Setting Limits on Screen Time for Children (6-to-12 Years): The Integral Role of Parents and Educators. [version 1; peer review: 1 not approved]

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Abstract
This paper investigates the effects of screen time on child development and cognition and the setting of ‘safe’ screen time limits for young children, specifically children aged 6-to-12 years. Guidelines on screen time vary across constituencies, and the debate around screen time is contentious with many questions yet to be answered. A review of literature was undertaken to compare current screen time recommendations against the evidence from Neuroscience, Psychiatry, Psychology and Pediatrics that quantify screen time effects on the children's brain development. Based on this comparison, conclusions are made that can guide education policies around ‘remote learning’ and ‘home schooling’ to align them with the available research on the effects of screen time on children and inform a re-evaluation of the role of parents and educators in the setting of ‘safe’ limits on screen time.

Keywords
screen time, digital media, children, adolescents, brain development, cognition, neuroimaging, cerebral cortex, ADHD, Internet addiction, COVID-19, remote and distance learning
Introduction

The debate around screen time for children is contentious. This paper investigates the effects of screen time on child development and cognition and the setting of ‘safe’ screen time limits for young children. The focus in this paper is the cohort of children aged 6-to-12 years, that is, children enrolled in primary (elementary) and early secondary school in Australia (ACARA, 2019). At the centre of this investigation of screen time is the brain development and cognition of children. While it is acknowledged that genetics and everyday experiences and relationships combine to shape early brain development, it is the timing and quality of early experiences, including screen time, that shape the architecture of the brain (Harvard University, 2004, p.2; 2008, p.1).

Accordingly, evidence will be drawn from Neuroscience, Psychiatry, Psychology and Pediatrics to quantify the effects of screen time on the brain development of children in the years between 6 and 12 years, a critical period or ‘prime time’ for brain development (AEDC, 2019, p.1), and an ‘often-overlooked period of childhood’ (Hagan & Shaw, 2020, p.1). Given the importance of brain development and cognition in early childhood, and the growing interest in the ‘brain and body-based implications of technology use in children and adults’ (Gottschalk, 2019, p.6), longitudinal studies are included from studies of children who are both younger and older, that is, from before and after the primary (elementary) school years.

Growing up in a ‘digital’ world means children have unprecedented access to devices with screens and spend more time looking at screens than any previous generation. Consequently, children have ‘the most to gain and are most at risk from digital technologies’ (The Lancet Editorial, 2018, p.1; Straker et al., 2018, p.301). The debate around screen time, therefore, and the setting of ‘safe’ limits for children has never been more urgent. The word ‘safe’ refers to practices that ‘prioritise the safety and wellbeing of children’ and have the best interests of the child as a primary consideration (Australian Government, National Office for Child Safety, 2020, p.5). The term ‘screen time’ is defined as the ‘time spent viewing content displayed and projected from active and passive screen-media that present visual information on two-dimensional displays’ (Saggate & Martzog, 2020, p.2), using devices that include television screens, computer monitors, and mobile handheld devices such as smartphones and tablets to check email, listen to music, watch TV, and play video games (National Institute of Health, Educational Campaigns, 2013, p.1).

The debate around screen time is not new. Prior to the advent of computers and screen-based digital devices (Leiner et al., 1997, p.2), concerns about the negative influences of television on the health and behaviour of children were raised by parents and health professionals (Jordan et al., 2006, p.1; Bybee et al., 1982, p.4), that were associated with the increased prevalence of childhood obesity (Cui, 2011, p.1-8; Gortmaker et al., 1996, p.1), and ‘inappropriate, risky or illegal behaviours’ (Bar-on, 2010, p.1; Stranger, 1997 p.8; Cantor et al., 1996, p.4). Described in terms of ‘video deficit’, television ‘consistently failed to teach as much as live interaction’, resulting in lower performance on ‘simple imitation tasks, language learning, and emotional learning’ for children aged 2 years and younger (Anderson et al., 2005, p.1), with ‘imprecise long-term educational outcomes’ for children under 6 years (Kearney & Levine, 2019, p.318), and ‘poor longer-term educational achievement’ (Hancox et al., 2005, p.614).

