

An umbrella review of the benefits and risks associated with youths' interactions with
electronic screens

Taren Sanders^{*1}, Michael Noetel², Philip Parker¹, Borja Del Pozo Cruz^{3, 14, 15}, Stuart
Biddle^{4, 13}, Rimante Ronto⁵, Ryan Hulteen⁶, Rhiannon Parker⁷, George Thomas⁸, Katrien
De Cocker⁹, Jo Salmon¹⁰, Kylie Hesketh¹⁰, Nicole Weeks¹, Hugh Arnott¹, Emma Devine¹¹,
Roberta Vasconcellos¹, Rebecca Pagano¹², Jamie Sherson¹², James Conigrave¹, & Chris
Lonsdale¹

¹ Institute for Positive Psychology and Education, Australian Catholic University, North
Sydney, Australia

² School of Psychology, University of Queensland, Brisbane, Australia

³ Department of Sport Science and Clinical Biomechanics, University of Southern Denmark,
Odense, Denmark

⁴ Centre for Health Research, University of Southern Queensland, Springfield, Australia

⁵ Department of Health Sciences, Faculty of Medicine, Health and Human Sciences,
Macquarie University, Macquarie Park, Australia

⁶ School of Kinesiology, Louisiana State University, Baton Rouge, USA

⁷ The Centre for Social Impact, University of New South Wales, Sydney, Australia

⁸ The University of Queensland, Health and Wellbeing Centre for Research Innovation,
School of Human Movement and Nutrition Sciences, Brisbane, Australia

⁹ Department of Movement and Sport Science, Ghent University, Ghent, Belgium

¹⁰ Institute for Physical Activity and Nutrition, Deakin University, Geelong, Australia

¹¹ The Matilda Centre for Research in Mental Health and Substance Use, University of
Sydney, Sydney, Australia

¹² School of Education, Australian Catholic University, North Sydney, Australia

¹³ Faculty of Sport & Health Sciences, University of Jyväskylä, Finland

¹⁴ Department of Physical Education, Faculty of Education, University of Cádiz, Cádiz,
Spain

¹⁵ Biomedical Research and Innovation Institute of Cádiz (INiBICA) Research Unit, Puerta
del Mar University Hospital, University of Cádiz, Cádiz, Spain

Author Note

Correspondence concerning this article should be addressed to Taren Sanders*,
Berry St, North Sydney, NSW, Australia. E-mail: Taren.Sanders@acu.edu.au

Abstract

The influence of electronic screens on children and adolescents' health and education is not well understood. In this prospectively registered umbrella review (PROSPERO; CRD42017076051), we harmonised effects from 102 meta-analyses (2,451 primary studies; 1,937,501 participants) on screen time and outcomes. 43 effects from 32 meta-analyses met our criteria for statistical certainty. Meta-analyses of associations between screen use and outcomes showed small-to-moderate effects (range: $r = -0.14$ - 0.33). In education, results were mixed; for example, screen use was negatively associated with literacy ($r = -0.14$, 95% confidence interval [CI] -0.20 to -0.09 , $p = <0.001$, $k = 38$, $N = 18,318$), but this effect was positive when parents watched with their children ($r = 0.15$, 95% CI 0.02 to 0.28 , $p = 0.028$, $k = 12$, $N = 6,083$). In health, we found evidence for several small negative associations; for example, social media was associated with depression ($r = 0.12$, 95% CI 0.05 to 0.19 , $p = <0.001$, $k = 12$, $N = 93,740$). Limitations include a limited number of studies for each outcome, medium-to-high risk of bias in 95/102 included meta-analyses and high heterogeneity (17/22 in education and 20/21 in health with $I^2 > 50\%$). We recommend that caregivers and policymakers carefully weigh the evidence for potential harms and benefits of specific types of screen use.

Keywords:

Word count: 5312

An umbrella review of the benefits and risks associated with youths' interactions with electronic screens

Introduction

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.¹ 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.² 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.³

Today, the same arguments that were once levelled against reading, schooling, and radio are being made about screen use (e.g., television, mobile phones, and computers).⁴ Excessive screen use is the number one concern parents in Western countries have about their children’s health and behaviour, ahead of nutrition, bullying, and physical inactivity.⁵ Yet, the evidence to support parents’ concerns is inadequate. A Lancet editorial⁶ 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., excessive 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, an overview that identifies potential benefits and risks is needed.

Citing the negative associations between screen use and health (e.g., increased risk of obesity) and health-related behaviours (e.g., sleep), guidelines from the World Health Organisation¹² and numerous government agencies^{13,14} and statements by expert groups¹⁵ 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 no more than one hour engaged in recreational sedentary screen use per day, while children aged 5-12 and adolescents should spend no more than two hours. However, recent evidence suggests that longer exposures may not have adverse effects on children's behaviour or mental health—and might, in fact, benefit their well-being—as long as 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 use is positively related to educational outcomes.¹⁸ This evidence has led some researchers to argue that a more nuanced approach to screen use 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 media²⁰ 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. While there have been other overviews of reviews on screen use, these have tended to focus on a single domain (e.g., health²¹), focus on a particular exposure (e.g., social media^{22,23}) or provide only a narrative summary of the literature.²⁴ Focusing on a single domain or exposure makes it difficult to understand what trade-offs are involved in any guidelines around screen use. For example, prohibiting screen use might reduce exposure to advertising but may also thwart learning opportunities from interactive educational tools. Reviews on

either of these exposures or outcomes would likely miss being able to quantify these trade-offs. Overviews are one method of evidence synthesis that helps address these trade-offs, by providing ‘user-friendly’ summaries of a field of research.²⁵ These overviews provide a reference point for the field and allow for easier comparison of risks and benefits for the same behaviour. By analogy, reading is a sedentary behaviour, and only by comparing the health risks against the educational benefits can researchers and policymakers make clear recommendations about what young people should do.

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 outcome of electronic media exposure. We deliberately did not pre-specify outcomes, in order to get a list of areas where there is meta-analytical evidence. Adopting this broad approach allowed us to provide a holistic perspective on the associations between screen time and different aspects of 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.

Results

The searches yielded 50,649 results, of which 28,675 were duplicates. After screening titles and abstracts, we assessed 2,557 full-texts for inclusion. Of those, 217 met the inclusion criteria^{26–242} 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 physically active video games ($n = 31$), general screen use ($n = 27$), general TV programs and movies ($n = 20$), and screen-based interventions to promote health ($n = 14$). Supplementary File 1 provides a list of all exposures identified. The most frequently reported outcomes were body composition ($n = 30$), general learning ($n = 24$), depression ($n = 13$), and general literacy ($n = 12$). Of the 273 unique exposure/outcome combinations, 241 occurred in only one review, with 23 appearing twice, and 9 appearing three or more times. Full characteristics of the included studies are provided in Supplementary File 2. After removing reviews with duplicate exposure/outcome combinations, our process yielded 252 unique effect/outcome combinations (retaining multiple effects for different age groups or study designs) contributed from 102 reviews. These effects represent the findings of 2,451 primary studies, involving 1,937,501 participants. The characteristics of the included effects are available in Supplementary File 3.

TABLE 1

The quality of the included meta-analyses was mixed (see Table 1). Most assessed heterogeneity (n low risk = 93/102, 91% of meta-analyses), reported the characteristics of the included studies (n low risk = 86/102, 84%), and used a comprehensive and systematic search strategy (n low risk = 71/102, 70%). Most reviews did not clearly report if their eligibility criteria were predefined (n unclear = 71/102, 70%). Many papers also did not complete dual independent screening of abstracts and full text (n high risk = 20/102, 20%) or did not clearly report the method of screening (n unclear = 37/102, 36%). A similar trend

was observed for dual independent quality assessment (n high risk = 52/102, 51%; n high risk = 19/102, 19%). Overall, only 7 meta-analyses were graded as low risk of bias on all criteria.

Education Outcomes

There were 88 unique effects associated with education outcomes, including general learning outcomes, literacy, numeracy, and science. We removed 28 effects that did not provide individual study-level data, 19 effects with samples $< 1,000$, and 19 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 22 effects met our criteria for statistical credibility and are described in Figure 2. These 22 effects came from 17 meta-analytic reviews analysing data from 337 empirical studies with 262,497 individual participants.

Among the statistically credible effects, general screen use ($r = -0.11$, 95% confidence interval [CI] -0.24 to 0.01, $p = 0.071$, $k = 18$, $N = 13,100$), television viewing ($r = -0.10$, 95% CI -0.15 to -0.04, $p = <0.001$, $k = 18$, $N = 62,135$), and video games ($r = -0.08$, 95% CI -0.12 to -0.04, $p = <0.001$, $k = 10$, $N = 4,276$) were all negatively associated with learning. E-books that included narration ($r = 0.11$, 95% CI 0.05 to 0.17, $p = <0.001$, $k = 50$, $N = 2,288$), as well as touch screen education interventions ($r = 0.21$, 95% CI 0.15 to 0.28, $p = <0.001$, $k = 79$, $N = 5,810$), and augmented reality education interventions ($r = 0.33$, 95% CI 0.25 to 0.42, $p = <0.001$, $k = 15$, $N = 1,474$) were positively associated with learning. General screen use was negatively associated with literacy outcomes ($r = -0.14$, 95% CI -0.20 to -0.09, $p = <0.001$, $k = 38$, $N = 18,318$). However, if the screen use involved co-viewing (e.g., watching with a parent; $r = 0.15$, 95% CI 0.02 to 0.28, $p = 0.028$, $k = 12$, $N = 6,083$), or the content of television programs was educational ($r = 0.13$, 95% CI 0.03 to 0.23, $p = 0.012$, $k = 13$, $N = 1,955$), 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 ($r = 0.27$, 95% CI 0.21 to 0.33, $p =$

<0.001 , $k = 85$, $N = 36,793$) and video games that contained numeracy content ($r = 0.32$, 95% CI 0.21 to 0.43, $p = <0.001$, $k = 25$, $N = 2,008$).

As shown in Figure 2, most of the credible results (13 of 22 effects) showed statistically significant associations, with 99.9% confidence intervals not encompassing zero (strong evidence). The remaining six 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;²³⁰ $r = 0.21$, 95% CI 0.15 to 0.28, $p = <0.001$, $k = 79$, $N = 5,810$) 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;²⁹ $r = -0.10$, 95% CI -0.15 to -0.04, $p = <0.001$, $k = 18$, $N = 62,135$). The largest effect size observed was for augmented reality-based education interventions on general learning ($r = 0.33$, 95% CI 0.25 to 0.42, $p = <0.001$, $k = 15$, $N = 1,474$). Most effects showed high levels of heterogeneity (17 of 22 with $I^2 > 50\%$).

Health-related Outcomes

We identified 163 unique outcome-exposure combinations associated with health or health-related behaviour outcomes. We removed 39 effects that did not provide individual study-level data, 50 effects with samples $< 1,000$, and 53 effects with a significant Egger's test or insufficient studies to conduct the test. No remaining studies had statistically significant tests for excess significance. Effects not meeting one or more of these standards are presented in Supplementary File 5. The remaining 21 meta-analytic associations met our criteria for credible evidence and are described below (see also Figure 3). These 21 effects came from 15 meta-analytic reviews analysing data from 344 empirical studies with 859,562 individual participants.

