-users as well). This difference in scores would suggest an improvement that would equate to approximately ~5 months of normal development according to reported developmental trends (Howard & Melhuish, 2017). While no other executive function variables were significantly associated with app use levels, it is notable that visual-spatial working memory (MD 0.18; CI: -0.01, 0.38, p = 0.065); phonological working memory (MD 0.17; CI: -0.01, 0.35, p = .067); and shifting (MD = 1.39; CI: -0.01, 2.79, p = .052) consistently showed directional trends towards higher executive function for low dose app users (1 - 29 min/day) than non-users. While not statistically significant, these differences would suggest an improvement that would equate to approximately ~6 months of normal development in visual-spatial working memory, ~3 months of normal development in phonological working memory, and ~8 months of normal development in shifting. No other significant associations between app use and executive functions were observed.

In terms of psychosocial development, low dose app users (1 - 29 min/day) were indicated as having significantly fewer reported total difficulties (MD = -1.67; CI: -3.31, -0.02, p = .047) compared to non-users (high-dose users did not significantly differ from non-users in total difficulties score). Based on epidemiological data based from British children (5-to -16 years) derived from the SDQ, the relative risk of children in this sample developing a psychiatric disorder within three years is 23-38% lower when engaging in low dose app use (Goodman & Goodman, 2009). No other significant associations were observed between app use and psychosocial domains.
Table 5.3 Mean, and marginal mean differences (95% Confidence Intervals) for associations between dose of engagement in apps with executive functions and SDQ subscales and total difficulties scores.

<table>
<thead>
<tr>
<th></th>
<th>Mean (95% CI) for each group</th>
<th>Mean (95% CI) difference between groups</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Non-users (0 min/day)</td>
<td>Low dose users (&gt;1 – 29 min/day)</td>
</tr>
<tr>
<td><strong>Executive Functions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual spatial</td>
<td>241</td>
<td>1.15</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.95, 1.34)</td>
<td>(1.17, 1.49)</td>
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<tr>
<td></td>
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<td></td>
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<tr>
<td>Working Memory</td>
<td>235</td>
<td>1.63</td>
<td>1.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.41, 1.84)</td>
<td>(1.62, 1.98)</td>
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<tr>
<td>Phonological Working Memory</td>
<td>224</td>
<td>0.55</td>
<td>0.53</td>
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<tr>
<td></td>
<td></td>
<td>(0.50, 0.60)</td>
<td>(0.48, 0.57)</td>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Inhibition</td>
<td></td>
<td>3.71</td>
<td>5.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.63, 4.78)</td>
<td>(3.99, 6.20)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Shifting</td>
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<td>3.46</td>
<td>3.10</td>
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<td>(2.58, 4.34)</td>
<td>(2.29, 3.90)</td>
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<td>Psychosocial Development</td>
<td></td>
<td>5.80</td>
<td>4.49</td>
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<tr>
<td></td>
<td></td>
<td>(4.45, 7.15)</td>
<td>(3.37, 5.61)</td>
</tr>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems</td>
<td>223</td>
<td>7.32</td>
<td>7.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6.49, 8.15)</td>
<td>(6.99, 8.08)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Externalising problems</td>
<td>223</td>
<td>9.26</td>
<td>7.59</td>
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<tr>
<td></td>
<td></td>
<td>(7.31, 11.21)</td>
<td>(6.25, 8.92)</td>
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<td></td>
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<td>Total Difficulties</td>
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<td>(7.31, 11.21)</td>
<td>(6.25, 8.92)</td>
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</tbody>
</table>

Note. Linear regression models adjusted for age, sex, suburb-level socio-economic status, parental education, participation in sport, physical activity duration (MVPA), home learning environment, sleep duration, total program viewing, and childcare-level clustering. p < .05
5.4 Discussion

This study sought to investigate the cross-sectional associations of habitual electronic media use with executive functions and psychosocial development in preschool children. Given changing patterns and levels of electronic media use, understanding the potentially changing nature of associations with child development outcomes is essential. In line with prior studies, a majority of associations were non-significant, despite uniquely separating out electronic media behaviours and considering contemporary media behaviours. There were, however, some significant associations, which accounted for differences of 2-5 months in normal expected development across executive function domains. Specifically, visual-spatial working memory was lower at higher levels of total electronic media use and program viewing, and app users had significantly, and descriptively better executive functions. Furthermore, low dose app users demonstrated significantly fewer reported total psychological difficulties, compared to non-users.

These contrasting results suggest that different forms of electronic media use may be differentially associated with executive functions and psychosocial development in early childhood, which are in contrast to the literature that has predominantly examined traditional media behaviours (e.g., TV viewing). If so, this has implications for early guidelines and recommendations, as well as identification of electronic media behaviours and characteristics that may be beneficial or detrimental to child development.

The current findings are consistent with the broader evidence base suggesting that TV/program viewing may be detrimental to young children’s development (Poitras et al., 2017). Specifically, our findings suggest that program viewing (and indeed total media time, of which 84% was constituted by program viewing) were negatively associated with children’s visual-spatial working memory. Yet this finding was only evident for visual-
spatial working memory, and no other executive functions or psychosocial health is inconsistent with this claim that the results are comparable to the broader evidence base. Instead, these results largely align with the majority of existing cross-sectional and longitudinal studies reporting nil associations between media use (TV time) and executive functions or psychosocial development in preschool children.

A greater number of associations were observed, and in a more systematic fashion, for more contemporary forms of electronic media, however, for cognitive and psychosocial health. This is, to the best of our knowledge, the first demonstration of associations between early app use and better cognitive and psychosocial development. It is notable that directionally the most consistent associations were with low app use, suggesting that any possible effects of app use may be curvilinear (i.e., limited use with sound educational/developmental content may be beneficial, while high levels of use cannot replace the enriching environments and experiences they replace). This would parallel other findings in school-aged children, as such that reducing electronic media use has been found to be associated with better health and development (Carson et al., 2015), yet current data in the early years are unable to indicate what optimal levels might be given the scarcity of research on interactive devices. It is unclear if moderate levels of engagement in these devices may exert beneficial associations with domains of executive functions, however the positive associations observed may be due to their similarity to the key features of children’s play toys, in comparisons to passive electronic media use (Christakis, 2014). For example, Christakis (2014) summarizes, and compared traditional the key features of toys such as block play, to touch screen devices, and television. In his comparison Christakis suggested that theoretically interactive device differ from traditional passive media use (TV viewing), and interactive devices may be in fact superior to all traditional play devices
when comparing specific features. For example, Christakis suggests that a touch screen is reactive, promotes joint attention, and are highly portable; all of which can be provided by playing with traditional toys. However, touch screens also have the additional advantage of being interactive, tailorable and progressive, while a television provides none of these features. Nevertheless, the threshold of 30min/day has been raised as a reasonable and pragmatic recommendation (Christakis 2014), and our findings provide preliminary support for this threshold.

Discrepancies among studies within the literature for electronic media use, executive functions and psychosocial development could be due to many factors including; inconsistent reporting/classifications of media use (i.e., continuous vs. categorical variables); inconsistent definitions of electronic media use (i.e., electronic media use being inclusive of TV and computer us, with limited studies assessing contemporary media behaviours in comparison to more traditional media behaviours); the majority of studies have utilized screen time measures that lack psychometric properties, and thus these tools may not be valid or reliable; variations in what covariates are accounted for; cultural differences across studies, or a lack of heterogeneity across outcome measures (i.e., parent vs. educators reported SDQ).

A number of mechanistic pathways could explain the observed detrimental, nil or positive associations in this study for differing types of media use. One important consideration is the differing characteristics of contemporary interactive electronic apps use vs passive media use such as program viewing, which might account for the discrepancies observed across the different types of electronic media use. For instance, during app use, children may be presented with different images or shapes (visual processing), attend to the locations of these images or objects (spatial imagery), and may be required to respond to
verbal directions (phonological working memory) in which the child would respond and progress at their own pace when interacting with the stimuli, as opposed to the passive nature of TV viewing (Subrahmanyam & Renukarya, 2015). They may need to shift their attention between the tasks and rules (shifting) and maintain information in their mind over time (Subrahmanyam & Renukarya, 2015). Interactive media use may have the potential to be highly engaging for preschool children. While the specific qualities, characteristics, doses, and patterns of app use that may be beneficial to child development requires further investigation (see, for example; Radesky, Schumacher & Zuckerman. 2015; Radesky and Christakis. 2016), that there were more frequent and robust associations with app use suggests the possibilities inherent in this form of electronic media use for cognitive and psychosocial development.

Additionally, time spent engaging in program viewing may displace time away from other developmentally rich exploratory activities that require direct manipulation of objects in the physical environment (e.g., puzzles, block play, or card games), or displace time away from real world experiences that might be more beneficially to a child’s visual-spatial working memory development. However, it is important to also consider the predominately null associations observed for program viewing and developmental outcomes. This may be explained for the context of the viewing behavior itself. For example, program viewing at this age is very ubiquitous, in that the majority of children engage in this form of electronic media behavior, therefore it is difficult to differentiate between those children who are low and high in executive functions. Further, program viewing at this age is relatively new, so program viewing has not had chance to become embedded, thus may not have much of an effect of executive functions or psychosocial development. In addition, in terms of program viewing, there may be positive and negative forms of programming content. For instance,
experimental evidence demonstrated that decreasing violent content and increasing pro-social content improved social behaviours in preschool children (Christakis et al., 2013). Likewise, inappropriate content, such as viewing of fast paced programs, might also be detrimental to young children’s executive function development (Lillard & Peterson, 2011). Although an analysis of media content was not within the scope of this study, it might be important to explore the influences of other factors related with all forms of electronic media exposures in future research (i.e., positive vs. negative program viewing) along with social context within which it occurs. Christakis (2014) suggests there is potential for both direct and indirect pathways in which electronic media use may influence development.

There are also plausible mechanisms that might explain why young children who use apps at a low dose might display fewer psychological difficulties than non-users. As observed in this study, app use may exert positive influence on executive functions, and evidence suggests that executive functions and self-regulatory behaviours underlie children’s psychosocial development (Hofmann et al., 2012). Because better executive functions are associated with psychosocial development during early childhood (Benavides-Nieto et al., 2017), it may be hypothesized that low dose app use promotes self-regulatory behaviours that promotes focused attention and reduces hyperactivity, thus impacting psychosocial development through improvements in executive functioning. However, additional longitudinal and experimental studies are required to confirm our preliminary findings and investigate potential mechanistic pathways.

A particular strength of this study was exploring modern electronic media formats, where previous studies focus on activities that are becoming increasingly less common. In addition, it considered those activities together and apart, to understand how associations might differ (e.g., be positive for some and negative for others) by type and duration of
electronic media use, in which differences in associations were revealed with developmental outcomes in young children. Additionally, direct assessments of multiple executive functions were completed using a battery that has strong validity, reliability, and developmental sensitivity (Howard & Melhuish, 2017). The inclusion of several covariates such as area-level SES, parental education, physical activity and sports participation, the home learning environment, and sleep duration that might confound associations with developmental outcomes adds further weight to the findings.

However, this study is not without its limitations, the findings are based on cross-sectional data, therefore limiting any inferences of causation. For instance, parents may use electronic media as a self-regulatory tool for children who have lower executive functions or low internal self-regulatory mechanisms, as way to keep them calm or distracted (i.e., self-regulation as a causal factor contributing to electronic media use; Cliff, Howard, Radesky, McNeill, & Vella, 2018; Radesky & Christakis, 2016). It could also be that children who show fewer behavioral problems have fewer restrictions on exposure to such devices from parents. Consequently, exposure to electronic media may be a response to children’s behavior rather than the cause of their behavior. Further, evidence has suggested that a child’s screen time use may be the result of an interaction between child and parent factors, that is highly influenced by parental attitudes however, this was not within the scope of this study (Lauricella, Wartella, & Rideout, 2015). For instance, ‘technoference’ a concept described as everyday interruptions in social interactions that occur due to digital and mobile technology devices have been observed. Bidirectional associations have been observed in which parents who feel stressed by their child’s difficult behavior, may then withdraw from parent–child interactions when using technology together, and, further this individual higher technology use during parent–child interactions may influence
psychosocial health over time (McDaniel & Radesky, 2018). Additionally, because parents reported their child’s electronic media use, there is potential for parents to intentionally or unintentionally misreport this outcome. Previous studies have indicated the possibility of both under-reporting and over-reporting of screen-time/television viewing (Colley et al., 2012; Robinson et al., 2006). This issue is common to all population-based observational studies of preschool children’s electronic media use (Hinkley, Teychenne, et al., 2014) because, at present, there are no practical alternative approaches. As such the results should be interpreted with caution. Further, another limitation may be the use of administration of executive function tasks on an iPad. However, the iPad-based measures function just as a paper-based assessment would (but without issues of inter-rater reliability), and do not introduce artefacts of technological expertise. Further, the assessments were very brief and thus highly unlikely to have influenced results by virtue of simply having done these assessments.

5.5 Conclusion

The current study nevertheless presents novel and interesting insights from which to continue these important investigations into children’s contemporary electronic device use and its developmental implications. That is, children who spent more time program viewing had at best the same, and at worst poorer, executive functions and psychosocial development. Conversely, children who were low dose app users appeared to have better executive functions and less psychosocial problems. Further research such as this, but longitudinal and experimental, is needed to further evaluate both the positive and negative developmental effects that are suggested by these results. This study provides an important
initial study into the likely viable targets and early expectations for further investigations in this area.
Chapter 6: Longitudinal associations of electronic application use and media program viewing with cognitive and psychosocial development in preschoolers.

This chapter published as:


Chapter 5 examined the associations of electronic media use with executive functions and psychosocial development in preschool children cross-sectionally. While cross-sectional study designs are important to establish associations, an understanding of the temporal nature of associations is needed. This chapter builds on chapter 5, and further address Aim 2: To examine the associations of electronic media use with executive functions and psychosocial health in preschool children *longitudinally*. In this chapter, the following research question is investigated:

Research Question 2: Do the associations between total electronic media use and executive functions or psychosocial health differ by the type of electronic media (i.e., program viewing or use of electronic apps) in preschool children?
6.1 Introduction

Executive functions are higher-order cognitive processes implicated in the ability to reason, problem-solve, and plan, through their enabling of manipulating information in mind (working memory), resisting distractions and impulsive behaviours (inhibition), and flexibly switching between task demands (shifting; Miyake et al., 2000). Executive functioning in the preschool period, in particular, is associated with later school readiness, academic achievement (Blair & Razza, 2007), risky life choices (Moffitt et al., 2011) and psychosocial health (Benavides-Nieto et al., 2017). These outcomes appear to be further influenced by the flow-on effect of negative trajectories in areas also influenced by executive functions, such as the health outcomes of poor psychosocial health (e.g., depression; Meagher et al., 2009). Understanding determinants of executive functions and psychosocial health in preschoolers may provide targets for prevention or early intervention, with implications for broad health and developmental outcomes in later life.

Electronic media, particularly watching television (TV), has been linked with detrimental child health outcomes (Poitras et al., 2017). Consequently, the US, Australia and Canada are consistent in recommending children aged 2-5 years should engage in no more than 1 hour/day of screen time (American Academy of Pediatrics, 2016; Okely et al., 2017; Tremblay et al., 2017). Despite these guidelines, US national data indicate that 2-to 4-year-olds engage in, on average, almost 2.5 hours of electronic media use per day (Common Sense Media, 2017). While children’s time engaging in electronic media use has remained relatively constant, exposure to and use of mobile devices has tripled from 2011-2017 among 0- to 8-year-olds in the US (Common Sense Media, 2017). Yet, current guidelines are premised predominantly on studies of traditional electronic media behaviours (i.e., TV/DVD viewing or electronic console gaming). There is a scarcity of research on
contemporary, interactive media, including electronic applications (apps; Poitras et al., 2017). Hypothesized mechanisms through which electronic media use might adversely affect young children, is via over stimulation of the developing brain, or displacement of time from social interactions or other developmentally beneficial activities (Radesky & Christakis, 2016; Radesky et al., 2015). There is speculation that contemporary interactive media with touch-screen technologies may have different effects due to the potential for reactivity, interactivity, tailorability, progressiveness, promotion of joint attentions, and portability (Christakis, 2014). Further research is needed to understand if interactive media use may have different associations with young children’s development (Poitras et al., 2017).

Of the two longitudinal studies that investigated the relationship between electronic media use and executive functions (Blankson et al., 2015; Zimmerman & Christakis, 2005), and the two longitudinal studies that investigated the relationship between electronic media use and psychosocial health (Hinkley, Verbestel, et al., 2014; Hinkley et al., 2017), only associations with traditional forms of media use are available (with results inconsistent across media types). That is, evidence from these studies reported that: TV time was not associated with executive functions or psychosocial health (Blankson et al., 2015; Hinkley, Verbestel, et al., 2014; Hinkley et al., 2017; Zimmerman & Christakis, 2005); computer use was positively associated with emotion problems, but not peer problems (Hinkley, Verbestel, et al., 2014); and electronic game use was positively associated with emotional health (Hinkley et al., 2017).

Notably, no longitudinal studies have examined associations of executive functions or psychosocial health with contemporary media behaviours (e.g., app use). As such, it is unclear whether associations for early contemporary interactive media use (i.e., apps) and
traditional passive media use (i.e., TV/ program viewing) may differ in their associations with children’s cognitive and psychosocial health. The current longitudinal study examined if electronic media use at 3- to 5-years, particularly total screen time, program viewing and app use, was associated with cognitive and psychosocial health in children 12-months later.

6.2 Methods

Centre recruitment

Data were drawn from the Preschool Activity, Technology and Health, Adiposity, Behaviour and Cognition (PATH-ABC) study (Cliff, McNeill, Vella, Howard, Kelly, et al., 2017), which had University of Wollongong Health and Medical Human Research Ethics Committee approval (HE14/310). Preschools were recruited based on a stratified sampling process from the Illawarra region of New South Wales, Australia. Preschools (long day cares and preschools) in the region were categorized according to the 2011 Socio-Economic Indices for Areas (SEIFA) Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) as a low (deciles 1-4), medium (deciles 5-7) or high socio-economic area (deciles 8-10; ABS (Australian Bureau of Statistics), 2011). The number of preschools invited to participate from each socio-economic group was proportional to the population distribution. A total of 24 ECEC’s were invited into the PATH-ABC project, and 18 (75%) consented. Baseline data were collected in preschools (n=18) between April and December 2015. Follow-up data were collected between April and December 2016, at preschools (n=17) or the child’s primary school (n=51).
Sample

Children were eligible to participate if they were 3- to 5-years of age, generally healthy, and were typically developing. Children could not participate if they had a learning or physical disability, known motor delay, or a diagnosed medical or psychological condition that was pertinent to the study’s outcome variables (e.g., conduct disorder). 503 children were recruited into the project, 13 children were not eligible, resulting in 490 eligible participants. At baseline 490 eligible participants were recruited, 243 had missing data and 12 did not consent to follow-up, thus 235 participants provided complete data. Of the 235 participants with complete data, 15 did not agree to be reconsented, and 35 were not contactable. Therefore, 185 participants were included in the analytic sample.

Participant characteristics are reported in Table 5.1. However, due to incomplete data for cognitive and psychosocial variables, sample sizes for the individual analyses varied (Table 5.2).

Measures

**Predictors: Electronic media use.** Parents reported the total number of electronic media devices in the house, and of those how many were available to the child at 3- to 5-years of age. Also reported was the total time a child spent engaging in electronic media behaviours separately for weekdays and weekend days during a typical week, and by the following types of media use; i) program viewing on traditional devices, e.g., TV/DVD; ii) program viewing on non-traditional devices, e.g., Tablet, DVD in car, computer, laptop, mobile phone; iii) apps on portable handheld devices or laptop/computer, e.g., tablet, mobile phone, handheld game system; iv) non-active console games, e.g., PlayStation or Xbox; and v) active console games, e.g., Wii or Xbox Kinect. Original electronic media use
items had established acceptable test-retest reliability (ICC = 0.68–0.69; Hinkley et al., 2012). The total time in each behaviour was averaged to calculate an average daily time of engagement in each behaviour, and then summed to calculate daily total electronic media time. Averages for traditional (e.g., TV) and non-traditional program viewing (e.g., tablet) were summed to calculate average daily total ‘program viewing’ and analysed as a continuous variable. A large proportion of children did not engage in app use (11%), consequently due to data distributions, app use on portable devices was analysed categorically, with daily estimates categorized as: i) non-users (0 min/day); ii) low dose users (1 – 29 min/day); or iii) high dose users (≥30 min/day). A limit of 30 min/day was chosen because it aligned with the lower pragmatic limit identified by Christakis (2014), a leading expert in the field, for young children’s app use. Average daily minutes using active consoles and non-active consoles were combined to calculate average daily console use, as a continuous variable.

**Outcomes: Cognitive development.** Executive function was assessed using measures drawn from the Early Years Toolbox, which has been psychometrically validated in preschool-aged children, in that it is developmentally appropriate, sensitivities enough to detect change, as well as being technologically dynamic (Howard & Melhuish, 2017). The measures have demonstrated validity (i.e., construct and convergent) and reliability (e.g., internal consistency). For instance, correlations of EYT measures with comparison measures selected from the NIH Toolbox were as follows: working memory, \( r(79) = .46, p < .001 \); Inhibition, \( r(80) = .40, p < .001 \); and Shifting, \( r(80) = .45, p < .001 \). Internal consistency analyses for Go/No-Go showed good reliability for both go (Cronbach’s \( \alpha = .95 \)) and no-go trials (Cronbach’s \( \alpha = .84 \)) in Australian pre-school samples (Howard & Melhuish, 2017). The iPad-based EYT is brief to administer, and offers a number of
pragmatic advances (e.g., data capture, standardization, engaging for young children).

Measures were administered in two assessment sessions grouped by outcomes: physical health; then cognitive development. The EYT assessments adopted index visual-spatial working memory (‘Mr Ant’), phonological working memory (‘Not This’), inhibition (‘Go-No-Go’) and shifting (‘Dimensional Change Card Sort’). Measures were administered by a trained researcher using an electronic tablet, through which all instructions, practice, familiarization, feedback and scoring are delivered and standardized, under the guidance of a data collector. Full details of the EYT methodology, reliability and validity have been reported elsewhere (Howard & Melhuish, 2017).

*Psychosocial health.* Psychosocial health was assessed at baseline and follow-up using the educator-reported version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), which has been validated for use Australian preschoolers (Hawes & Dadds, 2004). In addition, sufficient psychometric properties for internal consistency, test-retest reliability and inter-rater agreement have been reported across studies for the teacher version of the SDQ (Stone et al., 2010). The SDQ is comprised of 25-items assessing five psychosocial domains: conduct problems; hyperactivity; emotional problems; peer problems; and pro-social behaviour. Educators rate the typicality of each target behaviour (i.e., item) on a 3-point Likert scale ranging from not true (0) to certainly true (2). In low risk and general populations, a three-subscale model of the SDQ is appropriate, comprising: (1) internalising problems (sum of emotional problems and peer problems subscales); (2) externalising problems (sum of conduct problems and hyperactivity subscales); and (3) pro-social behaviours. Total psychological difficulties were also calculated by summing the 20 items pertaining to psychosocial problems (i.e., conduct problems, hyperactivity, emotional symptoms, and peer problems).
Child and parent covariates. Data on child and parent covariates were collected via parent-report survey. These covariates were child age, child sex, area-level socioeconomic status (SEIFA; Australian Bureau of Statistic [ABS], 2011) and primary caregiver education (categorized as less than Year 12 high school, Year 12 high school completion or trade, or tertiary qualification). In addition, due to evidence of their associations with children’s cognitive and psychosocial health, further covariates collected and considered were parent-reported: average sleep time (Chaput et al., 2017), sports participation (McNeill et al., 2018), Moderate-to-Vigorous intensity Physical Activity (MVPA; McNeill et al., 2018), and educational and extra-curricular experiences as an index of the quality of the home learning environment (Sammons et al., 2015). Parents reported children’s average daily sleep duration (hrs; Cliff, McNeill, Vella, Howard, Kelly, et al., 2017), sports participation (participant or non-participant; (McNeill et al., 2018), and the quality of the home learning environment (i.e., frequency with which parents engaged their children in going to the library, reading, listening to the child read, practicing numbers, or teaching them songs; Sammons et al., 2015). Children’s moderate-to vigorous intensity physical activity was assessed using accelerometry (Cliff, McNeill, Vella, Howard, Kelly, et al., 2017; McNeill et al., 2018).