In contemporary society, the increased role of electronic media in daily life has created ‘a digital minefield’ for children, parents and educators. Described as ‘the biggest educational experiment in history’ (Sahlburg, Gonski Institute for Education, 2020, p.1), screen time has been ‘normalised’. Globally, the COVID-19 pandemic (the pandemic), forced millions of children and families into mandatory periods of quarantine and isolation, estimated by UNESCO at over 1.5 billion students, or 87% of the world’s student population, across 165 countries (UNESCO, 2020, p.1). Where digital technologies could be mobilised, home and school became one-and-the-same, with screen-based devices used for both education and entertainment. Children moved seamlessly between online and offline environments, with daily communication and screen time ‘intertwined’ (Reid et al., 2016, p.1). Predictably, children spent more time on-screen, raising questions about the effects of screen time on learning, the content viewed (Sheen et al., 2020, p.1), and the role of parents and educators (Australian Broadcasting Corporation, 2020, p.1; Graham & Sahlberg, 2020, p.11). Parents, it was suggested, needed to be educated on the ‘harmful effects of early screen use’, through training in ‘adaptive parenting skills’, and strategies for intervention, with resources providing ‘alternative activities’ to enhance the mental, social, and emotional development of children (Wong et al., 2021, p.1; Trihn, 2019, p.77; Lauricella et al., 2015, p.1). However, in Australia, the mental health, wellbeing and education of children and adolescents, worsened during the pandemic (Australian Government, Office of the eSafety Commissioner, Open Letter to Australia’s Parents and Carers, 2021a, p.1; Murdoch Children’s Research Institute, 2021, p.1), highlighting the importance of children returning to classrooms and physical-face-to-face learning with their teachers (Murdoch Children’s Research Centre, 2020, p.1). Thus, many questions around screen time are yet to be answered. How much screen time is adequate, or not enough, or too much for young children? What are the effects of screen time on child development? Not surprisingly, the debate around screen time remains contentious, especially since the guidelines vary across constituencies.
The potential to promote learning using Information Communication Technology (ICT) and Technology Enhanced Learning (TEL) is already established (Graham & Sahlberg, 2021, pp.39-41; Hooft Graafland, 2018, p.45; The Lancet Editorial, 2018, p.1; AAP, 2016a, p.1). Value has been demonstrated in the use of the ‘Holistic Blended Learning Model’ (Chen et al., 2008, pp.252-253), that combines Physical Synchronous, Physical Asynchronous, Cyber Synchronous and Cyber Asynchronous modalities (Hastie, Hung, Chen, & Kinshuk, 2010). Research findings have documented ‘best practice’ in instructional design (Gagné et al., 2005, pp.1-17), in the Cyber Synchronous classroom (Hastie & Smith, 2017; Hastie, Chen, & Smith, 2011a; Hastie, Chen, & Kuo, 2007), and the management of cognitive load (Sweller, 1988, pp.257-285) to optimize student learning in screen-based learning environments (Hastie, Chen & Smith, 2012). Applications of these strategies are reported in studies of the teaching of Science, Technology, Engineering & Mathematics (STEM) and educational robotics via the Internet (Hastie, 2018; Hastie, 2016), and in professional development programs for teachers and medical educators working in e-learning paradigms (Hastie, Dornan, Chen, Smith & Elston, 2013; Hastie, Chen & Smith, 2011b; Marzano et al., 1997, pp.1-12; Hastie & Palmer, 1997). Irrespective of such potential benefits, the effects of screen-time on young children remain inconclusive. This paper then is a contribution to that discussion of education policy and pedagogy.

Discussion/Literature review
The literature is analysed from two perspectives. First, the current screen time recommendations for 6-to-12-year-old children are established. Second, to determine the effects of screen time on the brain development and cognition of young children, research findings from Neuroscience, Psychiatry, Psychology and Paediatrics are presented. Finally, a summary of this literature, based on a comparison of the two perspectives, is made to identify best practices. I now turn to these tasks.

Current guidelines on screen time and use of electronic media by children aged 6-to-12 years
The guidelines for screen time have changed over time and have been set largely by the American Academy of Pediatrics (AAP). In 2013, the AAP made the following recommendations on the use of electronic media, as listed in Table 1:

Then in 2016, the AAP released revised guidelines that acknowledged the ‘multifactorial effects of media use’ on children. Recommendations included the need for ‘mindful selection, curation, and co-viewing of content’ by parents, and a ‘personalized media use plan’ that attended to the ‘age, health, temperament, and developmental stage’ of each child. Also acknowledged were the significant challenges faced by parents in setting limits on screen time and in limiting the media consumed by children, especially when children owned their own digital devices (AAP, 2016b, p.1). Even so, parents of school-aged children were advised to ‘carve out’ media limits each day to include 8-10 hours of sleep, 2 hours of screen time, 1 hour of physical activity, and 0 sugary drinks (Swartz, 2016, p.1). Such limits were intended to ‘reduce the risks of obesity, lost sleep, and impaired school performance’, while allowing children to ‘connect online with friends and family and learn about the broader world’. The goal was to keep children off their devices, that is ‘unplugged’, for at least 2 hours per day (Christakis, Medscape Medical News, 2016, p.1).

