Benefits and risks associated with children's and adolescents' interactions with electronic screens: An umbrella review

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Abstract

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Benefits and risks associated with children's and adolescents' interactions with electronic screens: An umbrella review

Summary

Children's engagement in screen time is a complex issue. Parents, policymakers, and educators needing to weigh the risks that sedentary use of screens present alongside the potential benefits for learning and social connectedness. Hampering efforts to make an informed decision is the lack of comprehensive evidence. As a Lancet editorial [1] suggested, "Our understanding of the benefits, harms, and risks of our rapidly changing digital landscape is sorely lacking." In this study, we systematically harmonize data from existing meta-analyses of screen time on a range of outcomes, including health, education, and psychology, and identify the most statistically robust relationships. We show that some forms of screen time—such as social media—show consistent evidence of harm for children, with no clear evidence of a benefit. Other relationships are more complex. Video games, for example, are associated with poorer body composition and learning outcomes. However, video games for a specific educational purpose (such as numeracy) are associated with improvements in that subject area. Caregivers must therefore weigh the health risk against the educational benefit. The findings of this study provide parents and other caregivers with the information to make these informed decisions.

Background

In the 16th century, hysteria reigned around a new technology that threatened to be "confusing and harmful" to the mind. The cause of such concern? The widespread availability of books brought about by the invention of the printing press [2]. In the early 19th century, concerns about schooling "exhausting the children's brains" followed, with the medical community accepting that excessive study could be a cause of madness [3]. By the 20th century, the invention of the radio was accompanied by assertions that it would distract children from their reading (which by this point was no longer considered confusing and harmful) leading to impaired learning [4].

Today, the same arguments that were once leveled against reading, schooling, and radio are being made about screen use (e.g., television, mobile phones, and computers) [5]. Excessive screen time use is the number one concern parents have about their children's health and behaviour, ahead of nutrition, bullying, and physical inactivity [6]. Yet, the evidence to support parents' concerns is inadequate. A Lancet editorial [1] suggested that, "Our understanding of the benefits, harms, and risks of our rapidly changing digital landscape is sorely lacking."

While some forms of screen use (e.g., television viewing) may be detrimental to health and wellbeing [7,8], evidence for other forms of screen exposure (e.g., video games or online communication, such as Zoom™) remains less certain and, in some cases, may even be beneficial [9,10]. Thus, according to a Nature Human Behaviour editorial, research to determine the effect of screen exposure on youth is "a defining question of our age" [11]. With concerns over the impact of screen use including education, health, social development, and psychological well-being, a broad overview that identifies potential benefits and risks is needed.

Citing the negative effects of screens on health (e.g., increased risk of obesity) and

health-related behaviours (e.g., sleep), guidelines from the World Health Organisation [12] and numerous government agencies [13,14] and statements by expert groups [15] have recommended that young people's time spent using electronic media devices for entertainment purposes should be limited. For example, the Australian Government guidelines regarding sedentary behaviour recommend that young children (under the age of two) should not spend any time watching screens. They also recommend that children aged 2-5 years should spend a maximum of one hour engaged in recreational sedentary screen use per day, while children aged 5-12 and adolescents should spend no more than two hours. In contrast, some recent evidence suggests that exposure to electronic entertainment media that exceeds these guidelines (e.g., 3-4 hours per day) may not have meaningful adverse effects on children's behaviour or mental health, and might, in fact, benefit their well-being, as long as this exposure does not reach extreme levels (e.g., 7 hours per day)[16]. Some research also indicates that content (e.g., video games vs television programs) plays an important role in determining the potential benefit or harm of youths' exposure to screen-based media [17]. Indeed, educational screen time is positively related to educational outcomes [18]. This evidence has led some researchers to argue that a more nuanced approach to screen time guidelines is required [19].

In 2016, the American Academy of Pediatrics used a narrative review to examine the benefits and risks of children and adolescents' electronic media [20] as a basis for updating their guidelines about screen use [15]. Since then, a large number of systematic reviews and meta-analyses have provided evidence about the potential benefits and risks of screen use. Yet, no review has synthesised the evidence available across a broad range of outcome domains, such as physical health, education, physical and cognitive development, behaviour, and well-being.

In order to synthesise the evidence and support further evidence-based guideline development and refinement, we reviewed published meta-analyses examining the effects of

screen use on children and youth. This review synthesises evidence on any plausible outcome of electronic media exposure. Adopting this broad approach allowed us to provide a holistic perspective on the influence of screens on children's lives. By synthesising across life domains (e.g., school and home), this review provides evidence to inform guidelines and advice for parents, teachers, pediatricians and other professionals in order to maximise human functioning.

Methods

Eligibility criteria. *Population*: To be eligible for inclusion, meta-analyses needed to include meta-analytic effect sizes for children or adolescents (age 0-18 years). We included meta-analyses containing studies that combined data from adults and youth if meta-analytic effect size estimates specific to participants aged 18 years or less could be extracted (i.e., the highest individual study from the meta-analysis had a mean age was < 18 years). We excluded meta-analyses that only contained evidence gathered from adults (age >18 years).

Exposure: We included meta-analyses examining all types of electronic screens including (but not necessarily limited to) television, gaming consoles, computers, tablets, and mobile phones. We also included analyses of all types of content on these devices, including (but not necessarily limited to) recreational content (e.g., television programs, movies, games), homework, and communication (e.g., video chat). In this review we adopted a population-level perspective, meaning that we examined electronic media exposure that occurs during typical daily living activities (e.g., home, school-based electronic media exposure). Consistent with this population-level approach, we excluded technology-based treatments for clinical conditions. However, we included studies examining the effect of screen exposure on non-clinical outcomes (e.g., learning) for children and youth with a clinical condition. For example, a meta-analysis of the effect of television watching on learning among adolescents diagnosed with depression would be included. However, a meta-analysis of interventions designed to *treat* clinical depression delivered by a mobile phone app would be excluded.

