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Does adult-child co-use during digital media use improve children's learning aged 0–6 years? A systematic review with meta-analysis

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A R T I C L E I N F O

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A B S T R A C T

Young children spend a significant and increasing amount of time using digital media. Thus, a clear understanding of how best to support children's learning from digital media is important. A specific recommendation by some professional bodies is that parental co-use should be applied to scaffold children's learning from digital media. The aim of this meta-analysis was to assess the association between adult-child co-use on 0–6-year-old children's learning from digital media. The analysis was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We identified 17 studies investigating typically developing 0–6-year-old children's learning outcomes from digital media use with an adult for inclusion in this meta-analysis. We extracted 100 effect sizes (N_{total} = 1288) from studies published between 1977 and 2022. Our meta-analysis found a small positive association of adult-child co-use on children's learning from digital media (g = 0.198, 95% CIs: 0.059–0.337, p = 0.009); none of our moderator analyses were significant. While the evidence suggests a positive role of adult-child co-use, support for this conclusion was limited by small sample sizes and a lack of variety in study design. These issues limited the statistical power of our moderator analyses. The effect is, however, clearly significant and suggests that a real effect exists in the practice of co-use, but future research systematically exploring the mechanisms by which adult-child co-use supports children's learning is warranted.

1. Introduction

Digital media is now a ubiquitous part of our children's day to day lives, and as such may impact on children's early learning environments. Children are exposed to digital media including television, video, touchscreen apps, digital games and mobile devices through both indirect family media use (e.g., Braune-Krickau et al., 2021; Knitter & Zemp, 2020; McDaniel, 2019; Vanden Abeele et al., 2020; Wolfers et al., 2020) and direct media use. A recent meta-analysis found that globally, approximately 75.3% of children aged 0–2

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years are using digital media (McArthur et al., 2022). However, the authors highlight a reduction in digital media use for children aged 0–2 years in studies published more recently. Separate meta-analyses found that 64.4% of 2–5-year-olds are using digital media for more than 1 h per day and 44.0% 2–5-year-olds using digital media for more than 2 h per day (McArthur et al., 2022). It is important to note, however, that 47.6% of studies included in the meta-analysis were based on a North American sample. In addition, measures of screen time have a number of shortcomings with low levels of reliability and validity when they have been reported at all (Byrne et al., 2021). For this reason, accurate estimates of the time children are spending with digital media are lacking. Nevertheless, young children are clearly exposed to substantial amounts of digital media.

In response to children's exposure to digital media, some professional bodies have put in place clear guidelines for media use due to concerns around the potential negative impact of excessive digital media use on children's development (e.g., American Academy of Pediatrics, 2016; World Health Organization, 2019; Australian Government & Department of Health and Aged Care, 2021; Canadian Paediatric Society, Digital Health Task Force, Ottawa, & Ontario, 2017; Ponti, 2023; Royal College of Paediatrics and Child Health, 2019). Along with clear screen time limits set by most professional bodies (e.g., no screen use for children aged 0–2 years, up to 1 h per day for 2–5 year olds), the American Academy of Pediatrics (2016), Canadian Paediatric Society (Ponti, 2023) and Australian Government & Department of Health and Aged Care (2021) recommend that parents should use digital media with their children when children are exposed to digital media in order to scaffold children's learning by, for example, explaining what is happening on the screen. Importantly, the Royal College of Paediatrics and Child Health (RCPCH, 2019) do not specify a cut off for children's screen time and do not explicitly reference parents using digital media with their children though they do emphasise the importance of face-to-face interactions. Instead, the RCPCH (2019) refer to the need for "more and better research" (p.3) on the impact of children's digital media use on development. The current meta-analysis was undertaken to add to the literature by examining the relationship between adult-child co-use and children's learning outcomes from digital media.

1.1. Co-use and children's learning outcomes

Using digital media with children is also termed co-use, co-viewing, joint media engagement, scaffolding and active mediation in the literature (see Dore & Zimmermann, 2020). In their seminal study, Valkenburg et al. (1999) identified two types of parent-child co-use; instructive mediation and co-viewing. Instructive mediation involves the parent actively discussing the content of the media with the child either during or after media use and co-viewing involves the parent and child sharing the digital media experience but not interacting with one another. Despite clear guidance in the US to co-use digital media with children, according to Connell et al. (2015), parent-child co-use with children aged 0–8 years is influenced by parent demographics, child demographics and the time parents spend using digital media. Nevertheless, 89% of parents reported co-watching TV, 63% and 64% reported co-using mobile devices and touchscreens respectively with their children at least some of the time. More recently, Levine et al. (2019) found that parents of 0–36 month old children used mobile devices with their children 55% of the time and co-use was related to parent education, motivations for children's media use (educational or not) and children's self-regulation difficulties. Thus, several factors feed into whether or not parents co-use digital media with their children.

From a theoretical perspective, co-using digital media with a caregiver can facilitate learning from screen media because the caregiver can scaffold the learning material and tailor it to the child's prior knowledge (Bruner, 1978; Vygotsky, 1978). Traditionally, children have been shown to exhibit a transfer deficit, whereby children typically learn less from 2-dimensional (2-D) digital media compared to live interactions (see Barr, 2010; Hipp et al., 2017 for review). The transfer deficit can be attributed to perceptual differences between 2-D digital media and the 3-D real-world, memory demands and social contingency (Barr, 2010). Adult-child co-use can therefore potentially support transfer learning through social contingency and scaffolding. Indeed, parent-child shared storybook reading has a positive impact on a range of children's language skills (Noble et al., 2019).

