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Screen technology exposure and infant cognitive development: A scoping review

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ABSTRACT

Problem: There has been some concern that screen exposure is harmful to an infant's cognitive development, but the effects of screen technologies on cognition are not fully understood. A scoping review was conducted to determine what evidence exists about screen exposure and cognitive development in children ages birth to 24 months.

Eligibility criteria: Inclusion = 1) English language; 2) studies focusing on children under 24 months of age; 3) cognitive development; 4) screen exposure. Exclusion = 1) articles over 25 years old; 2) structure, function and physiology of the brain; 3) social development; 4) psychosocial development; 5) motor development; 6) abnormal development/mental health; 7) behavior; 8) content only, not screen exposure e.g., social media; 9) secondary sources.

Sample: Ten studies met the inclusion criteria. Articles included one retrospective chart review, six longitudinal studies, two cross-sectional studies, and one prospective study.

Results: Of the ten studies in this review, six reported correlations between screen exposure and cognitive delay, one study reported positive cognitive outcomes and three reported no significant positive or negative outcomes.

Conclusions: From the evidence in this scoping review, no causal relationship has been found between screen exposure and infant cognitive harm. Some correlations between screen exposure and cognitive delay were reported. Some positive cognitive outcomes were also reported.

Implications: Future research should focus on the context of screen viewing as opposed to dosage or exposure. More robust methodologies should be used to assess infant cognition and screen usage.

Introduction

From the introduction of television to the advent of electronic media, screen technology has become an integral part of family life. Innovations in screen technology have resulted in touch screen mobile devices that can support streaming media content, video calling, and interactive screen applications. Touchscreen devices are easy to use, even for infants with limited fine motor control (Cristia & Seidl, 2015). Approximately 98% of US children aged birth to 8 years reside in a home with an internet-connected device (Common Sense Media, 2020). Two surveys of American families found screen technology usage is increasing, even among infants and toddlers. Chen & Adler (2019) found screen time has risen among children ages birth-2 years from 1.32 h per day in 1997 to 3.05 h per day in 2014, which included 2.62 h of television viewing and 0.37 h on mobile devices. Rideout and Robb (2020) reported an average amount of screen time among children ages birth to two years to be 49 min a day, with most of that time spent watching television, DVDs, and streaming videos.

There has been some concern that screen technology may harm infants' cognitive development. The World Health Organization (WHO) and the American Academy of Pediatrics (AAP) have each issued updated recommendations for age-appropriate screen time usage. Parents worry about the effects of screen time on their children while paradoxically incorporating screens into the activities of family life. When surveyed about children's use of screen technologies, parents report allowing children screen time as a distraction when they are exhausted, trying to work, need to calm an upset child, or put them to bed (Kabali et al., 2015; Rideout & Robb, 2020).

The AAP recommends no screen time for children birth-18 months with exceptions for video chatting, while the WHO recommends no screens for children under two years of age (Pappas, 2020). These recommendations are problematic for families making media decisions for their children as the recommendations do not match the available

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evidence nor do they consider potential benefits of parental engagement when co-viewing digital screen technologies including: social engagement, sleep, behaviors, and language (Canadian Paediatric Society, Digital Health Task Force, Ottawa, Ontario, 2017; Pappas, 2020). Studies supporting the recommendations have methodological inconsistencies including 1) not all types of screens (television, mobile screens, touchscreens, video games) and screen time (media content) are equivalent; therefore, study findings cannot be integrated; 2) recommendations rely on correlational evidence which cannot support conclusions that screen time has a direct causal effect on children; and 3) screen exposure time is captured by parent self-report of children's viewing habits and does not take into account the context in which the screens are being viewed (Blum-Ross & Livingstone, 2018; Kostyrka-Allchorne et al., 2017; Lui et al., 2021; Pappas, 2020; Rideout & Robb, 2020). Context of screen viewing includes background viewing, parental co-viewing, and parental viewing (technoference). Background viewing occurs when television or electronic media devices are on in the background and showing adult content. There is some concern that adult content is detrimental to young children, particularly when the content contains violence (Anderson & Pempek, 2005). Parental co-viewing of children's educational programming has been associated with a higher quality of parent-child interaction and engagement during free play (Blumberg et al., 2017; Pempek & Lauricella, 2017). Technoference occurs when a parent is distracted from engaging in interpersonal activities with their child due to the use of mobile screen devices. This distraction interferes with a parents' ability to respond to their children's needs in a supportive and responsive manner (Mackay et al., 2022).