Analytical strategy

Analyses were conducted in STATA/IC (v13.1: Stata Corporation, College Station, TX). Differences between the analytical sample and those excluded due to missing data were tested using independent samples t-tests. It was determined that the level of missing data was too high for confident imputation, as such complete case analysis was used, and the resultant sample was investigated for any evidence of bias. Children with missing data
had lower IRSAD scores \( (p = .003) \) and lower phonological working memory scores at baseline \( (p = .028) \). Separate linear regression models were conducted, due to expected multicollinearity, to examine the associations of total electronic media use, program viewing, and app use at baseline with each executive function or psychosocial health subscale at follow-up. All models controlled for age, sex, area-level SES, parental education, sleep, participation in sport, MVPA, home learning environment quality, preschool-level clustering, participants’ educational setting at follow-up (i.e., preschool or primary school) and the baseline levels of the outcome variable. The model examining program viewing also controlled for app use, and the model examining app use controlled for total program viewing, due to these being the predominant forms of electronic media use in young children. Assumptions of normality for linear regression was assessed by examining distributions of residuals for each model, no variable required transformation. Participant characterises are presented as means ± standard deviations (SD), and distributions of the sample are presented as percentages. Regression results are presented as unstandardized beta coefficients \( (b) \) and 95% confidence intervals (95% CI) for continuous variables, and mean differences \( (MD) \) and 95% CIs for categorical variables. Unstandardized beta coefficients describe the unit change in the dependent variable given a 1-unit change in the independent variable, and indicate the effect size for continuous associations (Schroeder, Sjoquist, & Stephan, 2016). For significant categorical associations, Cohen’s d standardized effect size is reported, where effect sizes of approximately 0.2, 0.5 and 0.8 are generally considered small, medium and large effects, respectively (Cohen, 1988). Significance was set at \( p < .05 \).
6.3 Results

On average, children spent ~2.4 h/day engaging with electronic media at baseline (3- to 5-years of age), with the majority of this time (122 min/day; 85%) spent in program viewing, and 13% (19 min/day) and 2% (3 min/day) of the total time spent using apps and console devices, respectively. There were, on average, 10 (SD 3.4) electronic media devices in children’s homes, with 4 (SD 2.7) available for children to use. Compared to boys, girls experienced fewer externalising behaviour problems ($p = .014$), and fewer girls spent ≥30 min/day using apps ($p = .033$), remaining gender differences are reported in Table 6.1. Children’s mean executive function scores were in line with preliminary norms derived from EYT validation (Howard & Melhuish, 2017). Mean scores for internalising and externalising subscales, pro-social scores and total difficulties scores for the SDQ fell within the ‘normal’ ranges (Goodman & Goodman, 2009). From 3- to 5-years to 4- to 6-years of age, significant improvements were found for all executive function domains ($p < .001$) and for total difficulty scores ($p = .033$) (Table 6.2), but not for other SDQ subscales.
Table 6:1 Participant characteristics 3- to 5-years.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Boys</th>
<th></th>
<th>Girls</th>
<th></th>
<th>Total sample</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean (SD)</td>
<td>n</td>
<td>Mean (SD)</td>
<td>n</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Age (y)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>112</td>
<td>4.32 (0.66)</td>
<td>73</td>
<td>3.99 (0.57)</td>
<td>185</td>
<td>4.19 (0.64)&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>SES (IRSAD)</td>
<td>112</td>
<td>1027.20 (60.00)</td>
<td>73</td>
<td>1020.33 (55.02)</td>
<td>185</td>
<td>1024.0 (57.35)</td>
</tr>
<tr>
<td>Sleep (hrs/day)</td>
<td>112</td>
<td>10.52 (1.00)</td>
<td>73</td>
<td>10.62 (0.81)</td>
<td>185</td>
<td>10.56 (0.93)</td>
</tr>
<tr>
<td>Parental Education</td>
<td>n (%)</td>
<td></td>
<td>n (%)</td>
<td></td>
<td>n (%)</td>
<td></td>
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<tr>
<td>less than Year 12 High School (%)</td>
<td>10</td>
<td>8.9</td>
<td>21</td>
<td>28.8</td>
<td>31</td>
<td>16.8&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>Year 12 High School or Trade/ Diploma (%)</td>
<td>36</td>
<td>32.1</td>
<td>10</td>
<td>13.7</td>
<td>46</td>
<td>24.9&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>Degree/Postgraduate (%)</td>
<td>66</td>
<td>58.9</td>
<td>42</td>
<td>57.5</td>
<td>108</td>
<td>58.4</td>
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<td>Participant education sector</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>follow-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Preschool</td>
<td>62</td>
<td>55.4</td>
<td>51</td>
<td>69.9</td>
<td>113</td>
<td>61.1</td>
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<tr>
<td>Primary school</td>
<td>50</td>
<td>44.6</td>
<td>22</td>
<td>30.1</td>
<td>72</td>
<td>38.9</td>
</tr>
<tr>
<td>Electronic Media Avg.min/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total electronic media</td>
<td>112</td>
<td>145.45 (80.64)</td>
<td>73</td>
<td>143.70 (79.32)</td>
<td>185</td>
<td>145.04 (79.91)</td>
</tr>
<tr>
<td>Total program viewing TV</td>
<td>112</td>
<td>118.75 (64.83)</td>
<td>73</td>
<td>127.36 (74.30)</td>
<td>185</td>
<td>122.15 (68.65)</td>
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<tr>
<td>Total program viewing (traditional devices)</td>
<td>112</td>
<td>94.88 (48.87)</td>
<td>73</td>
<td>101.42 (61.38)</td>
<td>185</td>
<td>97.46 (54.09)</td>
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<tr>
<td>Total program viewing (non-traditional devices)</td>
<td>112</td>
<td>23.87 (33.40)</td>
<td>73</td>
<td>25.94 (33.74)</td>
<td>185</td>
<td>24.69 (33.46)</td>
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<tr>
<td>Apps use</td>
<td>112</td>
<td>22.79 (27.88)</td>
<td>73</td>
<td>13.55 (18.35)</td>
<td>185</td>
<td>19.15 (24.93)</td>
</tr>
<tr>
<td>Console use (combined)</td>
<td>112</td>
<td>3.91 (12.85)</td>
<td>73</td>
<td>2.79 (19.68)</td>
<td>185</td>
<td>3.74 (15.73)</td>
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<tr>
<td>Active console use</td>
<td>112</td>
<td>0.91 (4.36)</td>
<td>73</td>
<td>0.23 (1.41)</td>
<td>185</td>
<td>2.82 (14.82)</td>
</tr>
<tr>
<td>Non-active console use</td>
<td>112</td>
<td>3.0 (10.65)</td>
<td>73</td>
<td>2.56 (19.66)</td>
<td>185</td>
<td>0.65 (3.51)</td>
</tr>
<tr>
<td>App use</td>
<td>n (%)</td>
<td></td>
<td>n (%)</td>
<td></td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td>Non- users (0 min/day) (%)</td>
<td>27</td>
<td>24.1</td>
<td>27</td>
<td>37.0</td>
<td>54</td>
<td>29.2</td>
</tr>
<tr>
<td>Low-dose users (&gt;1 – 29 min/day) (%)</td>
<td>52</td>
<td>46.4</td>
<td>35</td>
<td>47.9</td>
<td>87</td>
<td>47.0</td>
</tr>
<tr>
<td>High-dose users (≥30 min/day) (%)</td>
<td>33</td>
<td>29.5</td>
<td>11</td>
<td>15.1</td>
<td>44</td>
<td>23.8&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: Data presented as mean (standard deviation) for continuous variables, and percentages for categorical variables. Abbreviations: SD, standard deviation; SES, socioeconomic status; IRSAD, Index of Relative Socio-economic advantage and disadvantage. <sup>a</sup>At enrolment into the study. <sup>b</sup>score range: 0 – 8, <sup>c</sup>score range: 0 – 8, <sup>d</sup>score range: 0 – 1, <sup>e</sup>score range: 0 – 12, <sup>f</sup>score range: 0 – 20, <sup>g</sup>score range: 0 – 20, <sup>h</sup>score range: 0 – 10, <sup>i</sup>score range: 0 – 4; <sup>*</sup>p <.05, <sup>**</sup>p <.01
Table 6.2 Mean (SD) Executive functions and SDQ subscales scores at 3- to 5-years and 4- to 6-years.

<table>
<thead>
<tr>
<th>Developmental outcomes</th>
<th>3-5 years</th>
<th>4-6 years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual-Spatial Working Memory&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.29 (1.02)</td>
<td>2.25 (0.92)&lt;sup&gt;†&lt;/sup&gt;</td>
</tr>
<tr>
<td>Phonological Working Memory&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.80 (0.79)</td>
<td>2.17 (0.71)&lt;sup&gt;†&lt;/sup&gt;</td>
</tr>
<tr>
<td>Inhibition&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.56 (0.21)</td>
<td>0.73 (0.16)&lt;sup&gt;†&lt;/sup&gt;</td>
</tr>
<tr>
<td>Shifting&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.51 (4.35)</td>
<td>7.64 (3.64)&lt;sup&gt;†&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Psychosocial Health</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.22 (2.85)</td>
<td>2.83 (3.17)</td>
</tr>
<tr>
<td>Externalising problems&lt;sup&gt;f&lt;/sup&gt;</td>
<td>5.27 (4.54)</td>
<td>4.41 (4.44)</td>
</tr>
<tr>
<td>Pro-social behaviours&lt;sup&gt;g&lt;/sup&gt;</td>
<td>7.23 (2.61)</td>
<td>7.49 (2.35)</td>
</tr>
<tr>
<td>Total difficulties&lt;sup&gt;h&lt;/sup&gt;</td>
<td>8.50 (5.78)</td>
<td>7.24 (6.22)&lt;sup&gt;†&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Note:*
- Characteristics of the participants are presented as mean ± SD, distributions of the sample are presented in percentages.
- <sup>a</sup>score range: 0 – 8;
- <sup>b</sup>score range: 0 – 8;
- <sup>c</sup>score range: 0 – 12;
- <sup>d</sup>score range: 0 – 1;
- <sup>e</sup>score range: 0 – 20;
- <sup>f</sup>score range: 0 – 20;
- <sup>g</sup>score range: 0 – 10;
- <sup>h</sup>score range: 0 – 40;
- <sup>†</sup>p < .05.

**Program viewing and total electronic media use**

Higher levels of program viewing at baseline were associated with more externalising problems at follow-up ($b = 0.008; 95\% CI: 0.002, 0.014, p = 0.010$) (Table 6.3). Higher levels of program viewing at baseline were associated with higher total difficulties at follow-up ($b = 0.013; 95\% CI: 0.005, 0.022, p = 0.005$). A 68 min/day (1SD) lower exposure to program viewing at 3- to 5-years equated to a 12-20% lower risk of being diagnosed with a psychiatric disorder within three years (Goodman & Goodman, 2009). Higher levels of program viewing at 3- to 5-years were also marginally associated with higher internalising behaviours at follow-up ($b = 0.005; 95\% CI: 0.000, 0.010, p =$
Total electronic media use and program viewing at baseline were not significantly associated with executive functions or prosocial behaviours at follow-up.

**Table 6.3** Unstandardised beta coefficients and 95% confidence intervals for associations of media use and program viewing at 3- to 5-years, and associations between executive functions, SDQ subscales and total difficulties scores at 4- to 6-years, controlling for executive functions, SDQ subscales and total difficulties scores at 3- to 5-years and adjusted for covariates.

<table>
<thead>
<tr>
<th></th>
<th>Total electronic media use</th>
<th>Program viewing&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>n</strong></td>
<td><strong>b</strong> (95% CI)</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual-spatial working memory</td>
<td>182</td>
<td>0.000 (0.001, 0.002)</td>
</tr>
<tr>
<td>Phonological working memory</td>
<td>175</td>
<td>0.000 (0.001, 0.001)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>167</td>
<td>-0.000 (0.000, 0.000)</td>
</tr>
<tr>
<td>Shifting</td>
<td>179</td>
<td>0.003 (-0.003, 0.010)</td>
</tr>
<tr>
<td><strong>Psychosocial Health</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prosocial behaviours</td>
<td>156</td>
<td>-0.002 (-0.004, 0.001)</td>
</tr>
<tr>
<td>Internalising problems</td>
<td>156</td>
<td>0.002 (-0.003, 0.008)</td>
</tr>
<tr>
<td>Externalising problems</td>
<td>156</td>
<td>0.004 (-0.001, 0.009)</td>
</tr>
<tr>
<td>Total Difficulties</td>
<td>156</td>
<td>0.007 (-0.002, 0.016)</td>
</tr>
</tbody>
</table>

*Note:* Linear regression models adjusted for age, sex, suburb-level socio-economic status, parental education, participation in sport, physical activity duration (MVPA), home learning environment, sleep duration, total program viewing, and childcare-level clustering. <sup>a</sup>Additionally adjusted for app use. <sup>p</sup> < 0.05, significant associations are in bold.
Application use

High dose app users (≥30 min/day) at baseline had a significantly lower inhibition score ($MD = -0.04 \ CI: -0.09, -0.00, p = 0.044, d = -0.19$) at follow-up than low dose app users (1 - 29 min/day) (Table 6.4). This difference equates to ~2.7 months of normal development (Howard & Melhuish, 2017), and represented a small effect ($d = -0.19$). There were no significant differences between non-users, and low or high dose app users in visual-spatial or phonological working memory, shifting, or psychosocial health at follow-up.
Table 6:4 Mean, and marginal mean differences (95% Confidence Intervals) for associations between dose of engagement in apps at 3- to 5-years, and associations between executive functions, SDQ subscales and total difficulties scores at 4- to 6-years, controlling for executive functions, SDQ subscales and total difficulties scores at 3- to 5-years and adjusted for covariates.

<table>
<thead>
<tr>
<th>Executive Functions</th>
<th>Mean (95% CI) for each group</th>
<th>Mean (95% CI) difference between groups, p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Non-users (0 min/day)</td>
</tr>
<tr>
<td>Visual spatial Working Memory</td>
<td>182</td>
<td>2.14 (1.83, 2.45)</td>
</tr>
<tr>
<td>Phonological Working Memory</td>
<td>175</td>
<td>2.21 (1.96, 2.45)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>167</td>
<td>0.73 (0.68, 0.79)</td>
</tr>
<tr>
<td>Shifting</td>
<td>179</td>
<td>7.53 (6.54, 8.52)</td>
</tr>
<tr>
<td>Psychosocial Health</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems</td>
<td>156</td>
<td>2.98 (1.50, 4.47)</td>
</tr>
<tr>
<td>Externalising problems</td>
<td>156</td>
<td>4.70 (3.45, 5.94)</td>
</tr>
<tr>
<td>Prosocial behaviours</td>
<td>156</td>
<td>7.32 (6.72, 7.92)</td>
</tr>
<tr>
<td>Total Difficulties</td>
<td>156</td>
<td>7.62 (5.36, 9.88)</td>
</tr>
</tbody>
</table>

Note: Linear regression models adjusted for age, sex, suburb-level socio-economic status, parental education, participation in sport, physical activity duration (MVPA), home learning environment, sleep duration, total program viewing, and childcare-level clustering. p < 0.05, significant mean differences are in bold.
6.4 Discussion

This longitudinal study sought to investigate associations of traditional and contemporary habitual electronic media use with executive functions and psychosocial development 12-months later in preschoolers. Higher levels of program viewing (e.g., TV or internet programs on any device) at age 3- to 5-years was associated with increases in externalising behaviour problems and total psychological difficulties 12-months later. Similarly, high dose app users (≥30 min/day) at age 3- to 5-years had lower inhibition 12-months later compared to low dose app users (1 - 29 min/day). Traditional forms of media use exerted detrimental associations with sub-domains of psychosocial health, which is consistent with the broader literature (Poitras et al., 2017). Whereas no associations were observed for low-dose app use (1-29 min/day) with developmental outcomes, some evidence suggests that high-doses of app use (≥30 min/day) exerted a detrimental effect on inhibition. These findings indicate that different types of electronic media use may exert independent effects on health and development, and further support recommendations to limit young children’s electronic media use, to avoid over-exposure. Such recommendations might be beneficial for a child’s future cognitive development, particularly their ability to control impulsive behaviour, and psychosocial health.

The negative associations we observed between program viewing and psychological development are generally consistent with the broader evidence base indicating that program viewing (combining TV and movies) may be detrimental to young children’s psychological health (Hinkley, Teychenne, et al., 2014; Poitras et al., 2017). However, not all studies conform to these findings. Hinkley et al. (2014) reported that TV viewing during the preschool years was not associated with an increased risk of emotional or peer problems.
2 years later (internalising problems), while another study found no associations with social and emotional skills 3 years later (Hinkley et al., 2017). Although Hinkley et al. (2014) also used SDQ items, they investigated associations separately for emotional or peer problem subscales, rather than their aggregate. Further, the current study examined had a shorter follow-up period (12 months) and narrower age range (3- to 5-years), which may account for the discrepancies observed. In contrast, these detrimental associations were not observed for contemporary electronic media use. Interestingly, the detrimental associations observed for program viewing and psychosocial development in this study were not observed cross-sectionally in using the same data set, highlighting the importance of examining these behaviours over time (McNeill et al., under review).

To our knowledge, no published longitudinal studies have examined associations between app use during the preschool years and later executive function development (Herodotou, 2018; Poitras et al., 2017). Conceptually, app use on portable handheld devices may fundamentally differ in nature from traditional media use (in a way that could support executive function development), in its active engagement of children, reactivity to children’s levels of competence, and promotion of joint attention and interaction (Christakis, 2014). In support of this possibility, a review by Herodotou (2018) reported positive effects of tablets with learning and development in young children. Similarly, improvements in problem-solving, planning ability, and executive functioning were observed in children aged 4-to-6 years after practicing with a tablet-based Tower of Hanoi puzzle and then applying this learning to a physical version (Huber et al., 2016).

Despite this, our study found no associations for low-dose app use at baseline (1 – 29 min/day) and executive functions at follow-up, but high-dose app users (≥30 min/day) at baseline displayed lower inhibition capabilities than low-dose app users (1 – 29 min/day),
equating to 2.7 months of functional developmental, however the effect size was small. This might suggest that the effects of some electronic media use (i.e., app use) might be curvilinear. For example, limited app use, <30 min/day of educational, interactive app use with sound education content may at best not be developmentally harmful, yet beyond a 30min/day threshold, app use may start to reduce other developmentally-boosting activities, potentially harming a child’s development. One cross-sectional study in preschoolers (n = 100) has examined associations for media other than TV viewing – specifically, playing video/computer games – with executive functions, and null associations were reported (Carson, Rahman, et al., 2017). Differences in media exposure classification, executive function measures, and study design may potentially contribute to the discrepancies in findings between studies. In addition, and in contrast to the present study, cross-sectionally it was observed that children who were low dose app users exhibited better executive functions, and high dose app users displayed higher phonological working memory compared to non-users in the same data set (McNeill et al., under review). This highlights the importance of using sound longitudinal methodologies that improve the quality and reliability of evidence, to explore possible associations in this complex yet growing area of research.

Our novel findings suggest that, while mild levels of app use may not be detrimentally associated with a child’s executive function, higher durations (≥30min/day) may be harmful to aspects of early executive function development. While some non-significant associations were observed, these findings may provide preliminary evidence of contemporary media use to support the proposed pragmatic limit for young children of <30 min/day of app use (Christakis, 2014), ideally involving developmentally appropriate, educational content.
A number of mechanistic pathways could explain the detrimental or null associations observed for the different types of media use in this study. Engaging in program viewing (activities that are passive in nature) may have little developmental benefit to young children’s executive functions, as observed in the predominantly null findings. Time spent engaging in this type of behaviour may displace opportunities for interaction, or activities that support aspects of health, such as engaging in play and socialisation with adults, siblings or peers, real-world experiences (Moreno, 2016), or active or interactive play (Golinkoff, Hirsh-Pasek, & Singer, 2006). Providing one explanation to the detrimental associations for psychosocial health. Contrastingly, similar associations were not observed when examining contemporary media use. No developmental gains, or detrimental associations were observed longitudinally for working memory, shifting, or psychosocial sub-domains, however high app exposure was detrimental to inhibition, relative to low dose exposure. High levels of app exposure may impact a child’s inhibition through neurobiological pathways. Extensive technology use can stimulate physiological arousal and the secretion of dopamine to cortical regions of the brain that are sensitive to reward and reinforcement, particularly when playing games and apps (Green & Bavelier, 2012). Therefore, it could be speculated that the dose response of time use maybe one part of this complex relationship. For example, no effects were observed for low dose exposure to contemporary media use with executive functions, but high exposure may result in time being taken away from other development-boosting activities which becomes detrimental. Alternatively, another plausible mechanism is that the child may become driven by external stimulus and instant reward and feedback, resulting in the child becoming unable to control their own attention, or self-regulatory behaviours (Radesky et al., 2015). Thus, it is plausible that app use of higher exposures
may be associated with neurochemical pathways that underpin executive functions, leading to impaired impulse control.

A strength of this study is the direct assessment of executive functions, using a battery that is valid, reliable, and developmentally sensitivity (Howard & Melhuish, 2017). Including covariates that have been associated with the developmental outcomes adds further weight to suggestion that associations are robust, rather than a consequence of other related factors. Although this study used a representative sampling approach, participants with missing data were of lower suburb-level socio-economic status and had lower phonological working memory at baseline than those in the analytic sample, which may influence the generalizability of the findings. Additionally, this study examined the dose and type of electronic media use; other characteristics, such as educational content (Huber et al., 2016), or social interaction (Radesky et al., 2015) may also influence developmental outcomes, but were not possible to investigate with the current data. Although the average time children spent engaging in traditional and contemporary media use was relatively consistent with another study reported in Australian children (Neumann, 2015), future research might consider adopting a more objective approach to capture the dynamic and flexible use of apps among preschoolers (e.g., using iOS’s time use app). Further, it is possible that associations between app use and inhibition may have occurred by chance, given the large number of outcome variables assessed in the study. Additional research is needed to confirm this finding. Lastly, due to the observational nature of this study, causality cannot be established. Additional experimental evidence is needed to identify mechanistic pathways.
6.5 Conclusion

In terms of more-traditional media use, program viewing at 3- to 5-years of age was detrimentally associated with changes in externalising problems and total difficulties one year later, in line with some previous studies. This study demonstrated for the first time that high-dose app use (≥30 min/day) was associated with lower inhibition performance 12 months later, relative to low-dose use (1 - 29 min/day). While further research is needed to investigate the exact nature of these media use behaviours, and their potentially differing effects, the current results provide initial evidence that reducing media program viewing and limiting electronic app use may be positively associated with preschool children’s psychosocial and cognitive development.
Chapter 7: Compliance with the 24-Hour Movement Guidelines for the Early Years: cross-sectional and longitudinal associations with executive function and psychosocial health.

This chapter is under review with *Preventive Medicine*

Chapter 3, 4, 5, & 6 examined the cross-sectional and longitudinal associations of physical activity, modified organised sport participation, and electronic media use with executive functions and psychosocial health in preschool children. With the release of the 24-Hour Movement Guidelines for the Early Years, it is important to examine the associations between meeting the recommendations, or portions thereof, and collectively, to understand how these behaviours can influence optimal cognitive and psychosocial health. This chapter address Aim 3: to examine adherence to the Australian 24-Hour Movement Guidelines for the Early Years, and associations with executive function and psychosocial health cross-sectionally, and longitudinally. In this chapter, the following research question is investigated:

Research Question 3: Is compliance with the 24-Hour Movement Guidelines for the Early Years associated with executive functions and psychosocial health in preschool children? Do associations differ for children meeting: i) individual guidelines (i.e., physical activity, screen time or sleep), ii) combinations of any two guidelines (i.e., sleep and physical activity, sleep and screen time or screen time and physical activity), or iii) meeting an increasing number of guidelines (i.e., 0/1 vs. 2 vs. 3)
7.1 Introduction

Sleep, physical activity and sedentary behaviour, including screen time, have recently been integrated as “movement behaviours” that interact continuously across a 24-hour period (Pedišić, Dumuid, & Olds, 2017). Indeed, researchers suggest that children’s health and development is likely to be optimized if adequate levels of these health behaviours can be achieved simultaneously (Chaput, Carson, Gray, & Tremblay, 2014). In support of this approach, numerous governments have released 24-Hour Movement Guidelines for the Early Years, integrating recommendations for sleep, sedentary behaviour and physical activity (Ministry of Health., 2017; Okely et al., 2017; Tremblay et al., 2017). For instance, the Canadian and Australian guidelines recommend that, for preschoolers, a healthy 24-hour day includes: i) at least 180 min of physical activity, of which at least 60 min is energetic play; ii) no more than 1 hour of sedentary screen time; and iii) 10 to 13 hours of good quality sleep. However, compared to research in school-aged children (Carson, Tremblay, Chaput, & Chastin, 2016), few studies have investigated the potential health benefits of these behaviours collectively in the early years (Kuzik et al., 2017). Thus, conclusions regarding associations between movement behaviours and health outcomes is limited. The early years cross-sectional studies that exist have reported low compliance with the 24-h movement behaviour guidelines in Belgian pre-school children (De Craemer, McGregor, Androutsos, Manios, & Cardon. 2019), positive associations of guideline compliance with social-emotional development (Cliff, McNeill, Vella, Howard, Santos, et al., 2017), and null associations with adiposity (Chaput et al., 2017; Lee et al., 2017) and weight status (Santos et al., 2017). Yet there is a need to examine associations for broader outcomes, including cognitive and mental health, as well as longitudinal associations.
One area of children’s development that appears critical for ongoing development is executive function. Executive functions are higher-order cognitive processes that develop rapidly during the preschool period (Best & Miller, 2010), and are routinely separated into: working memory, or the mental activation and coordination of information; inhibition, or the ability to resist impulses and distraction; and shifting, or the ability to flexibly shift attention. Early executive functions have been linked to a myriad of factors in early life (e.g., school readiness, social competence and psychosocial health; Riggs, Jahromi, et al., 2006). Psychosocial health, in particular, encompasses social, emotional, and behavioural functioning, and is linked with outcomes such as reduced levels of interpersonal behaviours and depression (Meagher et al., 2009). More than merely their immediate influences, early executive functions have also been linked to a broad range of health outcomes in later life, including substance dependence, metabolic syndrome, and respiratory disease (Moffitt et al., 2011).

Evidence suggests that, individually, sleep (Bernier, Beauchamp, Bouvette-Turcot, Carlson, & Carrier, 2013; Scharf, Demmer, Silver, & Stein, 2013), screen time (Lillard & Peterson, 2011; Verlinden et al., 2012), and physical activity (McNeill et al., 2018) are associated with early executive functions and psychosocial health. However, impacts of the aggregation of these behaviours is unclear as no studies in the early years have investigated associations of combinations of movement behaviours with cognition, and only one cross-sectional study has examined these associations with psychosocial health (Carson et al., 2019). Examining these associations will add to the limited evidence base on how the behaviours interact to influence health and development in early childhood and provide further evaluation of the benefits, if any, of meeting early movement behaviour guidelines. Thus, the aim of this study was to examine the cross-sectional and 12-month longitudinal
associations of meeting individual and combination of the Australian 24-Hour Movement Guidelines for the Early Years, with cognitive and psychosocial health outcomes in preschool.