Within the literature, studies suggest attention and attunement could be important mechanisms by which adult-child co-use might support children's learning from digital media. Twelve-to 18-month old infants show increased attention and responsiveness to television when watching television with a parent (Barr et al., 2008). Similarly, pre-school aged children show greater inter-subject synchronization of the pre-frontal cortex with their father when watching emotive scenes together compared to control (random) dyads indicating greater attunement to the other's emotional states (Azhari et al., 2021). Parental responsiveness and attunement with their child are important for supporting learning.

Recent work has suggested benefits for both children and their co-viewing caregivers. Foulds (2022) conducted a semi-naturalistic study in Egypt, Lebanon, Saudi Arabia, and the United Arab Emirates investigating the impact of a television show produced in the Middle East designed to teach emotion vocabulary and emotion regulation strategies. Parent-child dyads with children aged 4–6 years co-watched 13 episodes across a 4-week period. Survey data suggested that both parents and children learnt vocabulary words and emotion regulation strategies, though this was based on parent report rather than standardised measures and assessments. Of note, frequency and compliance with the study instructions were not assessed, meaning that the outcome is questionable. This was a common issue in the studies reviewed in the current analysis (see below).

1.2. Potential moderators

1.2.1. Child age

Studies suggest that as children get older they are better able to learn from digital media. In their meta-analysis on the video deficit effect – the finding that infants learn less from television than live interactions – Strouse and Samson (2021) found that the video deficit effect decreased with age. Similarly, Xie et al. (2018) found that age significantly moderated the effect size for children's learning from touchscreen tablets. Age could moderate children's learning from digital media due to developmental changes in their flexible memory retrieval (Hipp et al., 2017) or increased experience with digital media (Kirkorian & Choi, 2017). Further research has found that the interactivity of touchscreens could interact with age to impact positively or negatively on children's learning at different ages (Kirkorian et al., 2016). The interactive nature of touchscreens has the potential to support children's learning by facilitating active engagement, contingent responses to children's touch, tailored feedback and giving the child a sense of autonomy in the learning process (Hirsh-Pasek et al., 2015; Kirkorian, 2018; Kolak et al., 2021; Taylor et al., 2022). Importantly, it remains to be determined whether age could moderate the effect of adult-child co-use on children's learning from digital media. Children may not need an adult to scaffold their learning as they get older and are better able to learn from digital media. Alternatively, the ability of an adult to scaffold children within their zone of proximal development (Vygotsky, 1978) – the difference between what a child can learn with and without help – and adapt this across age could mean that adult-child co-use is beneficial regardless of a child's age.

1.2.2. Type of media

Children's learning from different types of digital media varies considerably due to the levels of interactivity and feedback afforded by different types of media. Therefore, the impact of adult-child co-use may also differ according to media type. Recently, Jing et al. (2023) found a small positive effect of digital media on 0–6-year-old children's vocabulary. This effect was moderated by media type with a larger effect size for e-books than TV and apps though these platforms also had a significant positive effect, while video chat was not significant. In the present meta-analysis, e-book use was excluded given their natural affordance for promoting adult-child co-use (similarly to books).

Television is limited in terms of the opportunities to interact with the viewer and the ability to offer children feedback to support their learning. A substantial number of studies suggests that children aged 0–6 years typically learn less from both live and pre-recorded videos than they do from live interactions when watching television alone (see Strouse & Samson, 2021 for a meta-analysis). Thus, adult-child interactions could scaffold children to facilitate learning from television by providing social interactions during television viewing (e.g., directing children's attention, discussing the content such as different character's feelings, asking children questions about the content, correcting any misunderstanding about the content, and responding to children's questions). For example, 5 year old children of mothers who use specific scaffolding strategies after watching a movie together gave a better account of the movie to the experimenter compared to children whose mothers did not use scaffolding strategies or who watched the movie alone (Clarke-Stewart & Beck, 1999). Adult-child interactions can therefore add social communication and feedback to support children's learning from digital media.

In contrast, touchscreen apps can be more interactive and can also offer tailored feedback to support children's learning. Indeed, in the UK the Department for Education (2020) recommended specific apps for pre-school age children to support their school readiness skills. In their meta-analysis, Xie et al. (2018) found a significant medium effect size for 0–5-year-old children's learning from touchscreens compared to non-touchscreens. It is important to note, however, that the quality of touchscreen apps for children varies drastically with respect to their educational potential (Meyer et al., 2021; Taylor et al., 2022) and also their interactivity (e.g., Booton et al., 2023; Kirkorian et al., 2022; Russo-Johnson et al., 2017) which can impact on children's learning. Furthermore, Hiniker et al. (2018) noted that touchscreens may afford less opportunities for co-use due to the device size and the necessity for it to be held, which makes it more suitable as a single-person device. Thus, adult-child co-use may be less supportive for children's learning from touchscreen apps.

1.2.3. Learning outcome measurement

Children are social learners and social interactions are a key component to supporting children's learning across all domains (Hirsh-Pasek et al., 2015; Meltzoff et al., 2009). Thus, adult-child co-use should be beneficial regardless of the learning material domain. Studies investigating the transfer deficit have found that the impact on children's learning is not domain specific (e.g., imitation, language, object retrieval, emotion processing; Barr, 2010; Strouse & Samson, 2021). However, Xie et al. (2018) found that the effect of learning from touchscreens was moderated by learning material domain with children learning STEM (Science, Technology, Engineering and Mathematics e.g., measuring, learning to tell the time, scientific trivia) material better than non-STEM material (vocabulary, story comprehension, puzzle solving) from touchscreens. With respect to adult-child co-use, if children's learning from digital technology is easier in some domains than others then this may moderate the effect of co-use.

