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RESEARCH ARTICLE

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Interactive technology use and child development: A systematic review

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Abstract

Background: There is mixed evidence regarding the impact of interactive digital devices on child development. Tentatively some studies suggested that the use of digital devices may correlate negatively with language, executive function, and motor skills. However, attempts to amalgamate this evidence has been limited related to the available number of experimental and cohort studies that have evaluated the impact of digital technology use on child development. We conducted this review to determine the impact of interactive digital devices on child development among children aged 7 years or younger. Interactive technology has been defined as methods, tools, or devices that users interact with in order to achieve specific tasks.

Data source: To carry out this systematic review, databases CINAHL, MEDLINE, Embase, PsychINFO, Scopus and Google Scholar were searched for relevant studies.

Study selection: We used the Joanna Briggs Institute methodology for systematic reviews.

Data extraction: Data extraction and synthesis was carried out by two reviewers and checked by a third reviewer. Studies were stratified into tiers depending on the level of evidence provided and the domain of development assessed.

Results: Fifty-three studies were eligible for inclusion in the review, 39 Tier 1 (randomized controlled trials and quasi-experimental studies) and 16 Tier 2 (descriptive studies). Children's use of interactive digital technology was positively associated with receptive language and executive function and negatively associated or unrelated to motor proficiency. Other critical aspects informing the evidence, such as dose of exposure, intensity, or duration, were inconsistently reported, making estimates of exposure tentative and imprecise.

Conclusion: The studies included in this review were predominantly correlational or comparative in nature and focuses on cognitive domains of learning rather than a specific developmental outcome. It is difficult to generalize our findings beyond the digital devices or applications that have been evaluated by earlier studies. The contextual factors that may moderate the relationship require elaboration in future studies.

KEYWORDS

cognitive development, digital child, language development, motor development, screen device, technology

1 | INTRODUCTION

The increased time that children engage in online activities has raised concerns about the potential impact of the use of computers, smart phones, tablets and/or electronic games on children's health (Görzig & Holloway, 2020). In response to those concerns, both Canadian and Australian governments have released 24-h movement guidelines for the early years (0–5 years) that recommend no screen time for children younger than 2 years and no more than 1 h per day for children aged 2–5 years (Joshi & Hinkley, 2021; McNeill et al., 2020). Estimates from primary research suggest only 17% of preschoolers in Australia meet screen-time guidelines of no more than 1 h per day (Cliff et al., 2017). Recent evidence suggests that supporting children to meet the 24-h movement guidelines associated with better cognitive development (McNeill et al., 2020) and better social-cognitive development in preschool children (Cliff et al., 2017). However, this evidence was limited for meeting the physical activity guidelines at 3–5 years of age and not evident for screen time (McNeill et al., 2020) or psychosocial outcomes (Hinkley et al., 2020).

An earlier systematic review in this area conducted by Poitras et al. (2017) examined the relationships between sedentary behavior and health indicators in children aged 0 to 4 years highlighted the value of minimizing screen time for health promotion in the early years and the potential cognitive benefits of interactive non-screen-based sedentary behaviors such as storytelling, reading, and puzzles. Another two systematic reviews in these special issues conducted by Madigan et al. (2020) and Reus and Mosley (2018) of studies examining the association between screen use and child development indicated minimal discussion of interactive digital devices use in young children, or its impact other than on language or cognitive domains. Interactive digital technology is a broad term that refers to methods, tools or devices that allow individuals, machines, or organization to engage in mediated communication to facilitate the planning and consummation of exchanges between them (Varadarajan et al., 2010, p. 97). Reus and Mosley (2018) suggested a negative relationship between touchscreen use and cognition, language and executive functioning among children less than 5 years. However, their scoping review lacked a systematic approach in the assessment of digital technology use as well as the methods of assessment of child development. The findings were broad and included 24 published studies that correlated screen media use with cognition, language, executive functioning, obesity, and socio-emotional development.

The same finding was detected in the meta-analysis of 42 studies conducted by Madigan et al. (2020), where a greater quantity of screen use, such as duration of use and background television noise, was associated with a reduction in language skill development in children. The authors of this meta-analysis suggested both a negative and positive impact of screen media use on language development and recommended high-quality programming and co-viewing when possible. Overall, evidence from earlier reviews (Madigan et al., 2020; Reus & Mosley, 2018) concluded that what is missed in many, if not most, published studies is a discussion of the differential effects of content available to children and the type of programming watched. Therefore, conclusions regarding the potential benefits of limited screen time and children development in the early years remain limited, and there is a need to examine the potential benefits or risks for broader outcomes, including motor, language, and cognitive development.

Key messages

- Use of digital technology can lead to no gains or may associate negatively with fine motor development.
- Children's use of interactive digital technology is commonly associate with enhanced receptive language, executive function and memory, but not with comprehension.
- When used in a learning context, digital technology interventions are effective in enhancing literacy and numeracy skills, manual dexterity, and visuo-spatial working memory.
- Better understanding of the dose of exposure to video games or screen devices is important prior to further research in this area.
- More reliable methods of measuring touchscreen usage, such as media diaries or device monitoring, are required.
- The constant advancement of interactive digital technologies means that many of the more recent releases have yet to be evaluated through research.

As Anderson and Subrahmanyam (2017) argue in a discussion paper published on behalf of the Cognitive Impacts of Digital Media Workgroup, recent studies have failed to identify the impact of digital screen device use on young children. Published research on how and how much children younger than 5 years of age learn from digital technology through screen use is limited. Therefore, the knowledge base regarding the impact of digital technology overall on child development and the impact of digital screen devices remains sparse. The field of early child development is often broken down into three basic domains of cognitive, language, and motor development. The combination of linguistic learning (language) and cognitive abilities has been linked to a myriad of factors such as later academic outcomes and abilities to learn (Picard et al., 2014; Riggs et al., 2006). Children's motor skills have been likely to affect motor and cognitive outcomes at school age, but not mental health (Baumann, 2020). This is in addition to being reported as an important precursor of long-term outcomes across multiple psychological domains (Baumann, 2020). A systemic literature review of recent studies examining the impact of interactive digital devices on child development will enable healthcare professionals to provide evidence-based care to families and carers of children. It will help to build new understandings about the influence of digital devices on children's motor, language, and cognitive development to inform recommendations and guidelines. Other social and emotional aspects of child development were not included as their consideration would have involved a greatly expanded scope of work.

2 | AIM

We conducted a systematic review to determine the impact of interactive digital devices on the development of children aged 7 years or younger.

3 | METHODS

3.1 | Design

This systematic literature review was carried out following the Joanna Briggs Institute (JBI) methodology for systematic reviews and research syntheses (Munn et al., 2019) and in accordance with a protocol that was published in PROSPERO (registration number was deleted to promote anonymous review).

3.2 | Data source

We searched seven databases for primary research studies published over the last 11 years, between January 2010 and August 2021. We excluded studies published prior to 2010 as the focus of the review was on contemporary technologies with regards to the definitions and context of interactive digital devices and the impact of use. The databases searched were CINAHL, MEDLINE, PsychINFO, Embase, Scopus, and Google Scholar. Manual or hand searching of reference lists was also conducted. The key search terms were developed in collaboration with a research librarian and included three sets of keywords: (1) 'child' OR 'infant' OR 'toddler' OR 'pre-schooler'; AND (2) 'digital technology' OR 'digital media' OR 'screen time' OR 'computer' OR 'smartphones' OR 'tablets' OR 'videogame'; AND (3) 'impact' OR 'effect' OR 'outcome' (see Appendix A).

3.3 | Study inclusion criteria

In agreement with the Joanna Briggs Institute recommendation for systematic review (JBI, 2014; Tufanaru et al., 2015), authors, when feasible, should include RCTs and quasi-experimental and observational studies in their review of impact or effectiveness. Thus, we have included all study designs in this review as it is the most inclusive approach. All studies were assessed against the following general inclusion criteria: Primary research studies related to the usage of technology, published in English language, and studies of children aged 7 years or younger (different from published protocol). Commentary, anecdotal, and review studies were excluded. Studies limited to children with functional disabilities such as autism spectrum disorders (ASD), attention deficient hyperactivity disorders (ADHD), and cerebral palsy (CP) were excluded. Studies that included assessment of literacy and numeracy skills were eligible for inclusion in this review if they were measured as an outcome of cognitive development. In this review, numeracy skills were defined as the child's ability to perform basic arithmetic operations, recognize numbers, and count accurately. Only screen-based technologies were considered in this review. Internet-connected toys were not included in this review. This review excluded articles with a limited focus on TV viewing and general screen time as there was no current gap in the literature.

It should be noted that although the inclusion criteria specified developmental outcomes for children aged 7 years or younger, some studies including children older than 5 years were not excluded from the review because they contributed relevant data on the population of interest. This included, for example, studies involving children older than 7 years but with data stratified by age or developmental group.

Inclusion criteria in the form of a PICOS statement (Population, Intervention/Phenomena, Comparison/Context, Outcome) are provided in Table 1.

3.3.1 | Studies selection

We used Rayyan, an online systematic review tool, to assist in the selection process (Ouzzani et al., 2016). After removal of duplicates, two reviewers independently read title and abstracts of articles acquired in the initial search. Both reviewers screened the relevant articles identified by the search strategy on inclusion and exclusion criteria to identify studies that examined the impact of digital technology on child development. A third reviewer adjudicated on any

TABLE 1 PICO's statement for the systematic literature search

Population	**Infants, toddlers and preschoolers between the ages of 6 months and 5 years exposed to digital technology in various forms**
Intervention	The use of interactive digital technology including computers, touch screens devices and videogames.
Comparison	No comparator
Outcome	Aspects of child development
Study design	Quantitative (case reports, case series, cohort studies, case–control studies, randomized, controlled trails), and qualitative studies whose a priori purpose was to explore the perceptions of parents, carers, teachers, or healthcare professionals about the impact of digital technology use on child development

disagreements between the two reviewers and cross-checked data from all eligible studies.

3.3.2 | Process used for data extraction

Data extraction was carried out by two reviewers and checked by a third reviewer. For each study included, information was extracted using a structured data sheet that included information about first author's last name, year of publication, country, study design, aim, sample, type and content of interactive digital technology, methods of measuring developmental outcomes, and main results.

3.3.3 | Definition of outcome and conceptual issues

For the purpose of this review, we defined digital technology as the use of digital devices including computers, tablets, and mobile phones and smart phones, as well as the digitally mediated activities that children engage in via these devices, such as using the Internet, going on social networking sites, chatting, or playing video games (Anderson & Subrahmanyam, 2017). Child development was defined as an orderly progression of gross and fine motor, cognitive and language skills that are formed by an interaction of genetic potential and environmental opportunities (Black et al., 2015, p. 853).

Based on the Black et al. (2015) definition, we defined child performance indicators on gross and fine motor, cognition, and language as measures of child development. For the purpose of this review, we considered acquisition of perceptual-motor skills and manual dexterity as indicators of motor development. For example, while writing and drawing are perceived as complex skills that require the combination of motor, perceptual, and cognitive components (Otake et al., 2017), we used writing or drawing as an indicator of fine motor skills. We also did not distinguish between vocabulary acquisition or word learning in categorizing approaches to language development. We defined vocabulary acquisition and word learning as the primary means by which a child learns to communicate and advance language skills.

There is substantive variability in how researchers define and measure cognitive development. Our definition of cognitive development subsumes both learning and executive functioning. For this review, a good understanding of the particular definition of executive function used to guide the selection of cognitive tasks to assess the construct was central because it can influence our ability to interpret the results. McNeill et al. (2019) suggested that executive function is a higher order cognitive processes implicated in the ability to reason, problem solve, and plan through their enabling of manipulating information in the mind (working memory), resisting distractions and impulsive behaviors (inhibition), and flexibly switching between task demands (shifting). It was also conceptualized as the cognitive process that organized simple ideas, behaviors, and affects into complex action (The Diagnostic and Statistical Manual of mental Disorders, 4th edition).

3.4 | Selection of outcome data for synthesis

As the definition of 'child development' is broad, the potential range of outcomes of eligible studies is also large. However, not all outcome data were relevant for analysis. In this review, data synthesized included only those studies that specifically addressed how different forms of interactive digital devices impacted on developmental outcomes in children including but not limited to motor, language, and cognition.

We used narrative synthesis (Siddaway et al., 2019) to analyze the included studies and structured the synthesis around a summary table presenting descriptive details of each developmental domain included in the review. Three main questions were used to guide the synthesis of data: What are the developmental outcomes examined in the evidence? What is the evidence on whether different types/contents of interactive digital devices lead to different developmental outcomes in children? What is the overall evidence on the impact of various types/contents of interactive digital devices for children aged 5 years relative to younger children?

For the narrative synthesis, the studies were grouped into three different categories of development: Motor skills, language acquisition, and learning and cognitive development. In the data synthesis of this review, all findings were discussed with appropriate emphasis given to the studies that were more methodologically robust. The narratives were written by one reviewer, yet all decisions were arrived at through discussion and a consensus process by two reviewers.

3.4.1 | Quality assessment

In this review, we classified experimental and quasi-experimental studies as Tier 1 studies, and the remaining qualitative, descriptive surveys/with or without comparison were classified as Tier 2 studies. Then, quality assessment of eligible studies was evaluated using the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses (Aromataris & Munn, 2020; Porritt et al., 2014). RCT studies were assessed by 13 questions and quasi-experimental by nine questions. Cross-sectional studies and case report were assessed by eight questions, whereas qualitative studies were assessed by 10 questions, and cohort studies were assessed by 12 questions. An item would be scored 0 if it was answered "no" or "unclear" and a score of 1 if the criteria were met. Using the JBI checklist tool, methodological quality was considered as low quality if a score of 50% or less was assigned through critical appraisal, the predetermined cut off score agreed upon by the research team. Two reviewers appraised each study and discrepancies were discussed with a third reviewer. No studies were excluded on the basis of the minimum quality threshold.

4 | RESULTS

4.1 | Search outcome

Across the six databases, we initially retrieved 7632 studies, 1757 studies were excluded based on duplicate records and 5705 studies were removed after screening the title and abstract. An additional 117 studies were excluded after reading the full text document. Consequently, 53 studies met the inclusion criteria and were included in the review (Figure 1).

4.1.1 | Characteristics of included reviews

Fifty-three studies were eligible for inclusion in the review, 39 Tier 1 and 14 Tier 2. The studies ranked as Tier 1 were defined as studies used RCT and quasi-experimental designs, where studies ranked as Tier 2 were defined as studies used descriptive designs including cross-sectional, cohorts, case control and qualitative.