Digital advertising of unhealthy foods—both traditional advertising ($r = 0.23$, 95% CI

0.10 to 0.37, $p = <0.001$, $k = 13$, $N = 1,756$) and video games developed by a brand for promotion ($r = 0.18$, 95% CI 0.10 to 0.25, $p = <0.001$, $k = 15$, $N = 3,842$)—were associated with higher unhealthy food intake. Social media use and sexual content were positively associated with risky behaviors (e.g., social media and risky sexual behaviour; $r = 0.21$, 95% CI 0.14 to 0.28, $p = <0.001$, $k = 14$, $N = 23,096$). Television viewing was negatively correlated with sleep duration, but with stronger evidence only observed for adolescents ($r = -0.06$, 95% CI -0.10 to -0.01, $p = 0.018$, $k = 10$, $N = 9,798$). Both television and video games were associated with body composition (e.g., television $r = 0.06$, 95% CI 0.03 to 0.10, $p = <0.001$, $k = 12$, $N = 3,196$). Screen-based interventions which target health behaviours appeared mostly effective.

Across the health outcomes, most (14 of 21) effects were statistically significant at the 99.9% confidence interval level, with the remaining four significant at 95% confidence. However, most of the credible effects exhibited high levels of heterogeneity, with all but two having $I^2 > 75\%$. Additionally, most effects were small, with the association between internet use and depression the largest at $r = 0.25$ (95% CI 0.22 to 0.27, $p = <0.001$, $k = 118$, $N = 527,696$). Most of the effect sizes (17/21) had an absolute value of $r < 0.2$.

Discussion

The primary goal of this review was to provide a holistic perspective on the association between screen use and a broad range of health- and education-related aspects of children's lives. 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 use harm. We found evidence for a small association with poorer academic performance and literacy skills for general television watching²⁹. 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.¹⁴³ 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.^{29,173} However, when the video game were designed specifically to teach numeracy, playing these games showed learning benefits.⁵² 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—albeit small—associations with poor 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.²¹⁸ These results align with meta-analytic evidence from adults indicating that social media use is also associated with increased risk of depression.^{214,233} 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.²⁴³

One category of exposure appeared to be consistently associated with 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 use 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,²³⁰ as did augmented reality.²⁰⁷

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. Given the differences in development across childhood and adolescence and the different ways children of various ages use screens, further examination of age-based differences is needed. However, in the absence of this work, our study has shown how children are affected by screens in general.

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.

Our results have several 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.²⁴⁴⁻²⁴⁶ 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.^{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.

Given our results, we support the continuing trend of guidelines moving away from recommendations to reduce ‘screen use’, and instead focusing on the type of screen use. For

example, we suggest that guidelines should discourage high levels of social media and internet use. Guidelines may also consider adapting recommendations that promote the use of educational apps and video games, although these recommendations need to be balanced against the (very small) risks to adiposity.¹⁵¹

Our results also have implications for future research. Screen use research is extensive, varied, and rapidly growing. Reviews tended to be general (e.g., all screen use) 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 criteria failed to provide study-level data (or did not provide sufficient 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.²⁴⁷ 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 use research is small in scale, and there is a need for larger, high-quality studies.

Our results highlight the need for the field to more carefully consider if the term 'screen use' remains appropriate for providing advice to parents. Instead, our results suggest that more nuanced and detailed descriptions of the behaviours to be modified may be required. Rather than suggesting parents limit 'screen use', for example, it may be better to suggest that parents promote interactive educational experiences but limit exposure to advertising.

Screen use research has a well-established measurement problem, which impacts the individual studies of this umbrella review. The vast majority of screen use research relies on self-reported data, which not only lacks the nuance required for understanding the effects of screen use, but may also be inaccurate. In one systematic review on screen use 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 use data has questionable validity. In a meta-analysis of 47 studies comparing self-reported media use with logged measures, Parry et al²⁴⁸ 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 use of 0–6 year-olds, only 69 provided any sort of psychometric properties for their measure, with only 19 studies reporting validity.²⁴⁹ While some researchers have started using newer methods of capturing screen behaviours—such as wearable cameras²⁵⁰ or device-based loggers²⁵¹—these are still not widely adopted. It may be that the field of screen use research cannot be sufficiently advanced until accurate, validated, and nuanced measures are more widely available and adopted.

There were a number of strengths and limitations to our work. Our primary goal for this umbrella review was to provide a high-level synthesis of screen use research, by examining a range of exposures and the associations with a broad scope of outcomes. Our results represent the findings from 2,451 primary studies comprised of 1,937,501 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., GRADE²⁵²). As such, we made decisions regarding the credibility of evidence, where others may have used different thresholds or metrics. In addition, when faced with duplicate outcome/exposure combinations we chose to keep the one with the largest pooled sample size, assuming that this would capture the most comprehensive and most recent review. Inspection of the excluded effect sizes suggests that this decision was not that impactful: our

results would have been almost exactly the same as we used the number of included studies (k) or the most recent review by publication year. However, we provide the complete results in Supplementary Files 4 & 5, along with the dataset (Supplementary File 6) for others to consider alternative criteria.

Our high-level approach also means that we could not engage with the specific mechanisms behind each association, and as such, we cannot make claims on the directions of causality. These likely depend on the specific exposure and outcome. It is tempting to draw inferences that the associations are due to screen use causing these outcomes, but we cannot rule out reverse causality, a third variable, or some combination of influences. Many of the individual reviews go into more detail about the strength of the evidence for causal associations, but those judgements were difficult to synthesise across more than 200 reviews. Readers who wish to more deeply understand one specific relationship are directed to the cited review for that effect, where the authors could engage more deeply with the mechanisms.

We converted all effect sizes to a common metric (Pearson's r) to allow for comparisons of magnitude, but acknowledge that this assumes a linear relationship between the variables. Some previous research suggests that associations are typically linear.¹⁸ However, others have identified instances where non-linear relationships exist, especially for very high levels of screen use.^{17,253,254} Additionally, our conversion may not always adequately account for differences in study design or measures of exposures and outcomes. Care is needed, therefore, when interpreting the effect sizes. 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.

Screen use 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 screen use is associated with 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) outcomes. Based on our findings, we recommend that parents, teachers, and other caregivers need to carefully weigh the evidence for pros and cons of each specific activity for potential harms and benefits. However, our findings also lead us to suggest that in order to aid caregivers to make this judgement, researchers need to conduct more careful and nuanced measurement and analysis of screen use, with less emphasis on measures that aggregate screen use and instead focus on the content, context, and environment in which the exposure occurs.

Methods

We prospectively registered our methods on the International Prospective Register of Systematic Reviews (PROSPERO; CRD42017076051) in October 2017. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.²⁴⁷

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 mean age for any individual study included in the meta-analysis was < 18 years). A meta-analysis was still included if the age range exceed 18 years, provided that the mean age was less than 18. 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 focused on electronic media exposure that would be considered typical for children and youth. That is, exposure that may occur in the home setting, or during schooling. Consistent with this 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 on benefits and risks.

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 September 27, 2022. 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 in Supplementary File 7. 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 items. From each included meta-analysis, two researchers independently

extracted data into a custom-designed database. 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 tool²⁵⁵ (see Table 1). 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. We excluded effect sizes which were reported as relative risk ratios or odds ratios, as meta-analyses did not contain sufficient information to meaningfully convert to a correlation. We also excluded effect size estimates when the authors did not provide a sample size. Where possible, we also extracted effect sizes from the primary studies included in each meta-analysis.

To facilitate comparisons, we converted effect sizes to Pearson's r using established formulae.^{256,257} Effect sizes on the original metric are provided in Supplementary File 6. Throughout the results section we interpret the size of the effects using Funder and Ozer's guidelines:²⁵⁸ very small ($0.05 < r \leq 0.1$), small ($0.1 < r \leq 0.2$), medium ($0.2 < r \leq 0.3$), large ($0.3 < r \leq 0.4$), and very large ($r \geq 0.4$). These are similar to other interpretations based on empirical data.²⁵⁹

Synthesis methods. After extracting data, we examined the combinations of exposure and outcomes and removed any effects that appeared multiple times (i.e., in multiple meta-analyses, or with multiple sub-groups in the same meta-analysis), 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 age-groups (e.g., children vs adolescents), or were drawn using different study designs (e.g., cross-sectional vs longitudinal) we retained both estimates in our dataset.

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 package²⁶⁰ in R²⁶¹ (version 4.3.0) 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 test²⁶² when the number of studies within the review was ten or

more,²⁶³ and conducted a test of excess significance.²⁶⁴ 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 participants²⁶⁵ 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 (i.e., 95% confidence intervals did not cross zero) and $P < 10^{-3}$ (i.e., 99.9% confidence intervals did not cross zero) for strong evidence. An effect with statistical credibility but with $P > .05$ (i.e., 95% confidence intervals included zero) was taken to indicate no association of interest.

Deviations from protocol. As described above, we have summarised the meta-analytic findings from all included systematic reviews. In our protocol, we originally planned to also conduct a narrative synthesis of all systematic reviews, even those without meta-analyses. However, we determined that combining results from the meta-analyses alone allow 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 8.

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 use and a given outcome.

Data availability statement

All data for this review are available from the authors’ GitHub repository (https://github.com/motivation-and-Behaviour/screen_umbrella) or from the Open Science Foundation (<https://osf.io/3ubqp/>).

Code availability statement

All code used in these analyses are available on the authors’ GitHub repository (https://github.com/motivation-and-Behaviour/screen_umbrella).

Acknowledgements

The authors received no specific funding for this work.

Author contributions

TS, MN, PP, and CL conceptualised the review and drafted the manuscript. TS, MN, and PP conducted the analyses. All authors contributed to data extraction, interpretation, and editing of the manuscript.

Competing interests

The authors declare no conflicts of interest.

Tables

Table 1: Review characteristics and quality assessment for meta-analyses providing unique effects

Figure legends

Figure 1: PRISMA flow diagram.

Figure 2: Education outcomes. Forest plot for 22 unique effect sizes related to educational outcomes which met the criteria for statistical certainty. Findings are presented as correlations (two-sided) with both 95% and 99.9% confidence intervals.

Figure 3: Health and health-related behaviour outcomes. Forest plot for 21 unique effect sizes related to health and health-related behaviour outcomes which met the criteria for statistical certainty. Findings are presented as correlations (two-sided) with both 95% and 99.9% confidence intervals.