Outcomes: We included all reported outcomes.

Publications: We included meta-analyses (or meta-regressions) of quantitative evidence. To be included, meta-analyses needed to analyse data from studies identified in a

systematic review. For our purposes, a systematic review was one in which the authors attempted to acquire all the research evidence that pertained to their research question(s). We excluded meta-analyses that did not attempt to summarise all the available evidence (e.g., a meta-analysis of all studies from one laboratory). We included meta-analyses regardless of the study designs included in the review (e.g., laboratory-based experimental studies, randomised controlled trials, non-randomised controlled trials, longitudinal, cross-sectional, case studies), as long as the studies in the review collected quantitative evidence. We excluded systematic reviews of qualitative evidence. We did not formulate inclusion/exclusion criteria related to the risk of bias of the review. We did, however, employ a risk of bias tool to help interpret the results. We included full-text, peer-reviewed meta-analyses published or 'in-press' in English. We excluded conference abstracts and meta-analyses that were unpublished.

Information sources. We searched records contained in the following databases: Pubmed, MEDLINE, CINAHL, PsycINFO, SPORTDiscus, Education Source, Embase, Cochrane Library, Scopus, Web of Science, ProQuest Social Science Premium Collection, and ERIC. We conducted an initial search on August 17, 2018 and refreshed the search on May 13, 2020. We searched reference lists of included papers in order to identify additional eligible meta-analyses. We also searched PROSPERO to identify relevant protocols and contacted authors to determine if these reviews have been completed and published.

Search strategy. The search strategy associated with each of the 12 databases can be found here. We hand searched reference lists from any relevant umbrella reviews to identify systematic meta-analyses that our search may have missed.

Selection process. Using Covidence software (Veritas Health Innovation, Melbourne, Australia), two researchers independently screened all titles and abstracts. Two researchers then independently reviewed full-text articles. We resolved disagreements at each stage of the process by consensus, with a third researcher employed, when needed.

Data collection process. From each included meta-analysis, two researchers independently extracted data into a custom-designed database.

Data items. From each meta-analysis we extracted the following items: First author, year of publication, study design restrictions (e.g., cross-sectional, observational, experimental), region restrictions (e.g., specific countries), earliest and latest study publication dates, sample age (mean), lowest and highest mean age reported, outcomes reported, and exposures reported.

Study risk of bias assessment. For each meta-analysis, two researchers independently completed the National Health, Lung and Blood Institute's Quality Assessment of Systematic Reviews and Meta-Analyses tool [21] (see Table **??**). We resolved disagreements by consensus, with a third researcher employed when needed. We did not assess risk of bias in the individual studies that were included in each meta-analysis.

Effect measures. Two researchers independently extracted all quantitative meta-analytic effect sizes, including moderation results. Where possible, they also extracted effect sizes from primary studies included in each meta-analysis. To facilitate comparisons, we converted effect sizes to Pearson's r using established formulae [22–24]. We excluded relative risk ratios from this conversion because meta-analyses did not contain sufficient information to meaningfully convert. Effect sizes on the original metric are provided in Supplementary File 1.

Synthesis methods. After extracting data, we examined the combinations of exposure and outcomes and removed any effects that appeared more than once, keeping the effect with the largest total sample size. In instances where effect sizes from the same combination of exposure and outcome were drawn from different populations (e.g., children vs adolescents) we retained both estimates in our dataset.

We excluded effect size estimates when the authors did not provide a sample size. We descriptively present the remaining meta-analytic effect sizes. To remove the differences in approach to meta-analyses across the reviews, we reran the effect size estimate using a

random effects meta-analysis via the metafor package [25] in R [26] (version 4.1.3) when the meta-analysis's authors provided primary study data associated with these effects. When required, we imputed missing sample sizes using mean imputation from the other studies within that review. From our reanalysis we also extracted I^2 values. To test for publication bias, we conducted Egger's test [27] when the number of studies within the review was ten or more [28], and conducted a test of excess significance [29]. We contacted authors who did not provide primary study data in their published article. Where authors did not provide data in a format that could be re-analysed, we used the published results of their original meta-analysis.

Evidence assessment criteria. *Statistical Credibility.* We employed a statistical classification approach to grade the credibility of the effect sizes in the literature. To be considered 'credible' an effect needed to be derived from a combined sample of >1,000 [30] and have non-significant tests of publication bias (i.e., Egger's test and excess significance test). We performed these analyses, and therefore the review needed to provide usable study-level data in order to be included.

Consistency of Effect within the Population. We also examined the consistency of the effect size using the I^2 measure. We considered $I^2 < 50\%$ to indicate effects that were relatively consistent across the population of interest. I^2 values of $> 50\%$ were taken to indicate an effect was potentially heterogeneous within the population.

Direction of Effect. Finally, we examined the extent to which significance testing suggested screen exposure was associated with benefit, harm, or no effect on outcomes. We used thresholds of $P < .05$ for weak evidence and $P < 10^{-3}$ for strong evidence. An effect that was neither significant at $P < .05$ or 10^{-3} that also passed the criteria for statistical credibility was taken to indicate no association of interest.

Deviations from protocol. We initially planned to include systematic reviews without meta-analyses in a narrative summary alongside the main meta-analytic findings.

However, we determined that combining results from the meta-analyses allowed readers to compare relative strength of associations more easily. Readers interested in the relevant systematic reviews (i.e., without meta-analysis) can consult the list of references in Supplementary File 2.

We altered our evidence assessment plan when we identified that, as written, it could not classify precise evidence of null effects (i.e., from large reviews with low heterogeneity and low risk of publication bias) as 'credible' because a highly-significant P-value was a criteria. This would have significantly harmed knowledge gained from our review as it would have restricted our ability to show where the empirical evidence strongly indicated that there was no association between screen time and a given outcome.