7.2 Methods and design

Study design

The cross-sectional and 12-month longitudinal associations in this paper are drawn from the Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition (PATH-ABC) prospective cohort study (Cliff, McNeill, Vella, Howard, Kelly, et al., 2017), approved by the University of Wollongong Health and Medical Research Ethics Committee (HE14/310).

Sampling and recruitment

Preschools were recruited based on a stratified sampling process from the Illawarra region of New South Wales, Australia. Preschools (long day cares and preschools) in the region were categorized as a low (deciles 1-4), medium (deciles 5-7) or high socio-economic areas (deciles 8-10) based on suburb, using the 2011 Socio-Economic Indices for Areas (SEIFA) Index of Relative Socio-economic Advantage and Disadvantage (IRSAD). The number of preschools invited to participate from each socio-economic group was proportional to the population distribution. A total of 24 ECEC’s were invited into the PATH-ABC project, and 18 (75%) consented. This resulted in 503 children being recruited into the project, 13 children were not eligible, resulting in 490 eligible participants. Baseline data were collected in preschools (n=18) between April and December 2015.
Follow-up data were collected between April and December 2016, at preschools (n = 17) or the child’s primary school (n = 51).

**Study protocol**

Following written consent from parents/caregivers, demographic information was provided via a parent survey. Following verbal assent from children, data collection occurred in a quiet area of the child’s pre/school under supervision of an educator. Protocols were consistent across settings and time points.

**Measures**

*Sleep*: Parents reported children’s usual average daily sleep duration (in hrs). This approach has been validated against estimates from sleep logs and objective actigraphy in young children (Goodlin-Jones, Sitnick, Tang, Liu, & Anders, 2008).

*Electronic media use*: Parents reported the total time a child spent engaging in electronic media behaviours which included; i) program viewing on traditional devices, e.g., TV/DVD, and non-traditional devices, e.g., Tablet, DVD in car, computer, laptop, mobile phone; ii) applications (apps)/electronic games on portable handheld devices or laptop/computer, e.g., tablet, mobile phone, handheld game system; iii) non-active console games, e.g., PlayStation or Xbox. An average of time in each behaviour for weekdays and weekends was calculated to index total electronic media use per day. Original electronic media use items had established acceptable test-retest reliability (ICC = 0.68–0.69; Hinkley et al., 2012).

*Physical activity*: ActiGraph GT3X+ accelerometers (ActiGraph, Pensacola, FL) were used to assess physical activity due to the device’s established acceptability, validity
and reliability in young children (Cliff et al., 2009). Monitors were fitted on an elastic belt at the right hip, anterior to the iliac crest. Parents were instructed that children should wear the monitor for 24-hours over seven consecutive days and removed during water or bathing activities. Raw data was sampled at 30 Hz and then reintegrated into 15s epochs using ActiLife (v6.12.1) software. Non-wear time was defined as ≥20 min of consecutive “0” counts. Physical activity data were included in analyses if participants had a least 1 day of valid data (i.e., ≥360 min of valid wear time between 5 am and 11 pm; Bingham et al., 2016). Valid weekend day data were not a requirement for inclusion because evidence in preschoolers indicates that reliability of physical activity estimates is not substantially increased by inclusions of a weekend day (Bingham et al., 2016). Total physical activity (TPA; ≥25c/15 s, i.e., light-, moderate- or vigorous-intensity physical activity, and moderate- to vigorous-intensity physical activity (MVPA; ≥420c/15 s) were defined using age-appropriate cut-points that have been shown to be most accurate in young children (Pate et al., 2006).

Cognitive Development

Executive function was assessed using measures drawn from the Early Years Toolbox, which has been psychometrically validated in preschool-aged children, in that it is developmentally appropriate, sensitivities enough to detect change, as well as being technologically dynamic (Howard & Melhuish, 2017). The measures have demonstrated validity (i.e., construct and convergent) and reliability (e.g., internal consistency). For instance, correlations of EYT measures with comparison measures selected from the NIH Toolbox were as follows: working memory, r(79) = .46, p < .001; Inhibition, r(80) = .40, p < .001; and Shifting, r(80) = .45, p < .001. Internal consistency analyses for
Go/No-Go showed good reliability for both go (Cronbach’s $\alpha = .95$) and no-go trials (Cronbach’s $\alpha = .84$) in Australian pre-school samples (Howard & Melhuish, 2017).

Measures were administered by a trained researcher using an electronic tablet, through which all instructions, practice, familiarization, feedback and scoring are delivered and standardized, under the guidance of a data collector. Full details of the EYT methodology, the reliability and validity of the task battery has been reported elsewhere (Howard & Melhuish, 2017).

Psychosocial health

Psychosocial health was assessed using the educator-reported version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). Sufficient psychometric properties for internal consistency, test-retest reliability and inter-rater agreement have been reported across studies for the teacher version of the SDQ (Stone et al., 2010), and specifically it also has validity and reliability in Australian children (Hawes & Dadds, 2004). The SDQ is comprised of 25-items assessing five psychosocial domains: conduct problems, hyperactivity, emotional problems, peer problems and pro-social behaviour. Each item (i.e., child behaviour) is rated on a 3-point Likert scale from 0 = not true to 2 = certainly true.

Following recommendations for low-risk and general populations, we employed the three sub-scale model of the SDQ: (1) internalising problems (sum of emotional and peer problems subscales), (2) externalising problems (sum of conduct problems and hyperactivity subscales) and (3) pro-social behaviours (Goodman et al., 2010). Total psychological difficulties was also calculated as the sum of the 20 psychosocial ‘problems’ items (all items except those on prosocial behaviour).
Covariates

Covariates were collected via parent-report, including child age and sex, suburb-level socio-economic status (Socio-Economic Indices For Areas (SEIFA) Index of Relative Socio-economic Advantage and Disadvantage (IRSAD; ABS, 2011); primary caregiver education - categorized into three groups: (1) less than Year 12 high school; (2) year 12 high school or trade; or (3) tertiary qualification; and quantity of the child’s educational and extra-curricular experiences to index the quality of the home learning environment (Sammons et al., 2015).

Data reduction and Analyses

As recommended for surveillance studies, preschoolers were classified as meeting the overall 24-Hour Movement Guidelines for the Early Years if they met sleep duration (10–13 h/day), screen time (≤ 1 h/day), and physical activity (≥ 180 min/day of TPA including ≥60 min/day of MVPA) recommendations (Okely et al., 2017). Children were categorised as meeting or not meeting: i) individual movement behaviour guidelines of sleep, screen time, or physical activity; ii) combinations of any two movement behaviours, or; iii) the number of guidelines met (i.e., all three, two out of three, or one/none out of three (due to small numbers who met no guidelines), and; iv) meeting the integrated 24-Hour Movement Guidelines. Linear regression analyses were performed in Stata (v 13.1). Cross-sectional regression models adjusted for covariates and preschool clustering. Longitudinal regression models additionally adjusted for baseline development outcomes and participant education sector at follow-up (i.e., preschool or primary school).

Assumptions of normality for linear regression were assessed by examining distributions of
residuals for each model; no variable required transformation. Significance was set at \( p < .05 \).

7.3 Results

Of the 490 participants recruited at baseline, 188 children were missing at least one parent-reported variable, an additional 26 did not return their accelerometer, and of those who did return an accelerometer 29 had insufficient data, thus were excluded. Of the 247 eligible for follow up, 27 participants did not agree to follow-up, and 35 were not contactable. Therefore, 185 participants were included in the analytical sample. Due to incomplete data for developmental variables, sample sizes for individual analyses varied (Table 7.1). Children with missing data had lower IRSAD scores \( (p = .003) \), and a lower phonological working memory score at baseline \( (p = .028) \) compared to the analytical sample. When examining gender differences at baseline, girls were younger \( (p < .001) \), spent less time in MVPA \( (p = .002) \) and experienced fewer externalising behaviours \( (p = .014) \) than boys.
Table 7:1 Participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Total sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (n=148)</td>
<td>Mean (SD)</td>
<td>n (n=99)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>148</td>
<td>4.3 (0.7)</td>
<td>99</td>
</tr>
<tr>
<td>SES (IRSAD)</td>
<td>148</td>
<td>1025.8 (60.2)</td>
<td>99</td>
</tr>
<tr>
<td>HLE</td>
<td>148</td>
<td>25.9 (9.1)</td>
<td>99</td>
</tr>
<tr>
<td><strong>Parental Education (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school or lower (%)</td>
<td>17</td>
<td>11.5</td>
<td>27</td>
</tr>
<tr>
<td>Trade or Diploma (%)</td>
<td>43</td>
<td>29.1</td>
<td>14</td>
</tr>
<tr>
<td>Degree/Postgraduate (%)</td>
<td>88</td>
<td>59.5</td>
<td>58</td>
</tr>
<tr>
<td><strong>Movement behaviours</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep (hrs/d)</td>
<td>148</td>
<td>10.50 (1.0)</td>
<td>99</td>
</tr>
<tr>
<td>Screen time (min/d)</td>
<td>148</td>
<td>141.23 (82.65)</td>
<td>99</td>
</tr>
<tr>
<td>PA–TPA (min/d)</td>
<td>148</td>
<td>383.85 (64.39)</td>
<td>99</td>
</tr>
<tr>
<td>PA – MVPA (min/d)</td>
<td>148</td>
<td>109.78 (34.42)</td>
<td>99</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Spatial Working Memory&lt;sup&gt;a&lt;/sup&gt;</td>
<td>135</td>
<td>1.3 (1.1)</td>
<td>98</td>
</tr>
<tr>
<td>Phonological Working Memory&lt;sup&gt;b&lt;/sup&gt;</td>
<td>141</td>
<td>1.8 (0.8)</td>
<td>94</td>
</tr>
<tr>
<td>Shifting&lt;sup&gt;c&lt;/sup&gt;</td>
<td>137</td>
<td>4.5 (4.2)</td>
<td>95</td>
</tr>
<tr>
<td>Inhibition&lt;sup&gt;d&lt;/sup&gt;</td>
<td>133</td>
<td>0.5 (0.2)</td>
<td>92</td>
</tr>
<tr>
<td><strong>Follow-up</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Spatial Working Memory&lt;sup&gt;a&lt;/sup&gt;</td>
<td>112</td>
<td>2.4 (1.0)</td>
<td>73</td>
</tr>
<tr>
<td>Phonological Working Memory&lt;sup&gt;b&lt;/sup&gt;</td>
<td>109</td>
<td>2.1 (0.7)</td>
<td>72</td>
</tr>
<tr>
<td>Shifting&lt;sup&gt;c&lt;/sup&gt;</td>
<td>112</td>
<td>7.5 (3.8)</td>
<td>73</td>
</tr>
<tr>
<td>Inhibition&lt;sup&gt;d&lt;/sup&gt;</td>
<td>112</td>
<td>0.7 (0.2)</td>
<td>73</td>
</tr>
<tr>
<td><strong>Psychosocial health</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems&lt;sup&gt;e&lt;/sup&gt;</td>
<td>136</td>
<td>3.2 (2.8)</td>
<td>87</td>
</tr>
<tr>
<td>Externalising problems&lt;sup&gt;f&lt;/sup&gt;</td>
<td>136</td>
<td>5.7 (4.8)</td>
<td>87</td>
</tr>
<tr>
<td>Pro-social behaviours&lt;sup&gt;g&lt;/sup&gt;</td>
<td>136</td>
<td>7.0 (2.6)</td>
<td>87</td>
</tr>
<tr>
<td>Total difficulties&lt;sup&gt;h&lt;/sup&gt;</td>
<td>136</td>
<td>8.9 (5.9)</td>
<td>87</td>
</tr>
<tr>
<td><strong>Follow-up</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internalising problems</td>
<td>101</td>
<td>2.8 (2.8)</td>
<td>55</td>
</tr>
<tr>
<td>Externalising problems</td>
<td>101</td>
<td>5.0 (4.8)</td>
<td>55</td>
</tr>
<tr>
<td>Pro-social behaviours</td>
<td>101</td>
<td>7.3 (2.5)</td>
<td>55</td>
</tr>
<tr>
<td>Total difficulties</td>
<td>101</td>
<td>7.9 (6.4)</td>
<td>55</td>
</tr>
</tbody>
</table>

*Note: Characteristics of the participants are presented as mean ± SD, distributions of the sample are presented in percentages. <sup>a</sup>score range: 0–8; <sup>b</sup>score range: 0–8; <sup>c</sup>score range: 0–12; <sup>d</sup>score range: 0–1; <sup>e</sup>score range: 0–20; <sup>f</sup>score range: 0–20; <sup>g</sup>score range: 0–10; <sup>h</sup>score range: 0–40; *p < .05
High proportions of children met the sleep (89.9%) and physical activity (94.3%) guidelines, whereas fewer children met the screen time guideline (17.4%) (Table 7.2). Consequently, high proportions of children met the combined sleep and physical activity guidelines (84.6%), whereas, fewer met the sleep and screen time (17.4%), and screen time and physical activity guidelines (17.4%). Overall, 17.4% of children met all 24-Hour Movement Guidelines for the Early Years.

**Table 7.2** Proportion of participants meeting the sleep, screen time, and physical activity recommendations, and combinations of these recommendations at baseline and follow-up.

<table>
<thead>
<tr>
<th>Meeting recommendation (%)</th>
<th>Baseline (n = 247)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated 24-Hour Movement Guidelines</td>
<td>17.4</td>
</tr>
<tr>
<td>Screen time and PA only</td>
<td>17.4</td>
</tr>
<tr>
<td>Sleep and PA only</td>
<td>84.6</td>
</tr>
<tr>
<td>Sleep and screen time only</td>
<td>17.4</td>
</tr>
<tr>
<td>PA only</td>
<td>94.3</td>
</tr>
<tr>
<td>Screen time only</td>
<td>17.8</td>
</tr>
<tr>
<td>Sleep only</td>
<td>89.9</td>
</tr>
<tr>
<td>None</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**General combinations of movement behaviours (%)**

| All three                                                                 | 17.4              |
| Two out of three                                                          | 67.2              |
| One out of three                                                         | 15                |
| None                                                                     | 0.4               |

*Note: PA physical activity*

**Cross-sectional associations**

Cross-sectional associations of guideline compliance with the cognitive and psychosocial outcomes are presented in Table 7.3. Children who met a combination of the sleep and physical activity guidelines displayed better phonological working memory ($MD = 0.30, p = .026$) and shifting performance ($MD = 1.36, p = .034$) compared to those who
These differences were equivalent to approximately 5 and 8 months of normal functional development, respectively (Howard & Melhuish, 2017). Compared to children who met one/no guidelines, children who met two guidelines displayed significantly better phonological working memory ($MD = 0.28, p = .037$), whereas the difference for children meeting three guidelines and phonological working memory approached significance ($MD = 0.35, p = .060$). These differences were equivalent to 4.8 and 5.9 months of normal functional development, respectively (Howard et al., 2017). In contrast, children who met three guidelines demonstrated better shifting scores ($MD = 1.94, p = .017$) compared to children who met one/no guidelines, while meeting two guidelines approached significance for performance on shifting ($MD = 1.23, p = .066$). The differences were equivalent to 11.3 and 7.2 months of normal functional development, respectively (Howard & Melhuish, 2017). Meeting an individual movement guideline (i.e., sleep, sedentary behaviour or physical activity), or the 24-Hour Movement Guideline compared to those who did not meet were not significant for executive functions. No significant associations were observed for any psychosocial health outcomes.
Table 7:3 Cross-sectional associations between meeting individual movement behaviours, combinations of behaviours, number of behaviours met and meeting the 24-Hour Movement Guidelines for the Early with executive function and psychosocial health.

<table>
<thead>
<tr>
<th>Cognitive Health</th>
<th>Psychosocial Health</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VSWM (n=241)</td>
</tr>
<tr>
<td>Meeting individual behaviours</td>
<td></td>
</tr>
<tr>
<td>Sleep (≥10 h/d &amp; ≤13 h/d)</td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>0.133</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.531, 0.796)</td>
</tr>
<tr>
<td>Screen Time (≤60 min/d)</td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.060</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.265, 0.144)</td>
</tr>
<tr>
<td>Physical Activity (≥180 min/d of TPA including ≥60 min/d of MVPA)</td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.173</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.520, 0.174)</td>
</tr>
<tr>
<td>Combination of movement behaviours</td>
<td></td>
</tr>
<tr>
<td>Sleep + Screen Time</td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.075</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.295, 0.145)</td>
</tr>
<tr>
<td>Sleep + PA</td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>0.008</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.479, 0.495)</td>
</tr>
<tr>
<td>Screen + PA</td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.075</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.295, 0.145)</td>
</tr>
<tr>
<td>Number of guidelines met</td>
<td></td>
</tr>
<tr>
<td>2–1/0 MD (95% CI) difference</td>
<td>-0.023</td>
</tr>
<tr>
<td>3–2 MD (95% CI) difference</td>
<td>0.079</td>
</tr>
<tr>
<td>3-1/0 MD (95% CI) difference</td>
<td>-0.126, 0.284</td>
</tr>
<tr>
<td>Meeting 24-hour Movement guidelines</td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.075</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.296, 0.145)</td>
</tr>
</tbody>
</table>

Note: VSWM Visual-spatial working memory, PWM Phonological working memory, Linear regression models adjusted for age, sex, Socio-economic Status, caregiver education, the Home Learning Environment, and preschool level clustering, *p < .05, †p = 0.060, ‡p = 0.066.
Longitudinal Associations

The associations for guideline compliance at baseline with the cognitive and psychosocial outcomes at follow-up are presented in Table 7.4. Children who met the physical activity guideline at 3- to 5-years displayed higher shifting performance 12 months later \((MD = 3.95, p = 0.002)\), compared to those who did not. This difference equates to an additional 2.3 years of development over and above typical age-related change.

Associations for meeting individual guidelines, more guidelines or the integrated guidelines were not significant for remaining executive functions. No longitudinal associations were observed for psychosocial health outcomes.
| Table 7:4 Longitudinal associations between meeting individual movement behaviours, combinations of behaviours, number of behaviours met and meeting the 24-Hour Movement Guidelines for the Early at baseline, with executive function and psychosocial health. at follow-up (12-months). |
|-----------------|-----------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | Cognitive Health |                  |                  |                  | Psychosocial Health |                  |                  |
|                  | VSWM (n=182)     | PWM (n=175)      | Shifting (n=179) | Inhibition (n=167) | Internalising problems (n=156) | Externalising problems (n=156) | Pro-social behaviours (n=156) | Total difficulties (n=156) |
| **Meeting individual behaviours** |                  |                  |                  |                  |                  |                  |                  |
| **Sleep (≥10 h/d & ≤13 h/d)** |                  |                  |                  |                  |                  |                  |                  |
| Not Meeting vs Meeting | -0.339          | -0.163           | 0.938            | 0.033            | -0.628           | 0.402           | 0.014           | -0.151           |
| MD (95% CI) difference | (-0.840, 0.161) | (-0.494, 0.167) | (-0.798, 2.675)  | (-0.038, 0.104)  | (-1.828, 0.572)  | (-1.219, 2.025) | (-0.846, 0.874)  | (-2.842, 2.538)  |
| **Screen Time (≤60 min/d)** |                  |                  |                  |                  |                  |                  |                  |
| Not Meeting vs Meeting | -0.124           | -0.026           | 0.807            | -0.012           | -0.115           | 0.159           | -0.048           | -0.080           |
| MD (95% CI) difference | (-0.490, 0.242) | (-0.253, 0.201) | (-0.539, 2.154)  | (-0.074, 0.050)  | (-0.788, 0.557)  | (-1.011, 1.330) | (-0.507, 0.412)  | (-1.526, 1.366)  |
| **Physical Activity (≥180 min/d of TPA incl ≥60 min/d of MVPA)** |                  |                  |                  |                  |                  |                  |                  |
| Not Meeting vs Meeting | -0.042           | 0.140            | -3.946**         | -0.063           | -0.983           | -0.559           | 0.177            | -1.700           |
| MD (95% CI) difference | (-0.553, 0.468) | (-0.171, 0.451) | (-6.191, -1.700) | (-0.219, 0.093)  | (-4.384, 2.418)  | (-4.736, 3.618) | (-0.037, 2.391)  | (-8.639, 5.239)  |
| **Combination of movement behaviours** |                  |                  |                  |                  |                  |                  |                  |
| Sleep + Screen Time |                  |                  |                  |                  |                  |                  |                  |
| Not Meeting vs Meeting | -0.124           | -0.026           | 0.808            | -0.012           | -0.115           | 0.159           | -0.048           | -0.080           |
| MD (95% CI) difference | (-0.490, 0.242) | (-0.253, 0.201) | (-0.539, 2.154)  | (-0.074, 0.050)  | (-0.788, 0.557)  | (-1.012, 1.330) | (-0.507, 0.412)  | (-1.526, 1.366)  |
| Sleep + PA |                  |                  |                  |                  |                  |                  |                  |
| Not Meeting vs Meeting | -0.255           | -0.075           | -0.681           | 0.003            | -0.748           | 0.091           | 0.068            | -0.665           |
| MD (95% CI) difference | (-0.647, 0.137) | (-0.364, 0.213) | (-2.392, 1.028)  | (-0.069, 0.075)  | (-2.122, 0.626)  | (-1.878, 2.059) | (-0.914, 1.050)  | (-3.790, 2.459)  |
| Screen + PA |                  |                  |                  |                  |                  |                  |                  |
| Not Meeting vs Meeting | -0.124           | -0.026           | 0.808            | -0.012           | -0.115           | 0.159           | -0.048           | -0.080           |
| MD (95% CI) difference | (-0.490, 0.242) | (-0.253, 0.201) | (-0.539, 2.154)  | (-0.074, 0.050)  | (-0.788, 0.557)  | (-1.012, 1.330) | (-0.507, 0.412)  | (-1.526, 1.366)  |
| **Number of guidelines met** |                  |                  |                  |                  |                  |                  |                  |
| 2–1 MD (95% CI) difference | 0.240            | 0.072            | 0.836            | -0.006           | 0.002            | -0.149           | 0.059            | -0.019           |
| MD (95% CI) difference | (-0.175, 0.655) | (-0.220, 0.366) | (-0.882, 2.555)  | (-0.078, 0.065)  | (-0.663, 0.666)  | (-1.389, 1.091) | (-0.419, 0.538)  | (-1.591, 1.554)  |
| 3–2 MD (95% CI) difference | 0.086            | 0.015            | -0.930           | 0.013            | 0.002            | -0.149           | 0.059            | -0.019           |
| MD (95% CI) difference | (-0.300, 0.472) | (-0.216, 0.247) | (-2.566, 0.395)  | (-0.049, 0.075)  | (-0.663, 0.666)  | (-1.389, 1.091) | (-0.419, 0.538)  | (-1.591, 1.554)  |
| 3-1/0 MD (95% CI) difference | 0.343            | 0.157            | -0.170           | 0.015            | 0.774            | -0.219           | -0.012           | 0.660            |
| MD (95% CI) difference | (-1.22, 0.809)  | (-0.168, 0.483)  | (-2.362, 2.023)  | (-0.075, 0.105)  | (-0.637, 2.185)  | (-2.236, 1.799) | (-0.997, 0.973)  | (-2.334, 3.656)  |
| **Meeting 24-hour Movement Guidelines** |                  |                  |                  |                  |                  |                  |                  |
| Not Meeting vs Meeting | -0.124           | -0.026           | 0.808            | -0.012           | -0.115           | 0.159           | -0.048           | -0.080           |
| MD (95% CI) difference | (-0.490, 0.242) | (-0.233, 0.201) | (-0.539, 2.154)  | (-0.074, 0.050)  | (-0.788, 0.557)  | (-1.012, 1.330) | (-0.507, 0.412)  | (-1.526, 1.366)  |

**Note:** VSWM Visual-spatial working memory, PWM Phonological working memory, Linear regression models adjusted for age, sex, Socio-economic Status, caregiver education, the Home Learning Environment, baseline developmental outcomes and preschool level clustering, *p < .05, **p < .01.
7.4 Discussion

The present study examined whether meeting the Australian 24-Hour Movement Guidelines for the Early Years was associated with cognitive and psychosocial health, in a prospective sample of Australian preschool children. Cross-sectional findings indicated that, children who met both the sleep and physical activity guidelines displayed better phonological working memory and shifting performance compared to those who did not. Children meeting two guidelines displayed better phonological working memory and marginally better shifting compared to those who did not. Children meeting all three guidelines displayed better shifting and marginally better phonological working memory scores compared to those who did not. Longitudinally, meeting the physical activity guideline in isolation at baseline was associated with better shifting performance 12-months later. Children who met the integrated guidelines did not display better cognitive or psychosocial health cross-sectionally or 12-months later, relative to those who did not meet the integrated guidelines.