References

1. Blair, A. Reading Strategies for Coping With Information Overload ca.1550-1700. *Journal of the History of Ideas* **64**, 11–28 (2003).
2. Bell, A. N. *The sanitarian*. vol. 11 (AN Bell, 1883).
3. Dill, K. E. *The Oxford handbook of media psychology*. (Oxford University Press, 2013).
4. Wartella, E. A. & Jennings, N. Children and computers: New technology. Old concerns. *The future of children* 31–43 (2000).
5. Rhodes, A. *Top ten child health problems: What the public thinks*. (2015).
6. The Lancet. Social media, screen time, and young people’s mental health. *The Lancet* **393**, 611 (2019).
7. Hale, L. & Guan, S. Screen time and sleep among school-aged children and adolescents: A systematic literature review. *Sleep Medicine Reviews* **21**, 50–58 (2015).
8. Sweetser, P., Johnson, D., Ozdowska, A. & Wyeth, P. Active versus passive screen time for young children. *Australasian Journal of Early Childhood* **37**, 94–98 (2012).
9. Li, X. & Atkins, M. S. Early childhood computer experience and cognitive and motor development. *Pediatrics* **113**, 1715–1722 (2004).
10. Warburton, W. & Highfield, K. Children and technology in a smart device world. in *Children, Families and Communities* 195–221 (Oxford University Press, 2017).
11. Nature Human Behaviour. Screen time: How much is too much? *Nature* **565**, 265–266 (2019).

12. World Health Organization. *Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age*. 33 p. (World Health Organization, 2019).

13. Australian Government. *Physical activity and exercise guidelines for all Australians*. (2021).

14. Canadian Society for Exercise Physiology. *Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep*. (2016).

15. Council On Communication and Media. Media Use in School-Aged Children and Adolescents. *Pediatrics* **138**, e20162592 (2016).

16. Ferguson, C. J. Everything in Moderation: Moderate Use of Screens Unassociated with Child Behavior Problems. *Psychiatric Quarterly* **88**, 797–805 (2017).

17. Przybylski, A. K. & Weinstein, N. A Large-Scale Test of the Goldilocks Hypothesis: Quantifying the Relations Between Digital-Screen Use and the Mental Well-Being of Adolescents. *Psychological Science* **28**, 204–215 (2017).

18. Sanders, T., Parker, P. D., del Pozo-Cruz, B., Noetel, M. & Lonsdale, C. Type of screen time moderates effects on outcomes in 4013 children: Evidence from the Longitudinal Study of Australian Children. *International Journal of Behavioral Nutrition and Physical Activity* **16**, 117 (2019).

19. Kaye, L. K., Orben, A., Ellis, D. A., Hunter, S. C. & Houghton, S. The Conceptual and Methodological Mayhem of ‘Screen Time’. *International Journal of Environmental Research and Public Health* **17**, 3661 (2020).

20. Chassiakos, Y. L. R. *et al.* Children and Adolescents and Digital Media. *Pediatrics* **138**, e20162593 (2016).

21. Stiglic, N. & Viner, R. M. Effects of screentime on the health and well-being of children and adolescents: A systematic review of reviews. *BMJ Open* **9**, e023191 (2019).

22. Valkenburg, P. M., Meier, A. & Beyens, I. Social media use and its impact on adolescent mental health: An umbrella review of the evidence. *Current Opinion in Psychology* **44**, 58–68 (2022).

23. Arias-de la Torre, J. *et al.* Relationship Between Depression and the Use of Mobile Technologies and Social Media Among Adolescents: Umbrella Review. *Journal of Medical Internet Research* **22**, e16388 (2020).

24. Orben, A. Teenagers, screens and social media: A narrative review of reviews and key studies. *Social Psychiatry and Psychiatric Epidemiology* **55**, 407–414 (2020).

25. Pollock, M., Fernandes, R., Becker, L., Pieper, D. & Hartling, L. Chapter V: Overviews of Reviews. in *Cochrane Handbook for Systematic Reviews of Interventions* (eds. Higgins, J. P. *et al.*) (Cochrane, 2022).

26. Öztop, F. & Nayci, Ö. Does the Digital Generation Comprehend Better from the Screen or from the Paper?: A Meta-Analysis. *International Online Journal of Education and Teaching* **8**, 1206–1224 (2021).

27. Abrami, P., Borohkovski, E. & Lysenko, L. The effects of ABRACADABRA on reading outcomes: A meta-analysis of applied field research. *Journal of Interactive Learning Research* **26**, 337–367 (2015).

28. Abrami, P. C., Lysenko, L. & Borokhovski, E. The effects of ABRACADABRA on reading outcomes: An updated meta-analysis and landscape review of applied field research. *Journal of Computer Assisted Learning* **36**, 260–279 (2020).

29. Adelantado-Renau, M. *et al.* Association Between Screen Media Use and Academic

580 Performance Among Children and Adolescents: A Systematic Review and Meta-analysis.
581 *JAMA Pediatrics* **173**, 1058 (2019).

582 30. Aghasi, M., Matinfar, A., Golzarand, M., Salari-Moghaddam, A. &
583 Ebrahimpour-Koujan, S. Internet Use in Relation to Overweight and Obesity: A Systematic
584 Review and Meta-Analysis of Cross-Sectional Studies. *Advances in Nutrition* **11**, 349–356
585 (2019).

586 31. Alimoradi, Z. *et al.* Internet addiction and sleep problems: A systematic review
587 and meta-analysis. *Sleep Medicine Reviews* **47**, 51–61 (2019).

588 32. Allen, M. S., Walter, E. E. & Swann, C. Sedentary behaviour and risk of anxiety:
589 A systematic review and meta-analysis. *Journal of Affective Disorders* **242**, 5–13 (2019).

590 33. Ameryoun, A., Sanaeinasab, H., Saffari, M. & Koenig, H. G. Impact of
591 Game-Based Health Promotion Programs on Body Mass Index in Overweight/Obese
592 Children and Adolescents: A Systematic Review and Meta-Analysis of Randomized
593 Controlled Trials. *Childhood Obesity* **14**, 67–80 (2018).

594 34. Anderson, C. A. *et al.* Violent video game effects on aggression, empathy, and
595 prosocial behavior in Eastern and Western countries: A meta-analytic review. *Psychological*
596 *Bulletin* **136**, 151–173 (2010).

597 35. Andrade, A., Correia, C. K. & Coimbra, D. R. The Psychological Effects of
598 Exergames for Children and Adolescents with Obesity: A Systematic Review and
599 Meta-Analysis. *Cyberpsychology, Behavior, and Social Networking* **22**, 724–735 (2019).

600 36. Arztmann, M., Hornstra, L., Jeuring, J. & Kester, L. Effects of games in STEM
601 education: A meta-analysis on the moderating role of student background characteristics.
602 *Studies in Science Education* **59**, 109–145 (2022).

37. Aspiranti, K. B., Larwin, K. H. & Schade, B. P. iPads/tablets and students with autism: A meta-analysis of academic effects. *Assistive Technology* **32**, 23–30 (2020).
38. Baradaran Mahdavi, S., Riahi, R., Vahdatpour, B. & Kelishadi, R. Association between sedentary behavior and low back pain; A systematic review and meta-analysis. *Health Promotion Perspectives* **11**, 393–410 (2021).
39. Barnett, A., Cerin, E. & Baranowski, T. Active Video Games for Youth: A Systematic Review. *Journal of Physical Activity and Health* **8**, 724–737 (2011).
40. Bartel, K. A., Gradisar, M. & Williamson, P. Protective and risk factors for adolescent sleep: A meta-analytic review. *Sleep Medicine Reviews* **21**, 72–85 (2015).
41. Baumann, H., Fiedler, J., Wunsch, K., Woll, A. & Wollesen, B. mHealth Interventions to Reduce Physical Inactivity and Sedentary Behavior in Children and Adolescents: Systematic Review and Meta-analysis of Randomized Controlled Trials. *JMIR mHealth and uHealth* **10**, e35920 (2022).
42. Bayraktar, S. A Meta-analysis of the Effectiveness of Computer-Assisted Instruction in Science Education. *Journal of Research on Technology in Education* **34**, 173–188 (2001).
43. Beck Silva, K. B., Miranda Pereira, E., Santana, M. L. P. de, Costa, P. R. F. & Silva, R. de C. R. Effects of computer-based interventions on food consumption and anthropometric parameters of adolescents: A systematic review and metanalysis. *Critical Reviews in Food Science and Nutrition* 1–13 (2022) doi:10.1080/10408398.2022.2118227.
44. Benavides-Varela, S. *et al.* Effectiveness of digital-based interventions for children with mathematical learning difficulties: A meta-analysis. *Computers & Education* **157**, 103953 (2020).

45. Beneria, A. *et al.* Online interventions for cannabis use among adolescents and young adults: Systematic review and meta-analysis. *Early Intervention in Psychiatry* **16**, 821–844 (2022).

46. Blok, H., Oostdam, R., Otter, M. E. & Overmaat, M. Computer-assisted instruction in support of beginning reading instruction: A review. *Review of Educational Research* **72**, 101–130 (2002).

47. Bochner, R. E., Sorensen, K. M. & Belamarich, P. F. The Impact of Active Video Gaming on Weight in Youth: A Meta-Analysis. *Clinical Pediatrics* **54**, 620–628 (2015).

48. Bossen, D. *et al.* Effectiveness of Serious Games to Increase Physical Activity in Children With a Chronic Disease: Systematic Review With Meta-Analysis. *Journal of Medical Internet Research* **22**, e14549 (2020).

49. Boyland, E. J. *et al.* Advertising as a cue to consume: A systematic review and meta-analysis of the effects of acute exposure to unhealthy food and nonalcoholic beverage advertising on intake in children and adults. *American Journal of Clinical Nutrition* **103**, 519–533 (2016).

50. Boyland, E. *et al.* Association of Food and Nonalcoholic Beverage Marketing With Children and Adolescents' Eating Behaviors and Health: A Systematic Review and Meta-analysis. *JAMA Pediatrics* **176**, e221037 (2022).

51. Burkhardt, J. & Lenhard, W. A Meta-Analysis on the Longitudinal, Age-Dependent Effects of Violent Video Games on Aggression. *Media Psychology* **25**, 499–512 (2022).

52. Byun, J. & Joung, E. Digital game-based learning for K-12 mathematics education: A meta-analysis. *School Science and Mathematics* **118**, 113–126 (2018).

53. Cai, Y., Pan, Z. & Liu, M. Augmented reality technology in language learning: A meta-analysis. *Journal of Computer Assisted Learning* **38**, 929–945 (2022).

54. Cao, Y., Huang, T., Huang, J., Xie, X. & Wang, Y. Effects and Moderators of Computer-Based Training on Children's Executive Functions: A Systematic Review and Meta-Analysis. *Frontiers in Psychology* **11**, 580329 (2020).

55. Cao, X. *et al.* Risk of Accidents or Chronic Disorders From Improper Use of Mobile Phones: A Systematic Review and Meta-analysis. *Journal of Medical Internet Research* **24**, e21313 (2022).

56. Carter, B., Rees, P., Hale, L., Bhattacharjee, D. & Paradkar, M. S. Association Between Portable Screen-Based Media Device Access or Use and Sleep Outcomes: A Systematic Review and Meta-analysis. *JAMA Pediatrics* **170**, 1202 (2016).

57. Casale, S. *et al.* A meta-analysis on the association between self-esteem and problematic smartphone use. *Computers in Human Behavior* **134**, 107302 (2022).

58. Champion, K. E. *et al.* Effectiveness of school-based eHealth interventions to prevent multiple lifestyle risk behaviours among adolescents: A systematic review and meta-analysis. *The Lancet Digital Health* **1**, e206–e221 (2019).