Results

Search Results. The searches yielded 41,928 results, of which 24,023 were duplicates. After screening titles and abstracts, we assessed 1,964 full-texts for inclusion. Of those, 117 met the inclusion criteria and we extracted the data from all of these meta-analyses. Figure 1 presents the full results of the selection process.

The most frequently reported exposures were general TV programs and movies ($n = 26$), physically active video games ($n = 15$), screen-based lifestyle risk behaviour interventions (at school) ($n = 14$), and general screen use ($n = 13$). Supplementary File 3 provides a list of all exposures identified. The most frequently reported outcomes were body composition ($n = 34$), general physical activity ($n = 15$), general literacy ($n = 13$), general learning ($n = 12$), and sleep duration ($n = 9$). In most cases (121/197), there was only one exposure/outcome combination for an age group, with 20 appearing twice, and 8 appearing three or more times. Full characteristics of the included studies are provided in Table **??**. After removing reviews with duplicate exposure/outcome combinations, our process yielded 165 unique effect/outcome combinations contributed from 51 reviews. These effects

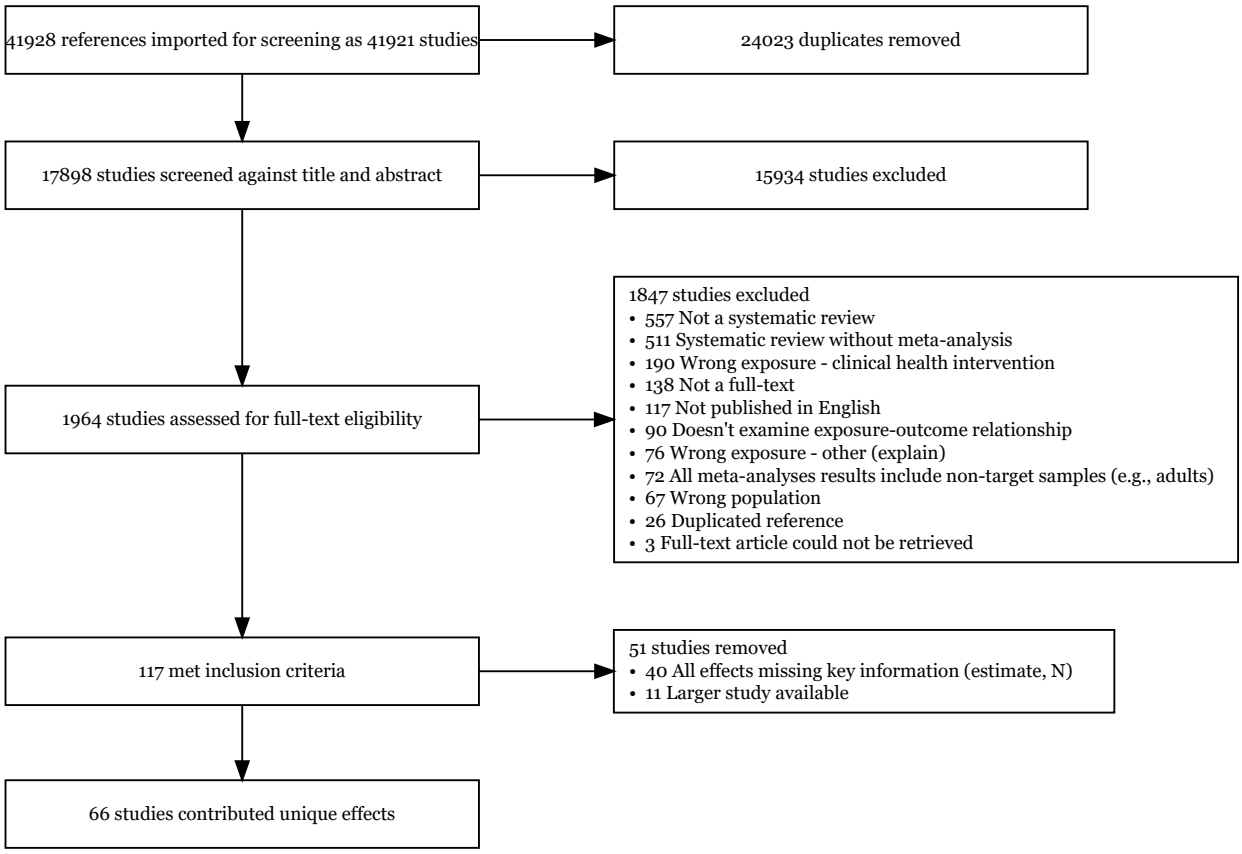

Figure 1. PRISMA Diagram

represent the findings of 2,171 primary studies comprised of 1,652,944 participants.

Table 1

Review characteristics for studies providing unique effects

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Abrami	2015	Include: Experimental; Quasi-experimental	None specified	2009 - 2015	Early childhood; School-age Children (Primary/Elementary)	Literacy: Listening comprehension Literacy: Phonics Literacy: Phonomic awareness Literacy: Reading comprehension Literacy: Reading fluency Literacy: Vocabulary knowledge	Intervention: Literacy (Abracadabra; in schools)
Adelantado-Renau	2019	Include: Cross-sectional studies	None specified	1982 - 2019	Children; Adolescents	Learning: General Literacy: General Numeracy: General	Screen use: General TV programs and movies: General Video games: General
Aghasi	2020	Include: Observational	None specified	2007 - 2016	All	Body composition	Internet use: General
Andrade	2019	Include: Interventions	None specified	2010 - 2017	Children; Adolescents	Healthy behavior: Self-efficacy Psychological health: Depression Psychological health: Enjoyment Self-perceptions: General Self-perceptions: Self-esteem	Video games: Physically active