To our knowledge, this is the first study to examine – in any country that has adopted 24-Hour Movement Guidelines for the Early Years – the extent to which compliance with movement guidelines in the early years is associated with cognitive outcomes, and the first to examine longitudinal associations with psychosocial outcomes. In contrast with the current study, the only study in preschoolers that included a measure of psychosocial health found that children not meeting the screen time guideline had worse psychosocial behavioural outcomes, compared to those children meeting the screen time guidelines (Carson et al., 2019). There was a significant trend, in that children meeting combinations of: (i) the physical activity and screen time recommendations, and; (ii) the sleep and screen time recommendations, displayed better internalising, externalising and
total psychological problems compared to those who did not (Carson et al., 2019). For general combinations of recommendations, meeting more recommendations was associated with better psychosocial health (Carson et al., 2019). In contrast to the methods used in the present study, Carson et al. (2019) used wrist-worn accelerometers to assess physical activity and sleep objectively, and applied cut-points to vector magnitude data collected at 60-second epochs. These differences in physical activity and sleep measurement and data reduction make comparisons challenging and may account for the differences observed. Further, although the study conducted by Carson and colleagues assessed similar screen time behaviours to the present study, 50.5% of participants met the screen time guidelines whereas only 17.4% met the screen time guidelines in the present study. These differences in the variation of children meeting the screen time guidelines may have contributed to differences in findings, in that the small group size in the present study may have limited the ability to detect associations.

Consistent with findings across both time points, Carson and colleague’s (2017) review indicated that physical activity was positively associated with measures of cognition in the early years. Beyond this review, only three cross-sectional studies have examined associations between habitual physical activity and executive functions in preschool children, in which negative (Willoughby et al., 2018) and null associations (Carson, Rahman, et al., 2017) were observed. However, in a previous report of results with this cohort, associations were partially consistent with those in the current study. That is, continuous measures of physical activity (particularly VPA) were associated with better working memory cross-sectionally (McNeill et al., 2018) and shifting longitudinally (McNeill - unpublished). Differences in methodological design (i.e., cross-sectional vs. longitudinal), the measurement of exposures (i.e., continuous and categorical measures of
physical activity, or only examining MVPA; Willoughby et al., 2018), or diverse measures of executive functions may have contributed to the differences observed between our cohort and other studies.

With respect to sleep, a review by Chaput and colleagues (2014) indicated that the findings on associations of sleep and cognition in the early years remain inconsistent. Only two studies specifically examine associations of sleep with executive functions in preschool, and do so cross-sectionally. Lam, Mahone, Mason, & Scharf (2011) reported that shorter sleep duration was detrimentally associated with inhibitory control, while Nathanson & Fries. (2014) observed no associations between sleep duration and executive functioning. Yet there is also mounting evidence showing links between sleep and executive functioning in children (Dutil et al., 2018) and adults (Lo, Groeger, Cheng, Dijk, & Chee, 2016), thus supporting the cross-sectional associations found in the current study. Thus, promoting healthy sleep behaviours in preschoolers’ may be beneficial to cognition, however it is important to note that longitudinally these associations did not remain significant and more research is needed to explore these possible relationships.

A number of plausible mechanisms exist that might contribute to the associations of meeting minimum thresholds of physical activity and/or sleep with executive functions. For one, increased blood flow in the brain following physical activity (Voss et al., 2014) may lead to improved access and mobilisation of cognitive resources. However, these mechanisms have not been fully established. Similarly, although mechanisms explaining the relationship between sleep and cognition is not fully understood, (Sadeh, Flint-Ofir, Tirosh, & Tikotzky, 2007) proposed adequate sleep may favour children’s cognitive functioning via: i) its role in brain maturation and memory consolidation; and, ii) by promoting daytime alertness, leading to favourable temperaments for learning.
It is unclear why meeting the screen time recommendation was not associated with cognitive and psychosocial outcomes at baseline or follow-up, particularly given findings from Poitras et al.’s (2017) systematic review that associations between screen time and indicators of adiposity, motor or cognitive, and psychosocial health were primarily unfavourable or null amongst young children. Indeed, consistent with the current null associations, two recent studies reported no associations of preschoolers meeting the screen time guideline with adiposity (Chaput et al., 2017) and social-emotional development (Cliff, McNeill, Vella, Howard, Santos, et al., 2017). Explanations for the lack of associations in the current study may, in part, be due to the large number of children not meeting the screen time recommendation. In contrast, with this same preschool cohort we have reported detrimental cross-sectional associations between total screen time, when measured continuously, and executive functions cross-sectionally (McNeill et al – under review). As such, an alternative possibility is that different types of screen behaviours might influence children’s development differently, with plausible influences being whether a screen behaviour is active and cognitively engaging. Interestingly, in previously reported cross-sectional analyses in this same cohort, high dose electronic app users (≥30 min/day) and low dose electronic app users (0 – 29min/day) demonstrated better working memory scores than non-users (McNeill et al – under review). Similarly, low dose app users displayed fewer behavioural problems compared to non-users (McNeill et al – under review). In contrast, screen time and program viewing was detrimentally associated with working memory. Therefore, it is plausible that combining different types of electronic media use when classifying compliance with the screen time guidelines may mask associations with cognitive and psychosocial health outcomes in young children. Further
research is needed to more clearly understand the impact of screen time and whether
guidelines require greater nuance than simple exposure limits.

A strength of this study was the direct assessments of executive functions,
completed using a battery that has strong validity, reliability, and developmental sensitivity
(Howard & Melhuish, 2017). The inclusion of several covariates that might confound
associations with developmental outcomes, and examination of associations longitudinally,
adds further weight to the findings. The objective measurement of physical activity (Cliff et
al., 2009) made it possible to investigate habitual activity, and the inclusion of
contemporary electronic media including use of electronic apps is novel, given previous
research predominately examines passive TV viewing and computer games (Poitras et al.,
2017).

However, although the PATH-ABC study used a representative sampling approach,
a considerable proportion of participants could not be included in the analytic sample due to
missing data. Because excluded participants had lower IRSAD scores and phonological
working memory scores, this may limit the generalizability of our findings to the broader
population. As reflected in the guidelines, our analyses focused on meeting the indicated
minimum/maximum threshold of movement behaviours, based on the average daily
duration of physical activity, screen time and sleep. Other aspects of these behaviours may
influence children’s executive function and psychosocial health, but were not included in
our analyses, such as: sleep disturbances; the quality, type or content of screen time; the
timing of exposure to screen time; and the quality of social interactions during screen time
or physical activity. Further, although measures also had demonstrated validity and
reliability, parent-reported electronic media use and sleep may still result in response bias.
(i.e., social desirability). This study was also non-experimental, meaning we can only speculate on any causal associations.

While many associations observed across time points were null, when exploring the combinations of meeting the Australian 24-h Movement guidelines for the Early Years with cognitive and psychosocial health outcomes, the current results nevertheless provide novel evidence for further exploration of the particular importance of sleep and physical activity guidelines specified within the Australian 24-Hour Movement Guidelines for the Early Years cross-sectionally, and of physical activity guidelines longitudinally. More longitudinal studies are needed to further explore these associations. Indeed, meeting these guidelines was cross-sectionally associated with better cognitive outcomes in preschool children. Likewise, meeting the physical activity guideline at 3- to 5-years of age was associated with better cognitive shifting 12-months later. However, associations were not evident for screen time, suggesting directions for future research. Yet supporting preschool children to meet all of these guidelines has demonstrated benefit for children’s early development, with the current study extending this evidence base to aspects of cognitive development.
Chapter 8: General Discussion
8.1 Introduction

This thesis examined cross-sectional and longitudinal associations of physical activity (Chapters 3 and 4), electronic media use (Chapters 5 and 6) and compliance with the Australian 24-Hour Movement Guidelines for the Early Years (Chapter 7) with executive functions and psychosocial health in preschoolers. This chapter will compare and contrast the findings from the individual studies reported in the thesis, as well with the current evidence base. In addition, the strengths and limitations of this thesis will be examined. Finally, recommendations for future research, practice, and policy will be made prior to the final thesis conclusions.

8.2 Research Question One

Do the associations between physical activity and executive functions or psychosocial health differ by the intensity (i.e., light-intensity physical activity, moderate-intensity physical activity, vigorous-intensity physical activity, moderate-to-vigorous-intensity physical activity, and light-to-vigorous intensity physical activity) or type (i.e., modified organised sports) of physical activity in preschool children? (Chapters 3 & 4).

8.2.1 Associations between the intensity of physical activity and executive functions

8.2.1.1 Summary of findings

Physical activity intensities were found to differentially associate with executive function. Cross-sectionally, VPA was positively associated with visual-spatial working memory, while LPA was negatively associated with visual-spatial working memory (Chapter 3). Clinically, a 15 min/day higher level of VPA corresponded to the equivalent to
~3 months improvement in functional working memory development (Howard & Melhuish, 2017). Longitudinally, the pattern of associations differed, however. After adjusting for executive function outcomes at baseline, VPA at 3- to 5-years was positively associated with shifting performance 12-months later. A positive longitudinal association between MVPA and shifting performance approached significance (Chapter 4), likely driven by the association with VPA. Clinically, a 32 min/day increase in MVPA corresponded to an additional ~3 months of development, beyond expected age-related change. However, the majority of associations examining physical activity intensity with cognitive and psychosocial health outcomes were not significant. From the few significant associations observed, activity of higher intensity, particularly VPA, was found to be positively associated with specific aspects of executive functioning in preschoolers.

8.2.1.2 Comparison with the evidence base and possible mechanisms for findings

A recent systematic review by Carson, et al. (2017) summarising the relationship between physical activity and health indicators in the early years (0 - 4), along with studies following this review, suggest that there are eight relevant cross-sectional studies that have examined associations between physical activity and domains of cognition in preschoolers. Two of these investigations concluded that physical activity was unfavourably associated with cognition (Matheny & Brown, 1971; Willoughby et al., 2018), while three reported null associations (Ansari, Pettit, & Gershoff, 2015; Irwin, Johnson, Vanderloo, Burke, & Tucker, 2015; Carson et al., 2017). In contrast, positive associations have been observed with physical activity with cognition and linguistic development (Lee et al., 2017), self-regulation (Becker et al., 2014), and behaviour control (Campbell et al., 2002). Unlike the inconsistent cross-sectional evidence, physical activity was consistently (>60% of studies)
associated with improved health indicators in the review conducted by Carson and colleagues, and specifically was positively associated with all experimental studies examining cognitive outcomes. Although the Carson, et al. (2017) review found that VPA and MVPA were consistently associated with multiple health indicators in young children, conclusions could not be drawn for the associations of VPA and MVPA with cognitive outcomes specifically due to a limited number of studies examining associations for different intensities. Interestingly, no studies examined associations longitudinally, thus more research is needed that helps to identify the temporal nature of potential relationships between physical activity and cognition.

As discussed in Chapters 3 and 4, two cross-sectional papers have examined associations of objectively measured physical activity with executive functions in preschool children. These studies reported negative associations with MVPA (Willoughby., et al 2018) and null associations (Carson et al., 2017) with all intensities of activity. The reasons for possible differences in findings between these studies are discussed in chapter 3. Briefly, the studies reported in this thesis used different measures of executive functions, which was the main difference with Carson et al. (2017) and additional domains of executive functions were examined in this thesis. Further, this thesis included a larger sample, investigated associations separately for VPA, which was not examined in Willoughby et al. (2018), and assessed associations longitudinally (Chapter 4). These differences may have contributed to the differences observed. In summary, the systematic review by Carson and colleagues (2017) concluded, based on experimental evidence, that physical activity was consistently associated with improved cognitive development in young children. Despite being inconsistent with the available observational evidence, the findings from this thesis tends to support the conclusion by Carson and colleagues (2017).
Further, the findings from this thesis extend previous results: i) specifically to executive functions, ii) by providing longitudinal evidence, and iii) by suggesting that high intensity physical activity, specifically VPA, may be particularly influential.

Plausible mechanisms to explain the associations observed between higher intensity physical activity and executive functions cross-sectionally may be the neurobiological mechanistic pathway. This suggests that changes to brain composition can occur through increased cerebral blood flow resulting from higher intensity physical activity (Voss et al., 2014). This increased blood flow may create opportunities for effective acquisition of cognitive resources. If the changes in the brain are functional, rather than structural, then engaging in high intensity activity may result in momentary improvements, for instance, increased attention right after exercise, that may not persist if that intensity is not maintained or recently done, which may suggest why the cross-sectional associations with some domains of executive functions were not maintained longitudinally. However, given that only specific domains of executive functions were improved by physical activity, this would not conform to the general blood flow hypothesis, as we would expect improvements in all executive function domains. Thus, although the findings from this thesis support the possibility of such mechanisms, more experimental evidence is needed to further understand these mechanisms, particularly in children. Alternatively, as Diamond (2012) suggest, improvements in executive functions depends on the amount of time a child spends working on skills, pushing themselves to improve. Although this study could not determine the context of the physical activity, it maybe plausible that at this age, VPA-style activities may be characterised by an impulsive pursuit of an aim (e.g., to tag someone who is not it), while flexibly shifting attention to pursue this aim (e.g., shifting targets) and avoid risks (e.g., not run into something that could cause injury). There may be less time or
impetus for effortful and explicit processing of information or strategies in working memory during VPA, or resistance of impulses with inhibition. Thus, children may have less conscious use of working memory and inhibition, resulting in less practice of these executive functions.

8.2.2 Associations between the type of physical activity and executive functions

8.2.2.1 Summary of findings

With respect to the type of physical activity, children who participated in modified organised sport displayed better shifting performance compared to those children who did not participate in cross-sectional analyses. However, non-sport participants at 3- to 5-years demonstrated better inhibition scores 12-months later compared to sports participants in longitudinal analyses. Consequently, although some cross-sectional evidence indicated that sport participation might be positively associated with executive functions in preschool children, the longitudinal results did not support this finding and suggested the opposite. Furthermore, predominantly null associations were observed.

8.2.2.2 Comparison with the evidence base and possible mechanisms for findings

It has been suggested that participation in sport might be beneficial for cognition among children, specifically executive functions (Diamond, 2015; Best, 2010). Three studies were retrieved from a review on organised physical activity and health in preschool children (Venetsanou et al., 2015). Exposures included aerobic fitness, motor skills and classroom-based music movement skills with cognitive parameters that included, working memory, attention, creative fluency, imagination, phonological awareness and
communications. Two of the three studies reported positive associations (Niederer et al., 2011; Zachopoulou, Trevlas, Konstadinidou, & Group, 2006), and one reported mixed positive and null associations (Yazejian & Peisner-Feinberg, 2009) with cognition. However, none of these studies specifically examined associations between sport participation and executive functions. Interestingly, Diamond and Ling (2016) speculated in their review of interventions to improve executive function, that cognitively-engaging physical activities, such as sport are well suited to provide the qualities that foster the development of executive function (i.e., players need to have the cognitive flexibility to adapt to a rapid and constantly changing situation, and shift their attention between players and strategies), which would conform to the cross-sectional associations observed for participation in modified organised sport and shifting performance. Yet only one observational study examined associations of organised physical activity (e.g., swimming lessons, skating lessons, gymnastics) with executive functions and observed no associations (Carson et al., 2017) therefore general conclusions are limited for this age group (Carson et al., 2017).

Interestingly, longitudinal findings in Chapter 4 indicated that sports participants at 3- to 5-years of age displayed poorer inhibitory performance than non-participants after 12-months. One explanation for these results is that the small sample of children (n = 31) not participating in modified organised sport may influence the ability to detect associations. Alternatively, another explanation is that parents of children with inhibition difficulties are more likely to enrol their child in sports due to feeling like they need to ‘work it off and run around’. Combined with the results from this thesis, and the available evidence in preschool children, a positive association between participation in modified organised sport and executive function in preschool children appears to be limited. Interestingly, and in contrast
to this study, a longitudinal study reported marginal bi-directional associations between participation in individual sport at ages 4-5, with children’s self-regulation two years later, but no associations for team sports (Howard et al., 2018). The authors proposed that within the context of individual sports, children may have less opportunity to switch off and disengage, while at the same time receive more parental guidance to help them engage and maintain their executive functions. Larger observational and experimental studies would assist in clarifying these findings (see part 8.7 for a more detailed discussion on research recommendations).

8.2.3 Associations between the intensity of physical activity and psychosocial health

8.2.3.1 Summary of findings

Cross-sectionally, VPA was associated with fewer internalising behaviours, but MPA and MVPA were weakly associated with more externalising behaviours, while VPA trended in the same direction as MPA and MVPA and approached significance (Chapter 3). However, no significant associations were observed in longitudinal analyses (Chapter 4). Therefore, although the cross-sectional results in this thesis provided some evidence that higher intensity physical activity may exhibit different associations with different domains of young children’s psychosocial health, those results seem to be more fleeting in nature as these results were not supported by longitudinal evidence. Thus, the evidence for associations is inconsistent and limited.
8.2.3.2 Comparison with the evidence base and possible mechanisms for findings

From Carson et al.’s (2017) systematic review of the relationship between physical activity and health indicators in the early years, along with studies following this review, a total of ten investigations (eight cross-sectional, and two longitudinal) have examined the relationships between physical activity and domains of psychosocial health. One of these cross-sectional studies examined associations for internalising and externalising behaviours, which were domains consistent with some of those assessed in this thesis. Of the ten studies, two cross-sectional (Hinkley, Brown, Carson, & Teychenne, 2018; Lee & Carson, 2017) and one longitudinal study (Wang et al., 2008) observed favourable associations of physical activity with at least one marker of psychosocial health. However, four cross-sectional studies observed unfavourable associations with one measure of psychosocial health (Matheny & Brown, 1971; Ebenegger et al., 2012; Yu, Protudjer, Anderson, & Fieldhouse, 2010; Yu, Ziviani, Baxter, & Haynes, 2012), and three studies - two cross-sectional (Fleck, Daemen, Roelofs, & Muris, 2015; Irwin et al., 2015), and one longitudinal (Hinkley et al., 2017), observed no associations with psychosocial health. In summary, associations are mixed for the relationship between physical activity and psychosocial health.

Contrastingly, based on experimental studies included in the review, Carson et al. (2017) concluded that physical activity was consistently associated with improved psychosocial health in two of three studies. Yet the review could not make conclusions on associations of VPA, MPA, and MVPA with psychosocial health due to the limited number of studies using objective measures to examine associations for different intensities. Thus, the findings in this thesis were relatively consistent with the wider evidence base of observational studies reviewed by Carson and colleagues, in that predominantly
inconsistent associations were observed between physical activity and psychosocial health. Larger observational studies are needed to help establish the temporal nature of associations, and to better understand possible mechanisms to help explain and experimental studies will help to establish cause and effect relationships.

The mixed associations observed between the intensity of physical activity and psychosocial health across timepoints in this thesis may possibly be explained by aspects of the design and methods of the longitudinal study. At follow-up, different educators may have completed the SDQ compared to those at baseline (e.g., due to staff turnover, change in preschool room, etc.). Likewise, at follow-up, 72 children had transitioned from preschool into primary school. Although the transition was included as a covariate, these children would have been evaluated by a primary school teacher, within a new educational context, which again, may have contributed to potential differences in the assessment of psychosocial outcomes. Changes in respondents of children’s psychosocial health introduce the potential for inter-rater variability, which is conflated with the genuine levels of mental well-being. While more direct and objective measures of psychosocial well-being would be preferable in this regard (e.g., clinical diagnosis, evaluation by psychological professional), instances of this are rare at this age. As such, reports by those who are most familiar with the child remain the most accessible and viable means of capturing this information on a large scale.
8.2.4 Associations between the type of physical activity and psychosocial health

8.2.4.1 Summary of findings

In regard to the type of physical activity, no differences in psychosocial health outcomes were observed between children who participated in sport and those who did not, in both cross-sectional and longitudinal analyses.

8.2.4.2 Comparison with the evidence base and possible mechanisms for findings

Sport participation has been recognised as being beneficial for psychosocial health in youth (Fraser-Thomas, Côté, & Deakin, 2005), and some evidence from systematic reviews in school-aged children and adolescents provides evidence to support this hypothesis (Eime, Young, Harvey, Charity, & Payne, 2013; Ekeland, Heian, Hagen, Abbott, & Nordheim, 2009). Specifically, positive associations between organised physical activity in the forms of aerobic exercise, perceptual-motor programming, dance and with psychosocial health reported in four studies (Alpert et al., 1990; Biddle. 1993; Lobo & Winsler. 2006; Platzer. 1976) in the review conducted by Venetsanou and colleagues (2015). However, only one experimental study specifically examined sport participation and found significant improvements with dance and social competence in 39-62-month-old children. Venetsanou and colleagues concluded that more research is needed to confirm these findings given the limited available evidence.

Similar to the evidence in school-aged children, there is limited evidence of associations between sport and psychosocial health in preschoolers (Carson et al., 2017). The null associations observed between sports participation and psychosocial health in this thesis are inconsistent with the only other cross-sectional study in preschoolers, in that
Griffiths et al. (2010) observed positive associations between sport and psychosocial health in preschoolers. Potential reasons for the differences in findings are provided in Chapter 3 and 4. One limitation of the study conducted by Griffiths and colleagues (2010) is that no adjustment was made for habitual levels of physical activity. Thus, an accurate conclusion cannot be drawn from this study that represents the possible effects of the sporting context, as opposed to physical activity that is inherent in sport. Further research, both observational and experimental is warranted to examine the developmental aspects of sport independent of physical activity, given the limited evidence base.

The null associations observed between participation in modified organised sport and psychosocial health cross-sectionally and longitudinally may potentially have been influenced by methodological aspects of the studies in this thesis, as discussed previously in this chapter – in that different educators may have completed the SDQ from baseline to follow-up. Other considerations surround the dose and frequency of sport participation. In the current study, exposure was measured categorically, and as such we cannot be sure if children received different doses of sports participation. Furthermore, changes in sport participation over time might also be of interest on how this might influence developmental outcomes; however, at follow-up data collection 94% of children in the study participated in at least one type of sport, therefore making the non-sports participant group size too small for comparison. Similarly, aggregating participation in different sports may have masked potential associations for different types of sports.

Examining changes in sport, using larger samples might help increase the variation for sports participation and may help to shed light on associations for health outcomes in relation to changes in sports participation. Additionally, it might also be important to consider longer longitudinal studies, to allow for the effects of sport participation to
manifest, particularly across this rapid developmental period in the early years for positive associations to be evident with psychosocial health. In conclusion, there is limited evidence from the current thesis or previous studies that sport participation during the preschool years is beneficially associated with children’s psychosocial health. Further research is needed to address this and to unpack potential mechanisms of such associations.

8.3 Research Question Two

Do the associations between total electronic media use and executive functions or psychosocial health differ by the type of electronic media (i.e., program viewing or use of electronic apps) in preschool children? (Chapter 5 & 6).

8.3.1 Associations between the type of electronic media use and executive function

8.3.1.1 Summary of findings

The findings from Chapters 5 and 6 highlighted that preschool children’s total daily electronic media use duration as well as their program viewing duration were negatively associated with their visual-spatial working memory capabilities when analysed cross-sectionally, however this was not maintained in longitudinal analyses. In contrast, high-dose app users (≥30 min/day) displayed better phonological working memory performance compared to non-users. Further, low-dose app use (>1 – 29 min/day) was not harmful for executive functioning. In both cross-sectional and longitudinal analyses, these participants displayed a consistent trend of superior visual-spatial working memory, phonological working memory, and shifting capabilities compared to non-users, but were not statistically significant. Longitudinally, low dose app users at baseline had better inhibition capabilities.
12-months later compared to high dose app users, although neither group was significantly different to non-users. All other longitudinal associations of electronic media use with cognition were null.

8.3.1.2 Comparison with the evidence base and possible mechanisms

A recent systematic review has summarised evidence on associations between electronic media use and health indicators in early childhood (0- to 4-years), including cognition (Poitras et al., 2018). Studies in this review, and additional studies following this review indicate that among the 10 cross-sectional studies and 10 longitudinal studies, TV viewing was unfavourably associated with cognition in four cross-sectional studies (Byeon & Hong, 2015; Lee, Spence, & Carson, 2017; Lin, Cherng, Chen, Chen, & Yang, 2015; Nathanson et al., 2014) and five longitudinal studies (Cheng, Maeda, Yoichi, Yamagata, & Tomiwa, 2010; Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004; McKean et al., 2015; Pagani, Fitzpatrick, & Barnett, 2013; Pagani, Fitzpatrick, Barnett, & Dubow, 2010). Null associations were observed in five cross-sectional (Cheng, Maeda, Yoichi, Yamagata, & Tomiwa, 2010; McKean et al., 2015; Pagani, Fitzpatrick, Barnett, & Dubow, 2010; Ruangdaraganon et al., 2009; Zimmerman et al., 2009) and four longitudinal studies (Blankson et al., 2015; Foster & Watkins, 2010; Mistry, Minkovitz, Strobino, & Borzekowski, 2007; Schmidt, Rich, Rifas-Shiman, Oken, & Taveras, 2009), while one cross-sectional study (Miller, Marks, & Miller, 2007), and one longitudinal study (Zimmerman & Christakis, 2005) observed mixed null, unfavourable, and favourable associations with cognitive outcomes. In relation to associations between other electronic media outcomes and cognition, cross-sectionally, no associations were observed for computer use (Rajchanovska & Ivanovska, 2015), while unfavourable associations were
observed for mobile phone use (Rajchanovska & Ivanovska, 2015) and total screen time/media use (Duch et al., 2013; Ferguson & Donnellan, 2014). Consequently, the null and negative associations observed in this thesis is consistent with the broader evidence base, suggesting that TV viewing may be detrimental to children’s cognitive health. However, interestingly low dose app use was not harmful to executive functions, yet there is limited evidence from previous studies that have examined these media behaviours independently, therefore conclusions for interactive media use with executive functions is needed to help draw conclusions.