59. Chan, K. K. & Leung, S. W. Dynamic Geometry Software Improves Mathematical Achievement: Systematic Review and Meta-Analysis. *Journal of Educational Computing Research* **51**, 311–325 (2014).

60. Chan, G. *et al.* The impact of eSports and online video gaming on lifestyle behaviours in youth: A systematic review. *Computers in Human Behavior* **126**, 106974 (2022).

61. Chauhan, S. A meta-analysis of the impact of technology on learning effectiveness

of elementary students. *Computers & Education* **105**, 14–30 (2017).

62. Chen, L., Ho, S. S. & Lwin, M. O. A meta-analysis of factors predicting cyberbullying perpetration and victimization: From the social cognitive and media effects approach. *New Media & Society* **19**, 1194–1213 (2017).

63. Chen, C.-H., Shih, C.-C. & Law, V. The Effects of Competition in Digital Game-Based Learning (DGBL): A Meta-Analysis. *Educational Technology Research and Development* **68**, 1855–1873 (2020).

64. Cheung, A. C. K. & Slavin, R. E. How features of educational technology applications affect student reading outcomes: A meta-analysis. *Educational Research Review* **7**, 198–215 (2012).

65. Cheung, A. C. K. & Slavin, R. E. The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review* **9**, 88–113 (2013).

66. Cheung, A. C. K. & Slavin, R. E. Effects of Educational Technology Applications on Reading Outcomes for Struggling Readers: A Best-Evidence Synthesis. *Reading Research Quarterly* **48**, 277–299 (2013).

67. Cho, K., Lee, S., Joo, M.-H. & Becker, B. The Effects of Using Mobile Devices on Student Achievement in Language Learning: A Meta-Analysis. *Education Sciences* **8**, 105 (2018).

68. Chodura, S., Kuhn, J.-T. & Holling, H. Interventions for Children With Mathematical Difficulties: A Meta-Analysis. *Zeitschrift für Psychologie* **223**, 129–144 (2015).

69. Claussen, A. H. *et al.* All in the Family? A Systematic Review and Meta-analysis of Parenting and Family Environment as Risk Factors for Attention-Deficit/Hyperactivity

Disorder (ADHD) in Children. *Prevention Science* (2022) doi:10.1007/s11121-022-01358-4.

70. Clinton, V. Reading from paper compared to screens: A systematic review and meta-analysis. *Journal of Research in Reading* **42**, 288–325 (2019).

71. Comeras-Chueca, C. *et al.* The Effects of Active Video Games on Health-Related Physical Fitness and Motor Competence in Children and Adolescents with Healthy Weight: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health* **18**, 6965 (2021).

72. Comeras-Chueca, C. *et al.* Effects of Active Video Games on Health-Related Physical Fitness and Motor Competence in Children and Adolescents With Overweight or Obesity: Systematic Review and Meta-Analysis. *JMIR Serious Games* **9**, e29981 (2021).

73. Cox, R., Skouteris, H., Rutherford, L. & Fuller-Tyszkiewicz, M. The Association between Television Viewing and Preschool Child Body Mass Index: A systematic review of English papers published from 1995 to 2010. *Journal of Children and Media* **6**, 198–220 (2012).

74. Coyne, S. M. *et al.* A meta-analysis of prosocial media on prosocial behavior, aggression, and empathic concern: A multidimensional approach. *Developmental Psychology* **54**, 331–347 (2018).

75. Cunningham, S., Hudson, C. C. & Harkness, K. Social Media and Depression Symptoms: A Meta-Analysis. *Research on Child and Adolescent Psychopathology* **49**, 241–253 (2021).

76. Cushing, C. C. & Steele, R. G. A Meta-Analytic Review of eHealth Interventions for Pediatric Health Promoting and Maintaining Behaviors. *Journal of Pediatric Psychology* **35**, 937–949 (2010).

718 77. Darling, K. E. & Sato, A. F. Systematic Review and Meta-Analysis Examining the
719 Effectiveness of Mobile Health Technologies in Using Self-Monitoring for Pediatric Weight
720 Management. *Childhood Obesity* **13**, 347–355 (2017).

721 78. Davey, S. & Davey, A. Assessment of Smartphone Addiction in Indian Adolescents:
722 A Mixed Method Study by Systematic-review and Meta-analysis Approach. *International*
723 *Journal of Preventive Medicine* **5**, 1500–1511 (2014).

724 79. David, O. A., Costescu, C., Cardos, R. & Mogoase, C. How Effective are Serious
725 Games for Promoting Mental Health and Health Behavioral Change in Children and
726 Adolescents? A Systematic Review and Meta-analysis. *Child & Youth Care Forum* **49**,
727 817–838 (2020).

728 80. Oliveira, R. G. de & Guedes, D. P. Physical Activity, Sedentary Behavior,
729 Cardiorespiratory Fitness and Metabolic Syndrome in Adolescents: Systematic Review and
730 Meta-Analysis of Observational Evidence. *PLOS ONE* **11**, e0168503 (2016).

731 81. de Ribera, O. S., Trajtenberg, N., Shenderovich, Y. & Murray, J. Correlates of
732 youth violence in low- and middle-income countries: A meta-analysis. *Aggression and*
733 *Violent Behavior* **49**, 101306 (2019).

734 82. Di, X. & Zheng, X. A meta-analysis of the impact of virtual technologies on
735 students' spatial ability. *Educational technology research and development* **70**, 73–98 (2022).

736 83. Eirich, R. *et al.* Association of Screen Time With Internalizing and Externalizing
737 Behavior Problems in Children 12 Years or Younger: A Systematic Review and
738 Meta-analysis. *JAMA Psychiatry* **79**, 393 (2022).

739 84. Erçelik, Z. E. & Çağlar, S. Effectiveness of active video games in overweight and
740 obese adolescents: A systematic review and meta-analysis of randomized controlled trials.
741 *Annals of Pediatric Endocrinology & Metabolism* **27**, 98–104 (2022).

85. Fang, K., Mu, M., Liu, K. & He, Y. Screen time and childhood overweight/obesity: A systematic review and meta-analysis. *Child: Care, Health and Development* **45**, 744–753 (2019).

86. Fedele, D. A., Cushing, C. C., Fritz, A., Amaro, C. M. & Ortega, A. Mobile Health Interventions for Improving Health Outcomes in Youth: A Meta-analysis. *JAMA Pediatrics* **171**, 461 (2017).

87. Feng, J., Zheng, C., Sit, C. H.-P., Reilly, J. J. & Huang, W. Y. Associations between meeting 24-hour movement guidelines and health in the early years: A systematic review and meta-analysis. *Journal of Sports Sciences* **39**, 2545–2557 (2021).

88. Ferguson, C. J. & Kilburn, J. The Public Health Risks of Media Violence: A Meta-Analytic Review. *The Journal of Pediatrics* **154**, 759–763 (2009).

89. Ferguson, C. J. Do Angry Birds Make for Angry Children? A Meta-Analysis of Video Game Influences on Children's and Adolescents' Aggression, Mental Health, Prosocial Behavior, and Academic Performance. *Perspectives on Psychological Science* **10**, 646–666 (2015).

90. Ferguson, C. J., Nielsen, R. K. L. & Markey, P. M. Does Sexy Media Promote Teen Sex? A Meta-Analytic and Methodological Review. *Psychiatric Quarterly* **88**, 349–358 (2017).

91. Ferguson, C. J. 13 Reasons Why Not: A Methodological and Meta-Analytic Review of Evidence Regarding Suicide Contagion by Fictional Media. *Suicide and Life-Threatening Behavior* **49**, 1178–1186 (2019).

92. Ferguson, C. J., Copenhaver, A. & Markey, P. Reexamining the Findings of the American Psychological Association's 2015 Task Force on Violent Media: A Meta-Analysis. *Perspectives on Psychological Science* **15**, 1423–1443 (2020).

93. Ferguson, C. J. *et al.* Like this meta-analysis: Screen media and mental health. *Professional Psychology: Research and Practice* **53**, 205–214 (2022).

94. Fischer, P., Greitemeyer, T., Kastenmüller, A., Vogrincic, C. & Sauer, A. The effects of risk-glorifying media exposure on risk-positive cognitions, emotions, and behaviors: A meta-analytic review. *Psychological Bulletin* **137**, 367–390 (2011).

95. Folkvord, F. & van ‘t Riet, J. The persuasive effect of advergames promoting unhealthy foods among children: A meta-analysis. *Appetite* **129**, 245–251 (2018).

96. Foreman, J. *et al.* Association between digital smart device use and myopia: A systematic review and meta-analysis. *The Lancet Digital Health* **3**, e806–e818 (2021).

97. Fowler, L. A. *et al.* Harnessing technological solutions for childhood obesity prevention and treatment: A systematic review and meta-analysis of current applications. *International Journal of Obesity* **45**, 957–981 (2021).

98. Furenes, M. I., Kucirkova, N. & Bus, A. G. A Comparison of Children’s Reading on Paper versus Screen: A Meta-Analysis. *Review of Educational Research* **91**, 483–517 (2021).

99. Gao, Z., Chen, S., Pasco, D. & Pope, Z. A meta-analysis of active video games on health outcomes among children and adolescents: A meta-analysis of active video games. *Obesity Reviews* **16**, 783–794 (2015).

100. Gardella, J. H., Fisher, B. W. & Teurbe-Tolon, A. R. A Systematic Review and Meta-Analysis of Cyber-Victimization and Educational Outcomes for Adolescents. *Review of Educational Research* **87**, 283–308 (2017).

101. Garzón, J., Pavón, J. & Baldiris, S. Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality* **23**, 447–459 (2019).

102. Garzón, J. & Acevedo, J. Meta-analysis of the impact of Augmented Reality on

students' learning gains. *Educational Research Review* **27**, 244–260 (2019).

103. Ghobadi, S. *et al.* Association of eating while television viewing and overweight/obesity among children and adolescents: A systematic review and meta-analysis of observational studies: Television viewing, overweight, obesity, children. *Obesity Reviews* **19**, 313–320 (2018).

104. Grabe, S., Ward, L. M. & Hyde, J. S. The role of the media in body image concerns among women: A meta-analysis of experimental and correlational studies. *Psychological Bulletin* **134**, 460–476 (2008).

105. Graham, S., Hebert, M. & Harris, K. R. Formative Assessment and Writing: A Meta-Analysis. *The Elementary School Journal* **115**, 523–547 (2015).

106. Haghjoo, P., Siri, G., Soleimani, E., Farhangi, M. A. & Alesaeidi, S. Screen time increases overweight and obesity risk among adolescents: A systematic review and dose-response meta-analysis. *BMC Primary Care* **23**, 161 (2022).

107. Hammersley, M. L., Jones, R. A. & Okely, A. D. Parent-Focused Childhood and Adolescent Overweight and Obesity eHealth Interventions: A Systematic Review and Meta-Analysis. *Journal of Medical Internet Research* **18**, e203 (2016).