Social contingency and the language in a child's environment are both particularly important for supporting children's language development (Hart & Risley, 1995; Kuhl, 2007; Weisleder & Fernald, 2013). Adult-child co-use during children's digital media use would therefore provide both social contingency and language, including child-directed speech, which could support children's language learning from digital media. Indeed Madigan et al. (2020) found a significant positive effect of adult-child co-viewing on children's vocabulary. All 10 studies included in their moderator analysis for co-viewing, however, were based on correlational studies. In contrast, Yang et al. (2017) found no significant impact of parent-child co-use during television viewing on children's executive function (EF). However, a meta-analysis found no effect of children's digital media use on EF (Bustamante et al., 2023), though the authors suggest that other factors such as the content and context of digital media use may be more important for EF than time spent using digital media. Understanding the potential moderating role of learning material domain on the impact of adult-child co-use will provide valuable insight into the circumstances under which co-use would best be utilised.

1.2.4. Study design – type of co-use and control group

Along with the two types of co-use identified by Valkenburg et al. (1999), a recent systematic review found that parents use a number of strategies when co-using mobile devices with their children. These include interacting only when asked for help, supporting understanding and engagement with the content, providing encouragement and reassurance, providing physical and technical support and even instigating negative interactions such as pushing the child's hand away or taking the device (Ewin et al., 2021). Understanding the impact of type of co-use on children's ability to learn from digital media is therefore important for informing interventions and policy recommendations for promoting adult-child co-use. At present, policy recommendations specify that parents "coview with your children, help children understand what they are seeing, and help them apply what they learn to the world around them" (AAP, 2016, p. 3) or "whenever possible, co-view with children to model and encourage digital media literacy. Help children recognize and question advertising messages, stereotyping, and other problematic content" (Ponti, 2023, p. 188). Specific strategies to do this, however, are not specified.

Studies on children's learning from digital media differ with respect to the control groups included. In their meta-analysis with touchscreens, Xie et al. (2018) found that control group moderated the effect of touchscreens on children's learning. Importantly however, Xie et al. (2018) included baseline groups in their meta-analysis – groups with no exposure to the learning material – which would have inflated the effect size compared to accessing the learning material via alternative means (e.g., television, face to face teaching). Other than a no-exposure group, control groups for adult-child co-use could include passive co-use with limited to no interaction, child alone using digital media or co-use style interactions built into the digital media (e.g., an adult on the screen interacting with the child or child-directed questions). Control group could therefore impact on the effect size for adult-child co-use on children's learning from digital media.

1.3. The current study

Technology is advancing far more rapidly than academic research, which is needed to inform policy recommendations. Furthermore, different forms of technology have different strengths and weaknesses when it comes to facilitating children's learning and also for facilitating adult-child co-use. The proposed meta-analysis will synthesise the research to date on adult-child co-use with digital media to identify gaps in research and make research informed recommendations for adult-child co-use with digital media. We will assess the association between adult-child co-use on 0–6-year-old children's learning from digital media. Specifically, we will examine the following research questions:

1) Do children show improved learning from digital media when co-using digital media with an adult compared to children using digital media alone?
2) What types of co-use best support learning?
3) Are there additional moderators of the effect of co-use on children's learning from digital media?

This meta-analysis is reported using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines (Page et al., 2021).

2. Method

2.1. Protocol and registration

This systematic review with meta-analysis was registered on the Open Science Framework (OSF) on 18/10/2022 (https://osf.io/z7nxp/?view_only=17369dc7abbd4ec6807d125e139e8926) using the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols guidelines (PRISMA-P; Shamseer et al., 2015).

2.2. Eligibility criteria

For inclusion in this systematic review with meta-analysis, experimental studies were required to be published in English and to meet the following criteria:

1) Population. Typically developing 0–6-year-old children, 2) Intervention. Children's digital media use with an adult, 3) Comparison. Children's digital media use without an adult, and 4) Outcome. Measures of children's learning from the digital media content.

2.3. Information sources

On 18th October 2022, GT conducted a search for published studies on PsycInfo (APA PsycArticles Full Text; Ovid MEDLINE(R) and In-Process, In-Data-Review & Other Non-Indexed Citations 1946 to October 07, 2022; APA PsycExtra 1908 to September 12, 2022; APA PsycInfo 1806 to October Week 1 2022) and unpublished dissertations on Pro Quest Dissertations & Theses. In addition, emails were sent out via relevant mailing lists to identify unpublished and grey literature. To ensure literature saturation, we checked the reference lists of included studies and subsequent citations of papers using the backward/forward method (Webster & Watson, 2002). An updated search was conducted on 20th June 2023.