Of the 53 studies included in the review, the majority originated from high-income countries, most notably Western European countries (Bonneton-Botté et al., 2020; Clarke & Abbott, 2016; Desoete & Praet, 2013; Di Lieto et al., 2017; Fernández-Molina et al., 2015; Fikkers et al., 2019; Gremmen et al., 2016; Kiefer et al., 2015; Konok et al., 2021; Kosmas & Zaphiris, 2020; Mayer et al., 2020; Picard et al., 2014; Smeets & Bus, 2012; Teepe et al., 2017; Walter-Laager et al., 2017), followed by the United States (Antrilli & Wang, 2018; Diehm et al., 2020; Haegele et al., 2011; O'Toole & Kannass, 2018; Parish-Morris et al., 2013; Rogowsky et al., 2018; Russo-Johnson et al., 2017; Schmitt et al., 2018; Schroeder & Kirkorian, 2016; Xu et al., 2021; Zhen, 2017; Zheng & Sun, 2021; Zimmermann et al., 2015), Australia (Axford et al., 2018; Barnett et al., 2012; Huber et al., 2018; McNeill et al., 2019, 2021; Neumann, 2014, 2016, 2018; Trost & Brookes, 2021), the United Kingdom (Bedford et al., 2016; Herodotou, 2018; Outhwaite et al., 2019; Portugal et al., 2021; Ross et al., 2016), Taiwan (Lin, 2019; Lin et al., 2017; Lin et al., 2020), and

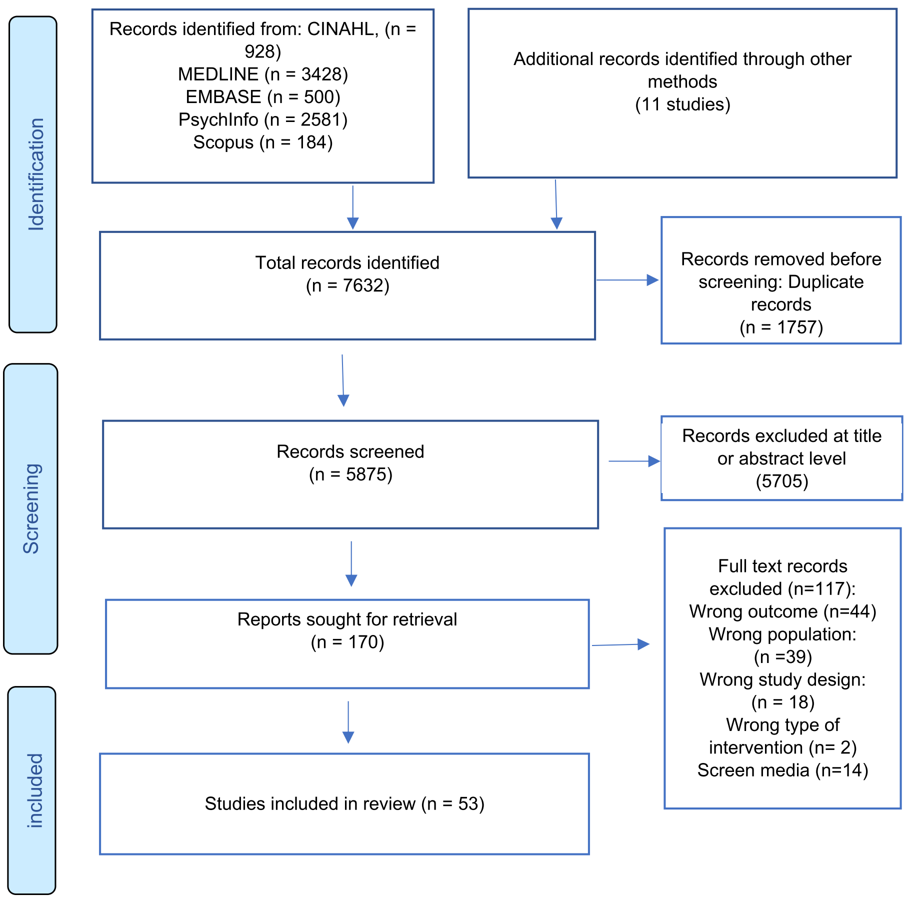

FIGURE 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of literature search and selection process

TABLE 2 Level of evidence for primary outcomes and conclusions of included studies

Author, year	Country	Level of evidence	JBI score	Dose of exposure	Timeframes
Antrilli & Wang, 2018	USA	Tier 1	10/13	9 min use touch screen play once only	-
Axford et al., 2018	Australia	Tier 1	9/9	30 min daily 9 weeks	9 weeks
Barnett et al., 2012	Australia	Tier 2	10/11	Parents reported on minutes per week using PlayStation/Nintendo Xbox, computer games	-
Bedford et al., 2016	UK	Tier 2	5/8	Parents reported on average daily touch screen usage	-
Bonneton-Botté et al., 2020	France	Tier 1	8/9	20–40 min per week	12 weeks
Chen et al., 2013	Taiwan	Tier 1	11/13	40 min per week	14 weeks
Clarke & Abbott, 2016	Northern Ireland	Tier 2	8/10	1-h daily use of iPad during school time	5 months
Courage et al., 2021	Canada	Tier 1	6/9	3 days—Day 1 35 min, Day 2 30 min, Day 3 10 min	3 days
Desoete & Praet, 2013	Belgium	Tier 1	10/13	25 min by 9 sessions on computer game over 5 weeks	5 weeks
Di Lieto et al., 2017	Italy	Tier 1	8/9	13 sessions of 75 min	6 weeks
Diehm et al., 2020	USA	Tier 1	7/9	3 min one session	-
Elimelech & Aram, 2020	Israel	Tier 1	10/13	8 sessions, 20 min	1 month (2 sessions a week)
Fernández-Molina et al., 2015	Spain	Tier 1	9/13	3 sessions, 10 min each	3 weeks (one session a week)
Fikkers et al., 2019	Netherland	Tier 2	10/11	Parent reported estimates the time their children played digital games	Longitudinal study—measured each year over 4 years
Gremmen et al., 2016	Netherland	Tier 1	8/9	15–20 min	-
Haegele et al., 2011	USA	Tier 1	9/13	15 min per day, 3 days per week.	6–9 weeks
Herodotou, 2018	UK	Tier 1	8/9	Angry birds 8 min for a maximum of 7 days—mean 50 min SD 14.49	7 days
Hu et al., 2020	China	Tier 2	7/8	Active screen time (computer etc.)—parents reported on hours per day	-
Huber et al., 2018	Australia	Tier 1	10/13	Brief screen intervention	-
Kiefer et al., 2015	Germany	Tier 1	9/9	16 training sessions, 25 min, 4 sessions per week	4 weeks
Konok et al., 2021	Hungary	Tier 1	6/9	Parents reported on their child's tablet/smartphone use.	-
Kosmas & Zaphiris, 2020	Cyprus	Tier 1	8/9	30 min, once a week (12 sessions)	3 months
Lin et al., 2020	Taiwan	Tier 2	8/8	Parents reported on children's use of touch screen device	-
Lin, 2019	Taiwan	Tier 1	9/9	Used tablets at least once a week for more than 20 min per time lasting more than 6 months	-
Lin et al., 2017	Taiwan	Tier 1	9/9	20 min per day for 24 weeks	24 week home fine motor program using a touch screen
Liu et al., 2021	China	Tier 1	6/9	2 sessions a week for 15 min a session	12 weeks
Mayer et al., 2020	Germany	Tier 1	9/9	-	7 weeks
McNeill et al., 2021	Australia	Tier 1	6/8	Parental questionnaire electronic media use	-
McNeill et al., 2019	Australia	Tier 2	10/11		12 months

TABLE 2 (Continued)

Author, year	Country	Level of evidence	JBI score	Dose of exposure	Timeframes
				Parental questionnaire electronic media use Non-users (0 min/day) Low-dose users (>1–29 min/day) High-dose users (≥30 min/day)	
Moon et al., 2019	Korea	Tier 2	6/8	Parental questionnaires to assess smart device usage	-
Neumann, 2014	Australia	Tier 2	6/8	Parental questionnaire to assess touch screen usage	-
Neumann, 2016	Australia	Tier 2	5/8	Parental questionnaire to assess touch screen usage	-
Neumann, 2018	Australia	Tier 1	11/13	30 min per week iPad literacy program	9 weeks
O'Toole & Kannass, 2018	USA	Tier 1	9/13	Not provided	
Outhwaite et al., 2019	UK	Tier 1	13/13	30 min a day for 5 days a week	12 weeks
Parish-Morris et al., 2013	USA	Tier 1	10/13	Electronic media books—once off	-
Picard et al., 2014	France	Tier 1	8/9	10-min one off session	-
Portugal et al., 2021	UK	Tier 2	5/8	Parents reported touch screen use	-
Rogowsky et al., 2018	USA	Tier 1	11/13	10 min a day	11 weeks
Ross et al., 2016	UK	Tier 1	9/9	One off reading session comparing print books to iPad story	-
Russo-Johnson et al., 2017	USA	Tier 2	6/8	One off test session approximately 8 min—test not an intervention	-
Schmitt et al., 2018	USA	Tier 1	10/13	Approximately 40 min per week	8 weeks
Schroeder & Kirkorian, 2016	USA	Tier 1	10/13	30 min playing the game—one off assessment	
Smeets & Bus, 2012	Netherlands	Tier 1	8/9	2 sessions per week (5 sessions in total) session time not included in the study	2.5 weeks
Souto et al., 2020	Brazil	Tier 2	6/8	Parents reported interactive media use (frequency and duration in minutes per day)	-
Spinosa et al., 2020	Brazil	Tier 1	12/13	One off experimental session	
Teepe et al., 2017	Netherlands	Tier 1	9/9	10-min sessions, 2 sessions in 2 weeks	2 weeks
Trost & Brookes, 2021	Australia	Tier 1	13/13	35.3% (6/17) families randomized to the intervention used the app 3 or more times a week; 35.3% (6/17) 2 times per week; And 29.4% (5/17) less than 2 times per week.	8 weeks
Walter-Laager et al., 2017	Switzerland	Tier 1	9/9	One up to 20-min session using the word-learning app	-
Xu et al., 2021	USA	Tier 1	7/9	One off experimental session lasting 5–10 min	-
Zhen, 2017	USA	Tier 1	8/9	13 min sessions conducted 3 to 4 times per week (approx. 34 sessions)	34 sessions—number of weeks not specified
Zheng & Sun, 2021	USA	Tier 2	7/8	Parents reported digital devices use.	-
Zimmermann et al., 2015	USA	Tier 1	9/13	60-s test—one off test	-

one study each from Canada (Courage et al., 2021), South Korea (Moon et al., 2019), and Israel (Elimelech & Aram, 2020). Only two studies were from middle-income countries Brazil (Souto et al., 2020; Spinosa et al., 2020) and China (Hu et al., 2020; Liu et al., 2021).

The general use of screen devices and touch screens, such as iPads, was the subject of 22 of 53 studies (Antrilli & Wang, 2018; Bedford et al., 2016; Clarke & Abbott, 2016; Chen et al., 2013; Gremmen et al., 2016; Haegele et al., 2011; Hu et al., 2020; Kiefer et al., 2015; Konok et al., 2021; Kosmas & Zaphiris, 2020; Lin, 2019; Lin et al., 2017, 2020; McNeill et al., 2021, 2019; Moon et al., 2019; Neumann, 2014, 2016, 2018; Picard et al., 2014; Zheng & Sun, 2021) and the use of specific digital applications/contents such as specific use of touch screen applications used on tablets and iPads was the subject of 13 studies (Axford et al., 2018; Chen et al., 2013; Desoete & Praet, 2013; Fernández-Molina et al., 2015; Huber et al., 2018; Liu et al., 2021; Mayer et al., 2020; Outhwaite et al., 2019; Rogowsky et al., 2018; Russo-Johnson et al., 2017; Trost & Brookes, 2021; Walter-Laager et al., 2017; Zhen, 2017).

The remaining 20 studies included the use of interactive learning videos, games, and touch screen story e-books within the broader education context (Barnett et al., 2012; Bonneton-Botté et al., 2020; Diehm et al., 2020; Di Lieto et al., 2017; Elimelech & Aram, 2020; Fikkers et al., 2019; Gremmen et al., 2016; Herodotou, 2018; Kosmas & Zaphiris, 2020; Smeets & Bus, 2012; Teepe et al., 2017; O'Toole & Kannass, 2018; Parish-Morris et al., 2013; Ross et al., 2016; Schmitt et al., 2018; Schroeder & Kirkorian, 2016; Souto et al., 2020; Spinosa et al., 2020; Xu et al., 2021; Zimmermann et al., 2015).

Below, we summarize our findings into three main categories: Motor, language, and learning and cognitive development.

Quality assessment of the included studies was conducted using the JBI quality appraisal checklist (Table 2). All of the 53 original studies were considered of high to moderate methodological quality.

As shown in Table 2, many important variables, including dose of exposure, duration, and intensity were inconsistently reported and varied significantly from 3 min in Diehm et al. (2020) to 75 min in Di Lieto et al. (2017). Dose of exposure to digital technology was informatively reported only in one study with Axford et al. (2018) showing that regular use of iPad application with over 30 min was negatively associated with fine motor skills. In another study by McNeill et al. (2019), high dose of exposure (≥30 min) was associated with lower inhibition capabilities 12 months later compared with low dose of exposure. These results underscore the importance of dose–response relationship that is important for understanding the impact of digital technology use.

In Bedford et al. (2016), the association between early touchscreen use and age of reaching developmental milestones was limited by the fact the only measure of child's usage of touchscreen was reported at the child's current age without being able to conclude how this relates to child's earlier usage. An evaluation of the dose–response relationship was not clearly included, although this is an important topic as the magnitude of any change in child's development is critical to the conclusions.

4.1.2 | Interactive digital devices and motor development

Fifteen studies related to motor development were identified (Table 3), of which nine studies were identified as Tier 1 (Axford et al., 2018; Bonneton-Botté et al., 2020; Kiefer et al., 2015; Lin, 2019; Lin et al., 2017; Mayer et al., 2020; Picard et al., 2014; Spinosa et al., 2020; Trost & Brookes, 2021) and six studies were identified as Tier 2 (Barnett et al., 2012; Bedford et al., 2016; Clarke & Abbott, 2016; Moon et al., 2019; Souto et al., 2020; Zheng & Sun, 2021). Variations in sample and type of content used on the digital device were noted.

In Tier 1, data were available from two RCT (Spinosa et al., 2020; Trost & Brookes, 2021) and seven quasi-experimental studies (Axford et al., 2018; Bonneton-Botté et al., 2020; Kiefer et al., 2015; Lin, 2019; Lin et al., 2017; Mayer et al., 2020; Picard et al., 2014). Two studies evaluated specific digital applications and compared digital technology use to no intervention (Axford et al., 2018; Bonneton-Botté et al., 2020), and six studies used a nontechnological intervention as the comparison/control group (Kiefer et al., 2015; Lin, 2019; Lin et al., 2017; Mayer et al., 2020; Picard et al., 2014; Spinosa et al., 2020). In six studies, there was a significant difference in motor development outcomes measured between the digital technology group and the comparator. Most studies suggested a negative association between the use of digital technology and fine motor development (Kiefer et al., 2015; Lin, 2019; Lin et al., 2017; Mayer et al., 2020; Picard et al., 2014).