108. Hao, T., Wang, Z. & Ardasheva, Y. Technology-Assisted Vocabulary Learning for EFL Learners: A Meta-Analysis. *Journal of Research on Educational Effectiveness* **14**, 645–667 (2021).

109. Mahdi, H. S. & Al Khateeb, A. A. The effectiveness of computer-assisted pronunciation training: A meta-analysis. *Review of Education* **7**, 733–753 (2019).

110. He, Z. *et al.* Effects of Smartphone-Based Interventions on Physical Activity in Children and Adolescents: Systematic Review and Meta-analysis. *JMIR mHealth and*

uHealth **9**, e22601 (2021).

111. Hernández-Jiménez, C. *et al.* Impact of Active Video Games on Body Mass Index in Children and Adolescents: Systematic Review and Meta-Analysis Evaluating the Quality of Primary Studies. *International Journal of Environmental Research and Public Health* **16**, 2424 (2019).

112. Ho, R. S.-T., Chan, E. K.-Y., Liu, K. K.-Y. & Wong, S. H.-S. Active video game on children and adolescents' physical activity and weight management: A network meta-analysis. *Scandinavian Journal of Medicine & Science in Sports* **32**, 1268–1286 (2022).

113. Huang, Q., Peng, W. & Ahn, S. When media become the mirror: A meta-analysis on media and body image. *Media Psychology* **24**, 437–489 (2021).

114. Hurwitz, L. B. Getting a Read on Ready To Learn Media: A Meta-analytic Review of Effects on Literacy. *Child Development* **90**, 1754–1771 (2019).

115. Kristensen, J. H., Pallesen, S., King, D. L., Hysing, M. & Erevik, E. K. Problematic Gaming and Sleep: A Systematic Review and Meta-Analysis. *Frontiers in Psychiatry* **12**, 675237 (2021).

116. Ivie, E. J., Pettitt, A., Moses, L. J. & Allen, N. B. A meta-analysis of the association between adolescent social media use and depressive symptoms. *Journal of Affective Disorders* **275**, 165–174 (2020).

117. Janssen, X. *et al.* Associations of screen time, sedentary time and physical activity with sleep in under 5s: A systematic review and meta-analysis. *Sleep Medicine Reviews* **49**, 101226 (2020).

118. Kates, A. W., Wu, H. & Coryn, C. L. S. The effects of mobile phone use on academic performance: A meta-analysis. *Computers & Education* **127**, 107–112 (2018).

119. Kim, J., Gilbert, J., Yu, Q. & Gale, C. Measures Matter: A Meta-Analysis of the Effects of Educational Apps on Preschool to Grade 3 Children's Literacy and Math Skills. *AERA Open* **7**, 233285842110041 (2021).

120. Kong, Y., Seo, Y. S. & Zhai, L. Comparison of reading performance on screen and on paper: A meta-analysis. *Computers & Education* **123**, 138–149 (2018).

121. Kroesbergen, E. H. & Van Luit, J. E. H. Mathematics Interventions for Children with Special Educational Needs: A Meta-Analysis. *Remedial and Special Education* **24**, 97–114 (2003).

122. Küçükalkan, K., Beyazsaçlı, M. & Öz, A. Ş. Examination of the effects of computer-based mathematics instruction methods in children with mathematical learning difficulties: A meta-analysis. *Behaviour & Information Technology* **38**, 913–923 (2019).

123. Lamb, R. L., Annetta, L., Firestone, J. & Etopio, E. A meta-analysis with examination of moderators of student cognition, affect, and learning outcomes while using serious educational games, serious games, and simulations. *Computers in Human Behavior* **80**, 158–167 (2018).

124. Lanca, C. & Saw, S.-M. The association between digital screen time and myopia: A systematic review. *Ophthalmic and Physiological Optics* **40**, 216–229 (2020).

125. Larwin, K. H. & Aspiranti, K. B. Measuring the Academic Outcomes of iPads for Students with Autism: A Meta-Analysis. *Review Journal of Autism and Developmental Disorders* **6**, 233–241 (2019).

126. Lee, J., Piao, M., Byun, A. & Kim, J. A systematic review and meta-analysis of intervention for pediatric obesity using mobile technology. *Nursing Informatics 2016* **225**, 491–494 (2016).

127. Li, Q. & Ma, X. A Meta-analysis of the Effects of Computer Technology on
School Students' Mathematics Learning. *Educational Psychology Review* **22**, 215–243 (2010).

128. Li, C., Cheng, G., Sha, T., Cheng, W. & Yan, Y. The Relationships between
Screen Use and Health Indicators among Infants, Toddlers, and Preschoolers: A
Meta-Analysis and Systematic Review. *International Journal of Environmental Research
and Public Health* **17**, 7324 (2020).

129. Li, S., Song, Y., Cai, Z. & Zhang, Q. Are active video games useful in the
development of gross motor skills among non-typically developing children? A meta-analysis.
BMC Sports Science, Medicine and Rehabilitation **14**, 140 (2022).

130. Li, F., Wang, X., He, X., Cheng, L. & Wang, Y. The effectiveness of unplugged
activities and programming exercises in computational thinking education: A Meta-analysis.
Education and Information Technologies **27**, 7993–8013 (2022).

131. Liao, Y.-K. Effects of Computer-Assisted Instruction on Cognitive Outcomes: A
Meta-Analysis. *Journal of Research on Computing in Education* **24**, 367–80 (1992).

132. Liao, Y.-k. C., Chang, H.-w. & Chen, Y.-w. Effects of Computer Application on
Elementary School Student's Achievement: A Meta-Analysis of Students in Taiwan.
Computers in the Schools **24**, 43–64 (2007).

133. Liao, Y., Liao, J., Durand, C. P. & Dunton, G. F. Which type of sedentary
behaviour intervention is more effective at reducing body mass index in children? A
meta-analytic review: Sedentary behaviour intervention effects. *Obesity Reviews* **15**, 159–168
(2014).

134. Liu, M., Wu, L. & Yao, S. DoseResponse association of screen time-based
sedentary behaviour in children and adolescents and depression: A meta-analysis of
observational studies. *British Journal of Sports Medicine* **50**, 1252–1258 (2016).

135. Liu, D. & Baumeister, R. F. Social networking online and personality of self-worth: A meta-analysis. *Journal of Research in Personality* **64**, 79–89 (2016).

136. Liu, D., Ainsworth, S. E. & Baumeister, R. F. A Meta-Analysis of Social Networking Online and Social Capital. *Review of General Psychology* **20**, 369–391 (2016).

137. Liu, D., Baumeister, R. F., Yang, C.-c. & Hu, B. Digital Communication Media Use and Psychological Well-Being: A Meta-Analysis. *Journal of Computer-Mediated Communication* **24**, 259–273 (2019).

138. Liu, M., Pang, W., Guo, J. & Zhang, Y. A Meta-analysis of the Effect of Multimedia Technology on Creative Performance. *Education and Information Technologies* **27**, 8603–8630 (2022).

139. Liu, M. *et al.* Time Spent on Social Media and Risk of Depression in Adolescents: A DoseResponse Meta-Analysis. *International Journal of Environmental Research and Public Health* **19**, 5164 (2022).

140. Lu, G.-L. *et al.* The correlation between mobile phone addiction and coping style among Chinese adolescents: A meta-analysis. *Child and Adolescent Psychiatry and Mental Health* **15**, 60 (2021).

141. Luckner, H., Moss, J. R. & Gericke, C. A. Effectiveness of interventions to promote healthy weight in general populations of children and adults: A meta-analysis. *European Journal of Public Health* **22**, 491–497 (2012).

142. Luo, Y. *et al.* Is Increased Video Game Participation Associated With Reduced Sense of Loneliness? A Systematic Review and Meta-Analysis. *Frontiers in Public Health* **10**, 898338 (2022).

143. Madigan, S., McArthur, B. A., Anhorn, C., Eirich, R. & Christakis, D. A.

Associations Between Screen Use and Child Language Skills: A Systematic Review and Meta-analysis. *JAMA Pediatrics* **174**, 665 (2020).

144. Major, L., Francis, G. A. & Tsapali, M. The effectiveness of technology-supported personalised learning in low- and middle-income countries: A meta-analysis. *British Journal of Educational Technology* **52**, 1935–1964 (2021).

145. Mallawaarachchi, S. R., Anglim, J., Hooley, M. & Horwood, S. Associations of smartphone and tablet use in early childhood with psychosocial, cognitive and sleep factors: A systematic review and meta-analysis. *Early Childhood Research Quarterly* **60**, 13–33 (2022).

146. Marciano, L., Schulz, P. J. & Camerini, A.-L. Cyberbullying Perpetration and Victimization in Youth: A Meta-Analysis of Longitudinal Studies. *Journal of Computer-Mediated Communication* **25**, 163–181 (2020).

147. Marciano, L., Ostroumova, M., Schulz, P. J. & Camerini, A.-L. Digital Media Use and Adolescents' Mental Health During the Covid-19 Pandemic: A Systematic Review and Meta-Analysis. *Frontiers in Public Health* **9**, 793868 (2022).

148. Mares, M.-L. & Woodard, E. Positive Effects of Television on Children's Social Interactions: A Meta-Analysis. *Media Psychology* **7**, 301–322 (2005).

149. Mares, M.-L. & Pan, Z. Effects of Sesame Street: A meta-analysis of children's learning in 15 countries. *Journal of Applied Developmental Psychology* **34**, 140–151 (2013).

150. Marino, C., Gini, G., Vieno, A. & Spada, M. M. The associations between problematic Facebook use, psychological distress and well-being among adolescents and young adults: A systematic review and meta-analysis. *Journal of Affective Disorders* **226**, 274–281 (2018).

151. Marker, C., Gnambs, T. & Appel, M. Exploring the myth of the chubby gamer: A
meta-analysis on sedentary video gaming and body mass. *Social Science & Medicine* **301**,
112325 (2022).

152. Marshall, S. J., Biddle, S. J. H., Gorely, T., Cameron, N. & Murdey, I.
Relationships between media use, body fatness and physical activity in children and youth:
A meta-analysis. *International Journal of Obesity* **28**, 1238–1246 (2004).

153. Martins, N. & Weaver, A. The role of media exposure on relational aggression: A
meta-analysis. *Aggression and Violent Behavior* **47**, 90–99 (2019).

154. Martins, N. C. *et al.* Influence of eating with distractors on caloric intake of
children and adolescents: A systematic review and meta-analysis of interventional controlled
studies. *Critical Reviews in Food Science and Nutrition* 1–10 (2022)
doi:10.1080/10408398.2022.2055525.

155. Mazeas, A., Duclos, M., Pereira, B. & Chalabaev, A. Evaluating the Effectiveness
of Gamification on Physical Activity: Systematic Review and Meta-analysis of Randomized
Controlled Trials. *Journal of Medical Internet Research* **24**, e26779 (2022).

156. McArthur, G. *et al.* Phonics training for English-speaking poor readers. *Cochrane
Database of Systematic Reviews* (2012) doi:10.1002/14651858.CD009115.pub2.

157. McArthur, G. *et al.* Phonics training for English-speaking poor readers. *Cochrane
Database of Systematic Reviews* **2018**, (2018).