The effects of screen technologies on brain development and cognition are not fully understood (Thompson & Steinbeis, 2020). Children birth-two years of age are in a period of rapid brain development, including the development of the cognitive processes involved in the formation of executive function. Executive function encompasses working memory, impulse inhibition, attention, and reasoning flexibility required for goal-directed behavior. The development of executive function relies on the integration of multiple sources of sensory information (Thompson & Steinbeis, 2020). Studies suggest the unnaturally rapid pace of screen media editing may affect sensory information pathways and the early formation of executive function, particularly in the area of attention (Kostyrka-Allchorne et al., 2017). It is difficult to determine whether exposure to screen media results in inattention or if a child's inattention drives the amount of screen time a parent allows a child.

Scoping reviews aim to describe the breadth of the existing knowledge base to inform future research, practice, and policy (Arksey & O'Malley, 2005; Munn et al., 2022). Arksey and O'Malley (2005) delineate four reasons for undertaking a scoping review: 1) to determine the extent of research on a given topic; 2) to identify the need for a systematic review; 3) to synthesize and disseminate research findings; 4) to identify gaps in the literature. A scoping review using Arksey and O'Malley's framework was conducted to determine the current state of knowledge regarding the impact of digital screen technologies on the cognitive development of infants. Arksey and O'Malley's framework outlines how to conduct a scoping review in six stages: 1. specify the research question. 2. identify the relevant literature, 3. select the studies, 4. map the data, 5. summarize, synthesize and report the results, 6. include expert consultation (this step is optional). A scoping review using Arksey and O'Malley's framework was conducted to determine the current state of knowledge on the impact of digital screen technologies on the cognitive development of infants. Phase one of Arksey and O'Malley's framework is to specify the research question: What evidence exists about screen exposure and cognitive development in children ages birth to 24 months?

Methods

Given the broad goal of locating all available literature on our topic, to identify all existing ideas and themes, and to detect knowledge gaps that merit further investigation, a decision was made to conduct a scoping review. For the purposes of this study, we used the Joanna Briggs Institute (JBI) definition of a scoping review: "…a type of evidence synthesis that aims to systematically identify and map the breadth of evidence available on a particular topic, often irrespective of source… within or across particular contexts" (Munn et al., 2022, p. 950).

Stage two of Arksey and O'Malley's framework consists of identifying relevant studies (Anderson & Pempek, 2005). To promote rigor, the research team coordinated with a health science librarian specializing in systematic reviews and adhered to scoping review guidelines outlined in Arksey and O'Malley's original methodological framework for scoping studies coupled with the PRISMA-Extension for Scoping Reviews (Tricco et al., 2018).

Potential search terms and subsequent synonyms were located, identified and agreed upon as a team. Once a finalized search string was decided upon, a repository search was conducted to check for any existing reviews on the topic. No such pre-existing reviews were located. The final keyword search terms were:

(("infant development" OR "infant behavior" OR "infant behavior" OR "child development" OR "cognitive development" OR "executive function" OR "developmental skills" OR "infant engagement" OR "intellectual development" OR "cognitive ability" OR "cognitive functioning" OR "cognitive skills" OR "infant cognition") AND ("Mobile Media" OR Screentime OR Screen-time OR "screen time" OR "screen exposure" OR "screen use" OR computer OR "electronic tablet" OR television OR tv OR "screen viewing" OR "digital media" OR "Screen Media" OR touchscreen OR "Touch Screen" OR "interactive media" OR "Digital devices" OR microcomputers OR "smart phone" OR "mobile device" OR smartphone OR cellphone OR "cell phone" OR "cellular phone" OR "mobile phone" OR "personal digital devices" OR "electronic screen based media" OR "handheld computers")). The search strategy as outlined for this review was not registered.

Modified search strings were utilized on various databases such as Pubmed, CINAHL, and Nursing and Allied Health to incorporate additional controlled vocabulary phrases when and where possible. Per PRISMA protocols on scoping reviews which require a full search strategy for at least one database, our search strategy for PubMed can be found here: https://hdl.handle.net/11274/13882.