It was claimed, however, that the AAP (2016b) guidelines, were based on ‘out-of-date research’ conducted before digital devices had become part of everyday life (University of Oxford, 2017, p.1). The time-lapse between the original research and publication made the recommendations ‘difficult to justify and implement’. A re-evaluation of the guidelines was suggested to determine whether they were good for the mental health and wellbeing of young children. Thus, the differing opinions of health and education authorities, as revealed here, created ‘policy and practice dilemmas’ and ‘conflicting guidelines’, on screen time for young children (Straker et al., 2018, p.300).

Importantly, ‘no consistent evidence of health benefits or safe thresholds’ for screen time for children and young people could be identified, with no evidence supporting ‘differential thresholds’ for younger children or adolescents.

<table>
<thead>
<tr>
<th>Age of child</th>
<th>Recommended use of electronic media</th>
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<tr>
<td>0-18 mths</td>
<td>- complete avoidance of electronic media</td>
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<tr>
<td>18-24 mths</td>
<td>- slow introduction to electronic media</td>
</tr>
<tr>
<td>2-5 yrs</td>
<td>- no more than 2 hours per day of electronic media use</td>
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<tr>
<td>5-18 yrs</td>
<td>- parents encouraged to establish a family home use plan for all media - schools, policymakers, product advertisers, and entertainment producers advised to recognise the influences of media on children and teenagers</td>
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</table>
Neuroimaging technologies, specifically developmental trajectory of children. To that end, the literature from medical science, specifically evidence-based devices, it is necessary to set them against what are known to be the effects of screen time on young children, and the corresponding, ‘threshold’ was also found in children with Fetal Alcohol Syndrome Disorder (FASD) in large areas of the brain (Zhou et al., 2020, p.42). Australian parents were advised there was ‘no magic figure’ that could be used to determine how much screen time was safe for young children. The ‘right’ amount of screen time depended on the age and maturity of the child, the kind of content the child was consuming, their learning needs and family routine (Australian Government, Office of the eSafety Commissioner, 2021b, p.1), and the cost of time spent on screen to health, wellbeing and opportunities to live a balanced life (Graham & Sahiberg, 2021, p.5; Longitudinal Study of Australian Children, 2016, p.99). Consequently, no maximum limit on screen time was set for Australian children. However, moderation of screen-use was recommended to promote cognitive development in children (Walsh et al., 2020, p.4), along with the need for the general discussion around screen time to ‘go beyond simply limiting screen time’, to promoting the use of screens in ways that are ‘positive’ for the brain (University of Washington, 2021, p.1).

The effects of screen time on the brain development and cognition of young children

While the current guidelines (AAP, 2016b; ACAP, 2020) provide criteria for the use of media and exposure to screen-based devices, it is necessary to set them against what are known to be the effects of screen time on young children, and the developmental trajectory of children. To that end, the literature from medical science, specifically evidence-based research from Neuroscience, Psychiatry, Psychology and Paediatrics, is investigated.

Screen time and structural changes in the brain

Neuroimaging technologies, specifically ‘Magnetic Resonance Imaging’ (MRI) and ‘functional MRI’ (fMRI), have provided evidence that correlate screen time with ‘structural changes’ in the brains of children aged 0-18 years (Raschle et al., 2012, p.2). ‘Lower microstructural integrity’ of brain white matter tracts were identified in children, aged 3-to-5 years, who used more than the screen time recommended by the AAP (2016b), that is, more than 1 hour per day without parental interaction (Hutton et al., 2019, p.8). Average screen time for these children was slightly more than 2 hours per day but ranged from 1 hour to slightly more than 5 hours per day. Tracts that supported ‘language and emergent literacy skills, cognition, and executive functions’, were ‘more disorganized and underdeveloped’. Screen time, it was concluded, was ‘too passive’ for brain development, and ‘displaced’ other experiences that could have ‘helped children reinforce brain networks more strongly’ (Hutton, LaMotte, CNN News Health, 2019, p.1). Premature ‘thinning’ of the cerebral cortex, that is, cell loss or ‘atrophy’ in the outermost layer of the brain was identified through neuroimaging in children aged 9-to-10 years who used screen-based media for more than 7 hours per day (World Economic Forum, 2018, p.1). Similarly, ‘structural deficits’ in the cortex, identified through neuroimaging, were attributed to excessive online gaming in Chinese adolescents and young adults. ‘Decreased left orbitofrontal grey matter volume’ was found after 6 weeks of daily online gaming in both ‘excessive gamers’ and ‘gaming-naïve’ subjects (Zhou et al., 2017, p.100-109). New rules were announced in China in 2021 to combat gaming addiction’ with online video games limited to 3 hours per week for children under-18 years (Reuters, 2021, p.1; AppInChina, 2007, p.1; China Daily, 2006, p.1).