As discussed in Chapter 5 and 6, only two cross-sectional (Carson et al., 2017; Nathanson et al., 2014) and two longitudinal (Blankson et al., 2015; Zimmerman et al., 2005) studies have examined associations between electronic media use, specifically with domains of executive function in preschool children. A detailed comparison between study methodologies and differences in findings can be seen in Chapter 5 and 6. Collectively the negative but inconsistent associations of program viewing and total electronic media use with executive functions in this thesis were somewhat consistent with the unfavourable cross-sectional associations observed by Nathanson et al. (2014), and null associations observed by Blankson et al. (2015), Carson et al. (2017) and Zimmerman, et al. (2005). However, to our knowledge, none of these studies examined associations for app use so direct comparisons are difficult. More research is needed to confirm the present results that, unlike program viewing, low dose app use was not detrimentally associated with executive function domains in preschool children.

Plausible mechanisms that may explain negative cross-sectional associations between program viewing and executive functions include program viewing’s potential to displace time away from developmentally rich, real world experiences and interactions that
might be more beneficial to a child’s cognition (Radesky & Christakis. 2016). Additionally, the program content and its appropriateness for preschool children may also influence executive functioning, which may be positive or negative, given that some fast paced programs has been observed to be negatively associated with executive functions (Lillard & Peterson, 2011). Although an analysis of media content was not within the scope of this study, it might be important to explore further in relation to electronic media use, both for program viewing and app use with executive functions, particularly given the proliferation of interactive media devices now available to children. Additionally, similar to that of program viewing, the time displacement hypothesis might also assist to explain why high-dose app users (≥30min/day) displayed poorer executive function outcomes than low-dose users (>1 – 29 min/day) longitudinally. Additionally, extensive use of electronic media has been reported to stimulate physiological arousal, and the secretion of dopamine to cortical regions of the brain that are sensitive to reward and reinforcement, particularly when playing electronic games and apps (Green. 2012), possibly explaining the negative association observed for app use with executive functions.

However, mechanisms related to time displacement or overstimulation do not appear to explain why app use in general was not detrimentally associated with executive function outcomes (i.e., app-users did not have significantly poorer executive functions than non-users), nor why high- and low-dose app users displayed significantly/marginally better executive functions outcomes than non-users cross-sectionally, or why low-dose app users generally descriptively displayed the strongest executive functions longitudinally. This might suggest that moderate levels of electronic media use are not harmful, and/or the relationship between engaging in electronic media use and health is not linear. Low-dose
app use may be advantageous (i.e., that are developmentally appropriate educational content), in that the potential reactivity, interactivity, tailorability, progressiveness, promotion of joint attentions of tablets may provide an avenue to foster the development of executive functions, whereas “overuse” may indeed displace alternate activities that are beneficial for cognitive development (Christikas, 2014).

Additionally, although analyses were adjusted for several covariates, other unmeasured factors, such as the quality of the preschool or school learning environment may have influenced executive functions at follow-up and thus longitudinal associations. One of the limitations of cross-sectional analyses is that it is difficult to determine if the hypothesised exposure is the cause – for example, if program viewing resulted in poorer executive functioning, or if children with poorer executive function tended to spend more time viewing programs. Although the lack of consistency in cross-sectional and longitudinal findings precludes clear conclusions on the plausible impacts of media use behaviours of different types, one relatively consistent finding across time points was that low dose app use was not harmful to executive functions. Indeed, children with low levels of app exposure generally displayed stronger executive function abilities relative to high dose or non-users. These results highlight the need to further examine associations for different types of electronic media independently in young children. The novel findings for app use provide support for the proposed pragmatic limit for young children of <30 min/day of app use (Christikas, 2014). Additional longitudinal and experimental studies would assist in confirming these findings, particularly for contemporary media use, and help to establish causality. This would help to better understand what the appropriate levels and types of media use may be for optimising health and developmental outcomes in young children.
8.3.2 Associations between electronic media use and psychosocial health

8.3.2.1 Summary of findings

Contrasting findings were observed when investigating associations between different types of electronic media and preschool children’s psychosocial health. In cross-sectional analyses, low-dose app users (>1 – 29 min/day) displayed significantly fewer total psychological difficulties than non-users, but program viewing was not associated with psychosocial outcomes (Chapter 5). However, in longitudinal analyses, higher levels of program viewing at 3- to 5-years were associated with increases in externalising behaviours and total psychological difficulties 12 months later (Chapter 6). No significant differences in psychosocial outcomes between app users and non-users were detected in longitudinal analyses. As such, program viewing appeared negatively associated with certain aspects of preschool children’s later psychosocial health, whereas app use was not, however associations with psychosocial health outcomes were predominantly null.

8.3.2.2 Comparison with the evidence and possible mechanisms

Consistent with these results, Poitras and colleagues’ (2017) recent systematic review, along with studies following this review, indicated that associations between electronic media use and psychosocial health indicators in young children were predominately null or unfavourable. Among seven cross-sectional studies and 10 longitudinal studies that examined associations between TV viewing and psychosocial health, two cross-sectional studies (Manganello & Taylor, 2009; Zimmerman, Glew, Christakis, & Katon, 2005), and two longitudinal studies (Watt, Fitzpatrick, Derevensky, & Pagani, 2015; Zimmerman et al., 2005) reported unfavourable associations. Null
associations were observed in two cross-sectional studies (Cheng et al., 2010; Miller, Grabell, Thomas, Bermann, & Graham-Bermann, 2012), and three longitudinal studies (Cheng et al., 2010; Hinkley, Verbestel, et al., 2014; Hinkley et al., 2017), while mixed unfavourable and null associations were observed in two cross-sectional studies (Lee & Carson, 2017; Teramoto, Soeda, Hayashi, Saito, & Urashima, 2005), and four longitudinal studies (Pagani, Fitzpatrick, & Barnett, 2013; Pagani et al., 2010; Verlinden et al., 2012, 2014). Lastly, mixed unfavourable and favourable associations were observed in one cross-sectional study (Intusoma, Mo-Suwan, Ruangdaraganon, Panyayong, & Chongsuvivatwong, 2013), and mixed null and favourable associations were observed in one longitudinal study (Mistry et al., 2007). Of the studies that examined associations for other screen behaviours, null associations were observed between video game use cross-sectionally (Linebarger, 2015), and e-gaming and computer use longitudinally (Hinkley, Verbestel, et al., 2014). However, one longitudinal study observed favourable associations between sedentary electronic games and psychosocial health, but unfavourable associations for computer use (Hinkley et al., 2017). Overall, among the evidence base it would suggest that associations for electronic media use, predominantly assessed using TV viewing are mixed, null and unfavourable for psychosocial health, while no studies’ examined associations for app use with psychosocial health.

More specifically related to the psychosocial outcomes of social and emotional health examined in this thesis, two cross-sectional studies observed mixed negative and null associations between TV viewing and social and emotional health in young children (Teramoto, Soeda, Hayashi, Saito, & Ucarsrashima, 2005; Lee & Carson, 2017), while two longitudinal studies observed null associations between TV viewing with domains of social and emotional health (Hinkley, Verbestel, et al., 2014; Hinkley, Timperio, Salmon, &
When examining associations for app use, few studies have examined electronic media behaviours other than TV viewing, and no studies have examined associations of app use with psychosocial health outcomes since the proliferation of electronic tablets and similar portable touch-screen devices. Thus making direct comparisons difficult. Consistently, the evidence reported in this thesis also observed mixed results; negative associations were observed with psychosocial outcomes for program viewing but not app use, and only in longitudinal analyses, these findings are somewhat consistent with the broader evidence base and systematic reviews (Poitras et al., 2017).

Plausible reasons as to why negative associations were observed for program viewing, but positive associations were observed for app use with psychosocial health may be due to the nature of the device. For instance, program viewing is predominately a passive activity, with little interaction, feedback or socialisation, in comparison to app use, in which the content may provide some level of interaction and feedback. Interaction with peers and adults are activities that support aspects of psychosocial health (Golinkoff, Hirsh-Pasek, & Singer, 2006; Moreno, 2016), however, app use although provide some interaction, will not provide the same experiences as a child may have with real-world interaction with their peers or adults, face to face. However, it could be speculated that some interaction and feedback gained from app use may have elements that are aligned with attributes that have a positive influence on aspects of psychosocial health, such as causing positive emotions, engagement, and a sense of accomplishment when interacting with apps. Other mechanisms as previously described in Chapter 5 that might be linked to the positive associations observed cross-sectionally for app use with executive functions, maybe due to the relationship between executive functions and self-regulatory behaviours.
that have been shown to underlie children’s psychosocial health (Hofmann et al., 2012). Such as, better executive functions have been associated with psychosocial health during early childhood (Benavides-Nieto et al., 2017), thus it may be hypothesized that low dose app use may encourage aspects of self-regulatory behaviours that may then promote behaviours associated with better psychosocial health. Yet the specific qualities, characteristics, doses, and patterns of app use that may be beneficial to child development requires further investigation.

It is important to note, however, the inconsistency of associations between electronic media use and psychosocial health over time. For example, it it unclear why low-dose app users (>1 – 29 min/day) displayed significantly fewer total psychological difficulties than non-users in cross-sectional analyses, but app use was not associated with psychosocial health 12 months later. One possible expanation could be that between baseline and follow-up assessments, children may have commenced engagement in alternative activities not assessed in this study that may provide support to psychosocial health or behaviours that underpin, or are associated with total difficulties thus neutralizing the possible effects of low-dose app use over time. Alternatively, it may be changes in the types of apps used, or the nature of their interaction with them, that might negate these benefits. Similar explanations to those described previously in section 8.3.1.2, the methodological design of this thesis may also help to explain why differences were observed across time points for electronic media use and psychosocial health. Different educators may have completed the SDQ at follow-up, which may have accounted for differences. A high drop-out rate between baseline and follow-up resulted in a smaller size, potentially contributing to differences in findings. Furthermore, although this study was inclusive of several covariates that have been associated with psychosocial outcomes, the quality of the preschool and
primary school environment was not accounted for, or other variables that were
unaccounted for may have influenced children’s psychosocial health at follow-up.
Likewise, the cross-sectional methodology of Chapter 5 limits the ability to determine if the
exposure of engagement in electronic media use is the cause or consequence of the
behaviour, for instance, did low-dose app use result in better psychosocial skills, or did
children with better psychosocial skills tend to be allowed to use apps in limited doses.
Because the associations were inconsistent across time points, the current results suggest
that the cross-sectional findings are not robust. However, one relatively consistent finding
across time points was that app use did not appear to be harmful to psychosocial health.

In summary, the unfavourable longitudinal associations of program viewing with
psychosocial health is consistent with the majority of longitudinal studies (Hinkley,
Verbestel, et al., 2014; Hinkley, Timperio, Salmon, & Hesketh., 2017). In addition, the lack
of studies examining app use with psychosocial health make comparisons difficult. Indeed,
the mixed positive cross-sectional, but nil longitudinal associations observed in the studies
in this thesis provides limited and unconvincing evidence that app use is positively
associated with psychosocial health. At best, the longitudinal results suggest app use it not
harmful. Yet larger observational and experimental studies would assist in clarifying these
findings, and help to understand possible mechanisms in how different types of electronic
media use may influence psychosocial health in preschool children.

8.4 Research Question Three

Is compliance with the 24-Hour Movement Guidelines for the Early Years
associated with executive functions and psychosocial health in preschool children? Do
associations differ for children meeting: i) individual guidelines (i.e., physical activity,
screen time or sleep), ii) combinations of any two guidelines (i.e., sleep and physical activity, sleep and screen time or screen time and physical activity), or iii) meeting an increasing number of guidelines (i.e., 0/1 vs. 2 vs. 3), (Chapter 7).

8.4.1 Associations between 24-Hour Movement Guideline for the Early Years compliance and executive function and psychosocial health in preschool children

8.4.1.1 Summary of findings

Cross-sectionally, preschool children who met the physical activity and sleep guidelines combined displayed significantly better phonological working memory than those who did not. Similarly, children meeting two guidelines displayed better phonological working memory, and children meeting three guidelines displayed better shifting scores, compared to children who met one/no guidelines in cross-sectional analyses.

Longitudinally, meeting the physical activity guideline at baseline was associated with better shifting scores 12 months later (Chapter 7). As such, the findings suggest that compliance with the physical activity guideline was consistently and favourably associated with domains of executive function across time points. In contrast, null associations were observed for meeting screen time guidelines, with executive functions cross-sectional or longitudinally, and nil associations were observed for meeting any combinations of the movement behaviour guidelines in the 24-Hour Movement Guidelines for the Early Years with psychosocial health cross-sectionally or longitudinally.

8.4.1.2 Comparison with the evidence base and possible mechanisms
As the 24-Hour Movement Guidelines for the Early Years were co-released in Australia (Okely et al., 2017) and Canada (Tremblay et al., 2017) in November 2017, only one cross-sectional study has examined if 24-hour movement guideline compliance is associated with psychosocial health in preschoolers (Carson et al., 2019). In contrast with the null associations observed between meeting any combination of guidelines with psychosocial health in Chapter 7, Carson and colleagues (2019) observed that children not meeting the screen time guideline had worse psychosocial behaviour scores, compared to those children meeting the screen time guidelines. There was a significant trend for children meeting combinations of: (i) the physical activity and screen time recommendations, and (ii) the sleep and screen time recommendations displayed better internalising, externalising and total problems compared to those who did not. For general combinations of recommendations, there was a significant trend in that meeting more recommendations were associated with better psychosocial health. Differences between the studies in physical activity and sleep measurement and data reduction make comparisons challenging. Carson et al. (2019) measured physical activity using wrist-worn accelerometers, collected data in 60-second epochs, and measured sleep objectively, whereas in the study reported in this thesis waist worn accelerometers, that collected data in 15-second epochs, and measured sleep subjectively, via parent report. These differing methods may have contributed to the differences in findings. Further, although the study conducted by Carson and colleagues included similar screen time behaviours to that of this thesis, 50.5% of participants meet the screen time guidelines whereas only 17.4% met the screen time guidelines in this thesis. These differences in the variation of children meeting the screen time guidelines in Carson’s study, in comparison to the small number of children meeting the screen time guideline may have accounted for different in that the small group size may have limited
the ability to detect associations. The longitudinal associations observed between physical activity guideline compliance and shifting scores in Chapter 7, align with associations observed between physical activity measured as a continuous exposure and domains of executive function in Chapter 4 of this thesis. However, null associations were observed between meeting the screen time guideline in isolation, or in combination with another behaviour, and executive function or psychosocial health. This is in contrast to mixed associations observed in Chapters 5 and 6, in that total screen time and program viewing was detrimentally associated with visual-spatial working memory cross-sectionally, and higher levels of program viewing at baseline were significantly associated with increases in psychosocial health longitudinally.

Discrepancies between cross-sectional and longitudinal findings, and when converted to adherence to 24-Hour Movement Guidelines for the Early Years may be partly due to methodological differences in screen time variables. Chapters 5 and 6 examined screen time continuously, while Chapter 7 examined screen time categorically, and additionally combined all electronic media use (i.e., program viewing and app use) together representing overall screen time, as recommended for guideline surveillance (Tremblay et al., 2017). Investigating total screen time in this way may have masked potential associations, given the differing associations observed for program viewing and electronic app use in Chapters 5 and 6. In order to investigate this further, supplementary analyses were conducted examining associations for a modified screen time variable that excluded app use when determining compliance with the screen time guideline cross-sectionally, and longitudinally, given that associations for low dose app use were not unfavourable with executive functions (Table 8.1 & 8.2).
When app use was excluded, compliance with the screen time guideline increased, with an additional 10 children (4%) meeting this recommendation. Cross-sectionally, there were no longer significant differences in phonological working memory between children who met two guidelines compared to those who met one/no guidelines (p > 0.05). Consequently, the differences between groups for those meeting 2 vs 0/1 guidelines became weaker and resulted in wider confidence intervals. Interestingly, differences in shifting between children meeting three guidelines compared to those meeting one/no guidelines remained consistent. Further, in contrast to the initial analyses, children who met the 24-Hour Movement Guidelines for the Early Years displayed better shifting capabilities cross-sectionally compared to those who did not in the supplementary analyses (Table 8.1 & 8.2).
Table 8.1: Mean, and marginal mean difference scores (95% Confidence Intervals) at baseline, for associations between meeting individual movement behaviours, combinations of behaviours, number of behaviours met and meeting the 24-H Movement Guidelines for the Early Years for executive functions, adjusting for covariates.

<table>
<thead>
<tr>
<th>Meeting individual behaviours</th>
<th>VSWM (n=241)</th>
<th>PWM (n=235)</th>
<th>Shifting (n=232)</th>
<th>Inhibition (n=224)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sleep (≥10 h/d &amp; ≤13 h/d)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>0.133</td>
<td>-0.185</td>
<td>-0.824</td>
<td>0.007</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.531, 0.796)</td>
<td>(-0.451, 0.080)</td>
<td>(-2.131, 0.483)</td>
<td>(-0.104, 0.120)</td>
</tr>
<tr>
<td><strong>Screen Time (≤60 min/d)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.060</td>
<td>-0.071</td>
<td>-1.063</td>
<td>-0.012</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.265, 0.144)</td>
<td>(-0.435, 0.294)</td>
<td>(-2.426, 0.300)</td>
<td>(-0.086, 0.062)</td>
</tr>
<tr>
<td><strong>Physical Activity (≥180 min/d of TPA including ≥60 min/d of MVPA)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.173</td>
<td>-0.399</td>
<td>-2.103</td>
<td>-0.048</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.520, 0.174)</td>
<td>(-0.975, 0.178)</td>
<td>(-4.654, 0.447)</td>
<td>(-0.242, 0.145)</td>
</tr>
<tr>
<td><strong>Combination of movement behaviours</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep + Screen Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.076</td>
<td>-0.127</td>
<td>-1.059</td>
<td>-0.001</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.308, 0.155)</td>
<td>(-0.771, 0.222)</td>
<td>(-2.478, 0.359)</td>
<td>(-0.075, 0.077)</td>
</tr>
<tr>
<td>Sleep + PA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>0.008</td>
<td>-0.301</td>
<td>-1.359</td>
<td>-0.013</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.479, 0.495)</td>
<td>(-0.562, -0.040)</td>
<td>(-2.602, -0.116)</td>
<td>(-0.126, 0.100)</td>
</tr>
<tr>
<td>Screen + PA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.076</td>
<td>-0.127</td>
<td>-1.059</td>
<td>-0.001</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.308, 0.155)</td>
<td>(-0.771, 0.222)</td>
<td>(-2.478, 0.359)</td>
<td>(-0.075, 0.077)</td>
</tr>
<tr>
<td><strong>Number of guidelines met</strong></td>
<td>-0.064</td>
<td>0.175</td>
<td>1.050</td>
<td>0.123</td>
</tr>
<tr>
<td>2–1/0 MD (95% CI) difference</td>
<td>(-0.566, 0.438)</td>
<td>(-0.142, 0.492)</td>
<td>(-0.108, 2.209)</td>
<td>(-0.101, 0.127)</td>
</tr>
<tr>
<td>3–2 MD (95% CI) difference</td>
<td>0.097</td>
<td>0.138</td>
<td>1.150</td>
<td>0.011</td>
</tr>
<tr>
<td>3–1/0 MD (95% CI) difference</td>
<td>0.033</td>
<td>0.313</td>
<td><strong>2.201</strong>*</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>(-0.500, 0.567)</td>
<td>(-0.102, 0.727)</td>
<td><strong>(0.559, 3.843)</strong></td>
<td>(-0.103, -0.058)</td>
</tr>
<tr>
<td><strong>Meeting 24-hour Movement Guidelines</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.088</td>
<td>-0.166</td>
<td><strong>-1.315</strong>*</td>
<td>-0.013</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.322, 0.146)</td>
<td>(-0.509, 0.176)</td>
<td>(-2.620, 0.010)</td>
<td>(-0.083, 0.057)</td>
</tr>
</tbody>
</table>

Note: VSWM: Visual-spatial working memory, PWM: Phonological working memory, Linear regression models adjusted for age, sex, socio-economic status, caregiver education, the Home Learning Environment, and preschool level clustering. *p < .05.
Table 8:2 Mean, and marginal mean difference scores (95% Confidence Intervals) for associations between meeting individual movement behaviours, combinations of behaviours, number of behaviours met and meeting the 24-Hour Movement Guidelines for the Early Years at baseline, and associations between executive functions, SDQ subscales and total difficulties scores at follow-up, controlling for executive functions, SDQ subscales and total difficulties scores at baseline and adjusted for covariates.

<table>
<thead>
<tr>
<th>VSWM (n=182)</th>
<th>PWM (n=175)</th>
<th>Shifting (n=179)</th>
<th>Inhibition (n=167)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Meeting individual behaviours</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sleep (≥10 h/d &amp; ≤13 h/d)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.339</td>
<td>-0.163</td>
<td>0.938</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.840, 0.161)</td>
<td>(-0.494, 0.167)</td>
<td>(-0.798, 2.675)</td>
</tr>
<tr>
<td><strong>Screen Time (≤60 min/d)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.081</td>
<td>-0.019</td>
<td>0.651</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.381, 0.219)</td>
<td>(-0.266, 0.229)</td>
<td>(-0.438, 1.741)</td>
</tr>
<tr>
<td><strong>Physical Activity (≥180 min/d of TPA including ≥60 min/d of MVPA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.042</td>
<td>0.140</td>
<td>-3.946**</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.553, 0.468)</td>
<td>(-0.171, 0.451)</td>
<td>(-6.191, -1.700)</td>
</tr>
<tr>
<td><strong>Combination of movement behaviours</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sleep + Screen Time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.087</td>
<td>-0.028</td>
<td>0.579</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.395, 0.221)</td>
<td>(-0.187, 0.243)</td>
<td>(-0.537, 1.696)</td>
</tr>
<tr>
<td><strong>Sleep + PA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.255</td>
<td>-0.075</td>
<td>-0.681</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.647, 0.137)</td>
<td>(-0.364, 0.213)</td>
<td>(-2.392, 1.028)</td>
</tr>
<tr>
<td><strong>Screen + PA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.081</td>
<td>-0.019</td>
<td>0.651</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.381, 0.219)</td>
<td>(-0.266, 0.229)</td>
<td>(-0.438, 1.741)</td>
</tr>
<tr>
<td><strong>Number of guidelines met</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2–1 MD (95% CI) difference</td>
<td>0.249</td>
<td>0.155</td>
<td>0.744</td>
</tr>
<tr>
<td></td>
<td>(-0.184, 0.682)</td>
<td>(-0.144, 0.454)</td>
<td>(-1.089, 2.577)</td>
</tr>
<tr>
<td>3–2 MD (95% CI) difference</td>
<td>0.046</td>
<td>-0.051</td>
<td>-0.691</td>
</tr>
<tr>
<td></td>
<td>(-0.287, 0.378)</td>
<td>(-0.271, 0.168)</td>
<td>(-1.842, 0.460)</td>
</tr>
<tr>
<td>3-1/0 MD (95% CI) difference</td>
<td>0.295</td>
<td>0.104</td>
<td>0.054</td>
</tr>
<tr>
<td></td>
<td>(-1.134, 0.724)</td>
<td>(-0.245, 0.452)</td>
<td>(-1.863, 1.970)</td>
</tr>
<tr>
<td><strong>Meeting 24-hour Movement Guidelines</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Meeting vs Meeting</td>
<td>-0.087</td>
<td>-0.028</td>
<td>0.579</td>
</tr>
<tr>
<td>MD (95% CI) difference</td>
<td>(-0.395, 0.221)</td>
<td>(-0.187, 0.243)</td>
<td>(-0.537, 1.696)</td>
</tr>
</tbody>
</table>

Note: VSWM Visual-spatial working memory, PWM Phonological working memory, Linear regression models adjusted for age, sex, socio-economic status, caregiver education, the Home Learning Environment, and preschool level clustering, *p < .05.
The difference in findings for the supplementary analyses for overall guideline compliance may have, in part, been due to removing the type of screen time that was not found to be unfavourably associated with executive functions in continuous analyses, and thus defining compliance with the screen time recommendation using predominantly program viewing which was unfavourably associated with executive functions. No changes were observed for the longitudinal analysis. This supplementary analysis suggests that by excluding app use when defining compliance with the screen time recommendation, different associations were observed between compliance with the 24-Hour Movement Guidelines for the Early Years and cognitive health outcomes. This is an important finding, as some evidence from this thesis observed mixed positive and negative associations for different media behaviours. The evidence reviewed (Poitras et al., 2017) to assist in the development of the 24-Hour Movement Guidelines for the Early Years, primarily included studies investigating the health consequences of TV or program viewing. These traditional forms of electronic media have different functionality compared to electronic games and apps on interactive touch-screen devices. More research is warranted to examine how contemporary interactive media behaviours are associated with health outcomes in young children, and if these behaviours differ compared to traditional, cognitively passive forms of media use. This will also help to inform and guide policy and practice on the appropriate levels and types of media use for optimal health outcomes in the early years.

In summary, the results presented in Chapter 7 show that meeting more guidelines, better sleep and physical activity, and meeting the physical activity guideline in isolation were associated with better cognition cross-sectionally. Longitudinally, only meeting the physical activity guideline was associated with cognition, and no associations were observed for meeting any combinations of the 24-Hour Movement Guidelines for the Early
Years. Thus, the limited studies examining executive functions, and the inconsistency with the results observed in this study in comparison to the other study examining psychosocial health outcomes (Carson et al., 2019) prevents clear conclusions to be drawn. This thesis, overall, did not provide convincing evidence to support the integrated guidelines, however, promoting adherence to the physical activity recommendation may be one means of improving executive functions in early childhood. Few children met the 24-Hour Movement Guidelines for the Early Years in this thesis, thus continued efforts are needed to promote healthy growth and development through adherence to these recommendations given that systematic reviews indicate that sleep (Chaput et al., 2017), recreational screen time (Poitras et al., 2017), and physical activity (Carson, Lee, et al., 2017) are individually associated with health and developmental outcomes among young children.