158. Mei, X. *et al.* Sleep problems in excessive technology use among adolescent: A
systemic review and meta-analysis. *Sleep Science and Practice* **2**, 9 (2018).

159. Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W. & Davis, T. J.
Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and

higher education: A meta-analysis. *Computers & Education* **70**, 29–40 (2014).

160. Moran, J., Ferdig, R. E., Pearson, P. D., Wardrop, J. & Blomeyer, R. L.
Technology and Reading Performance in the Middle-School Grades: A Meta-Analysis with
Recommendations for Policy and Practice. *Journal of Literacy Research* **40**, 6–58 (2008).

161. Mori, C., Temple, J. R., Browne, D. & Madigan, S. Association of Sexting With
Sexual Behaviors and Mental Health Among Adolescents: A Systematic Review and
Meta-analysis. *JAMA Pediatrics* **173**, 770 (2019).

162. Neitzel, A. J., Lake, C., Pellegrini, M. & Slavin, R. E. A Synthesis of Quantitative
Research on Programs for Struggling Readers in Elementary Schools. *Reading Research
Quarterly* **57**, 149–179 (2022).

163. Nesi, J. *et al.* Social media use and self-injurious thoughts and behaviors: A
systematic review and meta-analysis. *Clinical Psychology Review* **87**, 102038 (2021).

164. Nikkelen, S. W. C., Valkenburg, P. M., Huizinga, M. & Bushman, B. J. Media use
and ADHD-related behaviors in children and adolescents: A meta-analysis. *Developmental
Psychology* **50**, 2228–2241 (2014).

165. Oh, C., Carducci, B., Vaivada, T. & Bhutta, Z. A. Digital Interventions for
Universal Health Promotion in Children and Adolescents: A Systematic Review. *Pediatrics*
149, e2021053852H (2022).

166. Oldrati, V. *et al.* Effectiveness of Computerized Cognitive Training Programs
(CCTP) with Game-like Features in Children with or without Neuropsychological Disorders:
A Meta-Analytic Investigation. *Neuropsychology Review* **30**, 126–141 (2020).

167. Oliveira, C. B. *et al.* Effects of active video games on children and adolescents: A
systematic review with meta-analysis. *Scandinavian Journal of Medicine & Science in Sports*

974 **30**, 4–12 (2020).

975 168. Ozdemir, M., Sahin, C., Arcagok, S. & Demir, M. K. The Effect of Augmented
976 Reality Applications in the Learning Process: A MetaAnalysis Study. *Eurasian Journal of*
977 *Educational Research* **18**, 1–22 (2018).

978 169. Paik, H. & Comstock, G. The Effects of Television Violence on Antisocial
979 Behavior: A Meta-Analysis. *Communication Research* **21**, 516–546 (1994).

980 170. Park, J., Park, M.-J. & Seo, Y.-G. Effectiveness of Information and
981 Communication Technology on Obesity in Childhood and Adolescence: Systematic Review
982 and Meta-analysis. *Journal of Medical Internet Research* **23**, e29003 (2021).

983 171. Pearce, L. J. & Field, A. P. The Impact of ‘Scary’ TV and Film on Children’s
984 Internalizing Emotions: A Meta-Analysis. *Human Communication Research* **42**, 98–121
985 (2016).

986 172. Peng, W., Lin, J.-H. & Crouse, J. Is Playing Exergames Really Exercising? A
987 Meta-Analysis of Energy Expenditure in Active Video Games. *Cyberpsychology, Behavior,*
988 *and Social Networking* **14**, 681–688 (2011).

989 173. Poorolajal, J., Sahraei, F., Mohamdadi, Y., Doosti-Irani, A. & Moradi, L.
990 Behavioral factors influencing childhood obesity: A systematic review and meta-analysis.
991 *Obesity Research & Clinical Practice* **14**, 109–118 (2020).

992 174. Powers, K. L., Brooks, P. J., Aldrich, N. J., Palladino, M. A. & Alfieri, L. Effects
993 of video-game play on information processing: A meta-analytic investigation. *Psychonomic*
994 *Bulletin & Review* **20**, 1055–1079 (2013).

995 175. Prescott, A. T., Sargent, J. D. & Hull, J. G. Metaanalysis of the relationship
996 between violent video game play and physical aggression over time. *Proceedings of the*

- 997 *National Academy of Sciences* **115**, 9882–9888 (2018).
- 998 176. Prizant-Passal, S., Shechner, T. & Aderka, I. M. Social anxiety and internet use A
999 meta-analysis: What do we know? What are we missing? *Computers in Human Behavior*
1000 **62**, 221–229 (2016).
- 1001 177. Reynard, S., Dias, J., Mitic, M., Schrank, B. & Woodcock, K. A. Digital
1002 Interventions for Emotion Regulation in Children and Early Adolescents: Systematic Review
1003 and Meta-analysis. *JMIR Serious Games* **10**, e31456 (2022).
- 1004 178. Rodriguez Rocha, N. P. & Kim, H. eHealth Interventions for Fruit and Vegetable
1005 Intake: A Meta-Analysis of Effectiveness. *Health Education & Behavior* **46**, 947–959 (2019).
- 1006 179. Russell, S. J., Croker, H. & Viner, R. M. The effect of screen advertising on
1007 children’s dietary intake: A systematic review and meta-analysis. *Obesity Reviews* **20**,
1008 554–568 (2019).
- 1009 180. Ryan, A. W. Meta-Analysis of Achievement Effects of Microcomputer
1010 Applications in Elementary Schools. *Educational Administration Quarterly* **27**, 161–184
1011 (1991).
- 1012 181. Sadeghirad, B., Duhaney, T., Motaghipisheh, S., Campbell, N. R. C. & Johnston,
1013 B. C. Influence of unhealthy food and beverage marketing on children’s dietary intake and
1014 preference: A systematic review and meta-analysis of randomized trials. *Obesity Reviews* **17**,
1015 945–959 (2016).
- 1016 182. Saiphoo, A. N., Dahoah Halevi, L. & Vahedi, Z. Social networking site use and
1017 self-esteem: A meta-analytic review. *Personality and Individual Differences* **153**, 109639
1018 (2020).
- 1019 183. Scherer, R., Siddiq, F. & Sánchez Viveros, B. A meta-analysis of teaching and

learning computer programming: Effective instructional approaches and conditions.

Computers in Human Behavior **109**, 106349 (2020).

184. Scherer, R., Siddiq, F. & Sánchez Viveros, B. The cognitive benefits of learning computer programming: A meta-analysis of transfer effects. *Journal of Educational Psychology* **111**, 764–792 (2019).

185. Schroeder, N. L., Adesope, O. O. & Gilbert, R. B. How Effective are Pedagogical Agents for Learning? A Meta-Analytic Review. *Journal of Educational Computing Research* **49**, 1–39 (2013).

186. Scionti, N., Cavallero, M., Zogmaister, C. & Marzocchi, G. M. Is Cognitive Training Effective for Improving Executive Functions in Preschoolers? A Systematic Review and Meta-Analysis. *Frontiers in Psychology* **10**, 2812 (2020).

187. Shahab, L. & McEwen, A. Online support for smoking cessation: A systematic review of the literature. *Addiction* **104**, 1792–1804 (2009).

188. Shannon, H., Bush, K., Villeneuve, P. J., Hellemans, K. G. & Guimond, S. Problematic Social Media Use in Adolescents and Young Adults: Systematic Review and Meta-analysis. *JMIR Mental Health* **9**, e33450 (2022).

189. Shin, Y., Kim, S. K. & Lee, M. Mobile phone interventions to improve adolescents' physical health: A systematic review and meta-analysis. *Public Health Nursing* **36**, 787–799 (2019).

190. Shin, M., Juventin, M., Wai Chu, J. T., Manor, Y. & Kemps, E. Online media consumption and depression in young people: A systematic review and meta-analysis. *Computers in Human Behavior* **128**, 107129 (2022).

191. Slavin, R. E. Reading Effects of IBM's "Writing to Read" Program: A Review of

- 1043 Evaluations. *Educational Evaluation and Policy Analysis* **13**, 1 (1991).
- 1044 192. Slavin, R. E. & Lake, C. Effective Programs in Elementary Mathematics: A
1045 Best-Evidence Synthesis. *Review of Educational Research* **78**, 427–515 (2008).
- 1046 193. Slavin, R. E., Lake, C. & Groff, C. Effective Programs in Middle and High School
1047 Mathematics: A Best-Evidence Synthesis. *Review of Educational Research* **79**, 839–911
1048 (2009).
- 1049 194. Slavin, R. E., Lake, C., Hanley, P. & Thurston, A. Experimental evaluations of
1050 elementary science programs: A best-evidence synthesis. *Journal of Research in Science*
1051 *Teaching* **51**, 870–901 (2014).
- 1052 195. Soo Jung, K. & Yan Ping, X. A Synthesis of Computer-Assisted Mathematical
1053 Word Problem-Solving Instruction for Students with Learning Disabilities or Difficulties.
1054 *Learning Disabilities: A Contemporary Journal* **20**, 27–45 (2022).
- 1055 196. Stavrinou, D., Pope, C. N., Shen, J. & Schwebel, D. C. Distracted Walking,
1056 Bicycling, and Driving: Systematic Review and Meta-Analysis of Mobile Technology and
1057 Youth Crash Risk. *Child Development* **89**, 118–128 (2018).
- 1058 197. Steele, J. L., Bozick, R. & Davis, L. M. Education for Incarcerated Juveniles: A
1059 Meta-Analysis. *Journal of Education for Students Placed at Risk (JESPAR)* **21**, 65–89
1060 (2016).
- 1061 198. Strong, G. K., Torgerson, C. J., Torgerson, D. & Hulme, C. A systematic
1062 meta-analytic review of evidence for the effectiveness of the ‘Fast ForWord’ language
1063 intervention program. *Journal of Child Psychology and Psychiatry* **52**, 224–235 (2011).
- 1064 199. Strouse, G. A. & Samson, J. E. Learning From Video: A Meta-Analysis of the
1065 Video Deficit in Children Ages 0 to 6 Years. *Child Development* **92**, E20–E38 (2021).

200. Suleiman-Martos, N. *et al.* Gamification for the Improvement of Diet, Nutritional Habits, and Body Composition in Children and Adolescents: A Systematic Review and Meta-Analysis. *Nutrients* **13**, 2478 (2021).

201. Sun, L., Hu, L. & Zhou, D. Which way of design programming activities is more effective to promote K-12 students' computational thinking skills? A meta-analysis. *Journal of Computer Assisted Learning* **37**, 1048–1062 (2021).

202. Sung, Y.-T., Chang, K.-E. & Yang, J.-M. How effective are mobile devices for language learning? A meta-analysis. *Educational Research Review* **16**, 68–84 (2015).

203. Takacs, Z. K., Swart, E. K. & Bus, A. G. Can the computer replace the adult for storybook reading? A meta-analysis on the effects of multimedia stories as compared to sharing print stories with an adult. *Frontiers in Psychology* **5**, (2014).