Only two studies found significant benefits for using an iPad (Axford et al., 2018) or a digital notebook application (Bonneton-Botté et al., 2020) as a mean of developing fine motor skills. In contrast, Axford et al. concluded that children's use of iPads negatively associated with fine motor development when used for more than 30 min a day. One study suggested no significant difference in children's motor skills between groups (Spinosa et al., 2020), and another study (Trost & Brookes, 2021) suggested a positive association between digital application use and object control skills.

In Tier 2, data were available from 1 qualitative (Clarke & Abbott, 2016), 1 cohort (Barnett et al., 2012), 4 cross-sectional studies (Bedford et al., 2016; Moon et al., 2019; Souto et al., 2020; Zheng & Sun, 2021). One study (Clarke & Abbott, 2016) used a qualitative approach to explore the impact of iPad technology on learning and revealed a positive association between iPad use and children's writing and drawing skills. One cohort study (Barnett et al., 2012) investigated the use of videogames or computers and gross motor proficiency and reported mixed findings. All four of the cross-sectional studies investigated the use of computers and touch screens at home and found that prior use of interactive digital technology was associated positively with fine motor development (Bedford et al., 2016; Moon et al., 2019; Souto et al., 2020), whereas the remaining study associated negatively with the development of fine motor skills (Zheng & Sun, 2021).

TABLE 3 Summary of studies related to interactive technologies and motor skills

Author, year	Study design	Sample (number, age)	Purpose	Methods of assessment to developmental outcome	Major findings
Axford et al., 2018	Quasi-experimental	*N* = 53 children; age = 5 to 6 years Experimental = 28 children Control = 25 children	To determine the effectiveness of iPad applications in improving fine motor skills	Observations, Beery Developmental Test of Visual Motor Integration, 6th Edition; Shore Handwriting Screen; The Hawaii Early Learning Profile	iPad applications specifically developed for fine motor skills, were an engaging means of developing fine motor skills. Replacing regular hand use with over 30 min of iPad use a day, may not be beneficial, or may negatively impact fine motor skills development.
Barnett et al., 2012	Cohort/longitudinal	*N* = 53 children; age = 4.15 years ± 0.72 months	To determine the relationship between time playing electronic games, and the fundamental movement skills in children	Questionnaires, Test of Gross Motor Development Actigraph	Associations between video game playing, and children's fundamental movement skills. Preschool children who spent more time playing interactive video games, had greater object control skills. Interactive game use was not significantly associated with locomotor skill proficiency.
Bedford et al., 2016	Analytical cross sectional	*N* = 715 children; age = 19.52 ± 8.26 months	To determine the relationship between touchscreen use, and reaching developmental milestones in toddlers	Questionnaire	No relationship between the age of first touchscreen use, and any developmental milestones. Early touchscreen scrolling results in early fine motor achievement. No significant relationships between touchscreen use and gross motor milestones.
Bonneton-Botté et al., 2020	Quasi-experimental	*N* = 233 children; age = 5.4 years Intervention = 138 children Control = 95 children	To determine the impact of a digital notebook application on learning of handwriting, in kindergarten classrooms	Kaligo app	Training with the app was beneficial for children with a medium level at the start of the study.
Clarke & Abbott, 2016	Qualitative	P1 = 25 children; age = 4 to 5 years	To determine the impact of iPad technology on learning and pupil skills, in primary school children	Interviews	iPads helped with writing and drawing. There were increases in motivation, concentration, confidence, spontaneous peer collaboration, and early stages of peer assessment.
Kiefer et al., 2015	Quasi-experimental	*N* = 23 children; age = 5 years 6 months ± 4 months	To determine the influence of pen and keyboard writing on reading and	Letter writing, free letter writing, and word writing	Handwriting training was superior to typing training in work writing. The

(Continues)

TABLE 3 (Continued)

Author, year	Study design	Sample (number, age)	Purpose	Methods of assessment to developmental outcome	Major findings
		Group 1 (typing) = 11 children; age = 66.1 ± 4.7 months Group 2 (handwriting) = 12 children; age = 66.0 ± 3.1 months	writing performance in preschool children		study supports theories of action-perception coupling assuming a facilitatory influence of sensory-motor representations established during handwriting on reading and writing.
Lin, 2019	Quasi-experimental	*N* = 72 children; age = 61.9 ± 7.3 months Intervention = 36 children; age = 61.8 ± 7.4 months Control = 36 children; age = 61.9 ± 7.2 months	To determine whether or not there were differences between children using tablets and non-tablets in visual perception and fine motor skills, in preschool children	Fine motor performance; The Bruininks–Oseretsky Test of Motor Proficiency, 2nd Edition; Cognitive ability - Chinese version of the PPVT-R	Children and fine motor skills. The children in the non-tablet group showed significantly higher scores than those in the tablet group for fine motor precision, fine motor integration, and manual dexterity.
Lin et al., 2017	Quasi-experimental	*N* = 80 children; age = 61.0 ± 7.6 months Intervention = 40 children; age = 61.0 ± 7.6 months Control = 40 children; age = 61.0 ± 7.6 months	To determine the effect of touch screen tablet use on fine motor development, in children	Fine motor performance. The Bruininks–Oseretsky Test of Motor Proficiency, 2nd Edition; Pinch strength. (Measured using a hand-held pinch dynamometer)	Using a touch screen tablet extensively appears to be disadvantageous for the fine motor development of preschool children.
Mayer et al., 2020	Quasi-experimental	*N* = 145 children; age = 5.97 ± 0.53 years Group 1 (pencil) = 49 children; age = 5.98 ± 0.59 years Group 2 (stylus) = 49 children; age = 5.10 ± 0.48 years Group 3 (keyboard) = 47 children; age = 5.90 ± 0.50 years	To determine the influence of writing tool type (pencil, keyboard, tablet stylus) on literacy skills at the word level, in kindergarten children	Letter recognition; letter writing; word reading; word writing; letter reading; visuo-spatial skills	Handwriting with a pencil fosters acquisition of letter knowledge and improves visuo-spatial skills compared with keyboarding. The stylus on a touchscreen is the least effective tool.
Moon et al., 2019	Analytical cross sectional	*N* = 117 children; age 4.5 ± 0.9 years Group 1 = 40 children; age = 3.5 ± 0.3 years Group 2 = 36 children; age = 4.4 ± 0.3 years Group 3 = 41 children; age = 5.4 ± 0.3 years	To determine the relationship between smart device use, and development levels in children	Parental questionnaire for smart device usage status, the Korean-developmental screening test	In three years', old child, smart device usage was positively correlated with fine motor development
Picard et al., 2014	Quasi-experimental	*N* = 46 children Kindergarten group = 22; age = 5 years Grade 2 group = 24; age = 7 years	To determine the impact of pen-on-paper versus finger-on-screen, on drawing quality, in children	Standardized graphic scale yielding an overall graphic score	Graphic scores were lower in the finger on screen using an iPad when compared to the pen on paper. Finger on screen drawings were

TABLE 3 (Continued)

Author, year	Study design	Sample (number, age)	Purpose	Methods of assessment to developmental outcome	Major findings
					slightly poorer than pen on paper drawings.
Souto et al., 2020	Analytical cross sectional	*N* = 78 children; age = 26 to 42 months Frequent tablet use at home = 26 children; age = 26 to 42 months No experience with tablet use = 52 children; age = 27 to 42 months	To determine the relationship between interactive tablet use, and fine motor skills, in young children	Bayley Scales of Infant Development, 3rd Edition	Young children with previous tablet-use experience had slightly better fine motor skills.
Spinosa et al., 2020	RCT	*N* = 131 children; age = 3 to 11 years Group 1 (3- to 5-year-old) = 39 children; age = 4.25 ± 0.71 years Group 2 (6- to 8-year-old) = 41; age = 7.16 ± 0.79 years Group 3 (9- to 11-year-old) = 51 children; age = 10.13 ± 0.84 years	To determine the effect of digital and live demonstrations on fundamental motor skills, in children	Two fundamental motor skills from the assessment protocol of the TGMD-2: horizontal jump (locomotion skill) and over-the-shoulder throw (object control skill).	Comparing digital (augmented reality) and live demonstration of two motor skills to children it was found there was no significant difference in the children's motor skills.
Trost & Brookes, 2021	RCT	*N* = 34 children, age = 5.3 ± 1.3 years	To evaluate the effect of the Moovosity™ program, digital application on movement skills proficiency, in 3- to 6-year-old children.	Test of gross motor development, Burdettet Outdoor Playtime Checklist, parents support for physical play.	There was a significant group by time interaction for object control skills. Intervention children exhibited significant improvements in object control skills, while children in the wait-list control group exhibited a modest decline. Intervention children also exhibited improvements in locomotor skills, while wait-listed controls exhibited minimal change.
Zheng & Sun, 2021	Analytical cross sectional	*N* = 877 children aged 3–6 years.	To investigate the relationship between the use of digital devices by preschool children in Hong Kong and their early development	Hong Kong development scale and movement assessment battery, survey parents' digital devices use and whether children used digital devices and time they spent using it.	Use of digital devices and time spent using digital devices were found to negatively predict children's fine motor skills, and gross motor skills. Watching cartoons was found to negatively predict children's performance on early academic achievement and their fine motor skills. Children's digital devices use before bedtime or on request also had a negative relationship with their performance on fine motor skills.

4.1.3 | Interactive digital devices and language development

Eleven studies related to language acquisition (Table 4), of which seven were identified as Tier 1 (Diehm et al., 2020; Gremmen et al., 2016; Kosmas & Zaphiris, 2020; Smeets & Bus, 2012; Teepe et al., 2017; Walter-Laager et al., 2017; Zimmermann et al., 2015), and 4 were identified as Tier 2 (Bedford et al., 2016; Hu et al., 2020; Lin et al., 2020; Moon et al., 2019). Data in Tier 1 studies included one RCT (Zimmermann et al., 2015) and six quasi-experimental studies (Diehm et al., 2020; Gremmen et al., 2016; Kosmas & Zaphiris, 2020; Smeets & Bus, 2012; Teepe et al., 2017; Walter-Laager et al., 2017). One study evaluated the use of learning videos and vocabulary acquisition in toddlers and reported lower impact of learning videos on children's productive vocabulary as compared to children learning from live presentations (Zimmermann et al., 2015). All six quasi-experimental studies compared digital technology use to no intervention and reported a positive association between use of interactive technologies and language acquisition when used in educational settings. Data from Tier 1 studies provided plausible evidence that technology that integrate educational content may be effective in promoting both receptive language skills and vocabulary acquisition in children.

In Tier 2, data were available from four cross-sectional studies (Bedford et al., 2016; Hu et al., 2020; Lin et al., 2020; Moon et al., 2019). Two cross-sectional studies explored the relationship between touchscreen use and language development in toddlers and suggested no association between children using touch screen devices and language development (Bedford et al., 2016; Lin et al., 2020). Hu et al. (2020) studied screen time and social development in children and reported mixed findings, but active computer and screen device use was generally associated with higher receptive language skills in children. Moon et al. (2019) presented a contrasting view that a higher level of touch screen device use was associated with poorer language development in children aged 1.5 to 3 years. These findings could suggest a positive association between language development and use digital technology.

4.1.4 | Interactive digital devices and cognitive development

Twenty-nine studies were related to cognitive development (Table 5), of which 22 studies were Tier 1 (Antrilli & Wang, 2018; Chen et al., 2013; Courage et al., 2021; Desoete & Praet, 2013; Di Lieto et al., 2017; Elimelech & Aram, 2020; Fernández-Molina et al., 2015; Haegele et al., 2011; Herodotou, 2018; Huber et al., 2018; Konok et al., 2021; Liu et al., 2021; Neumann, 2018; O'Toole & Kannass, 2018; Outhwaite et al., 2019; Parish-Morris et al., 2013; Ross et al., 2016; Rogowsky et al., 2018; Schmitt et al., 2018; Schroeder & Kirkorian, 2016; Xu et al., 2021; Zhen, 2017), and seven studies were identified as Tier 2 (Fikkers et al., 2019; McNeill et al., 2019; McNeill et al., 2021; Neumann, 2014; Neumann, 2016; Neumann, 2018; Portugal et al., 2021; Russo-Johnson et al., 2017).

Among Tier 1 studies, 14 RCTs (Antrilli & Wang, 2018; Chen et al., 2013; Desoete & Praet, 2013; Elimelech & Aram, 2020; Fernández-Molina et al., 2015; Haegele et al., 2011; Huber et al., 2018; Neumann, 2018; O'Toole & Kannass, 2018; Outhwaite et al., 2019; Parish-Morris et al., 2013; Rogowsky et al., 2018; Schmitt et al., 2018; Schroeder & Kirkorian, 2016) and eight quasi-experimental studies were included in the synthesis (Courage et al., 2021; Di Lieto et al., 2017; Herodotou, 2018; Konok et al., 2021; Liu et al., 2021; Ross et al., 2016; Xu et al., 2021; Zhen, 2017). Studies in Tier 2 included one cohort and five cross-sectional studies.

All studies in both tiers were exclusively aimed at exploring the association between use of interactive digital devices and cognitive skills and were focused on general use of touchscreen devices (Courage et al., 2021; Konok et al., 2021; McNeill et al., 2019; McNeill et al., 2021) and educational software system (Fernández-Molina et al., 2015; Haegele et al., 2011; Huber et al., 2018; Outhwaite et al., 2019; Rogowsky et al., 2018; Zhen, 2017), digital applications such as e-books (O'Toole & Kannass, 2018; Parish-Morris et al., 2013), multimedia (Chen et al., 2013), or videogames (Desoete & Praet, 2013; Elimelech & Aram, 2020; Fikkers et al., 2019; Herodotou, 2018; Russo-Johnson et al., 2017; Schmitt et al., 2018; Schroeder & Kirkorian, 2016). The studies included children from 2 to 5 years. Most digital technology content aimed to enhance executive function and literacy and/or numeracy skills, but not comprehension level.

Both Tier 1 and Tier 2 studies reported a positive association between use of interactive digital technology and executive function (Courage et al., 2021; Fernández-Molina et al., 2015; Huber et al., 2018), visual perception skills (Chen et al., 2013), visuo-spatial working memory and inhibition skills (Di Lieto et al., 2017), fluid intelligence and problem-solving skills (Fikkers et al., 2019). Positive association with cognitive skills was also reported for literacy and/or numeracy skills (Desoete & Praet, 2013; Elimelech & Aram, 2020; Neumann, 2014; Neumann, 2016; Neumann, 2018; O'Toole & Kannass, 2018; Outhwaite et al., 2019; Rogowsky et al., 2018; Ross et al., 2016; Schmitt et al., 2018; Schroeder & Kirkorian, 2016) and learning (Haegele et al., 2011; Herodotou, 2018; Russo-Johnson et al., 2017). In one study by McNeill et al. (2019), reducing media program viewing and limiting electronic app use was positively associated with preschool children's cognitive development. There was less evidence to support the association between interactive digital technology and cognitive flexibility (Antrilli & Wang, 2018), visual perception (Chen et al., 2013), and comprehension (Parish-Morris et al., 2013; Xu et al., 2021). Most studies lacked discussion on how developmental outcomes may vary by age and gender. Two studies in this review included children with needs for auditory and/or visual supports (Elimelech & Aram, 2020) and children with developmental delay (Chen et al., 2013). Findings from these studies highlight key areas of concern for improving not only access to interactive technologies, but for promoting digital equity as well.