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Bartel	2015	None	None specified	2004 - 2014	Adolescents	Sleep: Bedtime Sleep: Duration Sleep: Time to fall asleep	Computer use: General Internet use: General Screen use: General (mobile phone) TV programs and movies: General Video game console: General
Blok	2002	None	None specified	1990 - 2000	All	Literacy: Reading fluency	Intervention: Literacy
Bossen	2020	Include: Randomised controlled trials	None specified	2011 - 2018	Children	Body composition Cardiometabolic health: Fitness Physical activity: General Physical health: Muscular fitness	Video games: Health promoting content
Boyland	2016	Include: Experimental	None specified	2004 - 2015	Children; Adolescents	Diet: Food intake	Advertising: Unhealthy food
Byun	2018	Include: All quantitative designs	None specified	2006 - 2014	School-age Children	Numeracy: General	Video games: Numeracy
Carter	2016	Include: All quantitative designs	None specified	2011 - 2015	Children; Adolescents	Sleep: Inadequate duration Sleep: Lethargy Sleep: Poor quality	Screen use: General (mobile phone at bed time)

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Champion	2019	Include: Randomised controlled trials	None specified	2003 - 2017	School-age Children	Body composition Diet: Fat consumption Diet: Fruit and vegetable intake Diet: Fruit intake Diet: Sugary drinks and snacks Physical activity: General Physical activity: Moderate-to-vigorous intensity Risky behavior: Alcohol consumption Risky behavior: Smoking Screen time: General	Intervention: Lifestyle risk behaviour (at school)
Chan	2014	Include: Experimental; Quasi-experimental	None specified	2002 - 2012	School-age Children	Numeracy: General	Intervention: Dynamic geometry software
Cheung	2012	Include: Randomised controlled trials	None specified	1982 - 2010	School-age Children	Literacy: Reading	Intervention: Reading (in schools)
Cheung	2013	Include: Experimental; Quasi-experimental	None specified	1980 - 2010	School-age Children	Numeracy: General	Intervention: Mathematics (in schools)
Coyne	2018	None	None specified	1975 - 2017	Children; Adolescents	Prosocial Behavior: General	Screen use: Prosocial content

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Cushing	2010	Include: All quantitative designs; Experimental	None specified	1989 - 2009	Children; Adolescents	Healthy behavior: General	Intervention: Health behaviours
Darling	2017	Include: Intervention	None specified	2006 - 2016	Children; Adolescents	Body composition Diet: Healthy dietary behaviour Physical activity: General	Intervention: To promote health (via mobile phone)
de Oliveira	2016	Include: Observational	None specified	2010 - 2014	Adolescents	Cardiometabolic health: Metabolic Syndrome	Screen use: General
Fang	2019	Include: Cohort; Case-control; Cross-sectional	None specified	2006 - 2019	Children; Adolescents	Body composition	Computer use: General Screen use: General TV programs and movies: General
Ferguson	2017	None	None specified	2005 - 2017	Children; Adolescents	Risky behavior: Sexual activity Risky behavior: Sexual activity (initiation of sex)	Screen use: Sexual content
Folkvord	2018	Include: Interventions	None specified	2007 - 2018	Children; Adolescents	Diet: Food intake (calories)	Advertising: Advergames
Gardella	2017	Include: Cross-sectional	Include: North America	2006 - 2014	Adolescents	Learning: Educational achievement problems Learning: School attendance problems	Internet use: Cyberbullying victimization
Ghobadi	2018	Include: Cohort; Case-control; Cross-sectional Exclude: Interventions	None specified	2009 - 2014	Children; Adolescents	Body composition	TV programs and movies: Mealtime

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Graham	2015	Include: Experimental; Quasi-experimental	None specified	2004 - 2011	School-age Children (Primary/Elementary/Middle School)	Literacy: Writing	Intervention: Writing feedback
Hammersley	2016	Include: Randomised controlled trials	None specified	2003 - 2013	Children; Adolescents	Body composition	Intervention: To promote healthy weight (obesity prevention)
Hassan-Saleh	2019	Include: Experimental; Quasi-experimental	None specified	2008 - 2016	Children; Adolescents	Literacy: Pronunciation	Intervention: Pronunciation
Hernandez-Jimenez	2019	Include: Experimental; Quasi-experimental	None specified	2009 - 2017	Children; Adolescents	Body composition	Video games: Physically active
Hurwitz	2018	None	Include: North America	1997 - 2018	Early childhood/pre-school; School-age Children (Early Primary/Elementary)	Literacy: General	Intervention: Literacy videos
Janssen	2020	Include: Experimental; Cross-sectional; Longitudial	None specified	2007 - 2019	Children	Sleep: Duration	Screen use: General
Kates	2018	None	None specified	2008 - 2016	School-age Children	Learning: General	Screen use: General (mobile phone)
Kroesbergen	2003	Include: Within subject design; between subject design	None specified	1985 - 1999	School-age Children (Primary/Elementary)	Numeracy: General	Intervention: Mathematics (via computer in classrooms)

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Kucukalkan	2019	Include: Experimental	None specified	2007 - 2016	School-age Children (Primary/Elementary)	Numeracy: General	Intervention: Mathematics
Lanca	2020	Include: Cohort; Case-control; Cross-sectional; Intervention trials. Exclude: Case reports; Retrospective studies.	None specified	2007 - 2016	Children; Adolescents	Eye health: Myopia	Screen use: General
Li	2010	Include: Experimental; Quasi-experimental	None specified	1991 - 2005	School-age Children	Numeracy: General	Intervention: Mathematics
Liao	2008	Include: All quantitative designs	Include: Taiwan	1990 - 2003	School-age Children (Primary/Elementary)	Learning: General	Intervention: Education (via computer)
Liao	2014	Include: Randomised controlled trials	None specified	1999 - 2012	Children; Adolescents	Body composition	Intervention: Screentime reduction
Liu	2016	Include: Cross-sectional; Case-control; Longitudinal	None specified	2001 - 2014	All	Psychological health: Depression	Screen use: General
Liu	2019	Include: All quantitative designs	None specified	2007 - 2014	All	Psychological health: Anxiety Psychological health: Depression Psychological health: Satisfaction	Social Media: Instant messaging Video games: General