2.4. Search strategy

The following search terms were used to search the databases:

child* OR baby OR babies OR toddler* OR infan* OR preschool* OR pre-school OR kid*

AND

"digital media use" OR "touchscreen device*" OR "electronic media" OR "digital technolog*" OR "screen media" OR "digital screen media" OR "educational media" OR TV* OR television OR screen OR video* OR "video chat" OR DVD OR wireless OR "cell phone*" OR "cellular phone*" OR mobile* OR laptop* OR iPAD* OR tablet* OR apps OR application* OR smartphone* OR "media exposure" OR "electronic play" OR "online environment*" OR "digital device*" OR "mobile device*" OR "digital toy*" OR "mobile technolog*" OR "screen time" OR screentime OR "interactive learning environment*" OR tech* OR "screen based" OR "screen-based" OR "video gam*" OR gaming OR "electronic gam*" OR digital OR media NOT screening

AND

co-view* OR coview* OR co-use OR interact* OR scaffold* OR "joint media engagement" OR jme OR "joint attention" OR responsive* OR support* OR scaffold* NOT therapy

The search terms were entered into PsycInfo and ProQuest Dissertations & Theses by "title" and limited to papers from 1960-current.

2.5. Study selection process

Four authors (GT, JK, PG, JL) were responsible for the selection process of the studies to be included. Two authors independently screened each title and abstract returned in the searches. Disagreements were resolved by discussion with all four authors or independently by a third author. Two authors then read each of the full text articles and any uncertain articles to assess eligibility. Again, disagreements were resolved by discussion with all four authors or independently by a third author.

2.6. Data collection process

All five authors independently extracted the data for separate samples of the articles eligible for inclusion and the first author (GT) checked the data collection for all authors. To obtain relevant data that was not included in the published article, the first or senior authors were contacted via email.

2.7. Data items

Eligible outcomes included any measure of learning from the digital media content and we included all outcomes when multiple measures of learning were reported. We also collected data on: 1) report details (authors, year, publication type), 2) research design (study design, learning material domain, learning measure, group allocation, type of digital media device, pre and post means and standard deviations), 3) intervention (person delivering the intervention, type of co-use, control group), 4) sample (age in months, sample size). See Table 1 for coding information.

Table 1
Coding criteria for data items.

Column Heading	Definition
Publication type	Dissertation, peer reviewed journal article
Design	Between, within
Learning material domain	a) Content comprehension and memory = any form of comprehension or memory test b) Communication and language = any form of language test, word learning etc c) Social and emotional = anything to do with teaching children EF and social and emotional skills d) Academic skills = literacy (letter recognition), mathematics (anything to do with maths or coding skills) and understanding the world (picture matching, classification, relations)
Group allocation	If another condition was used, whether participants were randomly allocated to groups
Type of digital media device	a) Video = presented on a computer, television or tablet b) Touchscreen app c) Television = live tv d) Video chat = Skype, Facetime, Closed Circuit TV set up
Person delivering the intervention	a) Researcher = experimenter, grad student, undergraduate student b) Parent = Mother or father
Type of co-use	a) Instruction = parents were told which things to discuss specifically b) Script = researchers followed a script c) Spontaneous = parents told to co-view with no other instructions
Type of control group	a) No interaction = child alone (adult not present or occupied with something else) or non-interactive (adult present and watching but not interacting) b) Digital interactive = adult present and watching but not interacting, content is interactive asking the child questions.

Table 2
Study characteristics for each study included in the meta-analysis.

Authors (Year): Country	Study Design	Sample size	Age in months (mean, SD)	Female (%)	Type of media	Type of co-use	Person co-using media	Learning outcome measures
Griffith, Hart, Mavrakis, & Bagner (2022): USA	between	26	62.07 (2.59)	25	touchscreen app	spontaneous	parent	Coding app assessment
Heimann et al. (2021): Sweden	between	121	25.15	–	video	instruction	parent	Action imitation
Krcmar (2014): USA	between	70	13.91 (5.49)	53	video	spontaneous	parent	Looking time to taught object
Morgenlander (2010): USA	between	112	57 (5.9)	49	video	script	researcher	Maths comprehension, social/ emotional comprehension; number learning; geometry
Myers, Crawford, Murphy, Aka-Ezoua, & Felix (2018): USA	between	40	27.49 (2.07)	45	video chat	script	researcher	Recognition of object, memorising book patterns, memorising book items, memorising actions
Neuman, Samudra, Wong, & Kaefer (2020): USA	within	83	51.6 (4.44)	–	video	script	researcher	Receptive and expressive words
Peebles, Bonus, & Mares (2018): USA	between	80	54.03 (9.11)	46.4	video	script	researcher	Labeling character emotions, Recognition of character emotions, Comprehension of character lies/ truths, Moral evaluation of character lies/truth, Moral abstraction in story context, Emotion Matching Task subsets (EMT; Izard et al., 2008), Comprehension of human lies/truth, Evaluations of human lies/truth, Transfer of moral lesson to novel context
Rasmussen et al. (2016): USA	between	71	38.98 (0.93)	48	video	spontaneous	parent	Griffith Empathy Measure (Dadds et al., 2008), Feelings about Myself and Peers subset (Lindsey & Mize, 2000), Emotion Recognition Interview
Reiser, Tessmer, & Phelps (1984): USA	between	23	46 (8)	52	television	script	researcher	Letter and digit recognition
Salomon (1977): Israel	between	93	65.76 (5.28)	–	television	spontaneous	parent	Letter match, number match, picture match, child embedded figures, parts of whole, relational concepts, classification, picture ordering
Samudra, Flynn, & Wong (2019): USA	between	128	53 (4.71)	45	video	script	researcher	Word labelling, audiovisual concept understanding, auditory word accuracy
Samudra, Wong, & Neuman (2020): USA	within	83	51.6 (4.44)	64	video	script	researcher	Story comprehension
Skouteris & Kelly (2006): Australia	between	77	62.6 (10.01)		video	instruction	parent	Comprehension scores
Strouse & Troseth (2014): USA	between	32	24.5 (0.66)	50	video	script	parent	Recognition of novel object
Strouse, O'Doherty, & Troseth (2013): USA	between	81	41.9 (3.86)	–	video	instruction	parent	EOW PVT, object naming from a screenshot, object naming from a drawing
Strouse, Troseth, O'Doherty, & Saylor (2018): USA	between	88	30.3 (0.95)	50	video	instruction	parent	Word learning
Watkins, Calvert, Huston-Stein, & Wright (1980): USA	between	80	63.6	50	video	script	researcher	Incidental recall questions, Central recall questions