Correspondingly, ‘reductions in cortical thickness’, across prefrontal, parietal, and temporal regions of the brain that was attributed to ‘social deprivation in early life’, was associated with attention deficit hyperactivity disorder (ADHD) approximately four or five times more often than other children (McLaughlin et al., 2014, p.8). Significant ‘cortical thinning’ was also found in children with ‘Fetal Alcohol Syndrome Disorder’ (FASD) in large areas of the ‘bilateral middle frontal lobe, pre- and post-central areas, lateral and inferior temporal and occipital lobes of the brain’ (Zhou et al., 2011, p.1). Excessive or long-lasting stress, known as ‘toxic stress’, that included ‘physical or sexual abuse, neglect or lack of affection, parental mental illness, family violence, poverty, and lack of adequate housing’, had a negative impact on brain development, especially in the early years (Harvard University, 2021, p.1). While thinning of previously thicker
areas of the brain is generally associated with aging, ‘Alzheimer’s disease’ (AD) and ‘progressive brain disorganization’ (Roe et al., 2021, pp.5-6), it is not observed in otherwise healthy children.

Research from animal models (Waxmonsky, 2019, p.1) found frequent exposure to rapidly changing audio and visual bombardment, the hallmarks of many television shows and video games, had prevented brain nerve tracks from developing as intended. These findings, when extrapolated to brain development in children, pointed to ‘what children were not doing’, and ‘what was not happening in their brains’, because they were ‘staring at screens’. It was concluded that there was ‘nothing inherently beneficial about viewing screens’, rather, ‘a matter of how much risk’ screens posed (Waxmonsky, 2019, p.1-2).

In Australian research, the synchronisation of social and emotional networks in the brain was correlated with active human engagement, known as ‘interpersonal neural synchronisation’ or neural coupling (Kerr, 2019, p.14). Physical face-to-face interactions ‘activate different parts of the brain’ that are not activated during virtual meetings (Hasson et al., 2012, pp.6-8). Intensive physical face-to-face interactions, when used within the Auditory-Verbal Therapy (A-VT) approach to teach Australian children (0-18 years) with hearing loss to listen and speak, built and strengthened neural pathways in the auditory area of the brain, in areas where cognitive growth and language development is promoted (Dornan et al., 2011, 2010, 2009, 2009, 2008, 2007).

Notably, changes in the anatomical and physiological development of the brain, particularly the connection between the prefrontal cortex and executive function, were aligned with Piagetian child development theory (Bolton & Hattie, 2017, p.22). It was concluded, therefore, that the first years of life needed to be focused on human interactions, specifically ‘healthy and stimulating experiences’, to ‘build brain architecture’ that can operate at its ‘full genetic potential’ (Harvard University, 2008, p.2).

**Screen time and cognition**

Higher daily screen time across all screen types was correlated with ‘lower cognition’ in children aged 9-to-10 years, with those in the ‘high’ (7.2 hours per day) and ‘middle’ (2.9 hours per day) screen time groups rated ‘lower in cognition’ when compared to children in the ‘low’ (1.2 hours per day) screen time group (Walsh et al., 2020, p.4). Early data from the NIH 2018 study indicated ‘lower scores in thinking and language tests’ for children whose screen time was ‘more than 2 hours per day’ (CBS News, 2018, p.1). ‘Heavy television use’ by Australian children was predictive of a ‘loss of reading of four months relative to peers two years later’, while ‘heavy computer use’ predicted a similar loss in numeracy two years based on a comparison of academic results from NAPLAN, the National Assessment Program Literacy and Numeracy (Mundy et al., 2020, p.11).

Conversely, ‘superior global cognition’ was identified in Canadian children aged 8-to-11 years who ‘adhered to recommendations of physical activity of 1 hour per day, recreational screen time of 2 hours or less per day, and sleep of 9-11 hours duration per night’, while the ‘limiting of recreational screen time’ and the ‘encouragement of healthy sleep’ was correlated with ‘improved cognition’ (Walsh et al., 2018, p.6; Rodriguez-Ayllon et al., 2020, p.5). Increased screen time, however, was correlated with ‘increased problem behaviours’ in children aged 9-to-10 years, whereas ‘sleep of longer duration’ was associated with ‘reduced problem behaviours’ (Guerrero et al., 2019, pp.3-9; Fakhouri et al., 2013, pp.227-228).

The ‘digital distractions and supernormal capacities for cognitive offloading’ offered during screen time, created a ‘non-ideal environment’ for the ‘refinement of higher cognitive functions during critical periods of brain development’ in children and adolescents (Firth et al., 2019, pp.126-127). ‘Complex and multi-method based visual stimuli’ on screens was associated with ‘overload on working memory’, ‘divided attention’ and ‘impaired recall’. The combination of ‘audio-visual graphics, text, and animations’ impeded the ability to ‘register, process, and remember information with accuracy’. Consequently, cognitive overload impacted the ‘quality of comprehension, prioritization, and deep-level processing of incoming information’. Short-term memory, in turn, could not be consolidated into long-term memory, and resulted in ‘poor processing and understanding of what was taught or said’ (Jha & Arora, 2020, p.1). It was argued ‘the screen should be the tool, not the teacher’ (Roseberry Lytle, University of Washington, 2015, p.1).