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Madigan	2020	Include: Observational Exclude: Qualitative	None specified	1973 - 2019	Children	Literacy: General	Intervention: Education (general) Screen use: General Screen use: General (coviewing) TV programs and movies: Coviewing TV programs and movies: Educational TV programs and movies: General TV programs and movies: General (in background)
Mares	2005	None	None specified	1969 - 1989	Children	Aggression: Towards peers Cognition: Reducing stereotypes Prosocial Behavior: Altruism Social interactions: General	TV programs and movies: General
Mares	2013	Exclude: Experimental	Exclude: North America	1973 - 2010	Children	Cognition: Moral reasoning and perception of out-groups Learning: General Learning: Literacy and numeracy Learning: Physical and social environment	Intervention: Sesame Street
Marshall	2004	None	None specified	1985 - 2002	Children; Adolescents	Body composition Physical activity: General	TV programs and movies: General Video games: General

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Martins	2019	Include: All quantitative designs	None specified	2003 - 2018	All	Aggression: Towards peers	Screen use: General
McArthur	2012	Include: Randomised controlled trials and quasi-RCTs.	None specified	1994 - 2009	All	Literacy: Phonics	Intervention: Literacy (phonics; via computer)
McArthur	2018	Include: Randomised controlled trials and quasi-RCTs.	Include: English speaking countries	1994 - 2015	Children; Adolescents	Literacy: General	Intervention: Literacy
Oldrati	2020	Include: Group-control experimental design	None specified	2006 - 2018	School-age Children	Cognition: Cognitive Functioning Cognition: Executive Functioning Cognition: Verbal skills Cognition: Visuospatial skills Numeracy: General Psychological health: Adjustment	Intervention: Cognitive training
Paik	1994	None	None specified	NA - NA	Children; Adolescents	Antisocial Behaviour: General	TV programs and movies: Violent content
Pearce	2016	Include: All quantitative designs	None specified	1986 - 2012	Children; Adolescents	Psychological health: Internalizing	TV programs and movies: Scary content

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Peng	2011	None	None specified	2001 - 2010	Children; Adolescents	Cardiometabolic health: Maximum oxygen consumption Physical activity: Energy expenditure Physical activity: Heart rate	Video games: Physically active
Poorolajal	2020	Include: Observational	None specified	1995 - 2018	Children; Adolescents	Body composition	TV programs and movies: General Video games: General
Prescott	2018	Include: Longitudinal	None specified	2008 - 2017	All	Aggression: Towards peers	Video games: Violent content
Rodriguez-Rocha	2019	Include: Experimental; Quasi-experimental	None specified	1999 - 2018	All	Diet: Fruit and vegetable intake	Intervention: Fruit and vegetable
Sadeghirad	2016	Include: Randomised controlled trials	None specified	1978 - 2014	Children; Adolescents	Diet: Unhealthy food choice	Advertising: Unhealthy food
Schroeder	2013	Include: Experimental; Quasi-experimental	None specified	2001 - 2009	All	Learning: General	Intervention: With digital characters
Scionti	2019	Include: Interventions	None specifed	2009 - 2019	Children	Cognition: Executive functioning	Intervention: Cognitive training

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Shin	2019	Include: Interventions	None specified	2013 - 2018	Children; Adolescents	Body composition Diet: Sugary drinks Physical activity: General Screen time: General	Intervention: To promote health (via mobile phone app) Intervention: To promote health (via mobile phone) Intervention: To promote health (via text message)
Slavin	2014	Include: Randomised controlled trials; Quasi-experimental; Observational	None specified	2000 - 2011	School-age Children (Primary/Elementary)	Science: General	Intervention: Science (in schools)
Takacs	2014	Include: Experimental; Quasi-experimental	None specified	1980 - 2014	NA	Learning: General	e-Books: Narration
Takacs	2019	Include: Randomised controlled trials and quasi-RCTs.	None specified	2001 - 2016	Children	Cognition: Executive Functioning (accuracy) Cognition: Executive Functioning (cognitive flexibility) Cognition: Executive Functioning (inhibition) Cognition: Executive Functioning (working memory)	Intervention: Education (via computer)
Tekedere	2016	None	None specified	2010 - 2015	All	Learning: General	Intervention: Augmented reality (in schools)

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Vahedi	2018	Include: Interventions (pre-post or controlled). Exclude: Cross-sectional	None specified	2015 - 2016	School-age Children (Middle/High School)	Risky behavior: Media literacy Risky behavior: Risk taking (attitude)	Intervention: Media literacy (web-based)
Vannucci	2020	Exclude: Qualitative; Case studies	None specified	2011 - 2018	Adolescents	Risky behavior: Risk taking (general) Risky behavior: Risky sexual behaviour Risky behavior: Substance abuse	Social Media: General
Xie	2018	Include: Experimental; Quasi-experimental; Pre-test post-test	None specified	2010 - 2018	Children	Learning: General	Intervention: Education (via touch screen)
Zhang	2016	Include: Cohort; Case-control; Cross-sectional	None specified	2001 - 2014	Children	Body composition	TV programs and movies: General
Zhou	2020	Exclude: Non-empirical studies; Qualitative; Systematic reviews or meta-analyses	None specified	2009 - 2018	All	Healthy behavior: General Healthy behavior: Self-efficacy Psychological health: Enjoyment	Video games: Health promoting content