### 8.5 Strengths

To the author’s knowledge, this study is the largest to examine the independent associations of objectively-measured physical activity intensity and type (i.e., modified organised sport), as well as contemporary forms of electronic media use, with executive function and psychosocial health cross-sectionally and longitudinally. Further, this was the first study to investigate if preschool-aged children who met the new Australian 24-h Movement Guidelines for the Early Years had better executive functioning and psychosocial health cross-sectionally and longitudinally.

A main strength of this study was its use of objective measures of physical activity. Accelerometers are the measure of choice for the assessment of free-living and habitual physical activity in young children (Cliff, Reilly, & Okely, 2009). This measure allowed the examination of the full physical activity intensity spectrum, and how time spent at these
different intensities may be associated with executive functions and psychosocial health in preschool children. In contrast, most studies examining physical activity and cognitive an psychosocial health have adopted subjective measures of physical activity (Carson, Lee, et al., 2017). Through the use of accelerometry to capture the intensity and duration of preschool children’s physical activity, this program of research was able to discover novel associations between: i) VPA and executive functions; and ii) guideline compliance, particularly for the physical activity recommendation, and executive functions.

To the author’s knowledge, no previous study has examined if participation in modified organised sport is associated with executive function domains and psychosocial health in young children, after adjusting for their habitual physical activity level. By doing this, the current study was able to investigate if other aspects beyond the physiological effects of physical activity, such as the environment or context, might influence young children’s executive functions and psychosocial health. The inclusion of a subjective measure of sport participation in these studies, to capture aspects of the physical activity context that cannot be assessed from accelerometers, helped to provide some insight into how cognitively engaging physical activity might be associated with the development of executive functions in this age group, at least cross-sectionally, independent of habitual MVPA.

The assessment and examination of traditional and contemporary forms of electronic media use made it possible to investigate how these different types of behaviours might hold distinct and separate associations with developmental outcomes in the early years. Consequently, the studies described in Chapters 5 and 6 were able to discover novel associations of: i) total electronic media use and program viewing with executive functions and psychosocial health; and ii) low-dose app use with psychosocial health.
The use of a direct measure of children’s executive functions that has very strong validity, reliability, and developmental sensitivity was an important contribution to the literature, where previous evidence has predominately focused largely on other cognitive domains such as language development (Carson, Hunter, et al., 2016; Carson et al., 2015; Poitras et al., 2017). Despite the availability of a range of measures to directly assess children’s executive functions, issues of appropriateness, accessibility and cost plague many of these options (Howard & Melhuish, 2017). The iPad-based EYT has been validated for use with young children, is brief to administer, and offers a number of pragmatic advances (e.g., data capture, standardization, engaging for young children) which address some of the limitations of alternative measures.

8.6 Limitations

Despite the strengths identified, this thesis is not without limitations. The findings in Chapters 3 and 5, and partly in Chapter 7, were cross-sectional, and therefore causality cannot be established. Although cross-sectional studies are inexpensive, allow researchers to collect vast amounts of information quickly, enable multiple variables to be collected and provide facilitation for further research, the cross-sectional results observed in this thesis should be interpreted with caution. Cross-sectional data may overinflate individual associations due to a lack of control of other factors that might be related to the topic under investigation, however this thesis included a large variety of covariates to increase validity of results. This lack of causality may be evident in the observed results in this thesis, as not all associations observed cross-sectionally were consistently associated when tested in longitudinal analyses, however the longitudinal design allowed the comparison of findings cross-sectionally and longitudinally. Similarly, most of the previous evidence on the
associations investigated in this thesis has been derived from cross-sectional data. Although this is helpful for hypothesis generation, and for informing longitudinal studies which help to capture long-term change, none of the cross-sectional studies allow for causal inferences. Yet, the cross-sectional studies in this thesis led to the extension into the longitudinal examination of associations and were in some cases amongst the first studies to provide insight into the temporal nature of associations for certain exposures, total electronic media use, program viewing and app use, and movement behaviour guideline compliance, with developmental outcomes such as executive functions and psychosocial health.

Furthermore, children in this study were only recruited from ECECs, and so children who attend family day-care or do not attend childcare were not included in the sampling frame. However, because 75%-85% of pre-school-aged children attend childcare in Australia, it is likely that a large and diverse proportion of the population could have been recruited to the study (Australian Institute of Family Studies, 2016).

Similarly, another limitation was the level of missing data across time points, due predominately to incomplete parent-report data. As such a complete case analysis was used, which reduced the sample size, resulting in significant differences in phonological working memory scores and IRSAD scores between the analytical sample and children with missing data. The analytical sample was investigated for further bias, yet the results should be interpreted with caution as generalizability may have been affected.

Likewise, although the sample contained sufficient variability in predictors and outcomes cross-sectionally and longitudinally, sample sizes for sub-groups (e.g., sport participants vs. non-sports participants, meeting the screen time guidelines) were relatively small. This may not have been sufficient to demonstrate novel or meaningful comparisons, and consequently may have limited the ability to detect significant associations.
In addition, because the studies in this thesis used a prospective observational design and given the limited evidence base examining the exposures and specific outcomes, an explanatory analysis approach was adopted, rather than a confirmatory analysis approach that would be applied to experimental data. As such, formal correction for multiple testing was not applied to the analytical strategy.

Further, because parents reported their child’s screen behaviour use, there is potential for parents to intentionally or unintentionally misreport this outcome. Previous studies have indicated the possibility of both under-reporting and over-reporting of screen-time/televison viewing (Colley, Harvey, Grattan, & Adamo, 2014; Robinson et al., 2006). This issue is common to all population-based observational studies of preschool children’s screen behaviours. Further, the majority of studies in a recent systematic review used some form of report to assess young children’s electronic media use (Poitras et al., 2017). At present, there are no practical alternative approaches.

Although accelerometers are the method of choice for assessing habitual physical activity in young children (Cliff et al., 2009), they are not without limitations. The device used in this study is not water-proof, and so water-based physical activities could not be included in the estimates of children’s physical activity. Additionally, hip-mounted accelerometers combined with cut-point data reduction approaches may be limited in their ability to differentiate between sitting and standing still (Van Loo et al., 2017). This measurement limitation may have affected the assessment of LPA and apparent associations with outcomes, and consequently the estimates of children’s physical activity.

In addition, this thesis did not examine associations for objectively measured sedentary behaviour. Consequently, where electronic media use was associated with developmental outcomes it is not entirely clear if the behaviour of sitting influenced these
associations. Mechanistic theories suggest that there are plausible aspects of electronic media use that might explain observed associations, but there are also plausible hypothesised mechanism connecting prolonged sitting with cognitive outcomes (Voss et al., 2014). Hip-mounted accelerometers are not ideal for assessing sedentary behaviour because they tend to misclassify standing still as sedentary behaviour (Van Loo et al., 2017). A plausible reason for LPA appearing to be detrimental to visual spatial working memory, may be due to its strong inverse relationship with sedentary behaviour ($r = -0.77$, $p < 0.01$). Children who spend more time sedentary at this age maybe spending more time in learning activities that challenge or assist development of visual-spatial working memory, such as reading. Therefore, time spent sedentary whilst doing academically stimulating activities might be positively associated with working memory, and thus LPA inversely associated. As such future studies may need additional measures such as thigh-mounted activity monitors that can more accurately measures sedentary behaviour (Van Loo et al., 2017) to more clearly ascertain if high levels if sitting are negatively associated with cognitive or psychosocial health outcomes in young children, or if different types of electronic media use are more strongly associated with these developmental outcomes, potentially due to other mechanisms.

Another important limitation was that different educators reported on children’s psychosocial health across time points, due to change over of staff, or because different educators supervised children. This was not within the control of the study, and it was decided based on previous experience that it would be difficult to get complete data from parents at multiple time points with a preschool-based recruitment strategy. Additionally, educators would also have a broader comparison with the other children at the preschool, resulting in their broad reference point to compare against other preschool children.
Another potential limitation was that other aspects of electronic media use were not investigated. For instance, the quality, type, context, or content of screen time (Christakis et al., 2013; Lillard, Drell, Richey, Boguszewski, & Smith, 2015), the timing of television viewing or exposure to background television (Christakis, 2009), or the quality of social interactions and co-viewing during screen time (Radesky et al., 2015). As such future studies in young children should not only examine different types of electronic media, but also their content, timing, and the social environment within which they occur, in relation to possible risks or benefits to health and development. Additionally, although sleep was controlled for in all studies as a covariate, other aspects of sleep, such as the timing of sleep onset, which has been associated with cognition (Reynaud, Vecchierini, Heude, Charles, & Plancoulaine, 2017), were not examined. In addition, future studies should examine the different aspects of sleep, and adopt objective measures that can assess sleep duration, sleep onset latency, number of awakenings, sleep efficiency and sleep depth, in relation to associations with health and development in preschoolers.

Further, this thesis examined levels of physical activity intensity and type, and electronic media use at 3- to- 5 years predicting developmental outcomes 12 months later. Additional longitudinal analyses could be conducted to understand if changes in behaviours are associated with changes in outcomes by using alternative statistical models and taking the behaviours at follow-up into account.

Similarly, this thesis examined associations for physical activity and electronic media behaviours in isolation, which is the approach that has traditionally formed the evidence base. Recently, and a paradigm shift occurred from examining these behaviours in isolation to more holistic conceptualizations (Pedišić, 2014; Pedišić et al., 2017). Achieving adequate levels of these behaviours simultaneously, such as sufficient physical activity and
sleep, and limited exposure to electronic screen devices for recreation are thought to allow for optimal health and development across a 24-hour period. This suggests these behaviours need to be treated as intrinsically co-dependent rather than independent, and investigating this appropriately requires different analytic techniques (Pedišić et al., 2017). Given the release of the Australian 24-H Movement guidelines for the Early Years (Okely et al., 2017), future research should consider a more holistic approach to evaluating movement behaviours in relation to children’s health and development such as through compositional data analysis (Carson, Tremblay, & Chastin, 2017).

8.7 Recommendations for research

The research in this thesis aimed to further understating of the most beneficial intensities and types of physical activity, and the most beneficial types of electronic media use, for cognitive and psychosocial health in preschool children. Recommendations for each research question are outlined below.

8.7.1 Research Question 1

High intensity physical activity displayed positive associations with cognition, but measurement issues related to the assessment of lower intensity physical activity using hip-mounted accelerometry and cut-point methodologies may have influenced the assessment of LPA and apparent associations with health outcomes. Future research could use alternative methodologies, such as thigh-mounted activity monitors that may differentiate between sedentary behaviour and LPA more accurately (Van Loo et al., 2017). Interestingly, participation in sport displayed both positive and negative associations with cognition. Studies that provide larger sub-groups; better distinguish between different types
of sports (i.e., team or individual sports; Howard et al., 2018); capture the weekly dose (e.g., min/week), and changes in participation (i.e., participation vs drop outs), will allow for a more clearer investigation into potentially important components of sport participation for healthy development.

8.7.2 Research Question 2

Similar to prior studies (Poitras et al., 2017), electronic media use was parent-reported making it susceptible to recall and social desirability biases. Future studies may consider objective measures of electronic media use (e.g., wearable cameras) although they present some ethical dilemmas, to more accurately capture these screen-based behaviours. Additionally, although not within the scope of this thesis, considering other potentially relevant components of electronic media use such as; the quality of content and the context of electronic media use, along with the timing of television viewing, exposure to background television, as well as the quality of social interactions and co-viewing may help to better understand associations with executive functions and psychosocial health.

Mixed associations were observed for traditional and contemporary media use. As screen-based devices are rapidly changing, it is imperative that research keeps up with the shifts in trends and use of electronic media for young children to understand their potential different associations with cognitive and psychosocial health. Larger studies, that provide larger sub-groups, and can better distinguish between app use at different levels and non-users, will allow for a clearer investigation into potentially important aspects of using interactive media devices for healthy development.
8.7.3 Research Question 3

Given the different associations observed in this thesis, in that app use was positively associated with cognition, while program viewing was negatively associated with cognition, further studies testing the inclusion versus exclusion of app use in screen time guideline might be informative for all aspects of health and development. Further, it may be that associations may differ for different health outcomes, e.g., physical health outcomes like obesity and motor development, versus cognitive development. In additional, the 24-Hour Movement Guidelines for the Early Years are new, and few studies have tested compliance to them with health outcomes. This thesis, overall, did not provide convincing evidence to support the overall guidelines or individual movement behaviours. Alternative thresholds for each behaviour could be tested to determine if alternative guidelines would be more appropriate, or if the current guidelines result in the best outcomes for young children.

8.7.4 Broader thesis recommendations

Consistent recommendations are needed across the three research questions presented in this thesis, and thus more broadly to confirm or refute the novel associations observed for physical activity and electronic media use with cognitive and psychosocial health outcomes. Larger, representative observational studies are needed, with lower levels of missing data to allow for generalisability of the results. Additionally, longer follow-ups are needed, with multiple examination periods to explore how associations of cognitive and psychosocial health may change over this critical developmental period. As observational studies cannot establish causation, experimental studies are needed to help establish cause and effect relationships, and to better understand possible mechanisms that underpin
possible associations. Furthermore, the inclusion of sleep, and adopting compositional analyses to appropriately consider how the movement behaviour composition over a 24-h period is associated with health outcomes will help to further understand the interaction these behaviours may have on cognitive and psychosocial outcomes.

For the studies that examine psychosocial health outcomes in preschoolers, utilising both parent and educator reports of the SDQ will help to gain a more wholistic perspective for the child’s psychosocial health. Six monthly assessments in a sub-sample might assist in confirming findings from educator reports, although this would increase participant burden and potentially increase missing data.

Research in this area has traditionally focused on the health implications of individual movement behaviours (i.e., sleep, sedentary behaviour, including electronic media use, and physical activity) as separate and independent. Yet, across the 24-hour period, these behaviours are conceptually related and co-dependent (Pedišić et al., 2017). Research should consider the trade-off between these behaviours. Pedisic (2014) identifies that most studies, included those reported in this thesis, have failed to correctly account for all behaviours on the movement continuum, yet due to multicollinearity, that this is not possible when using traditional regression analyses. Some evidence in older age groups have found a link between greater time spent using digital technology and reduced physical activity, albeit small reductions in adolescents (Leblanc et al., 2015), this association might be important to explore in early childhood. Promoting a synergistic approach to adopting multiple health behaviours may potentially have beneficial associations with health over time, as recommended through the 24-H Movement Guidelines for the Early Years (Okley et al., 2017; Tremblay et al., 2017). At present, no studies examine associations between the behaviour composition with cognitive and psychosocial health in young children. Future
research that employs appropriate analytic strategies for dealing with compositional movement behaviour data may be instrumental in influencing our understanding of the implications of these movement behaviours for development and health in young children. This may help to provide important information for public health guidance and policy while adopting a holistic, child-centred approach.

8.8 Recommendations for practice and policy

The studies presented in this thesis provide evidence that may have implications for practice and policy:

8.8.1 Research question 1

As VPA was positively associated with executive functions, and other evidence suggests that higher intensity physical activity might support children’s healthy development more broadly (Carson et al., 2017), strategies to assist educators, parents and the wider community to promote higher intensity physical activity among young children may be beneficial. Furthermore, following a recent update, Australia and Canada’s physical activity guidelines now recommend that 3-to-5 year-olds engage in >180min/day of LMVPA, including >60min/day of energetic play, which is operationalised as MVPA (Okely et al., 2017; Tremblay et al., 2017). The finding that VPA was positively associated with executive function provides additional evidence to support the inclusion of thresholds related to higher intensity physical activity in movement behaviour guidelines.
8.8.2 Research question 2

The negative associations observed for total electronic media use, and program viewing with cognitive and psychosocial health suggests that the promotion of strategies to assist educators, parents and the wider community to limit young children’s program viewing are warranted, as are guidelines to promote limits. However, findings suggested that app use was not detrimentally associated with executive function or psychosocial health. Although these findings are preliminary and need confirmation through additional studies, in combination with overall electronic media limits and reduction strategies, supporting children in engaging with electronic media, to exchange time spent in traditional passive program viewing with the use of developmentally-appropriate interactive apps at modest levels (<30min/d) may be less harmful to their cognitive and psychosocial health. Additionally, the cross-sectional findings related to low dose app use support the proposed pragmatic limit for young children of <30 min/day of app use (Christakis. 2014), ideally involving developmentally appropriate, educational content. It should be noted, however, that the positive associations of low dose app use compared to non-users with cognitive and psychosocial health were not supported longitudinally, although the findings indicate that low dose app users demonstrated more positive outcomes than high dose app users. These developments are reflected in American Academy of Paediatrics updated policy statement, which recommends less restrictive guidelines, recognizing the potential value of digital technology for the younger age groups (AAP, 2016). This is, however, inconsistent with the most recent updated 24-H Movement Guidelines for the Early Years, which do not differentiate between electronic media types (Tremblay et al., 2017). Setting limits on screen time, and providing consistent advice on different devices, duration and possibly
content may help to educate and inform policy, practice and parents and avoid confusion (Straker et al., 2018).

8.8.3 Research question 3

Meeting the physical activity guideline in isolation was beneficial for shifting. This suggests that strategies to support children to meet the physical activity guideline maybe warranted. This provided further evidence to support the current physical activity recommendation. However, the studies did not provide evidence that meeting the overall movement guidelines was beneficially associated with executive functions or psychosocial health. Further, there was limited evidence to support individual or combinations of guidelines in longitudinal analysis. Research evaluating different guideline thresholds may be warranted to more clearly support or refute current guidelines. Interestingly, the supplementary analysis presented in this discussion chapter found that, when using app use was excluded from the categorisation of screen time guideline compliance, meeting the overall movement guidelines was positively associated with shifting in cross-sectional analyses. Further evaluation of this is needed, but it provides preliminary evidence that recommendations related to screen time may need to consider different types of electronic media use, at least in relation to children’s cognitive development.

8.9 Conclusion

Findings from this Doctorate have contributed evidence and enabled a better understanding of this limited, albeit growing, area of research. The five studies have provided key findings on the relationships of different physical activity intensities, participation in modified organised sport, and types of electronic media use with health
outcomes in preschool children, specifically executive function and psychosocial health. Understanding the factors that impact healthy brain development in the early years is needed to inform future interventions aiming to promote optimal cognitive development.

While the majority of results observed in this thesis were null, with some significant associations, the results add to the limited, yet mounting evidence on the relationships of physical activity and electronic media use with cognitive and psychosocial health in preschoolers. It highlights the importance of examining different intensities of physical activity using objective measures, in addition to examining the type of activity which cannot be gained from accelerometers with aspects of cognitive and psychosocial health. Furthermore, the mixed, null and negative associations observed for electronic media use with cognitive and psychosocial health highlight the importance of researchers examining these behaviours independently. This is evident in this thesis that observed both positive and negative associations with different behaviours, across different time points with both health outcomes. It seems that the relationship between the intensity and type of physical activity, along with the type of electronic media use may vary in their sensitivity with executive function and psychosocial health domains over time. This may be due to the rapid developmental change the brain undergoes during the preschool period (3- to 5-years; Lenroot & Giedd, 2006), combined with the sporadic nature of physical activity and the complex and rapid increase in the use of electronic media use by preschoolers.

Although the evidence base is growing, an over reliance on cross-sectional studies may dilute the evidence base, given the inability to establish cause and effect relationships, thus much of the current evidence is limited by conceptual or methodological issues. This may contribute to confusion among researchers and in policies and practice recommendations, ultimately presenting mixed messages to parents, educators and
caregivers. It is recommended that future research focuses on robust methodological designs, that improve the quality and reliability of evidence in this complex area. An important challenge as researchers in young children’s physical activity and use of electronic media moves forward, is to further understand how the intensity or type of activity might affect health, and to understand if different types of electronic media use are more or less influential in supporting children’s optimal development. While further research is needed to confirm the evidence presented in this thesis, the results provide preliminary evidence supporting: i) the promotion of higher intensity physical activity and compliance with the physical activity guidelines, and ii) the reduction of, and limits to, media program viewing.
Chapter 9: List of References


Pedišić, Ž. (2014). Measurement issues and poor adjustments for physical activity and sleep undermine sedentary behaviour research - The focus should shift to the balance between sleep, sedentary behaviour, standing and activity. *Kinesiology, 46*(1), 135–146.


lifestyle impact neuronal and cognitive health through distinct mechanisms associated with sedentary behavior and physical activity? *Mental Health and Physical Activity*, 7(1), 9–24. https://doi.org/10.1016/j.mhpa.2014.01.001


Chapter 10: Appendices
10.1 Appendix A Ethical Approval – University of Wollongong
10.2 Appendix B Ethical Approval – Department of Education (NSW)
10.3 Appendix C Ethical Approval – Catholic School of Education (NSW)
PATH-ABC study

Participant Information Sheet

Dear Parent /Carer,

We would like to invite you and your child to participate in the PATH-ABC study. Full details about the project, its purpose, the researchers involved and what will be asked of you and your child, should you agree for your child to be involved, are provided in this information sheet.

What is the purpose of this study?
Early childhood involves rapid and important changes in physical development, brain development and social skills. Research in school-aged children has shown that levels of physical activity and screen-based entertainment (e.g., TV viewing, computer games, and computer use) influence these developmental changes. However, little is known about the links between these behaviours and emotional, social and cognitive (thought processing) development and cardiovascular health (heart and blood vessels) during early childhood. This study will investigate if physical activity and screen-based entertainment are linked to emotional and social development, thinking processes and vascular health among 500 preschoolers in the Illawarra. For children still attending the same early childhood service in 2016, participation in the study will involve completing assessments twice, once between completing assessments between April and November 2015, and a second time 12-months later between April and November 2016.

We are asking for your assistance in furthering research in this area, by allowing your child to participate in this study. Your participation in this research is voluntary.

What will we ask you and your child to do?
This study will use several different ways to collect information about your child’s behaviours and developmental outcomes, as detailed below.

Once we have received Parental/Guardian consent we will ask your child if they would like to participate in the activities in this study. We will say to your child “Hello, my name is ___________________, I work at the University of Wollongong. We have asked your parents if it is ok for you play some iPad games and do some other activities with us today. Your parents said it’s OK for you to play and to do these activities with us. Do you want to try the games? If you ever want to stop playing the games, just tell me. OK? Are you ready to play
While at their childcare service, children will have their **height, weight, waist circumference** measured by a researcher. Children will also have their **blood pressure** and **heart rate measured**. Heart rate will be measured by a small device, which will be attached by sensors (like stickers) to children on their right and left collarbone and hipbone for approximately 10min while playing two games on an iPad. Children will also have a photo of their eye (**retinal image**) taken using a portable camera. This photo is not invasive and is used to look at the development of the body’s small blood vessels, which are an indicator of cardiovascular health and development. Children will also have a photo of their eye (**retinal image**) taken using a portable camera. This photo is not invasive and is used to look at the development of the body’s small blood vessels, which are an indicator of cardiovascular health and development.

To examine cognitive development children will complete five 'games' at their childcare service that involve higher order thinking processes. These games evaluate children’s short-term or working memory, ability to self-regulate (inhibition), ability to shift between instructions (shifting) and their expressive vocabulary. All games are on an iPad, they include a working memory game about a cartoon ant, a working memory game using auditory instruction, a fish catching game to assess inhibition, an object naming game to assess vocabulary, and a card-sorting task to assess the ability to shift between different sets of rules. Together, these tasks will take approximately 15-20 minutes to complete, but children will get to have breaks between games. A trained data collector will sit with the child in a quiet but public area, away from the main group of children. Children’s Primary Educators will be present at all times. All research staff will have Working with Children Checks.

To understand children’s social and emotional development, children will be given cartoon scenarios and an accompanying story with a depicted character. Children will be asked to identify the appropriate emotional outcome (in each scenario). Children will then be shown photographs of children’s faces showing 5 different emotional expressions, and they will be asked to identify each emotion. Children will also watch a short video where a puppet will provide the child with a statement (e.g., seeing a child crying makes me feel like crying), and the child will respond by stating if they are like/not-like the puppet. Together these tasks will take approximately 15 minutes to complete.

To understand children’s level of physical activity and sleep, they will be asked to **wear an activity monitor** (known as an accelerometer) **for one week on their waist using an elastic belt**. Children will be asked to wear the monitor during the day and night, but monitors will be removed for water-based activities such as having a bath. The monitor is small, light and unobtrusive, and has been worn by many preschool-aged participants in previous studies by us and others. In our experience some children can be very excited about something unfamiliar like wearing an activity monitor on a belt, and others can be more hesitant. We will read story books to your child to familiarise them with the belt and assist in making your child comfortable and excited about wearing the activity monitor. These stories appeal to children’s imagination by pretending that the belt is
Parents/Guardians will be asked to complete:
- **an online Media and Activity Diary** – for five days (three week days and two weekend days) to record a detailed description of your child’s media use and participation in organised (e.g., swimming lessons) and non-organised physical activities (e.g., playing at a park). We estimate that each day’s diary will take approximately 10 minutes to complete. We will ask for your email address so that we can send you the link. Paper versions can be provided if necessary.
- **an online parent survey** - This will provide us with background information about those involved in the study. Some examples of these questions are ‘What is your full name?’,” “What is your postcode?” and “What is your marital status?”. This can be completed using paper format if you prefer.
- **an Activity Monitor Log** to record times when children remove their monitor (e.g., bath time and swimming lessons).

You will be provided with a sealed envelope to return your information and questionnaires completed via paper format. Please return these forms to the Director/educator at your service in the envelope provided. All information will be kept confidential, and will be passed on to the study team.

If your child attends their childcare service again in 2016, we will contact you via information sheets through the childcare service prior to repeating the same assessments in 12 months time.