**Screen time and physiological and psychological effects**

Screen time was correlated with ‘adverse physiological and psychological effects’ in children and adolescents, aged 0-to-18 years (Lissak, 2018, p.149). Physiological effects attributed to excessive screen time included ‘poor sleep’ and risk factors for ‘cardiovascular diseases (high blood pressure, low HDL cholesterol, obesity)’, ‘poor stress regulation (high sympathetic arousal and cortisol dysregulation)’, ‘Insulin resistance’, ‘impaired vision’ and ‘reduced bone density’ (Lissak, 2018, pp.149-157; Dahlgren, 2021, pp.2-5). Excessive screen time is defined as ‘sedentary time spent on screen,
such as watching television, playing video games, or using the computer for more than 2 hours per day’ (de Lucena et al., 2018, p.407) that ‘comes at the expense of other healthy activities’ (Dahlgren, 2021, p.1). Significantly, in 2018 the World Health Organization (WHO) included gaming disorder in the 11th International Classification of Diseases (WHO, 2018, p.1).

Psychological effects, specifically ‘developmental delay’, were associated with screen time in children aged 11-to-13 years when ‘screen versus non-screen interactions’ during early childhood were compared with behavioural problems in early adolescence (Wong et al., 2021, pp.7-11). The ‘duration’ of exposure to screens by children and the ‘frequency’ of non-screen parent-child activities correlated with ‘externalizing problems’ (rule-breaking behaviours, delinquency and aggression) and ‘internalizing problems’ (emotional symptoms, anxiety and depression) in early adolescence. Fewer externalizing problems were observed when young adolescents spent more time on ‘non-screen parent-child activities’, and less time on ‘child-alone’ video game activities. The overall ‘length’ of screen time, along with ‘violent’, ‘fast-paced’ content and ‘repetitive attentional shifts between multiple tasks’, was found to activate dopamine and reward pathways associated with ‘ADHD-related behaviours’, including ‘inattention’, ‘impulsivity’, ‘sleep problems’, and ‘impaired executive functioning’. Extensive screen time and use of technology were correlated with ‘heightened attention-deficit symptoms’, ‘impaired emotional and social intelligence’, ‘technology addiction’, ‘social isolation’, ‘impaired brain development’, and ‘disrupted sleep’, while ‘background media’ had a negative impact on ‘cognitive load’ and ‘attentional capacity’ (Lissak, 2018, p.149-157).

Constant use of technology offered ‘fewer opportunities to interact offline’ and meant ‘the brain could not reset to its default, or resting, mode’ (Small et al., 2020, p.179-187; Kerr, 2019, p.12). ‘Symptoms of ADHD’ were identified in children and adolescents aged 15-and-16 years after 6 weeks of digital media use, although no symptoms of ADHD were identified in baseline data (Ra et al., 2018, p.258-261). A significant association, therefore, was established between more frequent digital media use and ADHD symptoms. Importantly, it was found that ‘screen time induced ADHD-related behaviour’ could be ‘inaccurately diagnosed’ as ADHD, while reduced screen time was effective in decreasing

<table>
<thead>
<tr>
<th>Screen time per day (hours)</th>
<th>Age (years)</th>
<th>Effects on brain development and cognition, physiological and psychological development</th>
<th>Key References</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 2 hrs (excessive)</td>
<td>0–18</td>
<td>- poor sleep&lt;br&gt;- ADHD related behaviours&lt;br&gt;- risk factors for cardiovascular diseases (high blood pressure, obesity, low HDL cholesterol)&lt;br&gt;- poor stress regulation (high sympathetic arousal and cortisol dysregulation)&lt;br&gt;- Insulin resistance&lt;br&gt;- Impaired vision&lt;br&gt;- Reduced bone density</td>
<td>Lissak, 2018</td>
</tr>
<tr>
<td>Between 1-5 hrs (excessive)</td>
<td>3–5</td>
<td>- Lower microstructural integrity of brain white matter tracts&lt;br&gt;- Disorganized and underdeveloped tracts in areas that support language and emergent literacy skills, cognition, and executive functions</td>
<td>Hutton et al., 2019</td>
</tr>
<tr>
<td>More than 2 hrs (excessive)</td>
<td>5–13</td>
<td>- Developmental delay in children&lt;br&gt;- Behavioural problems in early adolescence</td>
<td>Wong et al., 2021</td>
</tr>
<tr>
<td>More than 7 hrs (excessive)</td>
<td>9–10</td>
<td>- Thinning of the cerebral cortex, cell loss or ‘atrophy’, in the outermost layer of the brain&lt;br&gt;- Lower scores on language&lt;br&gt;- Lower scores on thinking tests</td>
<td>World Economic Forum, 2018</td>
</tr>
<tr>
<td>More than 2 hrs (excessive)</td>
<td>23</td>
<td>- Decreased left orbitofrontal grey matter volume after six weeks of daily Internet gaming</td>
<td>Zhou et al., 2017</td>
</tr>
<tr>
<td>More than 2 hrs (extensive)</td>
<td>10–24</td>
<td>- Heightened symptoms of ADHD&lt;br&gt;- Impaired emotional and social intelligence&lt;br&gt;- Technology addiction&lt;br&gt;- Social isolation&lt;br&gt;- Impaired brain development&lt;br&gt;- Disrupted sleep</td>
<td>Small et al., 2020</td>
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ADHD-related behaviour (Lissak, 2018, p.149). Additionally, the association between screen time and ADHD, was identified in people at any age, with moderate or severe depression and obesity found in adults who spent more than 4 hours per day watching TV and using computers, outside work or school, with females at higher risk (Madhav et al., 2017, p.67-71; Teychenne et al., 2010, p.246-254).