Table 1

Review characteristics for studies providing unique effects (continued)

First Author	Year	Design Restrictions	Regions Restrictions	Study Range	Sample Age Restrictions	Outcomes Assessed	Exposures Assessed
Zucker	2009	Include: Randomised controlled trials; Quasi-experimental; Observational	None specified	1997 - 2006	School-age Children (Primary/Elementary)	Literacy: Decoding Literacy: Reading comprehension	e-Books: General

*

The quality of the included meta-analyses was mixed (see Table **??**). Most assessed heterogeneity (n low risk = 59/66, 89% of meta-analyses), reported the characteristics of the included studies (n low risk = 57/66, 86%), and used a comprehensive and systematic search strategy (n low risk = 56/66, 85%). Most reviews did not clearly report if their eligibility criteria were predefined (n unclear = 45/66, 68%). Many papers also did not complete dual independent screening of abstracts and full text (n high risk = 16/66, 24%) or did not clearly report the method of screening (n unclear = 21/66, 32%). A similar trend was observed for dual independent quality assessment (n high risk = 31/66, 47%; n unclear = 19/66, 29%). Overall, only 5 meta-analyses were graded as low risk of bias on all criteria.

Education Outcomes. There were 46 unique effects associated with education outcomes, including general learning outcomes, literacy, numeracy, and science. We removed 20 effects that did not provide individual study-level data, 7 effects with samples $<$ 1,000, and 8 effects with a significant Egger's test or insufficient studies to conduct the test. Effects not meeting one or more of these standards are presented in Supplementary File 4. The remaining 12 effects met our criteria for statistical credibility and are described in Figure 2. These 12 effects came from 8 meta-analytic reviews analysing data from 226 empirical studies with 186,631 individual participants.

Among the statistically credible effects, general screen use, television viewing, and video games were all negatively associated with learning. E-books that included narration, as well as touch screen education interventions, and augmented reality education interventions were positively associated with learning. General screen use was negatively associated with literacy outcomes. However, if the screen use involved co-viewing (e.g., watching with a parent), or the content of television programs was educational, the association with literacy was positive and significant at the 95% confidence level (weak evidence). Numeracy outcomes were positively associated with screen-based mathematics interventions and video games that contained numeracy content.

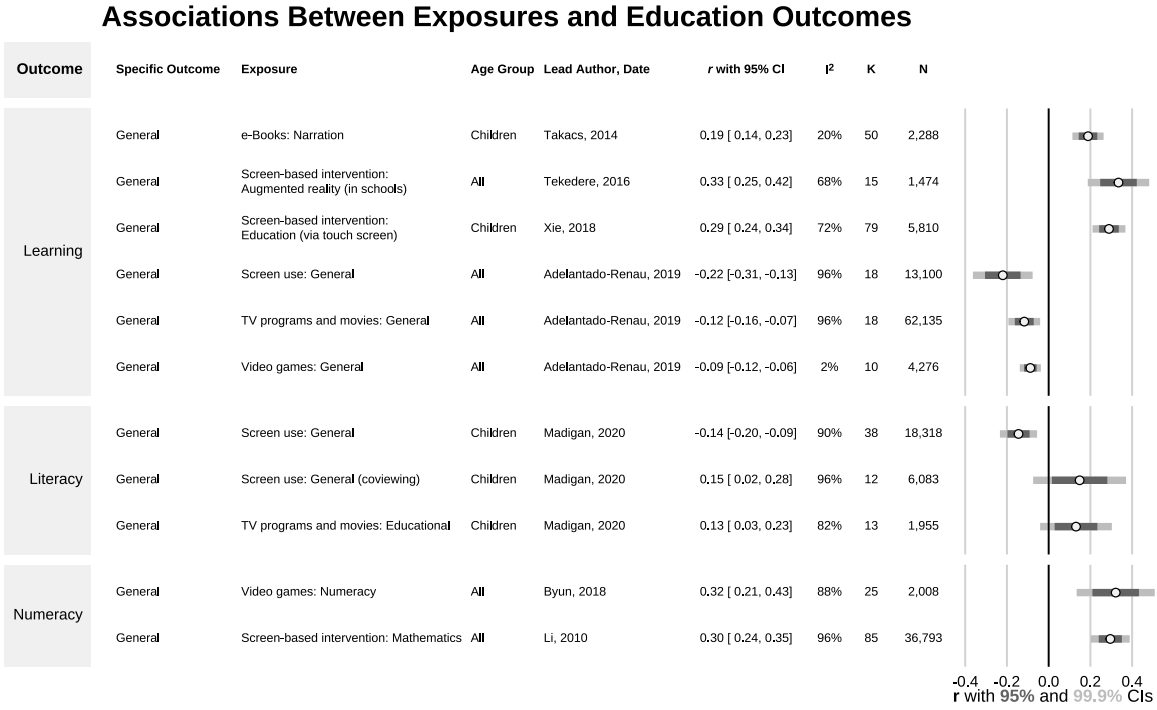

Figure 2. Education outcomes

As shown in Figure 2, most of the credible results (10 of 12 effects) showed statistically significant associations, with 99.9% confidence intervals not encompassing zero (strong evidence). The remaining two associations were significant at the 95% confidence level (weak evidence). All credible effects related to education outcomes were small-to-moderate. Screen-based interventions designed to influence an outcome (e.g., a computer based program designed to enhance learning [31]) tended to have larger effect sizes than exposures that were not specifically intended to influence any of the measured outcomes (e.g., the association between television viewing and learning [32]). The largest effect size observed was for augmented reality-based education interventions on general learning ($r = 0.33, k = 15, N = 1,474$). Most effects showed high levels of heterogeneity (10 of 12 with $I^2 > 50\%$).