TABLE 4 Summary of studies related to interactive technologies and language acquisition

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
Bedford et al., 2016	Analytical cross sectional	$N = 715$ children; age = 19.52 ± 8.26 months	To determine the relationship between touchscreen use, and reaching developmental milestones in toddlers	Questionnaire	No relationship between the age of first touchscreen use, and any developmental milestones. No significant relationships between touchscreen use and language milestones.
Diehm et al., 2020	Quasi-experimental	$N = 73$ children; age = 49.51 ± 8.06 months Group 1 = 30 children; age = 41.13 ± 3.23 months Group 2 = 47 children; age = 54.22 ± 3.47 months Group 3 = 6 children; age = 62.50 ± 3.53 months	To determine the effect of story presentation format on the narrative retelling ability of children	Systematic analysis of language transcript primary test of nonverbal intelligence	Video viewing resulted in a larger quantity and quality of language from a story retell.
Gremmen et al., 2016	Quasi-experimental	$N = 20$ children; age = 40.85 months	To determine the effect of multimedia versus paper elaborated pictures, on parent-toddler interaction, and toddlers' vocabulary development	Target vocabulary test - receptively and expressively	There was a significant effect of the multimedia condition on the receptive word learning of children.
Hu et al., 2020	Analytical cross sectional	$N = 579$ children; age = 5.08 ± 0.42 years	To determine the relationship between screen time, and cognitive and social development, in children	Questionnaire - demographics and screen time survey - completed by parents, tests - math, science, HTKS and C-PPVT-R - receptive vocabulary	Active screen time was positively associated with children receptive language skills
Kosmas & Zaphiris, 2020	Quasi-experimental	$N = 118$ children; age = 6.92 ± 0.66 years	To determine the relationship between embodied learning, and language acquisition and emotional performance, in children	The Greek version of the word finding vocabulary test	Students who were involved in the intervention significantly improved their expressive vocabulary and vocabulary acquisition.
Lin et al., 2020	Analytical cross sectional	$N = 161$ children; age = 25.63 ± 5.35 months	To determine the relationship between touch screen device exposure, and language development, in children	Communication and language screening test for birth to three Chinese-speaking infant-toddlers	Higher levels of touch screen device usage were not associated with language delay in children aged 18–36 months.
Moon et al., 2019	Analytical cross sectional	$N = 117$ children; age 4.5 ± 0.9 years Group 1 (3-year-old) = 40; age = 3.5 ± 0.3 years	To determine the relationship between smart device use, and development levels along with language scores, in children	Parental questionnaire for smart device usage status, the Korean-developmental screening test, the preschool receptive-expressive language scale	In three-year old child, smart device usage was negatively correlated with language development.

(Continues)

TABLE 4 (Continued)

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
		Group 2 (4-year-old) = 36; age = 4.4 ± 0.3 years Group 3 (5-year-old) = 41; age = 5.4 ± 0.3 years			
Smeets & Bus, 2012	Quasi-experimental	Experiment 1 = 20 children; age = 54.50 ± 2.52 months Experiment = 27 children; age = 57.56 ± 3.68 months	To determine whether interactive electronic storybooks facilitate vocabulary growth, in kindergarteners	Peabody picture vocabulary test, knowledge of target words - receptive target vocabulary and expressive target vocabulary	A computer-based "assistant" was added to electronic storybooks. The assistant posed extra textual vocabulary questions. When children read stories, children learned more words when reading with questions than without.
Teepe et al., 2017	Quasi-experimental	N = 71 children Experiment = 44 children; age = 39.41 ± 4.82 months Control = 27 children; age = 41.11 ± 4.46 months	To investigate how technology-enhanced storytelling enhance, children's vocabulary knowledge in preschool	Technology-enhanced storytelling characteristics; vocabulary knowledge - designed by team	The study demonstrates that technology enhanced storytelling can be considered as a promising context for fostering children's vocabulary development.
Walter-Laager et al., 2017	Quasi-experimental	N = 98 children; age = 27.3 months Pre-test = 86 children Post-test = 66 children	To determine the impact of interactive word-learning app as well as picture cards on vocabulary acquisition, in children	Language and development test for two-year-old; development test for children from 6 months to 6 years of age	For vocabulary acquisition, children who used the word-learning app when accompanied by an adult had the largest growth in vocabulary, and those who used the word-learning app without adult accompaniment showing the second largest growth. Less successful were those children who played with the picture cards (with or without adult accompaniment).
Zimmermann et al., 2015	RCT	N = 167 children Group 1 (2 years) = 88 children Group 2 (2.5 years) = 77 children	To determine how semantic contextual cues facilitates learning from video, in toddlers	MacArthur Communicative Development Inventory: Words and Sentences Short Form to measure children's productive vocabulary	Young children learn less vocabulary from video than live presentations.

TABLE 5 Summary of studies related to interactive technologies and cognitive development

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
Antrilli & Wang, 2018	RCT	*N* = 78 children; age = 32 months	To determine the effects of physical and touchscreen play on 2.5-year-old cognitive flexibility	Questionnaires Observations MacArthur-Bates Communicative Development Inventory–III	There is a greater short-term benefit for toddlers' cognitive flexibility, for physical activity, compared to touchscreen gaming. Social interaction during touchscreen play, can positively affect toddlers' cognitive flexibility
Courage et al., 2021	Quasi-experimental	*N* = 60 children, age = 12 to 36 months	To determine how successfully infants and toddlers operate touch screen devices for play and learning and to explore if they can acquire operating skills and learn new learning skills, and to identify if. Individual differences in executive functioning predict success in using and learning from the apps.	Shape matching materials, story book comprehension materials, The Minnesota Executive Function Scale	(1) Toddlers could use touch gestures and the manual interactions needed to use the tablet, (2) toddlers increased success and efficiency, made fewer errors, decreased completion times, (3) toddlers recognized more story content from the e-book and were less distracted than from the paper book, (4) executive functioning contributed unique variance to the outcome measures on both apps, and (5) 3-year-olds outperformed 2-year-olds on all measures
Chen et al., 2013	RCT	Pre-test = 72 children Post-test = 64 children Group 1 pre-test = 15; age = 61.13 ± 7.57 months Group 2 pre-test = 15; age = 59.47 ± 7.98 months Group 3 pre-test = 19; age = 61.16 ± 7.51 months Group 4 pre-test: *n* = 15; age = 65.93 ± 6.70 months	To compare the effectiveness of multimedia visual perceptual group training, multimedia visual perceptual individual training, and paper visual perceptual group training, in 4 to 6-year-old children with developmental delays	Test of Visual Perception Skills (non-motor), Third Edition Multimedia Visual Perceptual Training	Paper visual perceptual group could not overcome developmental effects. Both multimedia programs resulted in significant visual perception effects. Multimedia group program was more effective than the individual program for improving visual perception. Multimedia program is more effective than paper program.

(Continues)

TABLE 5 (Continued)

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
Desoete & Praet, 2013	RCT	*N* = 132 children; age = 69.6 ± 4 months	To determine the effect of a computerized loof-ahead approach in kindergarten children	WIPPSI-NL TEDI-MATH Kortrijk arithmetic test revised	Educational games can increase mathematical skills.
Di Lieto et al., 2017	Quasi-experimental	*N* = 12 children; age = 5 to 6 years	To determine the short-term effects of intensive educational robotics training on executive functions, in preschool children	Neuropsychological evaluations: Pippo Says test BVN test NEPSY-II test BVS test Leiter-R test Educational robotics test Educational robotics questionnaire	Visuo-spatial working memory and inhibition skills increased significantly.
Fernández-Molina et al., 2015	RCT	*N* = 52 children; age = 4 years old Experiment = 30 children Control = 22 children	To determine the suitability of an educational software system, as a computer-based learning system, for improving two executive functions, in children	Answer accuracy, answering time, compulsory school task: number and type of right and wrong answer, attentional level and strategies for task solving.	The study found that the children who obtained lower scores in the pre-test phase most benefited from the educational software training and improved working memory and attentional control capacities.
Fikkers et al., 2019	Cohort/longitudinal	Wave 1 = 934 children: Age = 5.41 ± 1.40 Wave 2 = 890 children Wave 3 = 842 children Wave 4 = 830 children	To determine the longitudinal relationship between digital game use, and fluid and crystallized intelligence, in children	The Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III; suitable for children aged 2:6 to 7:11 years); The Wechsler Intelligence Scale for Children (WISCIII; suitable for children aged 6:0 to 16:11 years)	The study found that digital games can improve fluid intelligence (problem solving abilities) but did not influence crystallized intelligence.
Haegele et al., 2011	RCT	*N* = 36 children; age: 4 and 5 years old. Intervention group = 12 children Control group = 24 children	To determine the impact of using a stimulus equivalence paradigm on words learning and language acquisition in children	18-trial computerized Ojibwe/Dakota written words and numerals	This research provides initial evidence that match-to-sample procedures administered via computerized instruction can be effective for teaching numbers in a second language.
Herodotou, 2018	Quasi-experimental	*N* = 32 children; age = 4.5 ± 0.57 years	To determine the impact of touch screen mobile game applications (angry birds) on science learning, in children	Examined how the angle of a slingshot affects the pathway and landing position of a ball and how force affects motion and landing position; questionnaire - demographics and game preferences; screen recordings of	An improvement in learning was observed only for the 5 years old specifically in relation to their understanding of how force affects projectile motion and the prediction of the pathway of the ball as being a parabola. No improvement was

TABLE 5 (Continued)

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
				children's game play; children's general performance	observed in relation to how the angle of the slingshot affects motion.
Huber et al., 2018	RCT	$N = 96$ children; age = 36.3 ± 7.0 months Group 1 (cartoon) = 29 children Group 2 (EduApp) = 31 children Group 3 (EduTV) = 17 children	To determine the impact of screen media content, on executive functioning, in children	Spin the pots (a visuo-spatial working memory task), R-reverse categorization task, gift delay task	The type of screen intervention effected executive function performance with children more likely to delay gratification after playing and educational app than after viewing a cartoon. In some instances, children's working memory improved after playing an educational app.
Konok et al., 2021	Quasi-experimental	$N = 40$ children, median age 5 years IQR 0.64–5.56 years; (22 girls and 18 boys)	To determine whether use of new media (mobile touchscreen devices) affects attentional control and socio-cognitive/emotional skills.	Strengths Difficulties Questionnaire Hungarian version, attention control Navon test, real apparent emotion task, static facial displays, dynamic gestural displays	The use of mobile touchscreen devices was associated with global precedence in selective attention tasks, but an atypical, local precedence in a divided attention task. Further, playing with a fast digital game eliminated the advantage of selective attention over divided attention observed in the non-digital and slow digital game conditions. Mobile touchscreen devices use was not associated with emotion recognition but was associated with worse theory of mind.
Liu et al., 2021	Quasi-experimental	$N = 65$ children, mean age = 45.5 months ± 3.2 months (34 boys and 31 girls)	To determine the effect of using an educational serious game in preschools on young children's attention development	Total fixation timespan, first fixation time using telemetry eye tracker, gaze duration	Gaze duration (which indicates sustained attention) and first fixation latency (which reveals attention orientation speed) were analyzed before and after the training. Although Children's fixation latency was not associated with the intervention, compared to the control group, the experimental group showed significant improvement in gaze duration, suggesting a better sustained attention development. The result reinforces the previous findings that educational digital game apps could promote young children's attention development

(Continues)

TABLE 5 (Continued)

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
McNeill et al., 2021	Analytical cross sectional	$N = 247$ children, mean age $= 4.2 \pm 0.6$ years	To explore the associations between electronic media use (program viewing and app use) and cognitive and psychosocial development, in preschoolers.	Time used on electronic media, cognitive development early years toolbox, executive function - visual spatial working memory (Mr. Ant) phonological working memory ("not this"), inhibition ("go/no-go"), and shifting ("card sort"), strengths and difficulties questionnaire	Small, but significant, negative associations were observed for total electronic media use and visual–spatial working memory. However, high-dose app users demonstrated higher phonological working memory scores compared to non-users. Similarly, compared to non-users, low-dose app users displayed statistically significantly fewer total difficulties.
McNeill et al., 2019	Cohort/longitudinal	$N = 185$ children (mean age $= 4.2 \pm 0.6$ years) App use, n (%) Non-users (0 min/day) = 54 children (29.2%) Low-dose users (>1–29 min/day) = 87 children (47%) High-dose users (≥30 min/day) = 44 children (23.8%)	To investigate the association of electronic media use and executive function of preschoolers (3–5 years)	Time used on electronic media, cognitive development (executive functions) were assessed at baseline and follow-up using measures drawn from the Early Years Toolbox (EYT); the YET- visual–spatial working memory ("Mr. Ant"), phonological working memory ("not this"), inhibition ("go/no-go") and shifting ("dimensional change card sort")	Children identified as high-dose app users (≥30 min/day) had a significantly lower inhibition score at follow-up compared to children identified as low-dose app users (1 to 29 min/day). Findings suggest although low exposure may not be detrimentally associated with a child's executive function, higher exposure and use (≥30 min/day) may be harmful to early executive function development of young children.
Neumann, 2014	Analytical cross sectional	$N = 109$ children; age $= 50.6 \pm 6.2$ months	To determine the relationship between touch screen tablet use at home, and emergent literacy skills, in children	Letter name and sound knowledge and numeral identification, name writing, print concepts (story book stones), word reading test. (clays ready to read test), home questionnaire.	Children with greater access to tablets had a higher letter sound and name writing skills. No relationships were found between time on tablets and emergent literacy skills.
Neumann, 2016	Analytical cross sectional	$N = 57$ children; age $= 42.4 \pm 9.02$ months	To determine the relationship between touch screen tablet use at home, and emergent literacy skills for writing and reading, in children	Letter name and sound and numeral name knowledge; letter writing; initial phoneme retrieval Aram and Levin; print concepts	The study found positive association between children's access to apps and print knowledge. A positive association was found between the frequency of writing with tablets and print awareness, print knowledge, and sound knowledge
Neumann, 2018	RCT	$N = 48$ children; age $= 45.19 \pm 8.82$ months	To determine the effect of literacy apps on emergent literacy skills, in children	Letter name and sound and numeral name knowledge; letter name and writing; print concepts	Children using iPads had significantly higher letter name and sound knowledge, print concepts and name

TABLE 5 (Continued)

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
		Intervention = 24; age = 45.68 ± 8.48 months Control = 24 children; age = 44.70 ± 9.31 months			writing skills than children in the control group. No significant group differences were found for letter writing skills or numeral knowledge.
O'Toole & Kannass, 2018	RCT	N = 100 children; age = 4.42 ± 0.28 years	To determine whether book type, narration, and attention moderate the relation between attention and learning	Standardized vocabulary measures The PPVT-4; word learning; story comprehension; attention coding; inattention and attention to experimenter	When controlling for vocabulary, the overall pattern of results revealed that children learned more words from the e-book and from the audio narrator, but story comprehension did not differ as a function of condition. Attention predicted learning, but only in some print book contexts, and significant effects of prior experience did not emerge.
Outhwaite et al., 2019	RCT	N = 389 children; age = 60.64 ± 3.62 months Treatment group = 126 children Time-equivalent treatment group: n = 131 children control group = 132 children	To determine the impact of interactive apps on achievement in math, in children	Children's mathematical ability was assessed using the PTM5 math assessment resource service.	There was a significantly greater math learning gains for children using an app compared with standard math practice. The math apps supported targeted basic facts and concepts and generalized to higher-level math reasoning and problem-solving skills.
Parish-Morris et al., 2013	RCT	N = 92 children, Age = 3–5 years Group 1 (three-year olds) = 46 children Group 2 (five-year olds) = 46 children	To determine the effects of electronic console (EC) books, CD-rom books, and e-book apps on literacy outcome and comprehensions, in children	Study 1: Coding Study 2: Coding, questionnaire, identification task, chronological task.	Parent–child dialogic reading and children's story comprehension were both negatively affected by the presence of electronic features.
Portugal et al., 2021	Analytical cross sectional	N = 40 children, age = 12 months, 18 months and 3.5 years	To assess exogenous and endogenous attention, in children who were stable high (HU) or low (LU) touchscreen users from toddlerhood to preschool	The gap overlap, the anti-saccade index	Results suggest that long-term high exposure to touchscreen devices is associated with faster exogenous attention and concomitant decreases in endogenous attention control.