**Educators will be asked to complete:**
- a one page survey about your child’s social and emotional development.

**What are the benefits and risks involved in this study?**
The findings of this study will provide information about the influence of physical activity and screen behaviours on health and developmental outcomes in young children. This knowledge may benefit parents, educators, health professionals and governments to develop and implement programs and policies that support children’s development and health. Other than the time spent completing the diary and questionnaire (approximately 60 minutes total over a week) and data collection activities such as supporting your child wear their activity monitor, there are minimal risks associated with this study. To recognise you and your child’s participation in the study you will be given a $10 gift voucher, redeemable at Coles/Myer, once the data collection forms have been returned and the activity monitor has been worn for at least 4 full days (including one weekend day) and returned.

There is a very small risk that the children may find wearing the activity monitor uncomfortable or that they may get injured at the point where the monitor is worn if they have a fall. From our experience with many families of preschool-aged children, these risks are minimal. Children will be free to remove the activity monitor if they cause any distress. One of the emotional understanding activities will require children to consider how another child might feel if their pet died, and other tasks require children to consider how they might
feel if another child was hurt, crying, or couldn’t find anyone to play with, which could potentially be upsetting for some children. Should this occur, educators and members of the research team will endeavour to comfort your child to minimise any associated distress, and they will no longer be required to complete these tasks. If your child has any contact allergies (e.g., to adhesive medical tape used for heart rate sensors) please notify us on the consent form.

Most of the assessments do not provide information that could be used to diagnose developmental or health conditions among children. Abnormal values for cardiovascular outcomes will be checked by a clinician and, where appropriate, parents will be contacted and advised to visit their child’s GP. If you are worried about your child’s development or behaviour, you can talk to your GP or paediatrician or child health specialist.

**Participation in the study**

You and your child are free to discontinue participation at any time. Discontinuation of your or your child’s involvement will not jeopardise your or your child’s current or future relationship with your childcare service or with the University of Wollongong. If your child withdraws from the study their data up to that point will be used in the analyses, unless you specifically request for the data not to be used. This can be done at any time during or after data has been collected by writing to the Chief Investigator or Project manager, or the service Director.

**What will happen to the information that you provide?**

All information collected during this study will be kept strictly confidential and be stored in a locked office or password protected computers for five years. All data collected will be property of the research team at the University of Wollongong. The data will only be accessible by members of the research team. Once data collection is completed, data will be de-identified. This means that all identifiable data, such as names, will be removed for the analysis and report writing. Data from parents, educators and children will be merged into a database, and examined for the group of participating children. Data may be used in research papers theses and conference presentations, however your identity, your child’s identity and that of your early childcare service will be kept strictly confidential. All data collected and results of any assessments will be kept fully confidential and not shared with your child’s service. Due to the nature of the assessments, it is not appropriate to provide feedback on individual child results to parents, as the nature and scope of the assessments does not allow a comprehensive evaluation of behaviour and cognition at an individual level.

**Who is conducting the study?**

- Dr Dylan Cliff, School of Education, University of Wollongong.
- Dr Steven Howard, School of Education, University of Wollongong.
- Dr Stewart Vella, School of Education, University of Wollongong.
- Prof Tony Okely, School of Education, University of Wollongong.
- Mrs Tamara Raso, School of Education, University of Wollongong.
- Mrs Melinda Smith, School of Education, University of Wollongong.
- Miss Jade McNeill, School of Education, University of Wollongong.
This study is funded by the Australian Research Council (DE140101588) and the Illawarra Health and Medical Research Institute.

If you are happy for your child to participate in this study, please complete the attached consent form and return it to the Director of your childcare service on your child’s next day of attendance.

Kind Regards,

Dr Dylan Cliff
ARC DECRA Senior Research Fellow
Early Start Research Institute
School of Education, University of Wollongong
dylanc@uow.edu.au
Ph: 4221 5929

If you have any questions regarding the study, please contact Ms Tamara Raso 02 4221 5517; email path-abc@uow.edu.au or Dr Dylan Cliff on 02 4221 5929. If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the University of Wollongong Ethics Officer on (02) 4221 3386 or email rso-ethics@uow.edu.au.

Your participation in this project will be greatly appreciated.
10.5 Appendix E Parent Consent Form

PATH ABC

Research Conducted by Dr Dylan Cliff, Dr Steven Howard, Dr Stewart Vella, Prof Tony Okely, Ms Tamara Raso, Ms Melinda Smith, Miss Jade McNeill, Prof Ian Wright and Dr Megan Kelly, Prof Marc de Rosnay, Mr Doug Angus.

Consent Form

I have been given information about the “Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition” study and have had the opportunity to discuss the study with my child’s childcare service Director, or Dr Dylan Cliff.

I understand that if I consent for my child to participate they will be asked to:

- Wear an activity monitor on their waist for one week;
- Participate in five short electronic games, picture games and watch a short video with puppets to examine their thinking process, cognitive and emotional development,
- Have their height, weight and waist circumference assessed by a trained research assistant;
- Have their blood pressure and heart rate measured, and
- Have photos of their eyes (retinal image) taken.

I understand that if I consent for my child to participate I will be asked to complete:

- An activity monitor log to record when my child’s monitor was worn or removed,
- An online Media Diary to record my child’s electronic media use and reading over a period of five days (link will be sent via email) and;
- An online parent survey (link will be sent via email).

☐ (Please tick if you would like to complete the Media Diary and Parent Survey in paper format)

I understand that an Educator at my child’s Childcare Service will be asked to complete:

- A survey about my child’s social and emotional development.
I have been advised of the potential risks and burdens associated with this study. I understand
that my participation and my child’s participation is voluntary and that I and/or my child are
free to withdraw from the study at any time. Withdrawal from the study will not affect my
relationship or that of my child’s, with our childcare service or with the University of
Wollongong, now or in the future. Furthermore, I understand that the information provided
may be used in papers, conferences presentations or future grant applications.

If I have any enquires about the study, I can contact Ms Tamara Raso 02 4221 5517; email path-
abc@uow.edu.au or Dr Dylan Cliff on 02 4221 5929. If I have any concerns or complaints
regarding the way the study is or has been conducted, I can contact the University of Wollongong
Ethics Officer on (02 ) 4221 3386 or email rso-ethics@uow.edu.au.

By signing below I am indicating my consent for my child and I to participate in this study as
it has been described to me in the information sheet and in discussion with my service Director
or Dr Dylan Cliff.

**If you would like your child to participate can you please return this completed form on
your child’s next day of attendance.**

Your co-operation in this study will be greatly appreciated

In the consent form below we request your address and contact phone numbers incase we
need to contact you to pick up activity monitors from you directly, instead of from the
centre your child attends. This may happen if your child does not attend the centre on the
days we are there to collect the monitors from you. We also ask for these details so that we
can contact you if there is incomplete information in the surveys and logs we ask you to
complete. All information will be kept entirely confidential and only accessible by those
listed in the Ethics application for this research project.

Data collected in this research project may be used in future research studies and theses,
research papers, conference presentations and grant applications, however your identity, your
child’s identity and that of your early childcare service will be kept strictly confidential.
PARENT CONSENT FORM

I (your name) ____________________________

agree for my child (child’s full name) ____________________________ to take part in the “Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition” study.

Child’s Date of Birth: ____________________________ (DD/MM/YYYY)

Sex of the Child: ____________________________ (male/female)

Address: ____________________________________________

Postcode: ____________________________________________

Phone: (H) ____________________________________________

(M) ____________________________________________

Email address: ____________________________________________

Signature: ____________________________________________

Date: ____________________________________________

Name of Childcare Service: ____________________________________________

Which days of the week does your child attend this Childcare Centre?

☐ 1 Monday  ☐ 2 Tuesday  ☐ 3 Wednesday  ☐ 4 Thursday  ☐ 5 Friday

In 12 months my child will be attending (please tick):

☐ 1 This preschool/ long day care  ☐ 2 Primary school  ☐ 3 Not sure

Please indicate if your child has any contact allergies (e.g., to adhesive medical tape used for heart rate sensors):

____________________________________________________________________
10.6 Appendix F Accelerometer Instruction sheet

Activity Monitor Instruction sheet

Thank you for taking part in the PATH-ABC study. As part of the study children will be asked to wear an activity monitor for 7 days including a weekend. The monitors are like pedometers but record more information. You don’t need to plan any special activities while your child is wearing the monitor - all you have to do is help your child to wear the monitor while they go about their normal week.

As the waist monitor is not waterproof, please remove it from your child for water activities (eg. baths, swimming, and beach visits). Otherwise the monitor can be left on, including during daytime naps and while sleeping at night because the information collected can be used to understand children’s sleep as well as their activity. If your child is particularly unwell and unable to wear the activity monitor, please delay wearing the belt until your child is well. If this exceeds five days please contact us. Once your child has worn the monitor for 7 days, please return it to their Childcare Centre in the envelope provided.

How to fit the activity monitor

Place the belt around your child’s waist

With the monitor at the front on the right hand side (in line with the right leg)
Ensure that the black circle on the monitor is facing up. The monitor can be worn on top, or underneath clothes, whichever is most comfortable. We recommend placing the monitor underneath a layer of clothing and then children tend to forget they have it on.

If you have any questions regarding the study, please contact Ms Tamara Raso 02 4221 5517, email: path-abc@uow.edu.au or Dr Dylan Cliff on 02 4221 5929.
10.7 Appendix G Parent Questionnaire

Thank you for taking the time to complete this survey. The MAIN CAREGIVER of the participating child/children should complete this survey. The main caregiver is the person who lives with the participating child/children and is most knowledgeable about their behaviour and daily care arrangements. The survey could take up to 15 minutes to complete, although it may vary depending on your answers.

If you have more than one child participating in the study, you will need to complete up to question 33 for each child.

The survey will provide valuable information about the children and families in the study. Every child is different and it is important that the information provided for each child is right for them. The researchers are interested in understanding the health and development of preschool children in the Illawarra – they are not interested in passing judgements about children, parents or childcare centres. All information will be treated confidentially, will be de-identified (names will be removed), and will only be seen by the research team. This is a paper version of the online parent survey. If you intend to complete this online, please follow the link and instructions that will be provided to you via email, and disregard this paper version.

Most questions can be answered by ticking or crossing in the boxes.

- Please answer each question the best you can
- Use only a black or dark blue pen to complete this questionnaire
- If you make a mistake, or want to change any of your responses, please put a cross through the incorrect response and print your new response just below or next to the one you have crossed out
- Please place the questionnaire in the envelope provided, seal it and return it back to your service
- If you need help completing this questionnaire, please contact our Project Manager Tamara Raso on (02) 4221 5517.

1. Your full name (first name then surname): ______________________________________
2. Your child’s full name __________________________________________
3. Child’s date of birth (DD/MM/YYYY): _______ - _______ - _______
4. What is your child sex? □ 1 Male □ 2 Female
5. What was your child’s birth weight (in kilograms) (please write "Don't Know" if you don't know)? _____________ kg
6. What was your child’s gestational age at birth? (e.g., 40 weeks
_________ weeks

7. What is your child’s country of birth?
   - 1 Australia
   - 2 Other (please specify) ________________________________

8. Is your child of Aboriginal and/or Torres Strait Islander origin? (Please shade **ONE** circle only)
   - 1 Yes, Aboriginal and/or Torres Strait Islander
   - 2 No
   - 3 Don’t know

9. Does your child have a family history of the following conditions from their biological mother or father: (please tick all that apply)
   - 1 Cardiovascular Disease/ Stroke/ Heart Disease
   - 2 Diabetes
   - 3 Cancer
   - 4 High Blood pressure

10. Please identify if your child’s biological mother or father currently has, or has had any of the following conditions (if known)

<table>
<thead>
<tr>
<th>Biological Mother</th>
<th>Biological Father</th>
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<tbody>
<tr>
<td>1 Cardiovascular Disease/ Stroke/ Heart Disease</td>
<td>1 Diabetes</td>
</tr>
<tr>
<td>2 Diabetes</td>
<td>2 Cardiovascular Disease/ Stroke/ Heart Disease</td>
</tr>
<tr>
<td>3 Cancer</td>
<td>3 Cancer</td>
</tr>
<tr>
<td>4 High Blood pressure</td>
<td>4 High Blood pressure</td>
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</tbody>
</table>

How many serves of the following foods and drinks does your child eat on a USUAL day (please refer to the serving sizes)?

<table>
<thead>
<tr>
<th>Foods and Drinks</th>
<th>None</th>
<th>1/2</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5+</th>
<th>Don't Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables (1 serve is 1/2 cup cooked fresh/frozen veg or 1/2 medium potato or 1 medium tomato or 1 cup of salad)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit (1 serve is 1 medium piece Eg. apple or 2 small pieces Eg. 2 plums or 1 cup fruit salad or 1/2 cup 100% juice)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breads and cereals (1 serve is 1 slice bread or 1/2 bread roll or 1/2 wrap or 1/2 cup cooked rice/pasta/noodles or 1/4 cup cereal or 1/2 cup porridge)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meat and alternatives (1 serve is 65g red meat/pork/lamb or 80g chicken or 100g fish or 2 eggs or 30g nuts/seeds or 1 cup cooked lentils/beans)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy and alternatives (1 serve is 1 cup fresh milk or 2 slices of cheese or 3/4 cup yoghurt)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11. How often would your child USUALLY eat and drink the following foods and beverages:

<table>
<thead>
<tr>
<th>Food Type</th>
<th>None/ rarely</th>
<th>1-3 times/mth</th>
<th>1-2 times/wk</th>
<th>3-4 times/wk</th>
<th>5-6 times/wk</th>
<th>Once a day</th>
<th>2 or more times/day</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Takeaway or fast food (eg hot chips, hamburgers, chicken nuggets, sausage rolls, hot dogs, pizza)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Sugary cereals (eg CocoPops, Froot Loops, etc)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Potato chips or other salty snacks (eg Twisties, Doritos)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Sweets (eg lollies, chocolate)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Cakes, doughnuts, sweet biscuits or muffins</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Sugary drinks (eg. soft drink, cordial, fruit drinks, sports/energy drinks)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

12. How many hours per night does your school age child usually sleep at the moment? (Please write the number)

__________________________ hours

13. Does anyone at home ever read to your child?

☐ 1 Yes ☐ 2 No (skip to Q16)

14. How often does someone at home read to your child?

☐ 1 Occasionally or less than once a week
☐ 2 Once a week
☐ 3 Several times a week
☐ 4 Once a day
☐ 5 More than once a day

15. Does anyone ever take your child to the library?

☐ 1 Yes ☐ 2 No (skip to Q18)
16. How often does someone at home take your child to the library?

- □ 1 On special occasions
- □ 2 Once a month
- □ 3 Once a fortnight
- □ 4 Once a week

17. Does anyone at home ever teach your child a sport, dance or physical activity?

- □ 1 Yes □ 2 No (skip to Q20)

18. How often does someone at home teach your child a sport, dance or physical activity?

- □ 1 Occasionally or less than once a week
- □ 2 1-2 days per week
- □ 3 3 times per week
- □ 4 4 times per week
- □ 5 5 times per week
- □ 6 6 times per week
- □ 7 7 times per week or more

19. Does anyone at home ever play with letters with your child?

- □ 1 Yes □ 2 No (skip to Q22)

20. How often does someone play with letters at home with your child?

- □ 1 Occasionally or less than once a week
- □ 2 1-2 days per week
- □ 3 3 times per week
- □ 4 4 times per week
- □ 5 5 times per week
- □ 6 6 times per week
- □ 7 7 times per week or more

21. Does anyone at home ever help this child to learn the ABC or the alphabet?

- □ 1 Yes □ 2 No (skip to Q24)

22. How often does someone teach your child the ABC or alphabet?

- □ 1 Occasionally or less than once a week
- □ 2 1-2 days per week
- □ 3 3 times per week
- □ 4 4 times per week
- □ 5 5 times per week
- □ 6 6 times per week
- □ 7 7 times per week or more
23. Does anyone at home ever teach your child numbers or counting?

☐ 1 Yes  ☐ 2 No (skip to Q26)

24. How often does someone at home try to teach your child numbers or counting?

☐ 1 Occasionally or less than once a week  
☐ 2 1-2 days per week  
☐ 3 3 times per week  
☐ 4 4 times per week  
☐ 5 5 times per week  
☐ 6 6 times per week  
☐ 7 7 times per week or more

25. Does anyone at home ever teach your child any songs, poems or nursery rhymes?

☐ 1 Yes  ☐ 2 No (skip to Q28)

26. How often has someone taught your child songs, poems or nursery rhymes?

☐ 1 Occasionally or less than once a week  
☐ 2 1-2 days per week  
☐ 3 3 times per week  
☐ 4 4 times per week  
☐ 5 5 times per week  
☐ 6 6 times per week  
☐ 7 7 times per week or more

27. Does your child ever paint or draw at home?

☐ 1 Yes  ☐ 2 No (skip to Q30)

28. How often does your child paint or draw at home?

☐ 1 Occasionally or less than once a week  
☐ 2 1-2 days per week  
☐ 3 3 times per week  
☐ 4 4 times per week  
☐ 5 5 times per week  
☐ 6 6 times per week  
☐ 7 7 times per week or more

29. Does your child have a TV in their bedroom?  

☐ 1 Yes  ☐ 2 No

30. Which and how many of the following do you have in your household, including in cars (please tick and specify the number of devices to all that apply)

TV  ☐ 1  N° of devices ________

DVD player  ☐ 1  N° of devices ________
31. In total, how many electronic media devices are available in your household for your child to use, including in cars (Please exclude devices that you don’t allow your child to use). __________________

32. **Thinking about the last month**, which of the following indoor LEISURE activities does your child USUALLY do during a typical WEEK? For this question, please think about the time your child is not at their child center. Please circle either ‘Yes’ or ‘No’ for each item. For items you have circled ‘Yes’, please write the TOTAL time your child participates in the activity for the WHOLE working/school week (that is, Monday + Tuesday + Wednesday + Thursday + Friday). Please also write the TOTAL time your child participates in the activity for the WHOLE weekend (that is, Saturday + Sunday). If you circle ‘Yes’ for an activity and your child only participates in that activity during either the working/ school week or the weekend, please write ‘0’ in the TOTAL hours column for the period they do not do that activity. **Here is an example**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Does your preschool child usually do this activity?</th>
<th>TOTAL hours/minutes Monday-Friday</th>
<th>TOTAL hours/minutes Saturday &amp; Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV/videos/DVD</td>
<td>Yes1, No2</td>
<td>15hrs</td>
<td>6hrs 30mins</td>
</tr>
<tr>
<td>Playstation/ Nintendo/ X-box/Gameboy</td>
<td>Yes1, No2</td>
<td>0</td>
<td>2hrs 0mins</td>
</tr>
<tr>
<td>TV programs/ movies/ Internet clips on traditional devices (e.g., TV/DVD)</td>
<td>Yes1, No2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TV programs/ movies/ Internet clips on other devices (e.g., Tablet, iPad, DVD in car, Computer, Laptop, Handheld-mobile phone etc.)</td>
<td>Yes1, No2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Games/Apps on portable/handheld devices (e.g., Tablet, iPad, mobile phone, handheld game system (Nintendo DS), Ipad)</td>
<td>Yes1, No2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Console Games (non-active) on Console game system (e.g., Playstation, Xbox)</td>
<td>Yes1, No2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Console Games (active) (e.g., Wii, Xbox kinnect,)</td>
<td>Yes1, No2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiet Play (e.g., Lego, books, train sets, dolls, board games, craft)</td>
<td>Yes1, No2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaginary games (e.g., dress ups, imitating TV characters)</td>
<td>Yes1, No2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading, looking at books, or being read to</td>
<td>Yes1, No2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
33. **Thinking about the last 6 months**, has your child regularly attended any special or extra cost activities that are not part of his/her normal child care, pre-school or school activities? (Regular means weekly or fortnightly activities, even if they lasted less than 6 months) *(please tick yes or no)*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swimming</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Gymnastics/Kindergym</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Team sport (athletics, football etc.)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Musical instruments or singing</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Ballet or other dance</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Children's religious group (Sunday school etc.)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

The following information questions provide important demographic information to describe the families involved in the study.

34. Your date of birth (DD/MM/YYYY): _______ - _______ - _______

35. What is your sex? *(please tick one)*  
☐ 1 Male ☐ 2 Female

36. What is the main language you speak at home? *(please tick one)*  
☐ 1 English ☐ 2 Other (please specify) _______________________

37. What is your **highest** level of schooling? *(please tick one only)*  
☐ 1 No formal qualification  
☐ 2 Year 10 or equivalent (e.g. School Certificate)  
☐ 3 Year 12 or equivalent (e.g. Higher School Certificate)  
☐ 4 Trade/apprenticeship/certificate (e.g. hairdresser, chef, plumber)  
☐ 5 Diploma (e.g. Business/Accounting)  
☐ 6 University degree  
☐ 7 Post-graduate qualification (e.g. Graduate Diploma, Masters, PhD)

38. Are you currently: *(Please tick one)*  
☐ 1 Employed full time  
☐ 2 Employed part time  
☐ 3 Home-duties full time  
☐ 4 A student  
☐ 5 Unemployed  
☐ 6 Other (please specify) _______________________

39. Before income tax is taken out, what is your combined household income from all sources in total?  
$ _______
40. What period does that cover?
   □ 1. Week
   □ 2. Fortnight
   □ 3. 4 weeks
   □ 4. Calendar month
   □ 5. Year
   □ 6. Other
   □ 7. Don’t know
   □ 8. Refused

41. Please specify how many people live in your household?

42. What is your current marital status?
   □ 1. Never married, single parent
   □ 2. Never married, live with partner
   □ 3. Married, live with spouse,
   □ 4. Separated/ Divorced
   □ 5. Widowed

43. Do you or your partner have a Health Care Card or Pension Card (from Centrelink)? (Please tick one)
   □ 1. Yes
   □ 2. No

Thank you very much for taking the time to complete this survey – Please return when your child next attends childcare.

If I have any enquires about the study, I can contact Ms Tamara Raso 02 4221 5517; email path-abc@uow.edu.au or Dr Dylan Cliff on 02 4221 5929. If I have any concerns or complaints regarding the way the study is or has been conducted, I can contact the University of Wollongong Ethics Officer on (02 ) 4221 3386 or email rso-ethics@uow.edu.au.
10.8 Appendix H Director Information sheet

PATH-ABC study

Director Information Sheet

Dear Director,

We would like to invite you and your service to participate in the PATH-ABC study. Full details about the project, its purpose, the researchers involved and what will be asked of your childcare service, are provided in this information sheet.

What is the purpose of this study?
Early childhood involves rapid and important changes in physical development, brain development and social skills. Research in school-aged children has shown that levels of physical activity and screen-based entertainment (e.g., TV viewing, computer games, and computer use) influence these developmental changes. However, little is known about the links between these behaviours and emotional, social and cognitive (thought processing) development and cardiovascular health (heart and blood vessels) during early childhood. This study will investigate if physical activity and screen-based entertainment are linked to emotional and social development, thinking processes and vascular health among 500 preschoolers in the Illawarra.

What will we ask you to do?
If you decide that you would like to participate in this study we ask that your service take part in the following:
1. We ask you to assist us in distributing Parent Information Sheets and Consent forms to recruit eligible families to participate in the study.
2. We ask permission for UOW Data Collectors to visit your service across five days to assess children who are participating. These assessments are outlined below.
3. We ask for your assistance in distributing and collecting all parent surveys, activity monitor logs and children’s activity monitors from the participants in the study. Parent surveys and children’s activity monitor logs will be returned by parents to the Service in sealed envelopes, and we ask that you collect these prior to collection by a member of the research team.
4. We will ask you and your staff to complete the same assessments 12 months later with the same consenting children.

**What we will ask your Educators to do?**
If you decide that you would like your service to take part in this study we would ask your educators to:

- **complete a questionnaire for each of the children that they supervise who are participating in the study (approximately 5 minutes each child).** The questionnaire will report on each child’s social and emotional development. We will ask educators to complete the questionnaire a second time in 2016 for participating children who are still attending your early childhood service.

*Given Parent/Guardian consent has been gained, what will we ask the children to do?*

This study will use several different ways to collect information about children’s behaviours and developmental outcomes, as detailed below.

While at their childcare service, children will **have their height, weight, and waist circumference measured** by a data collector. Children will also have their heart rate measured, and their blood pressure taken by a trained data collector. Heart rate will be measured by a small device, which will be attached by stickers to children on their collar and hipbone for approximately 10min while playing two games on an iPad. Children will also have a photo of their eye (**retinal image**) taken using a portable camera. This photo is not invasive and is used to look at the development of the body’s small blood vessels, which are an indicator of cardiovascular health and development. To examine cognitive development children will **complete five computer-based 'games' on an Ipad at their childcare service that involve higher order cognitive processes**, known as executive functions. These games evaluate children’s working memory, inhibition, expressive vocabulary and shifting between instructions. All tasks are completed on a Ipad, they include a working memory game about a cartoon ant, a working memory game using auditory instruction, a fish catching game to assess inhibition, a object naming game to assess vocabulary, and a card-sorting task to assess the ability to shift between different sets of rules. Together, these tasks will take approximately 15-20 minutes to complete. These tasks will take place within the childcare service. A trained data collector will sit with the child in a quiet but public area of their appropriate room, away from the main group of children. They will still be in constant visual and verbal contact with the Educators.