204. Takacs, Z. K., Swart, E. K. & Bus, A. G. Benefits and Pitfalls of Multimedia and Interactive Features in Technology-Enhanced Storybooks: A Meta-Analysis. *Review of Educational Research* **85**, 698–739 (2015).

205. Takacs, Z. K. & Kassai, R. The efficacy of different interventions to foster children's executive function skills: A series of meta-analyses. *Psychological Bulletin* **145**, 653–697 (2019).

206. Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C. & Schmid, R. F. What Forty Years of Research Says About the Impact of Technology on Learning: A Second-Order Meta-Analysis and Validation Study. *Review of Educational Research* **81**, 4–28 (2011).

207. Tekedere, H. & Göke, H. Examining the Effectiveness of Augmented Reality Applications in Education: A Meta-Analysis. *International Journal of Environmental and Science Education* **11**, 9469–9481 (2016).

- 1090 208. Tingir, S., Cavlazoglu, B., Caliskan, O., Koklu, O. & Intepe-Tingir, S. Effects of
1091 mobile devices on K-12 students' achievement: A meta-analysis: Effects of mobile devices.
1092 *Journal of Computer Assisted Learning* **33**, 355–369 (2017).
- 1093 209. Tokac, U., Novak, E. & Thompson, C. G. Effects of game-based learning on
1094 students' mathematics achievement: A meta-analysis. *Journal of Computer Assisted*
1095 *Learning* **35**, 407–420 (2019).
- 1096 210. Tokunaga, R. S. A meta-analysis of the relationships between psychosocial
1097 problems and internet habits: Synthesizing internet addiction, problematic internet use, and
1098 deficient self-regulation research. *Communication Monographs* **84**, 423–446 (2017).
- 1099 211. Tremblay, M. S. *et al.* Systematic review of sedentary behaviour and health
1100 indicators in school-aged children and youth. *International Journal of Behavioral Nutrition*
1101 *and Physical Activity* **8**, 98 (2011).
- 1102 212. Tsai, Y.-L. & Tsai, C.-C. Digital game-based second-language vocabulary learning
1103 and conditions of research designs: A meta-analysis study. *Computers & Education* **125**,
1104 345–357 (2018).
- 1105 213. Vahedi, Z., Sibalis, A. & Sutherland, J. E. Are media literacy interventions
1106 effective at changing attitudes and intentions towards risky health behaviors in adolescents?
1107 A meta-analytic review. *Journal of Adolescence* **67**, 140–152 (2018).
- 1108 214. Vahedi, Z. & Zannella, L. The association between self-reported depressive
1109 symptoms and the use of social networking sites (SNS): A meta-analysis. *Current Psychology*
1110 **40**, 2174–2189 (2021).
- 1111 215. van 't Riet, J., Crutzen, R. & Lu, A. S. How Effective Are Active Videogames
1112 Among the Young and the Old? Adding Meta-analyses to Two Recent Systematic Reviews.
1113 *Games for Health Journal* **3**, 311–318 (2014).

- 1114 216. van Ekris, E. *et al.* An evidence-update on the prospective relationship between
1115 childhood sedentary behaviour and biomedical health indicators: A systematic review and
1116 meta-analysis. *Obesity Reviews* **17**, 833–849 (2016).
- 1117 217. van Grieken, A., Ezendam, N. P., Paulis, W. D., van der Wouden, J. C. & Raat,
1118 H. Primary prevention of overweight in children and adolescents: A meta-analysis of the
1119 effectiveness of interventions aiming to decrease sedentary behaviour. *International Journal*
1120 *of Behavioral Nutrition and Physical Activity* **9**, 61 (2012).
- 1121 218. Vannucci, A., Simpson, E. G., Gagnon, S. & Ohannessian, C. M. Social media use
1122 and risky behaviors in adolescents: A meta-analysis. *Journal of Adolescence* **79**, 258–274
1123 (2020).
- 1124 219. Villegas-Navas, V., Montero-Simo, M.-J. & Araque-Padilla, R. A. The Effects of
1125 Foods Embedded in Entertainment Media on Children’s Food Choices and Food Intake: A
1126 Systematic Review and Meta-Analyses. *Nutrients* **12**, 964 (2020).
- 1127 220. Wahi, G. Effectiveness of Interventions Aimed at Reducing Screen Time in
1128 Children: A Systematic Review and Meta-analysis of Randomized Controlled Trials.
1129 *Archives of Pediatrics & Adolescent Medicine* **165**, 979 (2011).
- 1130 221. Shudong Wang, Hong Jiao, Young, M. J., Brooks, T. & Olson, J. Comparability of
1131 Computer-Based and Paper-and-Pencil Testing in K Reading Assessments: A Meta-Analysis
1132 of Testing Mode Effects. *Educational and Psychological Measurement* **68**, 5–24 (2008).
- 1133 222. Wang, J., Li, M., Zhu, D. & Cao, Y. Smartphone Overuse and Visual Impairment
1134 in Children and Young Adults: Systematic Review and Meta-Analysis. *Journal of Medical*
1135 *Internet Research* **22**, e21923 (2020).
- 1136 223. Wang, C.-p., Lan, Y.-J., Tseng, W.-T., Lin, Y.-T. R. & Gupta, K. C.-L. On the
1137 effects of 3D virtual worlds in language learning a meta-analysis. *Computer Assisted*

1138 *Language Learning* **33**, 891–915 (2020).

1139 224. Weng, P.-L., Maeda, Y. & Bouck, E. C. Effectiveness of Cognitive Skills-Based
1140 Computer-Assisted Instruction for Students With Disabilities: A Synthesis. *Remedial and*
1141 *Special Education* **35**, 167–180 (2014).

1142 225. Williams, P. A., Haertel, E. H., Haertel, G. D. & Walberg, H. J. The Impact of
1143 Leisure-Time Television on School Learning: A Research Synthesis. *American Educational*
1144 *Research Journal* **19**, 19–50 (1982).

1145 226. Wood, W., Wong, F. Y. & Chachere, J. G. Effects of media violence on viewers’
1146 aggression in unconstrained social interaction. *Psychological Bulletin* **109**, 371–383 (1991).

1147 227. Wouters, P., van Nimwegen, C., van Oostendorp, H. & van der Spek, E. D. A
1148 meta-analysis of the cognitive and motivational effects of serious games. *Journal of*
1149 *Educational Psychology* **105**, 249–265 (2013).

1150 228. Wouters, P. & van Oostendorp, H. A meta-analytic review of the role of
1151 instructional support in game-based learning. *Computers & Education* **60**, 412–425 (2013).

1152 229. Wu, Y., Amirfakhraei, A., Ebrahimzadeh, F., Jahangiry, L. &
1153 Abbasalizad-Farhangi, M. Screen Time and Body Mass Index Among Children and
1154 Adolescents: A Systematic Review and Meta-Analysis. *Frontiers in Pediatrics* **10**, 822108
1155 (2022).

1156 230. Xie, H. *et al.* Can Touchscreen Devices be Used to Facilitate Young Children’s
1157 Learning? A Meta-Analysis of Touchscreen Learning Effect. *Frontiers in Psychology* **9**, 2580
1158 (2018).

1159 231. Yang, Q., Liu, J. & Rui, J. Association between social network sites use and
1160 mental illness: A meta-analysis. *Cyberpsychology: Journal of Psychosocial Research on*

1161 *Cyberspace* **16**, (2022).

1162 232. Yin, X.-Q., de Vries, D. A., Gentile, D. A. & Wang, J.-L. Cultural Background
1163 and Measurement of Usage Moderate the Association Between Social Networking Sites
1164 (SNSs) Usage and Mental Health: A Meta-Analysis. *Social Science Computer Review* **37**,
1165 631–648 (2019).

1166 233. Yoon, S., Kleinman, M., Mertz, J. & Brannick, M. Is social network site usage
1167 related to depression? A meta-analysis of FacebookDepression relations. *Journal of Affective*
1168 *Disorders* **248**, 65–72 (2019).

1169 234. Zhang, G., Wu, L., Zhou, L., Lu, W. & Mao, C. Television watching and risk of
1170 childhood obesity: A meta-analysis. *The European Journal of Public Health* **26**, 13–18
1171 (2016).

1172 235. Zhang, Y., Li, S. & Yu, G. The relationship between social media use and fear of
1173 missing out: A meta-analysis. *Acta Psychologica Sinica* **53**, 273–290 (2021).

1174 236. Zhang, J., Yang, S. X., Wang, L., Han, L. H. & Wu, X. Y. The influence of
1175 sedentary behaviour on mental health among children and adolescents: A systematic review
1176 and meta-analysis of longitudinal studies. *Journal of Affective Disorders* **306**, 90–114 (2022).

1177 237. Zhang, Y., Tian, S., Zou, D., Zhang, H. & Pan, C.-W. Screen time and health
1178 issues in Chinese school-aged children and adolescents: A systematic review and
1179 meta-analysis. *BMC Public Health* **22**, 810 (2022).

1180 238. Zhang, J. *et al.* An updated of meta-analysis on the relationship between mobile
1181 phone addiction and sleep disorder. *Journal of Affective Disorders* **305**, 94–101 (2022).

1182 239. Zheng, B., Warschauer, M., Lin, C.-H. & Chang, C. Learning in One-to-One
1183 Laptop Environments: A Meta-Analysis and Research Synthesis. *Review of Educational*

1184 *Research* **86**, 1052–1084 (2016).

1185 240. Zhou, C., Occa, A., Kim, S. & Morgan, S. A Meta-analysis of Narrative
1186 Game-based Interventions for Promoting Healthy Behaviors. *Journal of Health*
1187 *Communication* **25**, 54–65 (2020).

1188 241. Zou, Z., Xiang, J., Wang, H., Wen, Q. & Luo, X. Association of screen time-based
1189 sedentary behavior and the risk of depression in children and adolescents: Dose-response
1190 meta-analysis. *Archives of Clinical Psychiatry (São Paulo)* **48**, 235–244 (2022).

1191 242. Zucker, T. A., Moody, A. K. & McKenna, M. C. The Effects of Electronic Books
1192 on Pre-Kindergarten-to-Grade 5 Students' Literacy and Language Outcomes: A Research
1193 Synthesis. *Journal of Educational Computing Research* **40**, 47–87 (2009).

1194 243. Seetharaman, G. W., Jeff Horwitz and Deepa. Facebook Knows Instagram Is
1195 Toxic for Teen Girls, Company Documents Show. *Wall Street Journal* (2021).

1196 244. Elson, M. *et al.* Do policy statements on media effects faithfully represent the
1197 science? *Advances in Methods and Practices in Psychological Science* **2**, 12–25 (2019).

1198 245. Ashton, J. J. & Beattie, R. M. Screen time in children and adolescents: Is there
1199 evidence to guide parents and policy? *The Lancet Child & Adolescent Health* **3**, 292–294
1200 (2019).

1201 246. Royal College of Paediatrics and Child Health. *The health impacts of screen time:*
1202 *A guide for clinicians and parents.* (2019).

1203 247. Page, M. J. *et al.* *The PRISMA 2020 statement: An updated guideline for*
1204 *reporting systematic reviews.* (2020) doi:10.31222/osf.io/v7gm2.