(Continues)

TABLE 5 (Continued)

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
Rogowsky et al., 2018	RCT	$N = 47$ Comparison: $n = 23$; age = 4.44 ± 0.65 Computer-assisted: $n = 24$; age = 4.4 ± 0.67	To determine the impact of computer-assisted instruction using an e-tablet on literacy and numeracy, in preschoolers	Bracken School Readiness Assessment3rd edition; Test of Preschool Early Literacy (TOPEL); Woodcock-Johnson Tests of Achievement (WJ-III)	Playful learning through educational software may enhance literacy and numeracy skills among preschoolers
Ross et al., 2016	Quasi-experimental	$N = 22$ children; age = 7 years 1 month ± 6 months Group 1 (The Prince's Bedtime print) = 11 children Group 2 (The Prince's Bedtime touch screen) = 11 children Group 3 (The Fantastic Flying Books of Mr. Morris Lessmore: print) = 11 children Group 4 (The Fantastic Flying Books of Mr. Morris Lessmore: touchscreen) = 11 children	To determine the impact of storybook format (traditional and print) on comprehension, in children	York Assessment of Reading Comprehension: Passage Reading Primary; Reading Environment Questionnaire; Story Comprehension Questions	High touch screen interactivity enriched emotional engagement and increased maternal praise, and touch screens had no detrimental effects on comprehension questioning and word help but there was no evidence that these observations related to comprehension.
Russo-Johnson et al., 2017	Analytical cross sectional	Study 1: $N = 77$ children; age = 2 to 5 years Group 1 (2-year-old) = 30 children Group 2 (4 and 5-year-old) = 47 children Group 3 (4-year-old) = 22 children	To determine the relationship between screen-directed actions, and self-regulation along with word learning, in children	Carlson's toddler snack self-regulation task; taps during instruction	Study 1, children's tapping behaviors during game play were related to their self-regulation, children with high self-regulation tapped significantly less during instruction portions of an app than children with low self-regulation. Study 2 Conditions in which children tapped or dragged a named object to move it across the screen required different

TABLE 5 (Continued)

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
		Group 4 (5-year-old) = 25 children Study 2: $N = 170$ children; age = 41.05 ± 10.51 months Group 1 (watch) = 58 children Group 2 (tap) = 60 children Group 3 (drag) = 52 children			amounts of effort and focus, compared to a non-interactive (watching) condition. Age by sex interactions revealed a particular benefit of dragging for preschool girls' learning compared to that of boys. Boys benefited more from watching than dragging.
Schmitt et al., 2018	RCT	$N = 136$; age = 5.24 ± 0.71 Preschool: $n = 94$; age = 4.86 ± 0.47 Kindergarten: $n = 42$; age = 6.09 ± 0.32	To determine the impact of literacy games, an educational website, on early literacy development, in children	PALS-PreK survey; phonics and vocabulary evaluated tool; The Get Ready to Read! - Revised Screener (GRTR-R)	Children in the intervention group outperformed control group peers on eight of these outcomes. Learning was most pronounced for alliteration and phonics, which are important early predictors of later reading abilities.
Schroeder & Kirkorian, 2016	RCT	$N = 44$ children; age = 4.2 ± 0.8 Younger group = 22 children Older group = 22 children Growth game play = 22 children Quantity game watch = 22 children Growth game watch = 22 children Quantity game play: $n = 22$ children	To determine character familiarity and game interactivity, and the extent they are learned and transferred from digital games, in preschoolers	Parent survey—demographic information, media use and familiarity with Dinosaur Train—a TV show; prior knowledge and direct learning; Receptive One-Word Picture Vocabulary Test—Fourth Edition (ROWPVT-4).	Preschoolers may benefit more by watching a video than by playing a game if the game is cognitively demanding, perhaps because making decisions while playing the game increases cognitive load.
Xu et al., 2021	Quasi-experimental	$N = 76$ children, age = 48.5 ± 9.7	To assess if children's interactions with hotspots increased their engagement with reading when using an e-book independently and how such interactions were related to their learning from the story.	Comprehension questionnaire developed by the authors, recorded hotspot usage, Reading engagement, observational protocol	Interacting with hotspots enhanced children's emotional engagement and sustained visual attention but not verbal engagement. Interacting with hotspots also benefited children's recall of story elements relevant to

(Continues)

TABLE 5 (Continued)

Author, year	Study design	Sample	Purpose	Methods of assessment to developmental outcome	Major findings
					the hotspot but not their overall comprehension of the story.
Zhen, 2017	Quasi-experimental	$N = 3$ children with developmental delay; age = pre-K (4–5 years)	To determine the impact of using an iPad app on early reading skills, in children with mild developmental delays	Peabody Picture Vocabulary Test-IV (PPVT-IV), Test of Early Reading Ability-3	Children improved their performance with computer assisted instruction on their target phonemes but also learned some of their peers' target phonemes through observational learning.

Search	Query
1	(MH “Child”) OR (MH “Child, Preschool”) OR “child*” OR “toddler” OR “pre-school*” OR “preschool*” OR “early childhood” OR (MH “Infant”) OR “infant”
	AND
2	“speech development*”OR “psycho-motor development” OR “development*” OR (MH “Language Development”) OR “language development”(MH “Motor skills”) “motor skill*” OR “fine motor skills” or “gross motor skill*”OR (MH “Child Development”) OR “cognitive development” OR “psychomotor development”
	AND
3	(MH “Screen Time”) OR “screen time” OR “screen media” OR “digital technol*” OR “digital media” OR (MH “Cellular Phone”) OR “cellular phone” OR “cell* phone*” OR (MH “Smartphone”) OR “smartphone*” OR “smart phone*” OR “mobile phone*” OR (MH “Computers, Portable”) OR “ipad*” OR (MH “Tablets”) OR “tablets” OR computer*
	AND
4	“impact*” OR “effect*” OR “influence*” OR “consequence*” OR “outcome*”
	Published 2010 onwards; English Language

5 | DISCUSSION

This paper reports a systematic review examining the impact of digital technology use on child development. The studies reviewed in this review were predominantly correlational or comparative in nature and focused on cognitive domains of learning rather than a specific developmental outcome. In addition, both RCT and quasi-experimental studies were mainly concerned with investigating whether or not there were differences between children using digital devices (tablets and non-tablets) in cognitive and motor skills. Therefore, it was difficult to conclude cause from effect regarding the relationship or impact of digital technology use on child development. One prominent explanation for these associations or effects suggests that children's use of interactive digital technology commonly associate with better receptive language and executive function, but not motor proficiency.

In this review, only three studies used longitudinal designs to clarify correlates (Barnett et al., 2012; Fikkers et al., 2019; McNeill et al., 2019), and seven studies (Bonneton-Botté et al., 2020; Clarke & Abbott, 2016; Desoete & Praet, 2013; Di Lieto et al., 2017; Konok et al., 2021; Liu et al., 2021; Trost & Brookes, 2021) reported on the impact on children when using computer applications or other touchscreen devices. In these studies, it was difficult to determine the magnitude of any change in child's development or whether it would be reasonable to expect that the use of certain interactive technology devices would play an important role in enhancing or embedding developmental outcomes. However, placed within the larger context of research on the digital technology's relations with child development, there was some evidence that use of interactive technology, such as computers and screen devices, can poorly associate or impact motor development in young children.

For motor skill development, a large body of Tier 1 studies suggested that the use of digital technology can lead to no gains or associate negatively with fine motor development. While Tier 2 studies hypothesized benefits for touchscreen use, we found no clear evidence that digital technology use was effective in improving gross motor outcomes in children (Barnett et al., 2012; Bedford et al., 2016; Spinosa et al., 2020).

The result of our review would have been much more meaningful if the dose of exposure to games, videos, computers, or mobile phones had been reported in an informative manner. This highlights the gap in defining the type, content, and intensity of digital technology use, rather than a gap in access to digital devices. Our findings showed critical aspects informing the evidence, such as dose of exposure, intensity, or duration were inconsistently reported and varied significantly across studies, making estimates of exposure tentative and imprecise. Bedford et al. (2016) suggested that more reliable methods of tracking current touchscreen usage, such as media diaries or device monitoring, are required along with the detailed analysis of other usage factors, such as co-use, physical context, and type of use. The longitudinal designs of McNeill et al. (2019) suggested that the relationship between some electronic media use and executive function may actually be curvilinear rather than linear. Therefore, the effects of some electronic media use could be stronger for some children due to higher dose of exposure (30 min/day threshold), which may reduce other regular developmentally appropriate experiences and practices, potentially harming a child's development. However, this idea remains largely unexamined and open to question. We were unable to locate similar reviews evaluating the digital impact on motor development to which we might compare findings. The impact of digital technology most prevalent in the literature included the developmental correlates of screen media exposure, mainly with relation to the physical activity and/or obesity/adiposity (Fang et al., 2019; Reus & Mosley, 2018; Stiglic & Viner, 2019). All reviews suggested increasing screen time and screen media exposure in children was predominantly adversely associated with obesity/adiposity and physical activity. The ways that motor proficiency was measured were not comparable, and therefore, these results were not comparable. Likewise, another systematic review by Kuzik et al. (2017) identified favorable associations with at least one motor development indicator in two RCT studies that examined the most ideal combinations of sedentary behavior and physical activity.

In our review, improved comprehension was not consistently associated with digital technology use, although use of digital technology was fairly associated with enhanced receptive language, executive function, and memory. This finding contrasts with a previous scoping review that suggested negative or no association between touchscreen media use and language development (Reus & Mosley, 2018). However, it should be noted that the positive association found in our review was not supported in other reviews other than in the receptive domain of language (Gremmen et al., 2016; Hu et al., 2020). While we present evidence that supports the receptive language development of specific interactive digital technologies, the level of benefit was reported as dependent on adult company or co-viewing (Walter-Laager et al., 2017), limited screen time (Duch et al., 2013), and being over 3 years of age (Moon et al., 2019).

On the cognitive domain, cited studies with a positive association or impact included enhanced literacy and numeracy skills, manual dexterity, and visuo-spatial working memory when used in a learning context. Use of touchscreen devices in Tier 1 studies were often intended to evaluate executive function and visual-motor integration and were particularly prevalent in studies of literacy learning. While there were reported benefits in this context, none of the Tier 1 studies reported significant impact of digital technology use in children on comprehension (Parish-Morris et al., 2013; Ross et al., 2016). Part of these findings were consistent with other studies, which reported positive association of specific TV programs or video games and cognitive development of children (Reus & Mosley, 2018). It was suggested that the use of educational computer programs or games can lead to short-term increases in visual processing skills, attention, and executive function skills (Anderson & Subrahmanyam, 2017). What remains unclear is not whether this effect depends on the content-specific or type of games played, but whether such positive cognitive impact can be prolonged and enhanced in those children.

In this review, the included studies were of high quality and the majority were classified as Tier 1. In our conclusion, we argue that an emphasis on rigorous study designs such as RCT and quasi-experimental rather than on cross-sectional and qualitative studies is necessary to provide casual evidence, but that should be countered by the issues of longer term effects and ability to adequately control sufficiently in real-world RCTs. We do not suggest negating the evidence generated by cross-sectional studies, rather that trials are "content-specific" more generally. We argue also that evaluation and understanding of the dose of exposure to video games or screen devices is important prior to any conclusion as dose of exposure may be a confounding factor for any impact on developmental outcomes.

We need to acknowledge that there were several limitations to this review including limitations with the search strategy, inclusion and exclusion criteria, and the search terms used. The search strategy used was comprehensive but did not include searches in grey data sets such as OpenGrey, Health Canda, or TRIp Pro. Our search strategy was designed to ensure quality by limiting studies to those published in peer-reviewed journal and those with good quality appraisal. In addition, the search used for this review was supplemented using reference lists; so, it is likely that most relevant articles were included. Another limitation is that our review did not specifically search for smart connected toys or electronic games. For example, articles that evaluated connected toys that are Internet-enabled devices with Wi-Fi, Bluetooth, or other capabilities were not included related to limitations of search strategy. However, evaluation of outcomes specifically related to Internet-connected toys, which are becoming increasingly popular among very young children (<7 years), is also important and should be analyzed in future studies.

Other limitations to be considered in our review is reported data for motor and language domains may suffer from different degrees of inconsistencies or may be incomplete due to the broad definition of child development and assessment methods. For example, in a few studies, assessment of manual dexterity and writing or drawing skills were used as one component of a general assessment of the cognitive and learning domain. This made it difficult to isolate the specific correlates of fine motor development because such skills require the combination of motor, perceptual, and cognitive components (Picard et al., 2014). A number of contextual factors that may moderate the association between digital technology use and child development was not adequately provided in the primary studies. This included stratified data by age group, gender, screen time, and content, in addition to other critical aspects informing the evidence, such as dose of exposure, intensity, or duration. Therefore, our findings suggest only a rudimentary level of understanding of the area.

Finally, while our review offers a thorough examination of the published studies in social and health science, the constant advancement of interactive digital technologies, including video games means that many of the more recent releases have yet to be evaluated through research. The review may not capture all digital technologies, and the question of whether interactive digital technology impacts literacy, vocabulary, and executive function among children will continue to evolve.

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AUTHOR CONTRIBUTION

DA, LW, and EM conceived the study. MA and SR performed the analysis. DA, MA, and SR collected and extracted relevant data. All authors contributed to manuscript preparation and revision for intellectual content.

CONFLICT OF INTEREST

The authors have no funding or conflicts of interest to disclose. This review was registered on PROSPERO (*registration number*: CRD42020171962) and developed accordance with the Joanna Briggs Institute (JBI) methodology for systematic reviews and reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guideline (Moher et al., 2009).