The following inclusion/exclusion criteria was agreed upon: Inclusion = 1) English language; 2) studies focusing on children under 24 months of age; 3) cognitive development; 4) screen exposure. Exclusion = 1) articles over 25 years old; 2) structure, function and physiology of the brain; 3) social development; 4) psychosocial development; 5) motor development; 6) abnormal development/mental health; 7) behavior; 8) content only, not screen exposure e.g., social media; 9) secondary sources.

The database selection included: PubMed, CINAHL, Nursing and Allied Health, PsycINFO, Scopus, Web of Science. Where the database allowed, limiters included: English language only, scholarly/academic journals only, and a twenty-five-year date range. This date range was selected in order to capture the evolution of screen technologies, from television to new electronic media, on children's cognition.

Articles returned were uploaded to the systematic review tool, Rayyan. Rayyan's duplicate detection tool was used to identify possible duplicates; these were then manually inspected and removed where appropriate.

The next step in the Arksey and O'Malley (2005) framework is study selection. Using PRISMA guidelines, articles underwent three rounds of consideration and elimination, 1) removal of duplicates; 2) screening record by title and abstract; 3) full report assessed for eligibility corresponding to the inclusion/exclusion criteria. Voting for the articles was blinded via Rayyan so reviewers could not be influenced by each other's voting preference. Any disputes in the choice between the main two reviewers were resolved via conversation per accepted protocols outlined by Arksey and O'Malley. Articles that made the final cut are referred to as the 'golden standard.'

A separate gray literature search was conducted. Gray literature searches included: AURA 99 titles, Helin 237 titles, Data Archiving and Networking Services (DANS), 2 titles. No articles meeting the scoping review criteria were found in the gray literature search. Disputes in choice between the main two reviewers were again resolved via conversation.

A search of available electronic journals produced no new results. A follow up search of the literature, to pull up any new articles that may have been published since the date of the initial search, was not deemed necessary.

The review team examined the golden standard's citation pages (historical citation search) and utilized Google Scholar's 'cited by' tool (forward citation search) to search for additional pertinent articles. Several new pertinent articles were found and added to the golden standard. These articles had their citations examined.

The health science librarian checked the articles selected for the golden standard and their citations for retractions. No retractions were identified. Fig. 1 illustrates the screening process.

Data Charting

According to Arksey and O'Malley (2005), after selecting articles for the scoping review, the next step is to chart the data. Data for charting should include author, year, location of study, intervention, population, study aim, study methods, outcome measures, and relevant results (Arksey & O'Malley, 2005). Details of the data for this scoping review are provided in Table 1.

Findings

This scoping review yielded 10 articles from five countries and one multinational collaboration of three countries. Four studies were conducted in the United States (Li et al., 2017; Myers et al., 2017; Stockdale et al., 2022; Tomopoulos et al., 2010), two in India (Varadarajan et al., 2021; Verma et al., 2018), and one each in Taiwan, Brazil, and Thailand (Lin et al., 2015; Rocha et al., 2021; Supanitayanon et al., 2020). The multinational collaboration was conducted in the United Kingdom, the United States, and the Netherlands (McHarg et al., 2020). This section presents articles that focus on the initial research question: What evidence exists about screen exposure and cognitive development in children ages birth to 24 months?

Aim of the Studies

Most articles described a multipurpose aim of assessing the effects of screen exposure on more than one aspect of child development. All the studies sought to assess the association between the prevalence of screen time or screen exposure on children's cognitive development. Four studies aimed to assess the effect on infant global development (Lin et al., 2015; Rocha et al., 2021; Tomopoulos et al., 2010; Varadarajan et al., 2021). Three studies evaluated the effect on cognitive skills or milestones (Li et al., 2017; Supanitayanon et al., 2020; Verma et al., 2018). Two studies measured parts of executive function specific to cognition (McHarg et al., 2020; Stockdale et al., 2022).. One study measured social contingency, which is a function of cognition (Myers et al., 2017). Three studies evaluated language skills in addition to other cognitive measures (Li et al., 2017; Stockdale et al., 2022;