2.8. Study risk of bias assessment

Two review authors independently assessed the risk of bias in each study by examining the risk of bias (unclear, high, medium, low) in study participation (categories: recruitment, sample demographics, attrition rate, reason for attrition provided) and outcome measurement (blind coding, valid and reliable tool, clear coding definition). Further information on our coding criteria and coding scheme can be found in Table 2 in our protocol: https://osf.io/z7nxp/?view_only=17369dc7abbd4ec6807d125e139e8926. Disagreements were resolved by discussion or by a third author. The overall risk of bias for each study was determined by the highest level of risk of bias across the categories.

2.9. Effect measures

The effect sizes for all outcome measures in each article were calculated using the standardised mean difference Hedge's *g* to compare the co-use conditions to controls. Standardised mean difference was chosen due to the measurement of different learning material domains and measures used in the articles. The sampling error variances were calculated using the equations reported in Schmidt and Hunter (2015).

2.10. Synthesis methods

A random-effects model was used for a frequentist meta-analysis. Unlike fixed-effect meta-analytic models, random-effect models allow between-study true variance (i.e., heterogeneity) to be greater than zero. Heterogeneity refers to the differences across effect sizes that cannot be accounted for by sampling error variance. The presence of heterogeneity thus indicates that moderating variables may affect the magnitude of the effect sizes. The potential role of the moderators was assessed in a single regression model. By contrast, a low to null heterogeneity suggests that sampling error variances are the sole cause of the observed between-effect-sizes differences and no further explanation is warranted.

Since the included primary studies often report more than one effect size, the heterogeneity needs to be decomposed into between-study heterogeneity and within-study heterogeneity. Therefore, a multilevel meta-analysis was employed. The statistical significance of the estimated heterogeneity was assessed using a *Q*-test for multivariate meta-analysis. The whole workflow is described in Pustejovsky and Tipton (2022).

2.11. Publication bias assessment

Publication bias was assessed with multiple methods. First, the funnel plot was visually inspected in order to evaluate whether the effect sizes are asymmetrically distributed. Funnel plots depict the distribution of the effect sizes in function of the squared root of their sampling error variance (i.e., their standard error). In the presence of publication bias, funnel plots exhibit a pronounced asymmetry in the distribution of the effect sizes due to the systematic suppression of studies with low precision (i.e., small sample sizes) and close to null effect sizes.

Then, two statistical tests for publication bias, PET-PEESE and selection models, were performed. PET-PEESE (Stanley, 2017) consists of two regression analyses putting in relationship effect sizes and their standard errors (PET) or sampling error variances (PEESE). If standard errors or sampling error variances significantly predict the magnitude of the effect sizes (i.e., the bigger the effect size, the lower the precision), then bias is probably present. The model intercept can be interpreted as the corrected overall effect size. When the PET intercept is significantly different from zero (with alpha = 0.10, one-tailed), the PEESE intercept has to be preferred as the bias-corrected overall effect size. Else, the PET intercept is the bias-corrected overall effect size. PET-PEESE was run after aggregating the effect sizes by study (Cheung & Chan, 2014).

Selection models (Vevea & Woods, 2005) assume that the probability of an effect size to be suppressed is a function of its statistical significance. For example, studies with statistically significant or positive results may have a higher probability of being published and included in the meta-analysis compared to studies with nonsignificant or negative results. By incorporating the probability of selection, a selection model attempts to account for the potential bias introduced by the selective reporting of studies and provides a corrected overall effect size. The selection models were run on the individual effect sizes to preserve the original *p*-value distribution.

Finally, sensitivity analysis was conducted on the individual effect sizes to assess for outliers using the Cook's distance (Viechtbauer & Cheung, 2010). This analysis served as a stress test to verify whether the overall effect size and heterogeneity are robust to outliers.

The software package R (R Core Team, 2021) was used to run the analyses. The *metafor* and the *weightr* R packages were employed for the analyses (Coburn & Vevea, 2019; Viechtbauer, 2010). All the data and codes necessary to run the analyses are retrievable from this OSF link (https://osf.io/z7nxp/?view_only=17369dc7abbd4ec6807d125e139e8926).

3. Results

3.1. Study selection

After conducting our literature search, we identified a total of 1401 records (see Fig. 1). Following the removal of duplicates, we screened the titles and abstracts of 1052 records. We identified 75 full-text records to be screened for eligibility and were able to access full-text articles for 68 of those records. From the initial search, 9 articles met the inclusion criteria. Additionally, 15 records were identified from the reference lists of eligible articles. Following full-text screening, 8 articles met the inclusion criteria. Thus, a total of 17 articles were included in this meta-analysis.