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

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Zheng, P., & Sun, J. (2021). Preschool children's use of digital devices and early development in Hong Kong: The role of family socioeconomic status. *Early Education and Development*, *33*, 893–911. https://doi.org/10.1080/10409289.2021.1920767

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APPENDIX A.

A.1 | Full text papers excluded with reasons

Author, year	Reason for exclusion
Accardo, A. P., Genna, M., & Borean, M. (2013). Development, maturation and learning influence on handwriting kinematics. *Human Movement Science*, *32*(1), 136–146. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=23369774&site=ehost-live&scope=site	Wrong outcome
Agina, A. M. (2012a). The effect of nonhuman's external regulation on young children's creative thinking and thinking aloud verbalization during learning mathematical tasks. *Computers in Human Behavior*, *28*(4), 1213–1226. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2012-11598-007&site=ehost-live&scope=site a.m.agina@utwente.nl	Wrong outcome
Agina the effect of nonhuman's external regulation on young children's self-regulation to regulate their own process of learning *Computers in Human Behavior*,. *28*(4),1140–1152. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2012-05308-001&site=ehost-live&scope=site a.m.agina@utwente.nl	Wrong outcome
Ahmad, M. I., Mubin, O., Shahid, S., & Orlando, J. (2019). Robot's adaptive emotional feedback sustains children's social engagement and promotes their vocabulary learning: A long-term child–robot interaction study. *Adaptive Behavior*, *27*(4), 243–266. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2019-40740-002&site=ehost-live&scope=site muneeb.ahmad@westernsydney.edu.au	Wrong population
Amornchewin, R., & Sitdhisanguan, K. (2017). Evaluation of the impact of tablet screen size on children tracing performance. *Artificial Life and Robotics*, *22*(2), 191–196. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85001655048&doi=10.1007%2fs10015-016-0343-0&partnerID=40&md5=8a48d34de6c54af7152bde369baefc5e	Wrong outcome
Axelsson, A., Andersson, R., & Gulz, A. (2016). Scaffolding executive function capabilities via play-&-learn software for preschoolers. *Journal of Educational Psychology*, *108*(7), 969–981. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84954420292&doi=10.1037%2fedu0000099&partnerID=40&md5=7187e88915c35167dda3484f4e9a64cb	Wrong outcome
Bassiouni, D. H., & Hackley, C. (2016). Video games and young children's evolving sense of identity: A qualitative study. *Young Consumers*, *17*(2), 127–142. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2016-33407-002&site=ehost-live&scope=site dbassiouni@aucegypt.edu	Wrong study design
Bentley, G. F., Turner, K. M., & Jago, R. (2016). Mothers' views of their preschool child's screen-viewing behaviour: a qualitative study. *BMC public health*, *16*, 718. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=27492488&site=ehost-live&scope=site https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4973523/pdf/12889_2016_Article_3440.pdf	Wrong study design
Bhatt, C. R., Benke, G., Smith, C. L., Redmayne, M., Dimitriadis, C., Dalecki, A., ..., Abramson, M. J. (2017). Use of mobile and cordless phones and change in cognitive function: a prospective cohort analysis of Australian primary school children. *Environmental health: A global access science source*, *16*, 1–10. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=123710929&site=ehost-live&scope=site	Wrong outcome
Blades, M., Blumberg, F. C., & Oates, C. (2013). The importance of digital games for children and young people. *Zeitschrift für Psychologie*, *221*(2), 65–66. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2013-23257-001&site=ehost-live&scope=site m.blades@sheffield.ac.uk	Wrong study design
Blankson, A. N., O'Brien, M., Leerkes, E. M., Calkins, S. D., & Marcovitch, S. (2015). Do hours spent viewing television at ages 3 and 4 predict vocabulary and executive functioning at age 5? *Merrill-Palmer Quarterly*, *61*(2), 264–289. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2015-22173-003&site=ehost-live&scope=site ablanks1@spelman.edu	Wrong outcome
Borg, M. (2019). "It's not for real": The tablet as palette in early childhood education. *International Journal of Education and the Arts*, 20. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85079698038&doi=10.26209%2fijea20n14&partnerID=40&md5=29a2cdc0bbfd3650ea636f3ec702d8d5	Wrong outcome
Bozzola, E., Spina, G., Ruggiero, M., Memo, L., Agostiniani, R., Bozzola, M., ..., Villani, A. (2018). Media devices in pre-school children: The recommendations of the Italian pediatric society. *Italian Journal of Pediatrics*, 44(1), N.PAG-N.PAG. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=130183838&site=ehost-live&scope=site	Wrong study design
Broda, M., Tucker, S., Ekholm, E., Johnson, T. N., & Liang, Q. (2019). Small fingers, big data: Preschoolers' subitizing speed and accuracy during interactions with multitouch technology. *Journal of Educational Research*, 112(2), 211–	Wrong outcome

Author, year	Reason for exclusion
222. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85059326574&doi=10.1080%2f00220671.2018.1486281&partnerID=40&md5=76c6ad7092c40960a54c009ab0d6b00f	
Cadoret, G., Bigras, N., Lemay, L., Lehrer, J., & Lemire, J. (2018). Relationship between screen-time and motor proficiency in children: A longitudinal study. Early *Child Development and Care*, 188(2), 231–239. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-01679-013&site=ehost-live&scope=site cadoret.genevieve@uqam.ca; screen time includes tv and DVDs	Screen time includes TV and DVDs
Cerniglia, L., Cimino, S., & Ammaniti, M. (2021). What are the effects of screen time on emotion regulation and academic achievements? A three-wave longitudinal study on children from 4 to 8 years of age. *Journal of Early Childhood Research*, 19(2), 145–160. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85097259702&doi=10.1177%2f1476718X20969846&partnerID=40&md5=1be1020deb30bfa3b99be9643a276848	Wrong outcome
Chandra, M., Jalaludin, B., Woolfenden, S., Descallar, J., Nicholls, L., Dissanayake, C.,…, Eapen, V. (2016). Screen time of infants in Sydney, Australia: a birth cohort study. *BMJ Open*, *6*(10), e012342. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=27798011&site=ehost-live&scope=site https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5093377/pdf/bmjopen-2016-012342.pdf	Wrong outcome
Christ, T., Wang, X. C., Chiu, M. M., & Cho, H. (2019). Kindergartener's meaning making with multimodal app books: The relations amongst reader characteristics, app book characteristics, and comprehension outcomes. *Early Childhood Research Quarterly*, *47*, 357–372. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2019-13004-033&site=ehost-live&scope=site ORCID: 0000-0003-2706-9393 ORCID: 0000-0002-5721-1971 ORCID: 0000-0003-0982-6530 hyonsuk.cho@und.edu mingchiu@eduhk.hk wangxc@buffalo.edu christ@oakland.edu	Wrong outcome
Cieśla, E., Mleczko, E., Bergier, J., Markowska, M., & Nowak-Starz, G. (2014). Health-related physical fitness, BMI, physical activity and time spent at a computer screen in 6 and 7-year-old children from rural areas in Poland. *Annals of Agricultural and Environmental Medicine*, *21*(3), 617–621. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L600196302 https://doi.org/10.5604/12321966.1120613	Wrong outcome
Cook, S. W., Friedman, H. S., Duggan, K. A., Cui, J., & Popescu, V. (2017). Hand gesture and mathematics learning: Lessons from an avatar. *Cognitive Science*, *41*(2), 518–535. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=27128822&site=ehost-live&scope=site	Wrong population
Coutinho, F. (2017). Two-dimensional solutions in a multi-dimensional world? A commentary on "effect of touch screen tablet use on fine motor development of young children". *Physical & occupational therapy in pediatrics*, *37*(5), 468–470. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=29020570&site=ehost-live&scope=site	Wrong study design
Coutinho, F., Bosisio, M.-E., Brown, E., Rishikof, S., Skaf, E., Zhang, X., …, Dahan-Oliel, N. (2017). Effectiveness of iPad apps on visual-motor skills among children with special needs between 4y0m–7y 11m. *Disability and Rehabilitation: Assistive Technology*, *12*(4), 402–410. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2017-13649-011&site=ehost-live&scope=site franzina.coutinho@mcgill.ca https://www.tandfonline.com/doi/pdf/10.1080/17483107.2016.1185648?needAccess=true	Wrong population
Crescenzi Lanna, L., & Grané Oro, M. (2019). Touch gesture performed by children under 3 years old when drawing and coloring on a tablet. *International Journal of Human Computer Studies*, *124*, 1–12. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85056809569&doi=10.1016%2fj.ijhcs.2018.11.008&partnerID=40&md5=f3d284f7bfb782809e4350df36f0749f	Wrong outcome
Dadson, P., Brown, T., & Stagnitti, K. (2020). Relationship between screen-time and hand function, play and sensory processing in children without disabilities aged 4–7 years: A exploratory study. *Australian Occupational Therapy Journal*. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85079034721&doi=10.1111%2f1440-1630.12650&partnerID=40&md5=cd12d3f29b1f358c471a3264450e7780	Screen time includes TV and DVDs
Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science (New York, N.Y.)*, *333*(6045), 959–964. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=21852486&site=ehost-live&scope=site https://science.sciencemag.org/content/sci/333/6045/959.full.pdf	Wrong population
Diehm, E. A., Wood, C., Puhlman, J., & Callendar, M. (2020). Young children's narrative retell in response to static and animated stories. *International Journal of Language & Communication Disorders*, 55(3), 359–372. Retrieved from https://www.embase.com/search/results?subaction=viewrecord&id=L630592556&from=export https://doi.org/10.1111/1460-6984.12523	Wrong outcome
Dorouka, P., Papadakis, S., & Kalogiannakis, M. (2020). Tablets and apps for promoting robotics, mathematics, STEM education and literacy in early childhood education. *International Journal of Mobile Learning and Organisation*, *14*(2), 255–274. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85083057772&doi=10.1504%2fIJMLO.2020.106179&partnerID=40&md5=4e04fc22bc9489a72939b68b08212827	Wrong study design

(Continues)

Author, year	Reason for exclusion
Duch, H., Fisher, E. M., Ensari, I., Font, M., Harrington, A., Taromino, C., …, Rodriguez, C. (2013). Association of screen time use and language development in Hispanic toddlers: A cross-sectional and longitudinal study. *Clinical Pediatrics*, 52(9), 857–865. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=89945695&site=ehost-live&scope=site	Screen time includes TV and DVDs
Ecalle, J., Kleinsz, N., & Magnan, A. (2013). Computer-assisted learning in young poor readers: The effect of grapho-syllabic training on the development of word reading and reading comprehension. *Computers in Human Behavior*, *29*(4), 1368–1376. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2013-14654-014&site=ehost-live&scope=site ecalle.jean@wanadoo.fr	Wrong population
Edwards, S., Skouteris, H., Rutherford, L., & Cutter-Mackenzie, A. (2013). 'It's all about Ben10™': Children's play, health and sustainability decisions in the early years. *Early Child Development and Care*, *183*(2), 280–293. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2013-01519-008&site=ehost-live&scope=site ORCID: 0000-0002-2499-8552 ORCID: 0000-0003-3940-3379 ORCID: 0000-0002-5945-0597 helen.skouteris@deakin.edu.au suzy.edwards@acu.edu.au	Wrong study design
Eisenchlas, S. A., Schalley, A. C., & Moyes, G. (2016). Play to learn: Self-directed home language literacy acquisition through online games. *International Journal of Bilingual Education and Bilingualism*, *19*(2), 136–152. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2016-04394-002&site=ehost-live&scope=site ORCID: 0000-0002-7700-8444 s.eisenchlas@griffith.edu.au	Wrong population
Flanagan, R. (2013). Effects of learning from interaction with physical or mediated devices. *Cognitive processing*, *14*(2), 213–215. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=23568034&site=ehost-live&scope=site	Wrong population
Felix, E., Silva, V., Caetano, M., Ribeiro, M. V. V., Fidalgo, T. M., Rosa Neto, F., …, Caetano, S. C. (2020). Excessive screen media use in preschoolers is associated with poor motor skills. *Cyberpsychology, Behavior, and Social Networking*, 23(6), 418–425. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2020-41583-003&site=ehost-live&scope=site erikafxs@gmail.com https://www.liebertpub.com/doi/pdfplus/10.1089/cyber.2019.0238	Screen time includes TV and DVDs
Flynn, R. M., & Richert, R. A. (2018). Cognitive, not physical, engagement in video gaming influences executive functioning. *Journal of Cognition and Development*, *19*(1), 1–20. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-03843-001&site=ehost-live&scope=site ORCID: 0000-0002-2522-2932 rachel.flynn@northwestern.edu	Wrong population
Fullwood, I. (2020). Increased screen time is associated with poorer developmental outcomes in early childhood. *Archives of Disease in Childhood. Education and Practice Edition*, 105(4), 253–254. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=31292148&site=ehost-live&scope=site https://ep.bmj.com/content/edpract/105/4/253.full.pdf	Wrong study design
Gabyzon, M. E., Engel-Yeger, B., Tresser, S., & Springer, S. (2016). Using a virtual reality game to assess goal-directed hand movements in children: A pilot feasibility study. *Technology & Health Care*, *24*(1), 11–19. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=112896164&site=ehost-live&scope=site	Wrong outcome
Ganz, J. B., Hong, E. R., Goodwyn, F., Kite, E., & Gilliland, W. (2015). Impact of PECS tablet computer app on receptive identification of pictures given a verbal stimulus. *Developmental Neurorehabilitation*, *18*(2), 82–87. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2015-11018-002&site=ehost-live&scope=site jeniganz@tamu.edu https://www.tandfonline.com/doi/pdf/10.3109/17518423.2013.821539?needAccess=true	Wrong study design
Genlott, A. A., & Grönlund, Å. (2013). Improving literacy skills through learning reading by writing: The iWTR method presented and tested. *Computers & Education*, *67*, 98–104. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2013-18255-010&site=ehost-live&scope=site ake.gronlund@oru.se angen_s@edu.sollentuna.se	Wrong outcome
Gentile, D. A., Berch, O. N., Khoo, A., Hyekyung, C., & Walsh, D. A. (2017). Bedroom media: One risk factor for development. *Developmental Psychology*, *53*(12), 2340–2355. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=126631707&site=ehost-live&scope=site	Wrong population
Giacomo Dina, D., Vincenza, C., Mascio Tania, D., Maria Rosita, C., Daniela, F., Rosella, G., & Pierpaolo, V. (2016). The silent reading supported by adaptive learning technology: Influence in the children outcomes. *Computers in Human Behavior*, *55*, 1125–1130. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=111740643&site=ehost-live&scope=site	Wrong population
Graham, R. (2013). The perception of digital objects and their impact on development. *Psychoanalytic Psychotherapy*, *27*(4), 269–279. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2013-44386-003&site=ehost-live&scope=site rgraham@tavi-port.nhs.uk	Wrong population
Gueron-Sela, N., & Gordon-Hacker, A. (2020). Longitudinal links between media use and focused attention through toddlerhood: A cumulative risk approach. *Frontiers in Psychology*, 11. Retrieved from http://ezproxy.ecu.edu.au/	Screen time includes TV and DVDs