Health and Health-related Behaviours. We identified 119 unique outcome-exposure combinations associated with health or health-related behaviour

outcomes. We removed 31 effects that did not provide individual study-level data, 30 effects with samples < 1,000, and 43 effects with a significant Egger's test or insufficient studies to conduct the test. No remaining studies showed evidence of excessive significance. Effects not meeting one or more of these standards are presented in Supplementary File 5. The remaining 17 meta-analytic associations met our criteria for credible evidence and are described below (see also Figure 3). These 17 effects came from 12 meta-analytic reviews analysing data from 231 empirical studies with 676,331 individual participants.

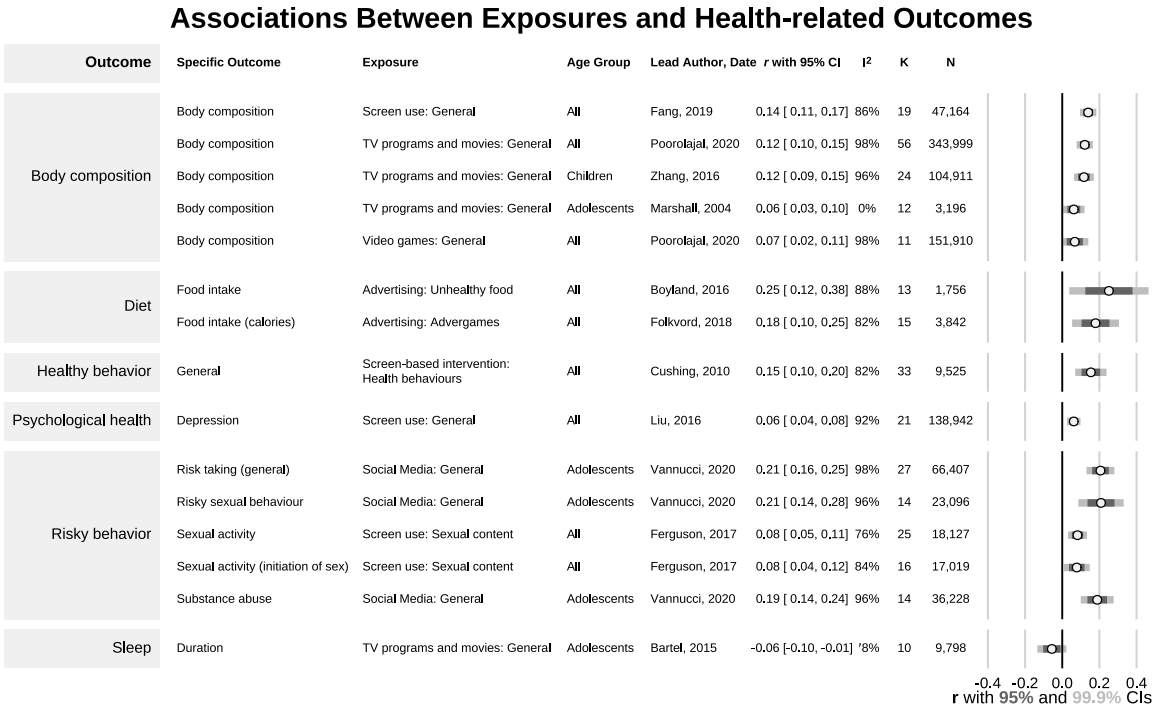

Figure 3. Health and health-related behaviour outcomes

Digital advertising of unhealthy foods—both traditional advertising and video games developed by a brand for promotion—were associated with higher unhealthy food intake. Social media use and sexual content were positively associated with risky behaviors (e.g., sexual activity, risk taking, and substance abuse). General screen use was positively associated with depression. Television viewing was negatively correlated with sleep duration, but only at the 95% confidence level (weak evidence). All forms of screen use

(general, television, and video games) were associated with body composition (e.g., higher BMI), although the association was smaller for children than for adolescents or for combined populations. Screen-based interventions which target health behaviours appeared effective.

Across the health outcomes, most (14 of 17) effects were statistically significant at the 99.9% confidence interval level, with the remaining three significant at 95% confidence. However, most of the credible effects exhibited high levels of heterogeneity, with all but one having $I^2 > 75\%$. Additionally, most effects were small, with the association between unhealthy food advertising and intake the largest at $r = 0.25$ ($k = 13, N = 1,756$). Most of the effect sizes (14/17) had an absolute value of $r < 0.2$.

Discussion

The primary goal of this review was to provide a holistic perspective on the influence of screens on children's lives across a broad range of outcomes. We found that when meta-analyses examined general screen use, and did not specify the content, context or device, there was strong evidence showing potentially harmful associations with general learning, literacy, body composition, and depression. However, when meta-analyses included a more nuanced examination of exposures, a more complex picture appeared.

As an example, consider children watching television programs—an often cited form of screen time harm. We found robust evidence for a small association with poorer academic performance and literacy skills [32]. However, we also found evidence that if the content of the program was educational, or the child was watching the program with a parent (i.e., co-viewing), this exposure was instead associated with better literacy [33]. Thus, parents may play an important role in selecting content that is likely to benefit their children or, perhaps, interact with their children in ways that may foster literacy (e.g., asking their children questions about the program). Similar nuanced findings were

observed for video games. The credible evidence we identified showed that video game playing was associated with poorer body composition and learning [32,34]. However, when the video game were designed specifically to teach numeracy, playing these games showed learning benefits [35]. One might expect that video games designed to be physically active could confer health benefits, but none of the meta-analyses examining this hypothesis met our thresholds for statistical credibility (see Supplementary Files 4 & 5) therefore this hypothesis could not be addressed.