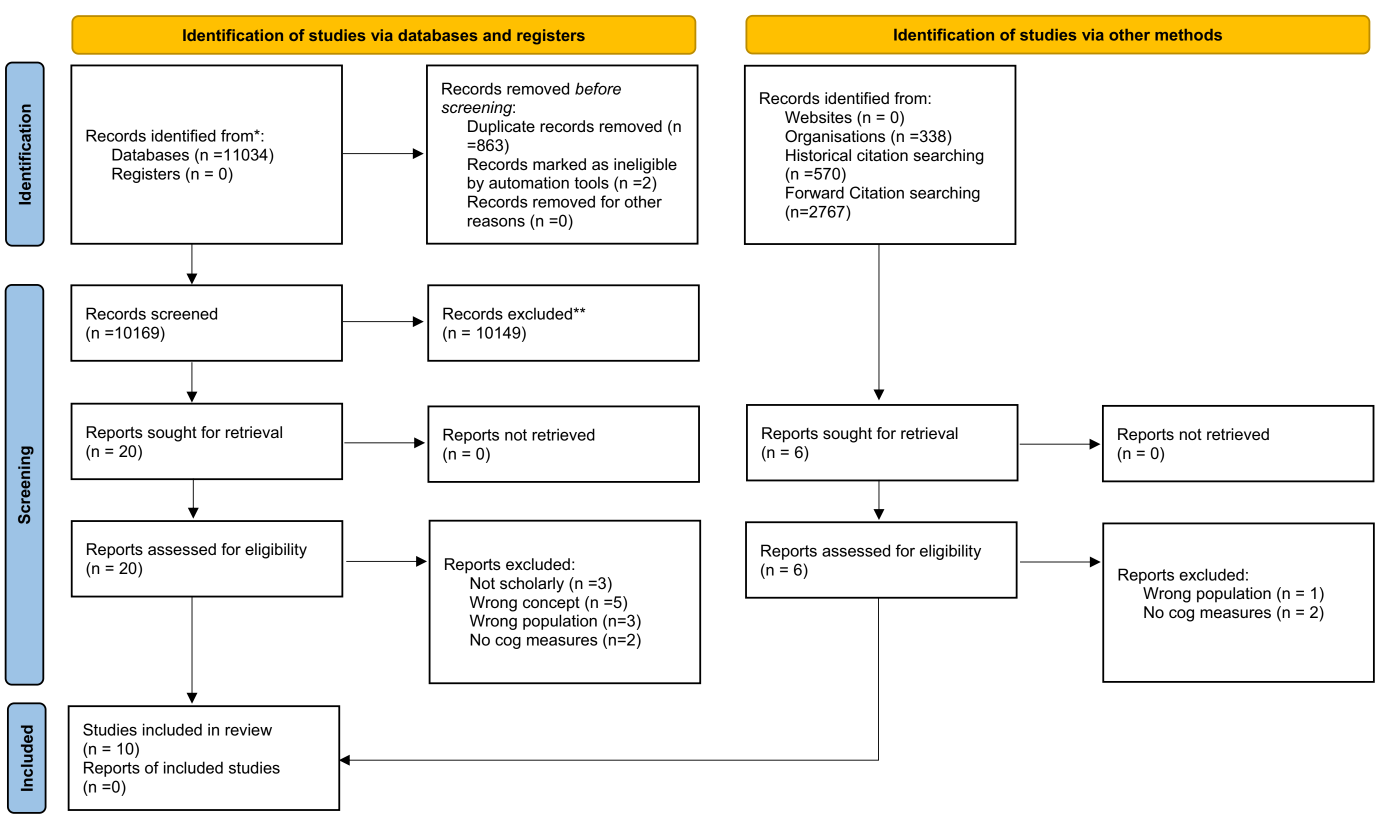

Fig. 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources.
*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.
From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: https://doi.org/10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/.

Table 1
Evidence table.