3.2. Study characteristics

We identified 17 studies investigating typically developing 0–6-year-old children's learning outcomes from digital media use with an adult for inclusion in this meta-analysis (see Table 2). Two studies (Neuman, Samudra, Wong, & Kaefer, 2020; Samudra, Wong, & Neuman, 2020) reported the same sample of participants and were then coded as the same sample in the multilevel meta-analyses. We extracted 100 effect sizes ($N_{total} = 1288$) from studies published between 1977 and 2022. Fifteen (88.24%) studies used a between participants design and digital media was typically pre-recorded videos (13 studies; 1 used touchscreen apps, 2 used television, 1 used video chat). In 9 studies, it was the parent who co-used the digital media with the child and the nature of co-use varied (4 spontaneous co-use; 4 instructed co-use; 1 script). When the researcher co-used the digital media with the child, a set script was always used (8 studies).

3.3. Risk of bias in studies

Almost all studies included in our meta-analysis (16/17) were considered to have high risk of bias in at least one domain (recruitment, sample demographics, attrition rate, reason for attrition, standardised tool, blind coding, and clear coding definition). The risk of bias typically occurred with community-based recruitment strategies rather than population-based recruitment (12/17) or by not using standardised measures (12/17). Attrition was commonly not reported in studies (11/17) but when attrition was reported clear reasons were given. For a summary of our risk of bias assessments, see Risk of bias in studies table at https://osf.io/z7nxp/?view_only=17369dc7abbd4ec6807d125e139e8926).

3.4. Results of individual studies

The individual effect sizes are summarized in two orchard plots (Nakagawa et al., 2021, Fig. 2). For more details, see the supplemental materials available at the OSF link (https://osf.io/z7nxp/?view_only=17369dc7abbd4ec6807d125e139e8926).

3.5. Results of syntheses

The intercept model estimates a significant, yet small overall effect size ($g = 0.252$, 95% CIs: 0.093–0.411, $p = 0.004$). The Cook's distance analysis identified five outliers (five effect sizes). Once they were removed, the overall effect size was slightly reduced, but still significant ($g = 0.198$, 95% CIs: 0.059–0.337, $p = 0.009$). Also, the exclusion of the outliers from the pool of the effect sizes caused a reduction of the heterogeneity, which became non-significant ($p = 0.113$). This result suggests that the literature exhibits a high degree of consistency both between- and within-studies, although it is worth noting that some residual true variance remains (Table 3).

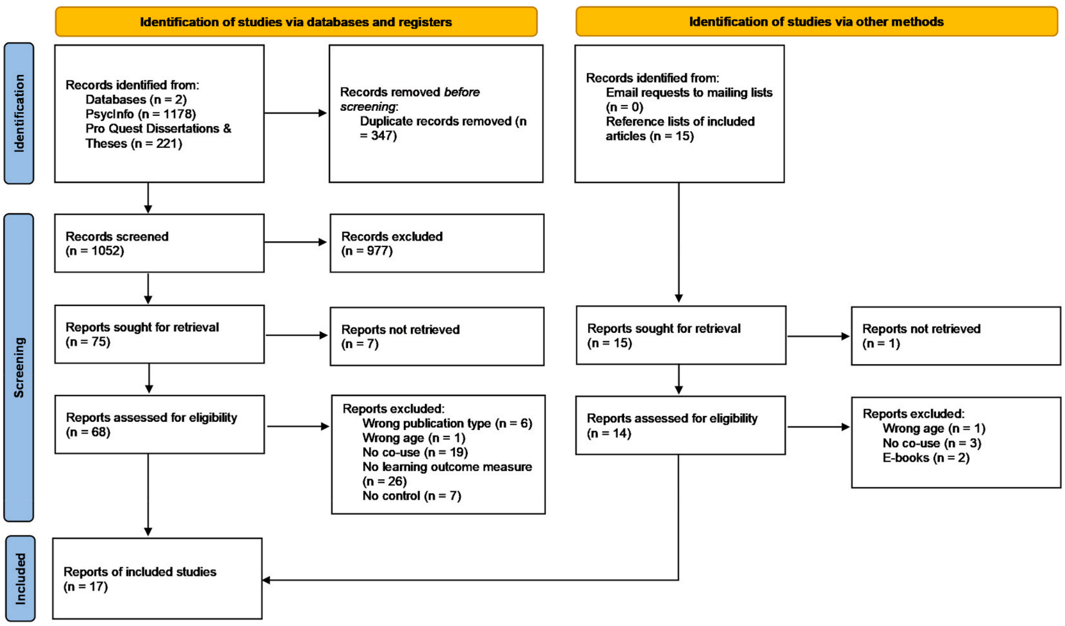

Fig. 1. PRISMA flow diagram showing the literature search and screening process.

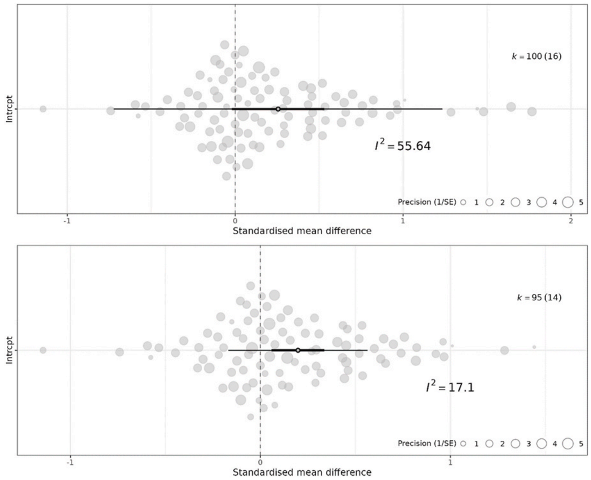

Fig. 2. Orchard plots with and without outliers (see below for the details). *k* indicates the number of effect sizes (number of studies) included in the meta-analysis. The grey circles represent the effect sizes and their dimension represent their precision. The little black circles, the thick black lines, and the thinner black lines, represent the overall effect sizes, the confidence intervals, and the prediction intervals, respectively.