Author, year	Reason for exclusion
login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2020-87056-001&site=ehost-live&scope=site gueron@post.bgu.ac.il	
Guilbert, J., Alamargot, D., & Morin, M.-F. (2019). Handwriting on a tablet screen: Role of visual and proprioceptive feedback in the control of movement by children and adults. *Human Movement Science, 65*. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=30219272&site=ehost-live&scope=site	Wrong outcome
Gülay Ogelman, H., Güngör, H., Körükçü, Ö., & Erten Sarkaya, H. (2018). Examination of the relationship between technology use of 5–6 year-old children and their social skills and social status. *Early Child Development and Care, 188*(2), 168–182. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-01679-008&site=ehost-live&scope=site hgungor@pau.edu.tr	Wrong population
Hardell, L. (2018). Effects of mobile phones on children's and adolescents' health: A commentary. *Child Development, 89*(1), 137–140. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2017-21887-001&site=ehost-live&scope=site lennart.hardell@regionorebrolan.se https://srcd.onlinelibrary.wiley.com/doi/full/10.1111/cdev.12831	Wrong study design
Hardy, L. L., Ding, D., Peralta, L. R., Mihrshahi, S., & Merom, D. (2018). Association between sitting, screen time, fitness domains, and fundamental motor skills in children aged 5–16 years: Cross-sectional population study. *Journal of Physical Activity & Health, 15*(12), 933–940. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2019-01439-008&site=ehost-live&scope=site louise.hardy@sydney.edu.au	Wrong population
Hawkes, N. (2014). Study will look at effect of mobile phones on children's cognitive development. *BMJ (Clinical Research ed.), 348*, g3407. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=24846208&site=ehost-live&scope=site https://www.bmj.com/content/bmj/348/bmj.g3407.full.pdf	Wrong study design
Hermawati, D., Rahmadi, F. A., Sumekar, T. A., & Winarni, T. I. (2018). Early electronic screen exposure and autistic-like symptoms. *Intractable and Rare Diseases Research, 7*(1), 69–71. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L621000111 https://doi.org/10.5582/irdr.2018.01007	Wrong population
Herrmann, D., Buck, C., Sioen, I., Kouride, Y., Marild, S., Molnár, D., …, Ahrens, W. (2015). Impact of physical activity, sedentary behaviour and muscle strength on bone stiffness in 2–10-year-old children-cross-sectional results from the IDEFICS study. *The International Journal of Behavioral Nutrition and Physical Activity, 12*. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2015-43437-001&site=ehost-live&scope=site ahrens@bips.uni-bremen.de prusso@isa.cnr.it	Wrong study design
Hilpert, M., Brockmeier, K., Dordel, S., Koch, B., Weiß, V., Ferrari, N., …, Graf, C. (2017). Sociocultural influence on obesity and lifestyle in children: A study of daily activities, leisure time behavior, motor skills, and weight status. *Obesity Facts, 10*(3), 168–178. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=28528341&site=ehost-live&scope=site	Wrong outcome
Hinkley, T., & McCann, J. R. (2018). Mothers' and father's perceptions of the risks and benefits of screen time and physical activity during early childhood: a qualitative study. *BMC Public Health, 18*(1), 1271. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=30453927&site=ehost-live&scope=site https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6245522/pdf/12889_2018_Article_6199.pdf	Wrong outcome
Hinkley, T., Verbestel, V., Ahrens, W., Lissner, L., Molnár, D., Moreno, L. A., …, De Bourdeaudhuij, I. (2014). Early childhood electronic media use as a predictor of poorer well-being: a prospective cohort study. *JAMA Pediatrics, 168*(5), 485–492. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=24639016&site=ehost-live&scope=site https://jamanetwork.com/journals/jamapediatrics/articlepdf/1844044/poi140005.pdf	Wrong study design
Holyfield, C., Drager, K., Light, J., & Gosnell Caron, J. (2017). Typical Toddlers' participation in "just-in-time" programming of vocabulary for visual scene display augmentative and alternative communication apps on mobile technology: A descriptive study. *American Journal of Speech-Language Pathology, 26*(3), 737–749. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=124667456&site=ehost-live&scope=site https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5829791/pdf/AJSLP-26-737.pdf	Wrong outcome
Horowitz-Kraus, T., & Hutton, J. S. (2018). Brain connectivity in children is increased by the time they spend reading books and decreased by the length of exposure to screen-based media. *Acta Paediatrica, 107*(4), 685–693. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-10619-027&site=ehost-live&scope=site tzipi.horowitz-kraus@cchmc.org https://onlinelibrary.wiley.com/doi/full/10.1111/apa.14176	Wrong population
Howe, T.-H., Wang, T.-N., Sheu, C.-F., & Hsu, Y.-W. (2010). Ball catching skills of 5- to 11-year-old typically developing children in real and virtual environments. *American journal of physical medicine & rehabilitation, 89*(7), 523–529.	Wrong population

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Author, year	Reason for exclusion
Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=20463566&site=ehost-live&scope=site	
Hsiao, H.-S., Chang, C.-S., Lin, C.-Y., & Hsu, H.-L. (2015). 'iRobiQ': The influence of bidirectional interaction on kindergarteners' reading motivation, literacy, and behavior. *Interactive Learning Environments*, *23*(3), 269–292. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2015-18033-002&site=ehost-live&scope=site chengsian1117@gmail.com	Wrong population
Hsiao, H.-S., & Chen, J.-C. (2016). Using a gesture interactive game-based learning approach to improve preschool children's learning performance and motor skills. *Computers & Education*, *95*, 151–162. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2016-12811-013&site=ehost-live&scope=site cv999999999@yahoo.com.tw hssiu@ntnu.edu.tw	Wrong outcome
Hsiao, H. S., Chang, C. S., Lin, C. Y., & Hu, P. M. (2010). Development of children's creativity and manual skills within digital game-based learning environment. *Journal of Computer Assisted Learning*, *30*(4), 377–395. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=107867914&site=ehost-live&scope=site	Wrong outcome
Hu, B. Y., Johnson, G. K., & Wu, H. (2018). Screen time relationship of Chinese parents and their children. *Children & Youth Services Review*, *94*, 659–669. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=132804420&site=ehost-live&scope=site	Wrong population
Huang, X., Zeng, N., & Ye, S. (2019). Associations of sedentary behavior with physical fitness and academic performance among Chinese students aged 8–19 years. *International Journal of Environmental Research and Public Health*, *16*(22). Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=31739629&site=ehost-live&scope=site	Wrong population
Huber, B., Tarasuik, J., Antoniou, M. N., Garrett, C., Bowe, S. J., Kaufman, J., & the Swinburne Babylab, T. (2016). Young children's transfer of learning from a touchscreen device. *Computers in Human Behavior*, *56*, 56–64. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84948397907&doi=10.1016%2fj.chb.2015.11.010&partnerID=40&md5=771f389eac5647f515ea99b489ab5495	Wrong outcome
Huber, B., Meyer, D., & Kaufman, J. (2019). Young children's contingent interactions with a touchscreen influence their memory for spatial and narrative content. *Media Psychology*. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85065716068&doi=10.1080%2f15213269.2019.1611451&partnerID=40&md5=c5020dc5ff53e015a03f21cd1232699f	Wrong outcome
Hutton, J. S., Dudley, J., Horowitz-Kraus, T., DeWitt, T., & Holland, S. K. (2019). Functional connectivity of attention, visual, and language networks during audio, illustrated, and animated stories in preschool-age children. *Brain Connectivity*, *9*(7), 580–592. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=31144523&site=ehost-live&scope=site	Wrong outcome
Hutton, J. S., Dudley, J., Horowitz-Kraus, T., DeWitt, T., & Holland, S. K. (2020). Associations between screen-based media use and brain white matter integrity in preschool-aged children. *JAMA Pediatrics*, *174*(1), e193869-e193869. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=141154805&site=ehost-live&scope=site	Wrong outcome
Jackson, L. A., Witt, E. A., Games, A. I., Fitzgerald, H. E., von Eye, A., & Zhao, Y. (2012). Information technology use and creativity: Findings from the children and technology project. *Computers in Human Behavior*, *28*(2), 370–376. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2012-00508-009&site=ehost-live&scope=site zhaoyo@msu.edu voneye@msu.edu fitzgerf8@msu.edu games@msu.edu wittedwa@msu.edu jackso67@msu.edu	Wrong population
John, J. J., Joseph, R., David, A., Bejoy, A., George, K. V., & George, L. (2021). Association of screen time with parent-reported cognitive delay in preschool children of Kerala, India. *BMC Pediatrics*, 21(1), 73. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=33573623&site=ehost-live&scope=site https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7875762/pdf/12887_2021_Article_2545.pdf	Screen time includes TV and DVDs
Johnson, T. M., Ridgers, N. D., Hulteen, R. M., Mellecker, R. R., & Barnett, L. M. (2016). Does playing a sports active video game improve young children's ball skill competence? *Journal of Science & Medicine in Sport*, *19*(5), 432–436. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=115243556&site=ehost-live&scope=site	Wrong population
Józsa, K., Barrett, K. C., & Morgan, G. A. (2017). Game-like tablet assessment of approaches to learning: Assessing mastery motivation and executive functions. *Electronic Journal of Research in Educational Psychology*, *15*(3), 665–695. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2017-56498-010&site=ehost-live&scope=site jozsa@edpsy.u-szeged.hu	Wrong outcome
Kao, C. P. (2016). The effect of SDLR and self-efficacy in preschool teachers by using WS learning. *Journal of Computer Assisted Learning*, *32*(2), 128–138. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2016-02415-001&site=ehost-live&scope=site kcp76@stust.edu.tw	Wrong population

Author, year	Reason for exclusion
Keane, E., Kelly, C., Molcho, M., & Gabhainn, S. N. (2017). Physical activity, screen time and the risk of subjective health complaints in school-aged children. *Preventive Medicine: An International Journal Devoted to Practice and Theory*, *96*, 21–27. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2017-10276-004&site=ehost-live&scope=site eimear.keane@nuigalway.ie https://www.sciencedirect.com/science/article/abs/pii/S0091743516304078?fr=RR-2&ref=pdf_download&rr=771b5ad25b2f1108	Wrong population
Kemp, N., & Bushnell, C. (2011). Children's text messaging: Abbreviations, input methods and links with literacy. *Journal of Computer Assisted Learning*, *27*(1), 18–27. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2011-00999-003&site=ehost-live&scope=site ORCID: 0000-0002-8214-5427 nenagh.kemp@utas.edu.au	Wrong population
Kirkorian, H. L., Travers, B. G., Jiang, M. J., Koeun, C., Rosengren, K. S., Pavalko, P., & Tolkin, E. (2020). Drawing across media: A cross-sectional experiment on Preschoolers' drawings produced using traditional versus electronic mediums. *Developmental Psychology*, *56*(1), 28–39. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=141035838&site=ehost-live&scope=site	Wrong outcome
Kiselev, S. (2020). Weakness in visuospatial abilities in children can be caused by computer game addiction. *Annals of Neurology*, 88, S62. Retrieved from https://www.embase.com/search/results?subaction=viewrecord&id=L633964666&from=export https://doi.org/10.1002/ana.25865	Wrong population
Kulikova, T. I., & Maliy, D. V. (2015). The correlation between a passion for computer games and the school performance of younger schoolchildren. *Psychology in Russia: State of the Art*, *8*(3), 124–135. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2016-07626-011&site=ehost-live&scope=site tativkul@gmail.com	Wrong outcome
Laukkanen, A., Pesola, A., Havu, M., Sääkslahti, A., & Finni, T. (2014). Relationship between habitual physical activity and gross motor skills is multifaceted in 5- to 8-year-old children. *Scandinavian Journal of Medicine & Science in Sports*, *24*(2), e102-e110. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=94972841&site=ehost-live&scope=site	Not a digital intervention
Levac, D. E., & Lu, A. S. (2019). Does narrative feedback enhance children's motor learning in a virtual environment? *Journal of Motor Behavior*, *51*(2), 199–211. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85046081669&doi=10.1080%2f00222895.2018.1454398&partnerID=40&md5=22fda2e96473a32984bae8220d54a906 https://www.tandfonline.com/doi/pdf/10.1080/00222895.2018.1454398?needAccess=true	Wrong population
Lu, X., Oda, M., Ohba, T., Mitsubuchi, H., Masuda, S., & Katoh, T. (2017). Association of excessive mobile phone use during pregnancy with birth weight: An adjunct study in Kumamoto of Japan environment and children's study. *Environmental Health and Preventive Medicine*, *22*(1), 52. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=29165149&site=ehost-live&scope=site https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5664573/pdf/12199_2017_Article_656.pdf	Wrong outcome
Lytle, S. R., Garcia-Sierra, A., & Kuhl, P. K. (2018). Two are better than one: Infant language learning from video improves in the presence of peers. *PNAS Proceedings of the National Academy of Sciences of the United States of America*, *115*(40), 9859–9866. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-63194-003&site=ehost-live&scope=site ORCID: 0000-0002-0197-8583 sarahr28@uw.edu https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6176610/pdf/pnas.201611621.pdf	Wrong outcome
Madigan, S., Browne, D., Racine, N., Mori, C., & Tough, S. (2019). Association between screen time and children's performance on a developmental screening test. *JAMA Pediatrics*, 173(3), 244–250. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=135186692&site=ehost-live&scope=site	Screen time includes TV and DVDs
Makin, S. (2018). Searching for digital technology's effects on well-being. *Nature*, *563*(7733), S138-S140. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=30487626&site=ehost-live&scope=site	Wrong study design
Maltese, A., Cerroni, F., Romano, P., Russo, D., Salerno, M., Gallai, B., …, Tripi, G. (2018). Digital natives: Lucky or jellied? *Acta Medica Mediterranea*, *34*(4), 945–950. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85048272633&doi=10.19193%2f0393-6384_2018_4_143&partnerID=40&md5=fdf5dc577c0abb55e3553fdc74107bad	Wrong study design
Markov, M., & Grigoriev, Y. (2015). Protect children from EMF. *Electromagnetic biology and medicine*, *34*(3), 251–256. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=26444201&site=ehost-live&scope=site https://www.tandfonline.com/doi/pdf/10.3109/15368378.2015.1077339?needAccess=true	Wrong study design
McClure, C., Cunningham, M., Bull, S., Berman, S., & Allison, M. A. (2018). Using mobile health to promote early language development: A narrative review. *Academic Pediatrics*, *18*(8), 850–854. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=30098442&site=ehost-	Wrong study design