To understand children’s social and emotional development, children will be given cartoon scenarios and an accompanying story with a depicted character. Children will be asked to identify the appropriate emotional outcome (in each scenario). Children will then be shown photographs of children’s faces showing 5 different emotional expressions, and they will be asked to identify each emotion. Children will also watch a short video where a puppet will provide the child with a statement (e.g., seeing a child crying makes me feel like crying), and the child will respond by stating if they are like/not-like the puppet. Together these tasks will take approximately 15 minutes to complete.
To understand children’s level of physical activity and sleep, they will be asked to **wear an activity monitor** (known as an accelerometer) **for one week on their waist using an elastic belt.** Children will be asked to wear the monitor during the day and night, but monitors will be removed for water-based activities such as having a bath. The monitor is small, light and unobtrusive, and has been worn by many preschool-aged participants in previous studies by us and others. The participating children will be wearing their monitor while in the childcare service, and may have times when they wish to remove their monitor. This is acceptable for them to remove their monitor if they do not wish to wear it anymore. We only ask that educators ask children if they would like to wear the monitor again after a short time or before they leave the service. If the child does not want to wear the monitor any longer then we ask if educators could place it in their bag and inform the parent/guardian when they are picked up where the monitor is. All research staff will have Working with Children Checks.

**Parents/Guardians will be asked to complete:**
- **an online Media Diary** – for five days (three week days and two weekend days) to record a detailed description of their child’s media and physical activities.
- **a online parent survey** - This will provide us with background information about those involved in the study.
- **an Activity Monitor Log** to record times when children remove their monitor (e.g., bath time and swimming lessons).

**What are the benefits and risks involved in this study?**
There is no direct benefit to Childcare Services or staff of participation in the study. There is a very small risk that the children may find wearing the activity monitor uncomfortable. From our experience with many families of preschool-aged children, the risk of this is minimal. Children will be free to remove the activity monitor if they cause any distress. One of the emotional understanding activities will require children to consider how another child might feel if their pet died, and other tasks require children to consider how they might feel if another child was hurt, crying, or couldn’t find anyone to play with, which could potentially be upsetting for some children. Should this occur, educators and members of the research team will endeavour to comfort the child to minimise any associated distress, and they will no longer be required to complete these tasks.

The findings of this study will provide information about the influence of physical activity and screen behaviours on health and developmental outcomes in young children. This knowledge may benefit parents, educators, health professionals and governments to develop and implement evidence-based strategies and policies to give young children the best start in life.
Participation in the study
Your childcare service is free to discontinue participation at any time. Discontinuation will not jeopardise your current or future relationship with the University of Wollongong. Your participation in this research is voluntary. This can be done at any time during or after data has been collected by writing to the Chief Investigator or Project manager, or the service Director.

What will happen to the information that parents and children provide?
All information collected during this study will be kept strictly confidential and be stored in a locked office or password protected computers for five years. Paper copies of data will be stored in a locked filing cabinet. Data entered into computer programs will be stored in password protected computers. All data collected will be property of the research team at the University of Wollongong.

Once data collection is completed, data will be de-identified. This means that all identifiable data, such as names, will be removed for the analysis and report writing. Data from parents, educators and children will be merged into a database, and examined for the group of participating children. Data may be used in research papers and theses conference presentations, however parent’s identity, the child’s identity and that of your early childcare service will be kept strictly confidential. All data collected and results of any assessments will be kept fully confidential and not shared with the service you attend. Due to the nature of the assessments, it is not appropriate to provide individual child results, as the nature and scope of the assessments does not allow a comprehensive evaluation of behaviour and cognition at an individual level.

Who is conducting the study?
- Dr Dylan Cliff, School of Education, University of Wollongong.
- Dr Steven Howard, School of Education, University of Wollongong.
- Dr Stewart Vella, School of Education, University of Wollongong.
- Prof Tony Okely. School of Education, University of Wollongong.
- Mrs Tamara Raso, School of Education, University of Wollongong.
- Mrs Melinda Smith, School of Education, University of Wollongong.
- Ms Jade McNeill, School of Education, University of Wollongong.
- Prof Ian Wright, Graduate School of Medicine, University of Wollongong.
- Dr Megan Kelly, Graduate School of Medicine, University of Wollongong.
- Prof Marc De Rosnay, School of Education, University of Wollongong.
- Mr Doug Angus, School of Psychology, University of Sydney.

If you are happy for your service to participate in this study, please complete the attached consent form and return it to the Project Manager or Research Assistant.

This study is funded by the Australian Research Council (DE140101588) and the Illawarra Health and Medical Research Institute.
Kind Regards,

Dr Dylan Cliff  
ARC DECRA Senior Research Fellow  
Early Start Research Institute  
School of Education, University of Wollongong  
dylanc@uow.edu.au  
Ph: 4221 5929

If you have any questions regarding the study, please contact Ms Tamara Raso 02 4221 5517; email path-abc@uow.edu.au or Dr Dylan Cliff on 02 4221 5929. If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the University of Wollongong Ethics Officer on (02) 4221 3386 or email rso-ethics@uow.edu.au.

Your participation in this project will be greatly appreciated.
10.9 Appendix I Director Consent Form

PATH-ABC study
Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition study

Director Consent Form

Research Conducted by Dr Dylan Cliff, Dr Steven Howard, Dr Stewart Vella, Prof Tony Okely, Mrs Melinda Smith, Mrs Tamara Raso, Miss Jade McNeill, Prof Ian Wright, Dr Megan Kelly, Prof Marc de Rosnay, Mr Doug Angus.

I have been given information about the study entitled: “PATH-ABC Study” and have had the opportunity to discuss the study with Dr Dylan Cliff or the Project Manager.

I understand that if I consent to participating I will be asked to:

- Assist researchers in distributing Parent Information Sheets, and Consent forms to eligible families.
- Assist UOW Data Collectors while they visit this Service across four days to assess children who are participating.
- Assist in distributing and collecting parent surveys and children’s activity monitors.
- Assist staff in completing a questionnaire for all consenting participants in the study.
- Assist in data collection over two time points 12 months apart (Once in 2015 and again in 2016).
I have been advised of the potential risks and burdens associated with this study. I understand that my participation is voluntary and that I am free to withdraw my childcare service from the study at any time. Withdrawal from the study will not affect my relationship with the University of Wollongong now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or future grant applications.

If I have any enquires about the study, I can contact Ms Tamara Raso 02 4221 5517; email path-abc@uow.edu.au or Dr Dylan Cliff on 02 4221 5929. If I have any concerns or complaints regarding the way the study is or has been conducted, I can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457 or by email on rso-ethics@uow.edu.au

By signing below I am indicating my consent to participate in this study as it has been described to me in the information sheet and in discussion with Dr Dylan Cliff.

Your co-operation in this study will be greatly appreciated
DIRECTOR CONSENT

I (your given and surname) ___________________________________

agree for my childcare service to take part in the study for the program entitled
“Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition study”

Signature: ________________________________________________

Date: ____________________________________________________

Name of Childcare Service: _________________________________

Postcode: ________________________________________________

Service Phone: ___________________________________________
Dear Educator,

We would like to invite you and your service to participate in the PATH-ABC study. Full details about the project, its purpose, the researchers involved and what will be asked of your childcare service, are provided in this information sheet.

What is the purpose of this study?
Early childhood involves rapid and important changes in physical development, brain development and social skills. Research in school-aged children has shown that levels of physical activity and screen-based entertainment (e.g., TV viewing, computer games, and computer use) influence these developmental changes. However, little is known about the links between these behaviours and emotional, social and cognitive (thought processing) development and cardiovascular health (heart and blood vessels) during early childhood. This study will investigate if physical activity and screen-based entertainment are linked to emotional and social development, thinking processes and vascular health among 500 preschoolers in the Illawarra.

What will we ask your service to do?
If you decide that you would like to participate in this study we ask that you take part in the following:

5. We ask you to assist us in distributing Parent Information Sheets and Consent forms to recruit eligible families to participate in the study.
6. We ask permission for UOW Data Collectors to visit your service across five days to assess children who are participating. These assessments are outlined below.
7. We ask for your assistance in distributing and collecting all parent surveys, activity monitor logs and children’s activity monitors from the participants in the study. Parent surveys and children’s activity monitor logs will be returned by parents to the Service in sealed envelopes, and we ask that you collect these prior to collection by a member of the research team.
8. We will ask you and your staff to complete the same assessments 12 months later with the same consenting children.
What we will ask you to do?
If you decide that you would like to take part in this study we would ask you to take part in the following:

1. We will ask you to complete a questionnaire (approximately 5 minutes) for each child that you supervise who are participating in the study. The questionnaire will report on the child’s social and emotional development.

Given Parent/Guardian consent has been gained, what will we ask the children to do?

This study will use several different ways to collect information about children’s behaviours and developmental outcomes, as detailed below.

While at their childcare service, children will have their height, weight, and waist circumference measured by a data collector. Children will also have their heart rate measured, and their blood pressure taken by a trained data collector. Heart rate will be measured by a small device, which will be attached by stickers to children on their collar and hipbone for approximately 10min while playing two games on an iPad. Children will also have a photo of their eye (retinal image) taken using a portable camera. This photo is not invasive and is used to look at the development of the body’s small blood vessels, which are an indicator of cardiovascular health and development. To examine cognitive development children will complete five computer-based 'games' on an Ipad at their childcare service that involve higher order cognitive processes, known as executive functions. These games evaluate children’s working memory, inhibition, expressive vocabulary and shifting between instructions. All tasks are completed on a Ipad, they include a working memory game about a cartoon ant, a working memory game using auditory instruction, a fish catching game to assess inhibition, a object naming game to assess vocabulary, and a card-sorting task to assess the ability to shift between different sets of rules. Together, these tasks will take approximately 15-20 minutes to complete. These tasks will take place within the childcare service. A trained data collector will sit with the child in a quiet but public area of their appropriate room, away from the main group of children. They will still be in constant visual and verbal contact with the Educators.

To understand children’s social and emotional development, children will be given cartoon scenarios and an accompanying story with a depicted character. Children will be asked to identify the appropriate emotional outcome (in each scenario). Children will then be shown photographs of children’s faces showing 5 different emotional expressions, and they will be asked to identify each emotion. Children will also watch a short video, a puppet will tell the child a statement, the child will respond by stating if they are like/not-like the puppet. Together these tasks will take approximately 15 minutes to complete.
To understand children’s level of physical activity and sleep, they will be asked to wear an activity monitor (known as an accelerometer) for one week on their waist using an elastic belt. Children will be asked to wear the monitor during the day and night, but monitors will be removed for water-based activities such as having a bath. The monitor is small, light and unobtrusive, and has been worn by many preschool-aged participants in previous studies by us and others. The participating children will be wearing their monitor while in the childcare service, and may have times when they wish to remove their monitor. This is acceptable for them to remove their monitor if they do not wish to wear it anymore. We only ask that educators ask children if they would like to wear the monitor again after a short time or before they leave the service. If the child does not want to wear the monitor any longer then we ask if educators could place it in their bag and inform the parent/guardian when they are picked up where the monitor is. All research staff will have working with children checks.

Parents/Guardians will be asked to complete:
- an online Media Diary – for five days (three week days and two weekend days) to record a detailed description of your child’s media and reading activities.
- an online parent survey - This will provide us with background information about those involved in the study.
- an Activity Monitor Log to record times when children remove their monitor (e.g., bath time and swimming lessons).

What are the benefits and risks involved in this study?
There is no direct benefit to Childcare Services or staff of participation in the study. There is a very small risk that the children may find wearing the activity monitor uncomfortable. From our experience with many families of preschool-aged children, the risk of this is minimal. Children will be free to remove the activity monitor if they cause any distress. One of the emotional understanding activities will require children to consider how another child might feel if their pet dies, which could potentially be upsetting for some children. Should this occur, educators and members of the research team will endeavour to comfort the child to minimise any associated distress.

The findings of this study will provide information about the influence of physical activity and screen behaviours on health and developmental outcomes in young children. This knowledge may benefit parents, educators, health professionals and governments to develop and implement evidence-based strategies and policies to give young children the best start in life.

Participation in the study
You are free to discontinue participation at any time. Discontinuation will not jeopardise your current or future relationship with the University of Wollongong. Your participation in this research is voluntary. This must be done in writing to the Chief Investigator or Project manager.
What will happen to the information that parents and children provide?
All information collected during this study will be kept strictly confidential and be stored in a locked office. Paper copies of data will be stored in a locked filing cabinet. Data entered into computer programs will be stored in password protected computers. All data collected is property of The University of Wollongong. Once data collection is completed for each child we will analyse the data, and at this point all data will be de-identified. This means that all identifiable data, such as names will be removed, for the analysis and report writing. Data may be used in research papers and theses conference presentations, however parent’s identity, the child’s identity and that of your early childcare service will be kept strictly confidential. All data collected and results of any assessments will be kept fully confidential and not shared with the service you attend. Due to the nature of the tests, it is not appropriate to provide individual child results.

Who is conducting the study?

- Dr Dylan Cliff, School of Education, University of Wollongong.
- Dr Steven Howard, School of Education, University of Wollongong.
- Dr Stewart Vella, School of Education, University of Wollongong.
- Prof Tony Okely, School of Education, University of Wollongong.
- Mrs Tamara Raso, School of Education, University of Wollongong.
- Mrs Melinda Smith, School of Education, University of Wollongong.
- Ms Jade McNeill, School of Education, University of Wollongong.
- Prof Ian Wright, Graduate School of Medicine, University of Wollongong.
- Dr Megan Kelly, Graduate School of Medicine, University of Wollongong.
- Prof Marc De Rosnay, School of Education, University of Wollongong.
- Mr Doug Angus, School of Psychology, University of Sydney.

If you are happy for your service to participate in this study, please complete the attached consent form and return it to the Project Manager or Research Assistant.

The Discovery Early Career Researcher Award (DECRA) PROJECT ID funds this study: DE140101588 under the supervision of Dr Dylan Cliff.

Kind Regards,

Dr Dylan Cliff
ARC DECRA Senior Research Fellow
Early Start Research Institute
School of Education, University of Wollongong
dylanc@uow.edu.au
Ph: 4221 5929
If you have any questions regarding the study, please contact Ms Tamara Raso 02 4221 5517; email path-abc@uow.edu.au or Dr Dylan Cliff on 02 4221 5929. If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the University of Wollongong Ethics Officer on (02) 4221 3386 or email rso-ethics@uow.edu.au.

Your participation in this project will be greatly appreciated.
10.11 Appendix K Educator Consent form

PATH-ABC study
Preschool Activity, Technology, Health
Adiposity, Behaviour and Cognition study

Educator Consent Form

Research Conducted by Dr Dylan Cliff, Dr Steven Howard, Dr Stewart Vella, Prof Tony Okely, Mrs Melinda Smith, Mrs Tamara Raso, Miss Jade McNeill, Prof Ian Wright, Dr Megan Kelly, Prof Marc de Rosnay, Mr Doug Angus.

I have been given information about the study entitled: “PATH-ABC Study” and have had the opportunity to discuss the study with Dr Dylan Cliff or the Project Manager.

I understand that if I consent to participating I will be asked to:

• Complete a questionnaire twice (once in 2015 or 2016 and again in 2016 or 2017) for all children that I supervise who are participating in the study.

I have been advised of the potential risks and burdens associated with this study. I understand that my participation is voluntary and that I am free to withdraw from the study at any time. Withdrawal from the study will not affect my relationship with the University of Wollongong now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or theses.

If I have any enquires about the study, I can contact Ms Tamara Raso 02 4221 5517, email: path-abc@uow.edu.au or Dr Dylan Cliff on 4221 5929. If I have any concerns or complaints regarding the way the study is or has been conducted, I can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457 or by email on rso-ethics@uow.edu.au
By signing below I am indicating my consent to participate in this study as it has been described to me in the information sheet and in discussion with Dr Dylan Cliff.

Your co-operation in this study will be greatly appreciated

EDUCATOR CONSENT

I (your given and surnames) ________________________________

agree to take part in the study for the program entitled
“Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition study”

Signature: ________________________________
Date: ________________________________
Name of Childcare Service: ________________________________
Dear Principal,

We would like to invite your school to participate in the PATH-ABC follow-up study. Full details about the project, its purpose, the researchers involved and what will be asked of your primary school, are provided in this information sheet.

What is the purpose of this study?
Early childhood involves rapid and important changes in physical development, brain development and social skills. Research in school-aged children has shown that levels of physical activity and screen-based entertainment (e.g., TV viewing, computer games, and computer use) influence these developmental changes. However, little is known about the links between these behaviours and emotional, social and cognitive (thought processing) development and cardiovascular health (heart and blood vessels) during early childhood. This study will investigate if physical activity and screen-based entertainment are linked to emotional and social development, thinking processes and vascular health among 450 young children in the Illawarra as they grow and develop. Children who participated in the study at their preschool in 2015, will be followed into their primary school. The study will invite them to take part in the follow-up at one of a number of locations, one of which could be their primary school, between April and November 2016.

What will we ask you to do?
If you allow your School take part in the study we ask permission for:
University of Wollongong Data Collectors to visit your primary school to assess children who are participating (approximately 60 minutes per child). These assessments are outlined below. All research staff will have Working with Children Checks.
**What will we ask Teachers to do?**

We will ask the child’s teacher to:

- **complete a 40-item questionnaire for each of the children that they teach who are participating in the study (approximately 5 minutes each child).** The questionnaire will report on each child’s social and emotional development.
  
  Example item: The child is considerate of other people’s feelings
  
  □ not true
  
  □ somewhat true
  
  □ certainly true

*Given Parent/Guardian consent has been gained,* **what will we ask the children to do?**

**Children will be asked to complete the same assessments that they completed in 2015:**

- Wear an activity monitor on their waist for one week while at school, and also at their home;
- Participate in five short electronic games, picture games and watch a short video with puppets to examine their thinking process, cognitive and emotional development,
- Have their height, weight and waist circumference assessed,
- Have their blood pressure and heart rate measured, and
- Have photos of their eyes (retinal image) taken.

Together, these tasks will take approximately 60 minutes to complete. A trained data collector will sit with the child in a quiet but public area of your primary school (e.g., their classroom).

**What are the benefits and risks involved in this study?**

There is no direct benefit to your primary school or staff for participation in the study.

The findings of this study will provide information about the influence of physical activity and screen behaviours on health and developmental outcomes in young children. This knowledge may benefit parents, teachers, health professionals and governments to develop and implement evidence-based strategies and policies to give young children the best start in life.

**Participation in the study**

Your school’s participation in this research is voluntary. Choosing not to participate will not jeopardise your current or future relationship with the University of Wollongong.

**What will happen to the information that teachers, parents and children provide?**

All information collected during this study will be kept strictly confidential and be stored in a locked office or password protected computers for five years. Paper copies of data will be stored in a locked filing cabinet. Data entered into computer programs will be stored in password protected computers. All data collected will be property of the research team at the University of Wollongong.
Once data collection is completed, data will be de-identified. This means that all identifiable data, such as names, will be removed for the analysis and report writing. Data from parents, teachers and children will be merged into a database, and examined for the group of participating children. Data may be used in research papers and theses conference presentations, however parent’s identity, the child’s identity and that of your school will be kept strictly confidential. All data collected and results of any assessments will be kept fully confidential and not shared. Due to the nature of the assessments, it is not appropriate to provide individual child results, as the nature and scope of the assessments does not allow a comprehensive evaluation of behaviour and cognition at an individual level.

**Who is conducting the study?**

- Dr Dylan Cliff, School of Education, University of Wollongong.
- Dr Steven Howard, School of Education, University of Wollongong.
- Dr Stewart Vella, School of Education, University of Wollongong.
- Prof Tony Okely, School of Education, University of Wollongong.
- Mrs Tamara Raso, School of Education, University of Wollongong.
- Mrs Melinda Smith, School of Education, University of Wollongong.
- Ms Jade McNeill, School of Education, University of Wollongong.
- Prof Ian Wright, Graduate School of Medicine, University of Wollongong.
- Dr Megan Kelly, Graduate School of Medicine, University of Wollongong.
- Prof Marc De Rosnay, School of Education, University of Wollongong.
- Mr Doug Angus, School of Psychology, University of Sydney.

This study is funded by the Australian Research Council (DE140101588).

Kind Regards,

Dr Dylan Cliff  
ARC DECRA Senior Research Fellow  
Early Start Research Institute  
School of Education, University of Wollongong  
dylanc@uow.edu.au  
Ph: 4221 5929

If you have any questions regarding the study, please contact Ms Tamara Raso 02 4221 5517; email path-abc@uow.edu.au or Dr Dylan Cliff on 02 4221 5929. If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the University of Wollongong Ethics Officer on (02) 4221 3386 or email rso-ethics@uow.edu.au.

Your participation in this project will be greatly appreciated.
10.13 Appendix M Parent Verbal Consent Form

PATH ABC Follow-up study – *Verbal Consent*

*NOTE to Research Staff* – *you must read this text to parents verbatim.*
Please acknowledge that you understand that if you consent for your child to participate they will be asked to:

- Wear an activity monitor on their waist for one week;
- Participate in five short electronic games, picture games and watch a short video with puppets to examine their thinking process, cognitive and emotional development,
- Have their height, weight and waist circumference assessed by a trained research assistant;
- Have their blood pressure and heart rate measured, and
- Have photos of their eyes (retinal image) taken.

Please acknowledge that you understand that if you consent for your child to participate you will be asked to complete:

- *An online parent survey* (link will be sent via email)
- *An optional online Activities Diary* to record my child’s electronic media use and reading over a period of five days (link will be sent via email);

*NOTE to Research Staff* – *please complete and check below.*

I (your name) ________________________________

*Child ID* ______________

☐ Have been given the PATH-ABC follow-up study information sheet and consent form.

I agree to provide verbal consent for my child ________________________________ to take part in the “Preschool Activity, Technology, Health, Adiposity, Behaviour and Cognition follow-up” study.

Date of consent: ________________________________ Time HH: MM:

Staff name: ________________________________

Staff Signature: ________________________________

The best method of contact is:

- ☐ Email ________________________________
- ☐ Mobile phone ________________________________
- ☐ Phone ________________________________

The best location for child assessments would be at:

- ☐ Their primary school (e.g., during class time with our research staff)
- ☐ Their previous preschool (e.g., after-school with parental supervision, if centre is open)
- ☐ The University of Wollongong
- ☐ Community centre
- ☐ Other: ________________________________
### Strengths and Difficulties Questionnaire

For each item, please mark the box for Not True, Somewhat True or Certainly True. It would help us if you answered all items as best you can even if you are not absolutely certain. Please give your answers on the basis of the child's behaviour over the last six months or this school year.

**Child’s full name:** ………………………………………

**DOB:** …………………………………………

**Educator Name:** ………………………………………

<table>
<thead>
<tr>
<th>Item</th>
<th>Not True</th>
<th>Somewhat True</th>
<th>Certainly True</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Considerate of other people's feelings</td>
<td></td>
<td></td>
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<tr>
<td>2: Restless, overactive, cannot stay still for long</td>
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<tr>
<td>3: Often complains of headaches, stomach-aches or sickness</td>
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<td>4: Shares readily with other children, for example toys, treats, pencils</td>
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<td>5: Often loses temper</td>
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<td>6: Rather solitary, prefers to play alone</td>
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<td>7: Generally well behaved, usually does what adults request</td>
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<td>8: Many worries, often seems worried</td>
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<td>9: Helpful if someone is hurt, upset or feeling ill</td>
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<td>10: Constantly fidgeting or squirming</td>
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<tr>
<td>11: Has at least one good friend</td>
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<td>12: Often fights with other children or bullies them</td>
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<td>13: Often unhappy, down-hearted or tearful</td>
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<td>14: Generally liked by other children</td>
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<td>15: Easily distracted, concentration wanders</td>
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<td>16: Nervous or clingy in new situations, easily loses confidence</td>
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<td>17: Kind to younger children</td>
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<td>18: Often argumentative with adults</td>
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<td>19: Picked on or bullied by other children</td>
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<td>20: Often volunteers to help others (parents, teachers, other children)</td>
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<td>21: Can stop and think things out before acting</td>
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<td>22: Can be spiteful to others</td>
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<td>23: Gets on better with adults than with other children</td>
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<td>24: Many fears, easily scared</td>
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<td>25: Sees tasks through to the end, good attention span</td>
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<td>26: Is calm and easy-going</td>
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<td>27: Likes to work things out for self; seeks help as last resort</td>
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<td>28: Shows wide mood swings</td>
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<td>29: Can work easily with others</td>
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<td>30: Does not need much help with tasks</td>
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<td>31: Gets over-excited</td>
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<td>32: Says “please” and “thank you” when reminded</td>
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<td></td>
<td>33: Chooses activities for themselves</td>
<td>34: Is easily frustrated</td>
<td>35: Gets over being upset quickly</td>
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10.15 Appendix O Author Contribution Form

Author Contributions for Chapters

I attest that Research Degree candidate Jade McNeill contributed to the following papers:


with executive function and psychosocial development. Preventive Medicine. (Under review)

For Chapter 3, Dr Dylan Cliff secured the funding. Ms Jade McNeill, Dr Dylan Cliff, Dr Stewart Vella and Dr Steven Howard conceived and designed the study. Ms Jade McNeill performed the data collection, analysed and interpreted the data and drafted the initial manuscript. Ms Jade McNeill, Dr Dylan Cliff, Dr Steven Howard, Dr Stewart Vella, and Dr Rute Santos interpreted the results, reviewed and revised the manuscript. All authors approved the final manuscript.

For Chapter 4, 5, 6 & 7, Dr Dylan Cliff secured the funding. Ms Jade McNeill, Dr Dylan Cliff, Dr Stewart Vella and Dr Steven Howard conceived and designed the study. Ms Jade McNeill performed the data collection, analysed and interpreted the data and drafted the initial manuscripts. Dr Dylan Cliff, Dr Steven Howard, and Dr Stewart Vella reviewed and revised the manuscript. All authors approved the final manuscript.

Ms Jade McNeill [3/05/2019]

Dr Rute Santos [3/05/2019]