3.5.1. *Publication bias*

The funnel plots showed a minimal asymmetry in the distribution of the effects, which further reduced after removing the outliers (Fig. 3).

PET-PEESE and the selection model provide estimates similar to the overall effect size after removing the outliers (0.170 and 0.143, respectively). The convergence of these results leads us to assert that the model's estimates are reliable and that the true overall effect size is around 0.150 standardized mean differences in favour of the treated samples.

3.5.2. *Moderator analyses*

Moderator analysis finds that the type of test (standardised vs. unstandardised) is the only significant variable affecting the effect sizes ($p = 0.003$; all other $ps \geq 0.183$; Table 4), showing that standardised tests are associated with smaller effect sizes (−0.088 and 0.347 for standardised tests and unstandardised tests, respectively).

4. Discussion

The aim of this meta-analysis was to assess the association between adult-child co-use on 0–6-year-old children's learning from digital media. Across 17 studies, 100 effect sizes and an overall sample of 1288 children aged 0–6 years, we found a small positive association ($g = 0.176$, $p = 0.008$) between adult-child co-use and young children's learning outcomes from digital media following the removal of outliers. Importantly, this effect held after correcting for publication bias and potential biases stemming from extreme effect sizes (outliers). Thus, adult-child co-use seems to be a beneficial activity to support 0–6-year-old children's learning from digital media compared to children's solitary digital media use, consistent with existing guidelines in some countries (American Academy of Pediatrics, 2016; Australian Government & Department of Health and Aged Care, 2021; Ponti, 2023).

Heterogeneity, that is, the degree to which the studies' results differ from each other beyond sampling error variance, was found to be low to non-significantly different from zero (after removing the outliers). This outcome suggests a high degree of between-study consistency in this literature. The moderator analysis was in line with the observed low degree of heterogeneity. We tested the impact of age, type of digital media, learning outcome measure, type of co-use and type of control group on the effect of co-use on children's learning outcome and found no significant moderators. The only significant moderator was the type of test (with studies employing standardised tests yielding a null overall effect). This effect did not, however, maintain statistical significance following outlier removal.

It is important to note however, that the effects of some moderators may have been missed due to low variety between studies (and

Table 3
Summary of the results of the meta-analysis.

Model	Studies	k	g	se	t	p	ci.lb	ci.ub	pi.lb	pi.ub	sigma2.1	sigma2.2	Q.p
Naive Model	16	100	0.252	0.075	3.380	0.004	0.093	0.411	−0.449	0.953	0.019	0.080	0.000
Outliers Out Model	14	95	0.198	0.064	3.068	0.009	0.059	0.337	−0.177	0.573	0.013	0.012	0.113

Note. Studies = numbers of studies; *k* = number of effect sizes; *g* = overall effect size; *se* = overall effect size's standard error; *t* = t-value statistics; *p* = overall effect size's significance; *ci.lb* = 95% lower bound CI; *ci.ub* = 95% upper bound CI; *pi.lb* = 95% lower bound Prediction Intervals; *pi.ub* = 95% upper bound Prediction Intervals; *sigma2.1* = between-study heterogeneity; *sigma2.2* = within-study heterogeneity; *Q.p* = heterogeneity significance.

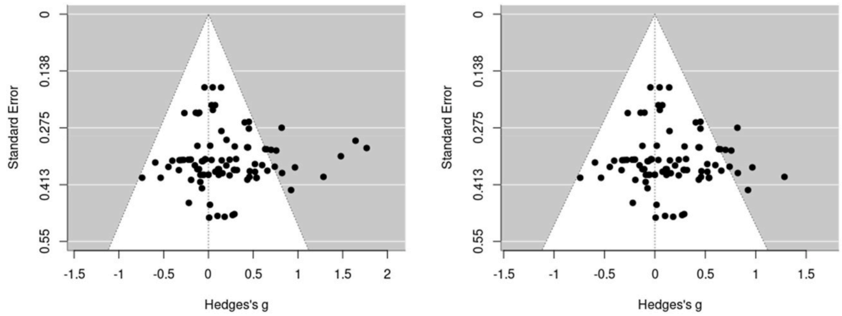

Fig. 3. Funnel plot as a function of Hedges's *g* and standard errors with (left panel) and without (right panel) outliers.

Table 4
Results of the moderator analysis.