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Author, year	Reason for exclusion
live&scope=site https://www.sciencedirect.com/science/article/abs/pii/S1876285918304765?fr=RR-2&ref=pdf_download&rr=771b5cde0fec1fcd	
McClure, E. R., Chentsova-Dutton, Y. E., Barr, R. F., Holochwost, S. J., & Parrott, W. G. (2015). 'Facetime doesn't count': Video chat as an exception to media restrictions for infants and toddlers. *International Journal of Child-Computer Interaction*, *6*, 1–6. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2016-24902-001&site=ehost-live&scope=site ORCID: 0000-0002-2974-0550 parrottg@georgetown.edu steven.holochwost@gmail.com rfb5@georgetown.edu yec2@georgetown.edu elisabethmcclure@gmail.com	Wrong outcome
McDonald, S. W., Kehler, H. L., & Tough, S. C. (2016). Protective factors for child development at age 2 in the presence of poor maternal mental health: Results from the all our babies (AOB) pregnancy cohort. *BMJ open*, *6*(11), e012096. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=28186930&site=ehost-live&scope=site https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5128911/pdf/bmjopen-2016-012096.pdf	No digital intervention
McGlashan, H. L., Blanchard, C. C. V., Sycamore, N. J., Lee, R., French, B., & Holmes, N. P. (2017). Improvement in children's fine motor skills following a computerized typing intervention. *Human Movement Science*, *56*, 29–36. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=126349913&site=ehost-live&scope=site	Wrong population
MacGowan, T. L., & Schmidt, L. A. (2021). Preschoolers' social cognitive development in the age of screen time ubiquity. *CyberPsychology, Behavior & Social Networking*, 24(2), 141–144. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=148677757&site=ehost-live&scope=site	Wrong outcome
McArthur, B. A., Browne, D., Tough, S., & Madigan, S. (2020). Trajectories of screen use during early childhood: Predictors and associated behavior and learning outcomes. *Computers in Human Behavior*, 113, N.PAG-N.PAG. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=145629867&site=ehost-live&scope=site	Screen time includes TV and DVDs
McArthur, B. A., Tough, S., & Madigan, S. (2021). Screen time and developmental and behavioral outcomes for preschool children. *Pediatric Research*. Retrieved from https://www.embase.com/search/results?subaction=viewrecord&id=L2011560041&from=export https://doi.org/10.1038/s41390-021-01572-w	Screen time includes TV and DVDs
McNeill, J., Howard, S. J., Vella, S. A., & Cliff, D. P. (2019). Longitudinal associations of electronic application use and media program viewing with cognitive and psychosocial development in preschoolers. *Academic Pediatrics*, 19(5), 520–528. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=137051871&site=ehost-live&scope=site https://pdf.sciencedirectassets.com/277741/1-s2.0-S1876285918X00072/1-s2.0-	Screen time includes TV and DVDs
Mitrofan, O., Paul, M., Weich, S., & Spencer, N. (2014). Aggression in children with behavioural/emotional difficulties: Seeing aggression on television and video games. *BMC Psychiatry*, *14*. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2014-51916-001&site=ehost-live&scope=site n.j.spencer@warwick.ac.uk s.weich@warwick.ac.uk moli.paul@warwick.ac.uk oana.mitrofan@warwick.ac.uk	Wrong outcome
Munzer, T. G., Miller, A. L., Weeks, H. M., Kaciroti, N., & Radesky, J. (2019). Parent-toddler social reciprocity during reading from electronic tablets vs print books. *JAMA Pediatrics*, *173*(11), 1076–1083. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=139565486&site=ehost-live&scope=site	Wrong outcome
Piotrowski, J. T., & Krcmar, M. (2017). Reading with hotspots: Young children's responses to touchscreen stories. *Computers in Human Behavior*, *70*, 328–334. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2017-10968-037&site=ehost-live&scope=site j.piotrowski@uva.nl	Wrong outcome
Poon, K. W., Li-Tsang, C. W. P., Weiss, T. P. L., & Rosenblum, S. (2010). The effect of a computerized visual perception and visual-motor integration training program on improving Chinese handwriting of children with handwriting difficulties. *Research in Developmental Disabilities*, *31*(6), 1552–1560. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=20621444&site=ehost-live&scope=site	Wrong population
Pujol, J., Fenoll, R., Forns, J., Harrison, B. J., Martínez-Vilavella, G., Macià, D., …, Sunyer, J. (2016). Video gaming in school children: How much is enough? *Annals of Neurology*, *80*(3), 424–433. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2016-40806-001&site=ehost-live&scope=site ORCID: 0000-0002-2226-2074 21404jpn@comb.cat https://onlinelibrary.wiley.com/doi/full/10.1002/ana.24745	Wrong population
Radesky, J. S., Silverstein, M., Zuckerman, B., & Christakis, D. A. (2014). Infant self-regulation and early childhood media exposure. *Pediatrics*, *133*(5), e1172-e1178. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.	Wrong outcome

Author, year	Reason for exclusion
ebscohost.com/login.aspx?direct=true&db=psyh&AN=2014-19250-003&site=ehost-live&scope=site jenny.radesky@bmc.org https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4006432/pdf/peds.2013-2367.pdf	
Robidoux, H., Ellington, E., & Lauerer, J. (2019). Screen time: The impact of digital technology on children and strategies in care. *Journal of Psychosocial Nursing and Mental Health Services*, *57*(11), 15–20. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85074266300&doi=10.3928%2f02793695-20191016-04&partnerID=40&md5=2f6c4917498c8f8b715ff89d756a3b79 https://www.healio.com/psychiatry/journals/jpn/2019-11-57-11/(Agina)/screen-time-the-impact-of-digital-technology-on-children-and-strategies-in-care	Wrong study design
Rodrigues, P. F. S., & Pandeirada, J. N. S. (2018). When visual stimulation of the surrounding environment affects children's cognitive performance. *Journal of Experimental Child Psychology*, *176*, 140–149. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-42759-001&site=ehost-live&scope=site pedro.filipe@ua.pt https://www.sciencedirect.com/science/article/abs/pii/S0022096518300390?fr=RR-2&ref=pdf_download&rr=771b5f0a7d8b1fc1	Wrong outcome
Rogowsky, B. A., Terwilliger, C. C., Young, C. A., & Kribbs, E. E. (2018). Playful learning with technology: The effect of computer-assisted instruction on literacy and numeracy skills of preschoolers. *International Journal of Play*, *7*(1), 60–80. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-13552-007&site=ehost-live&scope=site brogowsky@gmail.com	Wrong outcome
Salminen, J., Koponen, T., Räsänen, P., & Aro, M. (2015). Preventive support for kindergarteners most at-risk for mathematics difficulties: Computer-assisted intervention. *Mathematical Thinking and Learning*, *17*(4), 273–295. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2015-49060-003&site=ehost-live&scope=site ORCID: 0000-0002-0545-0591 jonna.salminen@jyu.fi	Wrong population
Seomun, G., Lee, J.-A., Kim, E.-Y., Im, M., Kim, M., Park, S.-A., & Lee, Y. (2013). Health effects of digital textbooks on school-age children: A grounded theory approach. *Western Journal of Nursing Research*, *35*(9), 1184–1204. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2013-31670-006&site=ehost-live&scope=site youngj@korea.ac.kr https://escholarship.org/content/qt3k84j96k/qt3k84j96k.pdf?t=ofcuy3	Wrong outcome
Staiano, A. E., & Calvert, S. L. (2011). Exergames for physical education courses: Physical, social, and cognitive benefits. *Child Development Perspectives*, *5*(2), 93–98. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2011-11911-005&site=ehost-live&scope=site ORCID: 0000-0001-7846-046X amandastaiano@gmail.com https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3339488/pdf/nihms370212.pdf	Wrong population
Supanitayanon, S., Trairatvorakul, P., & Chonchaiya, W. (2020). Screen media exposure in the first 2 years of life and preschool cognitive development: a longitudinal study. *Pediatric Research*. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L2004562419 https://doi.org/10.1038/s41390-020-0831-8	Screen time includes TV and DVDs
Taylor, G., Monaghan, P., & Westermann, G. (2018). Investigating the association between children's screen media exposure and vocabulary size in the UK. *Journal of Children and Media*, *12*(1), 51–65. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-03803-004&site=ehost-live&scope=site ORCID: 0000-0003-2803-1872 g.taylor4@salford.ac.uk	Wrong outcome
Tsuji, S., Fiévét, A.-C., & Cristia, A. (2021). Toddler word learning from contingent screens with and without human presence. *Infant Behavior & Development*, 63. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2021-52540-001&site=ehost-live&scope=site ORCID: 0000-0002-4612-9753 ORCID: 0000-0001-9580-4500 tsujish@gmail.com	Wrong outcome
Tyler, E. J., Hughes, J. C., Beverley, M., & Hastings, R. P. (2015). Improving early reading skills for beginning readers using an online programme as supplementary instruction. *European Journal of Psychology of Education*, 30(3), 281–294. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2015-01466-001&site=ehost-live&scope=site r.hastings@warwick.ac.uk m.beverley@bangor.ac.uk c.hughes@bangor.ac.uk e.j.tyler@bangor.ac.uk	Wrong population
van den Heuvel, M., Ma, J., Borkhoff, C. M., Koroshegyi, C., Dai, D. W. H., Parkin, P. C., …, Birken, C. S. (2019). Mobile media device use is associated with expressive language delay in 18-month-old children. *Journal of Developmental and Behavioral Pediatrics: JDBP*, 40(2), 99–104. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=30753173&site=ehost-live&scope=site	Wrong outcome
Varadarajan, S., Venguidesvarane, A. G., Ramaswamy, K. N., Rajamohan, M., Krupa, M., & Christadoss, S. B. W. (2021). Prevalence of excessive screen time and its association with developmental delay in children aged <5 years: A population-based cross-sectional study in India. *PloS One*, 16(7). Retrieved from https://www.embase.com/search/results?subaction=viewrecord&id=L2013458204&from=export https://doi.org/10.1371/journal.pone.0254102	Screen media
Vatavu, R. D., Cramariuc, G., & Schipor, D. M. (2015). Touch interaction for children aged 3 to 6 years: Experimental findings and relationship to motor skills. *International Journal of Human Computer Studies*, 74, 54–76. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84909979110&doi=10.1016%2fj.ijhcs.2014.10.007&partnerID=40&md5=e07e9e1ce2625680a301bb71eb9670d2	Wrong outcome

(Continues)

Author, year	Reason for exclusion
Vernadakis, N., Papastergiou, M., Zetou, E., & Antoniou, P. (2015). The impact of an exergame-based intervention on children's fundamental motor skills. *Computers & Education*, 83, 90–102. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2015-06487-010&site=ehost-live&scope=site ORCID: 0000-0003-3694-468X nvernada@phyed.duth.gr	Wrong population
Walsh, J. J., Barnes, J. D., Tremblay, M. S., & Chaput, J.-P. (2020). Associations between duration and type of electronic screen use and cognition in US children. *Computers in Human Behavior*, 108, N.PAG-N.PAG. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=142669949&site=ehost-live&scope=site	Wrong population
Weis, R., & Cerankosky, B. C. (2010). Effects of video-game ownership on young boys' academic and behavioral functioning: A randomized, controlled study. *Psychological Science*, *21*(4), 463–470. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2010-09433-001&site=ehost-live&scope=site weisr@denison.edu https://journals.sagepub.com/doi/pdf/10.1177/0956797610362670	Wrong population
Williams, J., Crowe, L. M., Dooley, J., collie, A., Davis, G., McCrory, P., …, Anderson, V. (2016). Developmental trajectory of information-processing skills in children: Computer-based assessment. *Applied Neuropsychology: Child*, *5*(1), 35–43. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=112410672&site=ehost-live&scope=site	Wrong population
Wood, C., Fitton, L., Petscher, Y., Rodriguez, E., Sunderman, G., & Lim, T. (2018). The effect of e-book vocabulary instruction on Spanish-English speaking children. *Journal of Speech, Language, and Hearing Research: JSLHR*, *61*(8), 1945–1969. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L627657895 https://doi.org/10.1044/2018_JSLHR-L-17-0368	Wrong outcome
Wood, C., Jackson, E., Hart, L., Plester, B., & Wilde, L. (2011a). The effect of text messaging on 9- and 10-year-old children's reading, spelling and phonological processing skills. *Journal of Computer Assisted Learning*, *27*(1), 28–36. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=104851537&site=ehost-live&scope=site	Wrong population

A.2 | Screen data only or no developmental outcome

Author, date	Reason for exclusion
Cadoret, G., Bigras, N., Lemay, L., Lehrer, J., & Lemire, J. (2018). Relationship between screen-time and motor proficiency in children: A longitudinal study. *Early Child Development and Care*, *188*(2), 231–239. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2018-01679-013&site=ehost-live&scope=site cadoret.genevieve@uqam.ca	Screen time includes tv and DVDs
Dadson, P., Brown, T., & Stagnitti, K. (2020). Relationship between screen-time and hand function, play and sensory processing in children without disabilities aged 4–7 years: A exploratory study. *Australian Occupational Therapy Journal*. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85079034721&doi=10.1111%2f1440-1630.12650&partnerID=40&md5=cd12d3f29b1f358c471a3264450e7780	Screen time includes tv and DVDs
Duch, H., fisher, E. M., Ensari, I., Font, M., Harrington, A., Taromino, C., …, Rodriguez, C. (2013). Association of screen time use and language development in Hispanic toddlers: A cross-sectional and longitudinal study. *Clinical Pediatrics*, *52*(9), 857–865. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=89945695&site=ehost-live&scope=site	Screen time includes tv and DVDs
Madigan, S., Browne, D., Racine, N., Mori, C., & Tough, S. (2019). Association between screen time and children's performance on a developmental screening test. *JAMA Pediatrics*, *173*(3), 244–250. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=135186692&site=ehost-live&scope=site	Screen time includes tv and DVDs
McNeill, J., Howard, S. J., Vella, S. A., & Cliff, D. P. (2019). Longitudinal associations of electronic application use and media program viewing with cognitive and psychosocial development in preschoolers. *Academic Pediatrics*, *19*(5), 520–528. Retrieved from http://ezproxy.ecu.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=137051871&site=ehost-live&scope=site https://pdf.sciencedirectassets.com/277741/1-s2.0-S1876285918X00072/1-s2.0-	Screen time includes tv and DVDs
Supanitayanon, S., Trairatvorakul, P., & Chonchaiya, W. (2020). Screen media exposure in the first 2 years of life and preschool cognitive development: a longitudinal study. *Pediatric Research*. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L2004562419 https://doi.org/10.1038/s41390-020-0831-8	Screen time includes tv and DVDs

Author, date	Reason for exclusion
Leeuwestein, H., Barking, M., Sodacı, H., Oudgenoeg-Paz, O., Verhagen, J., Vogt, P., …, & Leseman, P. (2021). Teaching Turkish-Dutch kindergartners Dutch vocabulary with a social robot: Does the robot's use of Turkish translations benefit children's Dutch vocabulary learning?. *Journal of Computer Assisted Learning*, *37*(3), 603–620. https://doi.org/10.1111/jcal.12510	Wrong outcome
Suggate, S. P., & Martzog, P. (2021). Children's sensorimotor development in relation to screen-media usage: A two-year longitudinal study. *Journal of Applied Developmental Psychology*, *74*, 101 279. https://doi.org/10.1016/j.appdev.2021.101279	Screen time
Sheedy, A. J., Brent, J., Dally, K., Ray, K., & Lane, A. E. (2021). Handwriting readiness among digital native kindergarten students. *Physical & Occupational Therapy in Pediatrics*, 1–15. 10.1080/01942638.2021.1912247	Wrong outcome