Social media was one type of exposure that showed consistent risks to health, with no indication of potential benefit. Social media showed strong evidence of harmful associations with risk taking in general, as well as unsafe sex and substance abuse [36]. These results align with meta-analytic evidence from adults indicating that social media use is also associated with increased risk of depression [37,38]. Recent evidence from social media companies themselves suggest there may also be negative effects of social media on the mental health of young people, especially teenage girls [39].

One category of exposure appeared to consistently confer benefits: screen-based interventions designed to promote learning or health behaviours. This finding indicates that interventions can be effectively delivered using electronic media platforms, but does not necessarily indicate that screens are more effective than other methods (e.g., face-to-face, printed material). Rather, it reinforces that the content of the screen time may be the most important aspect. The way that a young person interacts with digital screens may also be important. We found evidence that touch screens had strong evidence for benefits on learning [31], as did augmented reality [40].

Largely owing to a small number of studies or missing individual study data, there were few age-based conclusions that could be drawn from reviews which met our criteria for statistical certainty. If we expand to include those reviews which did not meet this threshold, there remained no clear pattern although there were some age-specific

differences in associations (data avilable in Supplementary Materials). For example, advertising of unhealthy food was associated with unhealthy food choice for young children, but was not statistically significant for other age groups [41]. Conversely, TV programs and movies were more strongly associated with lower physical activity for adolescents than for younger age groups [42].

Among studies that met our criteria for statistical certainty heterogeneity was high, with almost all effects having $I^2 > 50\%$. Much of this heterogeneity is likely explained by differences in measures across pooled studies, or in some cases, the generic nature of some of the exposures. For example, "TV programs and movies" covers a substantial range of content, which may explain the heterogeneous association with education outcomes.

Implications for Policy and Practice

Broadly, our findings align with the recommendations of others who suggest that current guidelines may be too simplistic, mischaracterise the strength of the evidence, or do not acknowledge the important nuances of the issue [43–45]. Our findings suggest that screen use is a complex issue, with associations based not just on duration and device type, but also on the content and the environment in which the exposure occurs. Many current guidelines simplify this complex relationship as something that should be minimised in all instances [12,13]. We suggest that future guidelines need to embrace the complexity of the issue, to give parents and clinicians specific information to weigh the pros and cons of interactions with screens.

Implications for Future Research

Screen use research is extensive, varied, and rapidly growing. Reviews tended to be general (e.g., all screen time) and even when more targeted (e.g., social media) nuances related to specific content (e.g., Instagram vs Facebook) have not been meta-analysed or have not produced credible evidence. Fewer than 20% of the effects identified met our

criteria for statistical credibility. Most studies which did not meet our critiera failed to provide study-level data (or did not provide sufficent data, such as including effect estimates but not sample sizes). Newer reviews were more likely to provide this information than older reviews, but it highlights the importance of data and code sharing as recommended in the PRISMA guidelines [46]. When study level data was available, many effects were removed because the pooled sample size was small, or because there were fewer than ten studies on which to perform an Egger's test. It seems that much of the current screen time research is small in scale, and there is a need for larger, high-quality studies.

Screen time research has a well-established measurement problem, which impacts the individual studies of this umbrella review. The vast majority of screen time research relies on self-reported data, which not only lacks the nuance required for understanding the effects of screen time, but may also be inaccurate. In one systematic review on screen time and sleep [7], 66 of the 67 included studies used self-reported data for *both* the exposure and outcome variable. It has been established that self-reported screen time data has questionnable validity. In a meta-analysis of 47 studies comparing self-reported media use with logged measures, Parry et al [47] found that the measures were only moderately correlated ($r = 0.38$), with self-reported problematic usage fairing worse ($r = 0.25$). Indeed, of 622 studies which measured the screen time of 0—6 year-olds, only 69 provided any sort of psychometric properties for their measure, with only 19 studies reporting validity [48]. While some researchers have started using newer methods of capturing screen behaviours—such as wearable cameras [49] or device-based loggers [50]—these are still not widely adopted. It may be that the field of screen time research cannot be sufficiently advanced until accurate, validated, and nuanced measures are more widely available and adopted.

Strengths and Limitations

Our primary goal for this umbrella review was to provide a high-level synthesis of screen time research, by examining a range of exposures and the associations with a broad scope of outcomes. Our results represent the findings from 2,171 primary studies comprised of 1,652,944 participants. To ensure findings could be compared on a common metric, we extracted and reanalysed individual study data where possible.

Our high-level approach limits the feasibility of examining fine-grained details of the individual studies. For example, we did not examine moderators beyond age, nor did we rate the risk of bias for the individual studies. Thus, our assessment of evidence quality was restricted to statistical credibility, rather than a more complete assessment of quality (e.g., GRADE [51]). As such, we made decisions regarding the credibility of evidence, where others may have used different thresholds or metrics. For this reason, we provide the complete results in the supplementary material, along with the dataset for others to consider alternative criteria. In addition, reviews provide only historical evidence which may not keep up with the changing ways children can engage with screens. While our synthesis of the existing evidence provides information about how screens might have influenced children in the past, it is difficult to know if these findings will translate to new forms of technology in the future.

Conclusions

Screen time is a topic of significant interest, as shown by the wide variety of academic domains involved, parents' concerns, and the growing pervasiveness into society. Our findings showed that the impact of screen time can be both positive (e.g., educational video games were associated with improved literacy) and negative (e.g., general screen use was associated with poorer body composition). The interplay of these findings show that parents, teachers, and other caregivers need to carefully weigh the pros and cons of each specific activity for potential harms and benefits. However, our findings also suggest that

in order to aid caregivers to make this judgement, researchers need to conduct more careful and nuanced measurement and analysis of screen time, with less emphasis on measures that aggregate screen time and instead focus on the content, context, and environment in which the exposure occurs.

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