Author/year	Country	Aim/purpose	Population/sample size	Methodology/design	Measurements	Key findings related to research question
Li et al., 2017	USA	Assess the prevalence of smartphone and tablet use between 0 and 3 years; determine the relationship between smartphone and tablet use (2D image) and infant development (3D translation)	65 families with children between 0 and 3 years	Retrospective chart review. Age at 1st touch to screen, and # of times	Cognitive Adaptive Test/Clinical Linguistic & Auditory Milestone Scale (CAT/CLAMS)	70% 1st touches by <3 years; avg. age of 1st touch 11.2 months; avg. daily time 17.5 min. No difference in CAT/CLAMS between groups. 1st touch was not associated with any benefit on cognition or language development.
Lin et al., 2015	Taiwan	How does television exposure relate to infant developmental skills?	150 children 15–35 months; split into 2 groups of 75 by time watched tv (matched) - < 2 years and > 2 years; Avg. age - 18.9 months	Population-based longitudinal study. Divided children into groups based on AAP guidelines of TV time watched: TV group ≤ 2 yrs., any tv, > 2, > 2 h/day. Control group ≤ 2 yrs., 0 tv, > 2 yrs., < 2 h/day. Development assessed by neurologist, PT, OT, psychiatrist, psychologist, and 2 speech therapists.	Bayley Scales of Infant Development & Peabody Development Motor Scales	Avg tv time = 181.1 min/day; TV exposure = more likely to have delayed development than control group ($n = 75$, x2 = 8.4 $p \leq 0.01$). Most significant risk factor to predict cognitive delay were time exposed to tv and maternal education. Frequently exposed to tv were 3.9 x more likely to have delay (95% CI: 1.4–5.9)
McHarg et al., 2020	UK, US, Netherlands	Estimate relationship between electronic screen-based media & executive function in toddlerhood.	416 pregnant couples who delivered healthy full term infants	Longitudinal study. Home visits at 4 and 14 months; measured time exposed to screen-based media at 4 months and assessed inhibition-prohibition task; working memory; cognitive flexibility at 14 months	Propensity score analysis. Administered the Inhibition test to measure prohibition; 3 boxes test measured working memory; Ball run test measured cognitive flexibility.	Media use at 4 months = lower inhibition, but not related to working memory or cognitive flexibility
Myers et al., 2017	USA	Whether social contingency would facilitate learning from video chat for children <2 years old	60 12–25-month-old (matched to 3 groups): 12–16 months, 17–21 months, 22–24 months; split into 2 groups (Face-time and Video). Mean matched age = 18.9 and 18.7 months (Facetime and Video group)	Longitudinal study. Real time video chat (Facetime) or watched pre-recorded video to see effect of contingency immediately during and memory 1 week after; then looked at synced behavior (prompted) and non-synced behavior and novel content	Social contingency or synced behaviors (whether or not prompting is required to induce cognitive behaviors; synced behaviors = less prompting).	Synced behaviors were significantly more frequent in the Facetime group (more contingency) No contingency for word learning
Rocha et al., 2021	Brazil	Evaluate the association of screen exposure with child communication, gross motor, fine motor, problem-solving & personal-social development scores	Cluster sample of children 0–60 months ($n = 3155$). Mean age 27.1 months	Population-based cross-sectional study with cluster sampling. Used World Health Organization definition of excessive screen time to divide sample: 0–23 months - any screen time = excessive; > 24 months - > 1 h/day = excessive.	Brazilian Ages & Stages	Increased screen time and interactive media time = decreased communication, problem-solving, & personal-social scores.
Stockdale et al., 2022	USA	Trajectories of tv viewing during 1–4 years and how trajectories relate to language and executive function.	256 caregiver-infant dyads in 4 waves: < 1 year; 1–2 year; 2–3 year; 3–4 year	Longitudinal study; Measured tv time during wave 1; measured executive function during wave 4	Rating inventory of executive function; NIH Toolbox Cognition Battery and the Behavior Rating Inventory of Executive Function—Preschool (BRIEF-P)	High tv time = more problems with executive function and decreased language
Supanitayanon et al., 2020	Thailand	Examine whether age of onset of media exposure, cumulative effect of high media exposure, and verbal interaction during screen time in the first 2 years of life were associated with 4 year old cognition by including parenting behaviors into the final construct.	274 children; to replace participants lost at age 2 years, 30 participants were added at 3 years of age.	Longitudinal study. Followed children from age 6 months until 4 years. Collected screen media data at 6, 12, 18, and 24 months. Assessed cognition at 2, 3, & 4 years.	Early Learning Composite (ELC); Mullen Scales of Early Learning	ELC at age 2 years was associated with later age of onset of media exposure ($\beta = 0.113$, $p < 0.05$), fewer months of high media exposure = above the upper quartile ($\beta = 0.282$, $p < 0.001$), and more months of verbal interaction during screen time ($\beta = 0.261$, $p < 0.001$). ELC at age 4 years was associated with ELC and positive parenting at