1205 248. Parry, D. A. *et al.* A systematic review and meta-analysis of discrepancies between
1206 logged and self-reported digital media use. *Nature Human Behaviour* **5**, 1535–1547 (2021).

- 1207 249. Byrne, R., Terranova, C. O. & Trost, S. G. Measurement of screen time among
1208 young children aged 0 years: A systematic review. *Obesity Reviews* **22**, (2021).
- 1209 250. Smith, C., Galland, B. C., de Bruin, W. E. & Taylor, R. W. Feasibility of
1210 automated cameras to measure screen use in adolescents. *American journal of preventive*
1211 *medicine* **57**, 417–424 (2019).
- 1212 251. Ryding, F. C. & Kuss, D. J. Passive objective measures in the assessment of
1213 problematic smartphone use: A systematic review. *Addictive Behaviors Reports* **11**, 100257
1214 (2020).
- 1215 252. Guyatt, G. *et al.* GRADE guidelines: 1. Introduction GRADE evidence profiles
1216 and summary of findings tables. *Journal of Clinical Epidemiology* **64**, 383–394 (2011).
- 1217 253. Twenge, J. M. More Time on Technology, Less Happiness? Associations Between
1218 Digital-Media Use and Psychological Well-Being. *Current Directions in Psychological*
1219 *Science* **28**, 372–379 (2019).
- 1220 254. Kelly, Y., Zilanawala, A., Booker, C. & Sacker, A. Social Media Use and
1221 Adolescent Mental Health: Findings From the UK Millennium Cohort Study.
1222 *EClinicalMedicine* **6**, 59–68 (2018).
- 1223 255. National Health, Lung, and Blood Institute. *Quality Assessment of Systematic*
1224 *Reviews and Meta-Analyses*. (2014).
- 1225 256. Bowman, N. A. Effect Sizes and Statistical Methods for Meta-Analysis in Higher
1226 Education. *Research in Higher Education* **53**, 375–382 (2012).
- 1227 257. Jacobs, P. & Viechtbauer, W. Estimation of the biserial correlation and its
1228 sampling variance for use in meta-analysis: Biserial Correlation. *Research Synthesis Methods*
1229 **8**, 161–180 (2017).

- 1230 258. Funder, D. C. & Ozer, D. J. Evaluating Effect Size in Psychological Research:
1231 Sense and Nonsense. *Advances in Methods and Practices in Psychological Science* **2**, 156–168
1232 (2019).
- 1233 259. Gignac, G. E. & Szodorai, E. T. Effect size guidelines for individual differences
1234 researchers. *Personality and Individual Differences* **102**, 74–78 (2016).
- 1235 260. Viechtbauer, W. *Metafor: Meta-analysis package for r*. (2023).
- 1236 261. R Core Team. *R: A language and environment for statistical computing*. (R
1237 Foundation for Statistical Computing, 2023).
- 1238 262. Egger, M., Smith, G. D., Schneider, M. & Minder, C. Bias in meta-analysis
1239 detected by a simple, graphical test. *BMJ* **315**, 629–634 (1997).
- 1240 263. Page, M. J., Higgins, J. P. & Sterne, J. A. Chapter 13: Assessing risk of bias due
1241 to missing results in a synthesis. in *Cochrane Handbook for Systematic Reviews of*
1242 *Interventions* (eds. Higgins, J. P. et al.) (Cochrane, 2021).
- 1243 264. Ioannidis, J. P. & Trikalinos, T. A. An exploratory test for an excess of significant
1244 findings. *Clinical Trials* **4**, 245–253 (2007).
- 1245 265. Papadimitriou, N. *et al.* An umbrella review of the evidence associating diet and
1246 cancer risk at 11 anatomical sites. *Nature Communications* **12**, 4579 (2021).

Table 1

Quality assessment for studies providing unique effects

First Author	Year	Quality Assessment						
		Elig. Crit. ¹	Lit. Search ²	Dual Screen ³	Dual Qual. ⁴	Studies Listed ⁵	Pub. Bias ⁶	Hetero. ⁷
Abrami	2020	U	U	L	H	L	L	L
Adelantado-Renau	2019	L	L	L	L	L	L	L
Andrade	2019	U	L	L	U	L	H	L
Arztmann	2022	U	H	H	H	H	L	L
Aspiranti	2020	U	L	L	H	L	H	L
Bartel	2015	L	L	U	U	L	U	U
Beck Silva	2022	L	L	L	L	L	H	L
Benavides-Varela	2020	U	H	L	H	L	L	L
Blok	2002	U	L	H	H	L	H	L
Bossen	2020	U	L	L	L	L	H	L
Boyland	2016	H	L	L	U	L	L	L
Byun	2018	U	U	U	H	H	H	H
Cao	2020	U	H	U	H	L	L	L
Champion	2019	L	L	L	L	L	L	L
Chan	2014	U	H	H	H	L	L	L
Chauhan	2017	U	L	U	H	H	L	L
Chen	2020	U	H	U	H	H	H	L
Cheung	2012	U	L	L	H	H	L	L
Cheung	2013	L	H	H	U	L	L	L
Cho	2018	U	H	U	H	L	L	L

Table 1

Quality assessment for studies providing unique effects (continued)

First Author	Year	Elig. Crit. ¹	Lit. Search ²	Dual Screen ³	Dual Qual. ⁴	Studies Listed ⁵	Pub. Bias ⁶	Hetero. ⁷
Claussen	2022	U	L	U	H	L	H	L
Clinton	2019	U	H	U	U	L	L	L
Comeras-Chueca	2021	L	U	L	U	L	H	L
Comeras-Chueca	2021	L	L	L	U	L	H	L
Coyne	2018	L	L	L	H	L	L	L
Cunningham	2021	U	L	L	H	L	L	L
Cushing	2010	U	L	H	H	L	L	L
Darling	2017	U	L	U	U	L	H	H
Eirich	2022	U	L	L	L	L	L	L
Feng	2021	L	L	L	L	L	H	L
Ferguson	2017	U	L	L	H	L	L	L
Ferguson	2020	L	U	L	L	L	L	L
Folkvord	2018	U	L	L	U	L	H	L
Furenes	2021	H	H	L	U	L	L	L
Gardella	2017	U	L	L	U	L	L	L
Garzón	2019	U	H	U	H	H	L	L
Graham	2015	U	L	H	H	L	L	L
Hammersley	2016	L	L	H	L	L	H	L
Hao	2021	U	L	L	L	L	H	L
Hassan-Saleh	2019	U	L	U	U	H	H	L
He	2021	L	L	L	L	L	L	L

Table 1

Quality assessment for studies providing unique effects (continued)

First Author	Year	Elig. Crit. ¹	Lit. Search ²	Dual Screen ³	Dual Qual. ⁴	Studies Listed ⁵	Pub. Bias ⁶	Hetero. ⁷
Hernandez-Jimenez	2019	U	L	H	L	L	L	L
Hurwitz	2018	L	L	H	H	L	L	L
Ivie	2020	U	L	L	L	L	L	L
Janssen	2020	U	L	L	L	L	U	L
Kates	2018	U	H	L	H	H	L	L
Kim	2021	U	L	U	L	L	L	L
Kroesbergen	2003	U	L	U	H	L	H	L
Kucukalkan	2019	U	L	U	U	H	L	L
Li	2010	U	L	L	U	L	H	L
Li	2022	L	H	L	L	L	H	L
Li	2022	U	H	L	H	L	L	L
Liao	2008	L	H	H	L	H	H	H
Liao	2014	U	L	H	L	L	L	L
Liu	2019	U	L	U	H	L	L	L
Liu	2022	U	H	U	H	H	L	L
Lu	2021	U	L	U	L	L	L	L
Madigan	2020	U	L	L	U	L	L	L
Major	2021	U	L	L	H	L	L	L
Mallawaarachchi	2022	L	L	L	L	L	L	L
Mares	2005	U	L	H	H	L	H	H
Mares	2013	U	H	H	H	L	H	L

Table 1

Quality assessment for studies providing unique effects (continued)

First Author	Year	Elig. Crit. ¹	Lit. Search ²	Dual Screen ³	Dual Qual. ⁴	Studies Listed ⁵	Pub. Bias ⁶	Hetero. ⁷
Marker	2022	U	L	H	L	L	L	L
Marshall	2004	U	L	H	H	H	H	L
Martins	2019	U	L	U	H	L	L	L
Martins	2022	L	L	L	L	L	H	L
Mazeas	2022	L	L	L	L	L	L	L
McArthur	2012	L	L	L	L	L	L	L
McArthur	2018	L	L	L	L	L	L	L
Mei	2018	U	H	U	L	L	H	L
Merchant	2014	U	L	H	H	H	H	L
Neitzel	2022	U	L	H	H	L	H	H
Oldrati	2020	U	L	U	H	L	L	L
Paik	1994	U	H	U	H	H	L	H
Pearce	2016	U	L	H	H	H	L	L
Peng	2011	U	L	U	U	L	H	L
Powers	2013	U	L	U	H	L	L	L
Prescott	2018	U	L	U	H	L	L	L
Reynard	2022	H	L	L	L	L	L	L
Rodriguez-Rocha	2019	U	L	L	L	L	L	L
Sadeghirad	2016	H	L	L	L	L	L	L
Scherer	2020	U	H	U	H	L	L	L
Schroeder	2013	L	L	U	H	L	L	L

Table 1

Quality assessment for studies providing unique effects (continued)

First Author	Year	Elig. Crit. ¹	Lit. Search ²	Dual Screen ³	Dual Qual. ⁴	Studies Listed ⁵	Pub. Bias ⁶	Hetero. ⁷
Scionti	2019	L	L	L	H	L	L	L
Shin	2019	U	L	L	L	L	H	L
Shin	2022	L	H	L	L	L	L	L
Slavin	2014	U	H	H	H	L	H	H
Strouse	2021	U	L	U	H	H	L	L
Takacs	2014	H	L	U	H	L	L	L
Takacs	2019	L	L	U	H	L	L	L
Tekedere	2016	U	H	U	U	L	L	L
Tokac	2019	U	H	L	H	L	L	L
Vahedi	2018	L	L	U	U	L	L	L
van Ekris	2016	U	L	L	L	L	H	L
Vannucci	2020	U	L	U	H	L	L	L
Williams	1982	U	U	H	U	L	H	H
Wouters	2013	U	H	U	H	L	L	L
Xie	2018	U	L	L	H	L	L	L
Yin	2019	U	H	U	H	L	L	L
Zhou	2020	U	L	U	H	L	L	L

Zucker	2009	L	L	U	H	L	H	L
--------	------	---	---	---	---	---	---	---

Note: Items are from the National Health, Lung and Blood Institute's Quality Assessment of Systematic Reviews and Meta-Analyses tool. Note that we excluded the first item of the

tool. U = Unclear; L = Low; H = High ¹ Eligibility criteria predefined and specified

² Literature search strategy comprehensive and systematic ³ Dual independent screening and

review ⁴ Dual independent quality assessment ⁵ Included studies listed with important

characteristics and results of each ⁶ Publication bias assessed ⁷ Heterogeneity assessed