A summary of the effects of screen time on the brain development and cognition of young children and adolescents, along with associated health consequences, is provided in Table 2:

Conclusions are now presented that are based on a comparison of the science and practice. Expressly, the findings from Neuroscience, Psychiatry, Psychology and Paediatrics on the quantified effects of screen time on the brain development and cognition of children are compared with the current screen time guidelines (AAP, 2016b) for children aged 6-to-12 years.

Conclusions
First, while genetics and everyday experiences and relationships combine to shape early brain development, it is the timing and quality of early experiences, such as screen time, that combine to shape the architecture of the brain. Environmental factors, particularly physical face-to-face interactions, play a critical role in early brain development that extends across the life span. However, screen time is correlated with adverse physiological and psychological effects in children and adolescents, aged 0-to-18 years. Much of what happens on screen, during Cyber Synchronous and Cyber Asynchronous interactions, provides ‘impovertised’ stimulation to the developing brain when compared to reality. Equated with ‘video deficit’, screen time is too passive for early brain development because it replaces other experiences, specifically physical face-to-face interactions and small motor activity, that reinforce and strengthen brain networks. Importantly, greater white matter microstructure in children is associated with higher levels of physical activity, particularly outdoor play and sport participation.

Second, changes in brain structure in children, specifically thinning of the cerebral cortex as quantified through neuroimaging, were directly correlated with screen time. For children aged 3-to-5 years, screen time that exceeded the AAP guidelines (2016) of more than 1 hour per day without parental interaction, was associated with lower microstructural integrity in brain white matter tracts, in those areas of the brain that support language, emergent literacy skills, and cognition. For children aged 9-to-10 years, more than 7 hours of screen time per day was correlated with a thinning of the cerebral cortex, while more than 2 hours per day was associated with lower scores on language and thinking skills. For children aged 11-to-13 years, screen activities in early childhood activities were associated with behavioural problems in early adolescence.

Extensive screen time and extensive use of technology by children and adolescents were correlated with heightened attention-deficit symptoms, impaired emotional and social intelligence, technology addiction, social isolation, impaired brain development, and disrupted sleep. Symptoms of ADHD were identified in both excessive gamers and gaming-naive subjects after just 6 weeks. Changes in brain morphology attributed to screen time were associated with lower general intellectual functioning (IQ), developmental delay and behavioural problems that extend from childhood across the life span. The evidence, therefore, confirms screen time, from as little as 1 hour per day, can have detrimental effects on the brain development and cognition of young children. Importantly, cortical thinning of the brain is not found in otherwise healthy children, however, it is associated with FASD, social deprivation in early life, aging and Alzheimer’s disease (AD) and progressive brain disorganization in later life. Ergo, the structural changes to the brains of young children attributed to screen time, match the descriptors for toxic brain stress and, as such, constitute physical abuse.

Third, the COVID-19 pandemic heightened issues around screen time, with millions of children globally making the ‘switch’ from physical face-to-face classrooms to ‘remote’ learning from home. Physical face-to-face interactions were replaced by cyber face-to-face, where it was possible to mobilise digital technologies, creating an unprecedented reliance on Information Communication Technologies and Technology Enhanced Learning. Consequently, the extra hours that students spent online for lessons, when added to their recreational screen activities, equated to significantly more screen time overall, at levels that were most likely excessive. In addition, the mental health, wellbeing and education of children and adolescents worsened during the pandemic due to protracted lockdowns and school closures. Further, the increased risks of moderate or severe depression in adults, especially females, due to increased screen time during the pandemic, raises important questions around the health of parents and educators and associated impacts on their role in ‘remote’ learning and teaching.