Moderator	estimate	se	t-value	p-value	ci.lb	ci.ub
intercept	1.244	0.795	1.565	0.169	−0.701	3.188
Standardised Test (Yes)	−0.484	0.161	−3.004	0.003	−0.804	−0.164
Control group (No interaction)	0.165	0.123	1.341	0.183	−0.079	0.408
Person Delivering Intervention (Researcher)	0.020	0.568	0.034	0.974	−1.370	1.409
Media (touchscreen app)[a]	−0.162	0.704	−0.231	0.825	−1.886	1.561
Media (video)[a]	−0.501	0.447	−1.120	0.305	−1.595	0.593
Media (video chat)[a]	−0.669	0.763	−0.877	0.414	−2.535	1.197
Co-use (script)[b]	−0.023	0.525	−0.043	0.967	−1.306	1.261
Co-use (spontaneous)[b]	−0.307	0.295	−1.042	0.300	−0.894	0.279
Sample mean age	−0.010	0.010	−1.009	0.352	−0.036	0.015

Note. *se* = Standard Error associated with the estimate; *ci.lb* = lower-bound of the 95% confidence interval; *ci.ub* = upper-bound of the 95% confidence interval.
However, this outcome is not robust to outliers. After removing the outliers, the same tendency emerged, but the effect became non-significant (p = 0.085).
[a] The reference level is "Television." This moderator did not reach significance in the omnibus test either (p = 0.232).
[b] The reference level is "Instruction." This moderator did not reach significance in the omnibus test either (p = 0.234).

the consequent lack of statistical power). For instance, the majority of the studies included in our meta-analysis investigated the role of adult-child co-use during a pre-recorded video or television. Given the affordances of other types of media such as touchscreen apps and video chat, and recommendations from professional bodies that these forms of media could be beneficial for young children's learning (American Academy of Pediatrics, 2016; Department for Education, 2020), it is essential to understand the role of adult-child co-use for these forms of media.

We also identified three types of co-use used in experimental studies including spontaneous co-use, instructed co-use and scripted co-use with scripted co-use always associated with the researcher as the adult co-user. Further research needs to systematically examine the role of different types of co-use for learning to understand the mechanisms by which adult-child co-use supports children's learning from digital media. For example, current research cannot tease apart the role of increased attention due to adult-child co-use, directed attention through parent-child interactions or the role of language and content-based discussions to support children's learning. In their study, Samudra, Wong, & Neuman (2020) found that 3- and 4-year old children watching a video with an adult attended to the video for longer than when the same children watched a different video alone. Children's comprehension was predicted by an interaction between co-use conditions, their attention during the video and their language skills (Samudra, Wong, & Neuman, 2020). However, in their study, co-use was scripted thus it is unclear whether children's attention would be increased with other types of co-use (e.g., spontaneous, instructed) or how increases in attention may differ between types of co-use. To develop clear policy recommendations for caregivers and educators, further research needs to better understand the differences between types of co-viewing for children's learning and also whether co-viewing needs to be one-to-one or whether the presence of an adult co-viewer has similar benefits for groups of children such as those experienced in educational settings.

While a strength of this meta-analysis is our focus on studies using experimental designs to test children's learning directly from media content, this does not tell us how persistent such learning is or how children's learning from digital media feeds into their development with respect to children's school readiness and early academic achievement. Correlational studies suggest an advantage to adult-child co-use on children's vocabulary (e.g., Madigan et al., 2020), however it is unclear whether co-use promotes language learning from digital media directly or whether it is the language used during co-use that promotes language learning. Co-use might also change parent-child interactions outside of digital media use through discussions about digital media content. Studies suggest that supplementing digital media content with a live interaction afterward can also help support children's learning (e.g., Clarke-Stewart & Beck, 1999; Roseberry et al., 2009). For example, in Roseberry et al. (2009) the live experimenter completed the action and verb labelling for the child that had just been played via video. Children under the age of 3 years in this study only learned the action and verb following the live interaction and not from the video alone or when the interaction occurred via video chat. Future research should therefore consider the long-term impact of adult-child co-use on children's learning from digital media and importantly, the mechanisms by which adult-child co-use impacts children's learning.

4.1. Limitations

The present meta-analysis is limited by the quality of the data on the effect of adult-child co-use on children's learning from digital media. Specifically, since the effect size of adult-child co-use on learning is modest at best (about 0.15 standardised mean difference), many, if not all, of the studies included in this meta-analysis are likely to be underpowered (i.e., too small sample sizes). In addition, based on our risk of bias assessment, all but one study was found to have a high risk of bias in at least one of our categories (recruitment, sample demographics, attrition rate, reason for attrition provided, valid and reliable tool, blind coding and clear coding definition). Thus, future work in the area should strive to produce well-powered and rigorous study designs to ensure that good quality experimental data is available to support the existing policy recommendations for adult-child co-use and to support specific recommendations about how to co-use digital media with children effectively.

4.2. Conclusion

With young children's prominent exposure to digital media and differences in recommendations around children's digital media use by professional bodies internationally, this meta-analysis demonstrates the benefit of adult-child co-use during children's digital media use on children's ability to learn from the digital content. Nevertheless, caregivers should continue to mediate children's digital media use to ensure that children are exposed to appropriate content and continue to take part in activities outside of digital media to support their development. Where digital media is used in educational settings, adult-child co-use is also encouraged wherever possible either through one-to-one support or in group settings, though further research is needed to explore co-use in educational settings. To provide a stronger evidence base for policy recommendations for children's digital media use, high powered research needs to 1) focus on newer forms of technology such as touchscreen apps and video chat, 2) understand the role of different types of co-use for learning both in home and in educational settings, 3) systematically explore the mechanisms by which co-use can support children's learning, and 4) understand the longer term impact of adult-child co-use on children's learning and development.

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Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data is available at: https://osf.io/z7nxp/?view_only=17369dc7abbd4ec6807d125e139e8926

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Appendix A. Supplementary data

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The asterisks (*) indicate studies included in the meta-analysis.
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