Fourth, the current guidelines for screen time, released by the AAP (2016b), and endorsed by ACAP in 2020, recommend children should be ‘unplugged’ and have no media use for at least 2 hours per day, in contrast to the 2013 recommendations.
of more adult-regulated and scrutinized media use for children aged 5-18 years. While the current screen time recommendations (AAP, 2016b) are more nuanced, they create confusion due to their reliance on personalized media use plans that attend to the age, health, temperament, and developmental stage of each child. Nonetheless, based on the 2016 guidelines, it could be estimated that, apart from daily physical activity (1 hour minimum), adequate sleep (8 to 12 hours, depending on age), quality family time and time away from media (2-4 hours), school-aged children, including children aged 6-to-12, could be on-screen for 7-13 hours per day, or possibly longer, at levels deemed excessive and which predispose them to Internet addiction.

Fifth, no consistent evidence was found of health benefits from screen time. Thus, the research comprehensively supports policy action to limit screen use by children and adolescents, with specific limits on screen time for preteens and teens. Essentially, action is needed to limit sedentary screen time, related to television, video games, and computers, to less than 2 hours per day, to ensure other healthy activities, specifically physical activity, are not displaced. While parents and educators are expected to manage screen time and help children develop the skills and habits needed to grow up in a digital world, this expectation of shared responsibility for digital education with its associated reliance on the use of sophisticated technological devices and resources is, by definition, a contributor to educational inequality.

Given these conclusions, education policies around ‘remote learning’ and ‘home schooling’, require a review to align them with the available research on the effects of screen time on the brain development and cognition of children aged 6-to-12 years, but more broadly from birth-to-18 years, along with a re-evaluation of the role of parents and educators in the setting of limits on screen time.

Finally, having established wide variance between the science on screen time and current practice, the question is how do we close the gap?

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Title: Setting Limits on Screen Time for Children (6-to-12 years): The Integral Role of Parents and Educators.

Thank you for the opportunity to review this manuscript (MS). The present review summarizes and discusses the literature examining the different screen time behaviours related to changes in children's brain development and cognition. The author further reflects the current and past screen time recommendations. I have below listed a number of suggestions for the author to consider.

Major recommendations:

General:
1. I think the role of parents and educators needs to be elaborated a lot more throughout the MS. It is promised in the title, but the MS mainly discusses developmental differences in youth related to screen time. Also, this review is an opportunity to discuss the role of paediatricians as the most reliable health source among both children and adolescents and parents themselves.

2. The methods section is completely missing. How was the search of articles conducted? Which databases were searched? Based on which criteria were the articles selected (setting, healthy or diseased children etc.)?

3. The single sections of the manuscript do not really differ in content, but show large information overlap between introduction, discussion and conclusion. Please structure the sections better to set the stage and motivate the review (Intro), discuss the results more in depth (Discussion) and summarize main findings that close current research gaps (Conclusion). Also, in the conclusion the argumentation was not clear.

Title:
The title indicates that the paper discusses the integral role of parents and educators in setting safe limits of screen time for children. This was not elaborated enough in the text.

Abstract:
“This paper investigates the effects of screen time on child development and cognition and the setting of ‘safe’ screen time limits for young children, specifically children aged 6-to-12 years.”

This sentence implies that the article is an original quantitative research article and not a review article. Hence, I suggest to rephrase and make clear that this paper is a review, which aims to synthesize and discuss the current literature investigating the effects of screen time on children’s brain development and cognition (still the role of parents and educators is not really elaborated in the MS, as promised in the title). I also would suggest to include the main findings in the abstract, also the methods and outcomes are missing.

Discussion/literature review
It is unclear how the different screen time behaviours, including multi-tasking, are associated with different measures of cognition, and what is the role of parents and educators in setting limits for each of these screen time behaviours. Do we need different limits for screen time duration and the type of media, with regard to on-line learning vs. “staring at screens”? What is the role of parents and educators here and do we set different rules? We would highly recommend to provide such a review.

Table 2: More descriptive information on the sample of each article would be helpful (e.g. sample size, sex, country etc.). Also, other information on the study (e.g. type of control, setting, year of data collection, study design etc.). If longitudinal study, what is the cohort duration? Why were these studies included? More importantly, such a table for the role of parents and educators is needed as well.

Page 4, 2nd paragraph: “The ‘right’ amount of screen time depended on the age and maturity of the child, the kind of content the child was consuming, their learning needs and family routine (Australian Government, Office of the eSafety Commissioner, 2021b, p.1)...”

I think it is necessary to elaborate more on which type of content and learning needs the author is referring to.

Minor comments:

Title:
I would suggest to include the type of the review conducted in the title, to inform the reader early in the paper. Also, I suggest removing the age group from the title.

Introduction:

First paragraph: Second sentence again implies that this article investigates the effects of screen time on child’s development. I suggest rephrasing to make clear that this paper is a review article. Moreover, first paragraph already presents the aim and motivation of the current paper without first explaining why screen time represents an important part of children’s daily activities and its potential role in their health outcomes. I suggest moving this paragraph later in the introduction,
more precisely before the section on discussion/literature review.

Second paragraph: Please mention the type of articles/studies that are considered in this review.

Second sentence: “...longitudinal studies are included from studies of children who are both younger and older, that is, from before and after the primary (elementary) school years.”

Unclear. Please rephrase. Did the author include only longitudinal studies for this review? From table 2, it does not seem to be the case. Moreover, this information should belong under the methods section and not in the introduction.

Fourth paragraph: Sentences are too long. Please consider rephrasing for clarity.

Sixth paragraph: Please clarify what are the Physical Synchronous, Physical Asynchronous, Cyber Synchronous and Cyber Asynchronous modalities. It can help the reader understand how ICT helps to optimize the students' learning processes.

Discussion/literature review

First paragraph: “The literature is analysed from two perspectives. First, the current screen time recommendations for 6-to-12-year-old children are established.”

I suggest rephrasing. The recommendations have been established by respective authorities or organisations. The author is discussing them in the current review. The review analysis strategy belongs to the methods section.

“Second, to determine the effects of screen time on the brain development and cognition of young children, research findings from Neuroscience, Psychiatry, Psychology and Paediatrics are presented. Finally, a summary of this literature, based on a comparison of the two perspectives, is made to identify best practices. I now turn to these tasks.”

Please rephrase to make clear the current article is a review of the literature investigating the effects of screen time on the brain development of young children. Indicate what type of studies are considered for the review: Randomised controlled trials (RCT), observational studies (longitudinal, cross-sectional), case-control studies, systematic reviews, grey literature etc. Consider removing the sentence “I now turn to these tasks.”

Page 3, 4th paragraph: “Such limits were intended to ‘reduce the risks of obesity, lost sleep, and impaired school performance’, while allowing children to ‘connect online with friends and family and learn about the broader world’. The goal was to keep children off their devices, that is ‘unplugged’, for at least 2 hours per day (Christakis, Medscape Medical News, 2016, p.1).”

Unclear. Please rephrase to make clear that the recommendation was such that children should not spend more than 2 hours per day with screen devices. As it is written here, it implies the contrary.

Table 1: I suggest also including the new recommendations from 2016, issued by AAP, which will help the reader to understand how the recommendations changed from 2013 to 2016.
Again, no difference between introduction, discussion and conclusion. Please streamline that.

**Page 4, 5th paragraph**: “Correspondingly, ‘reductions in cortical thickness’, across prefrontal, parietal, and temporal regions of the brain that was attributed to ‘social deprivation in early life’, was associated with attention deficit hyperactivity disorder (ADHD) approximately four or five times more often than other children (McLaughlin et al., 2014, p.8).”

Unclear. Please rephrase.

**Page 5, 5th paragraph**: Please explain what measures of cognition were investigated in the respective studies. Also, which problem behaviours were the authors referring to?

**Page 5, 6th paragraph**: “The ‘digital distractions and supernormal capacities for cognitive offloading’ offered during screen time, created a ‘non-ideal environment’ for the ‘refinement of higher cognitive functions during critical periods of brain development’ in children and adolescents (Firth et al., 2019, pp.126-127).”

I suggest to elaborate further on the critical periods of brain development in children and adolescents. Which periods are considered critical and why? Where is the role of parents and educators in tackling the digital distractions?

**Page 6, 1st paragraph**: “Extensive screen time and use of technology were correlated with ‘heightened attention-deficit symptoms’, ‘impaired emotional and social intelligence’, ‘technology addiction’, ‘social isolation’, ‘impaired brain development’, and ‘disrupted sleep’, while ‘background media’ had a negative impact on ‘cognitive load’ and ‘attentional capacity’ (Lissak, 2018, p.149-157)”

Please explain what “background media” refers to. Also, I suggest using the term “duration of screen time” instead of “length of screen time”.

**Page 8**: “Finally, having established wide variance between the science on screen time and current practice, the question is how do we close the gap?”

Based on the knowledge gained from this review, what are the author’s suggestions and recommendations to address this question?

I suggest harmonising the use of terminology throughout the manuscript. The author uses “screen time”, “digital media use”, “use of technology” etc., all at the same time. I find the use of quotation marks excessive. Please consider removing where appropriate throughout manuscript.

**Is the work clearly and accurately presented and does it cite the current literature?**
Partly

**Is the study design appropriate and is the work technically sound?**
No
Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
No source data required

Are the conclusions drawn adequately supported by the results?
Partly

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Child and adolescent health, epidemiology, health behaviour

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

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