Table 1 (*continued*)

Author/year	Country	Aim/purpose	Population/sample size	Methodology/design	Measurements	Key findings related to research question
						earlier ages. No significant correlation to screen exposure
Tomopoulos et al., 2010	USA	To determine whether duration and content of media exposure in 6 mo infants are associated with development at age 14 months.	259 mother-infant dyads	Longitudinal analysis; assessed total duration and content exposed at 6 months; assessed cognitive and language development at 14 months	Bayley Scales of Infant Development & Preschool Language Scale	Longer duration of exposure predicted lower cognitive & language development. > 60 min exposure = 1/3 had lower development scores; adjusted to normal with longest development
Varadarajan et al., 2021	India	Determine the burden of screen time, associated sociodemographic factors, and its impact on domains of child development	718 cluster sample < 5 years (< 6 months to 5 years); mean age 34.7 months	Population-based cross-sectional study. Used World Health Organization definition of excessive screen time to divide participants into groups; 6 months-2 years: any screen time = excessive; 2–5 years: > 1 h/day = excessive screen time.	Communication DEALL Developmental Checklist	Mean screen time = 2.39 h/day; increased screen time associated with developmental delay (especially language and communication)
Verma et al., 2018	India	Determine the effect of electronic gadgets on cognitive milestones of children below 2 years of age	100 children 6 months-2 years divided into 2 groups	Prospective study: 25 children who reached normal milestones (control group); 75 children who attained normal milestones were then introduced to electronic gadgets at different ages for a minimum of 4–5 h/day (study group).	No tool is described	Study group: 18 children with delayed cognitive milestones & irritability when device withdrawn. Gradual improvement during follow up after gradual withdrawal of devices.

Tomopoulos et al., 2010). For the purposes of this scoping review, only results directly related to cognitive function were considered.

Study Design Overview

Eight of the studies in this review employed observational designs (Li et al., 2017; Lin et al., 2015; McHarg et al., 2020; Rocha et al., 2021; Stockdale et al., 2022; Supanitayanon et al., 2020; Tomopoulos et al., 2010; Varadarajan et al., 2021). Interventional design was incorporated in two studies (Myers et al., 2017; Verma et al., 2018). Six of the articles described longitudinal studies (Lin et al., 2015; McHarg, et al., 2020; Myers et al., 2017; Stockdale et al., 2022; Supanitayanon et al., 2020; Tomopoulos et al., 2010); two were population-based cross-sectional studies (Rocha et al., 2021; Varadarajan et al., 2021). There was one prospective study and one retrospective study (Li et al., 2017; Verma et al., 2018). One consistent methodology in half of the articles was to gather parental reports of the daily time the participants were exposed to screens and to evaluate developmental parameters at a later time.

Sampling Methods

Only one study discussed attrition and described a process for accounting for lost participants. Supanitayanon et al. (2020) reported that the procedure for replacing lost participants at the 2-year phase was to add 30 participants at 3 years of age. Three studies utilized cluster sampling to recruit participants and divide them into groups based on screen exposure guidelines from either the WHO or the AAP (Lin et al., 2015; Rocha et al., 2021; Varadarajan et al., 2021). Lin et al. (2015) recruited participants ages 15 to 35 months, while participants in Rocha et al. (2021) and Varadarajan et al. (2021) were reported to be 0–60 months and <5 years respectively. Participants were placed into groups by matching according to age. The average age of participants between the three studies was 24.9 months.

Measurement Tools

While most of the studies reported evaluating development, there was no consistent measurement of development used. Only one scale, Bayley Scales of Infant Development, was used in two studies. Different measurements were used to evaluate development or cognition in every other study. Additionally, no standard or operational definitions of cognitive development or cognition were provided. Lin et al. (2015), Tomopoulos et al. (2010) and Varadarajan et al. (2021) assessed cognitive development as a whole using developmental assessment tools (Bayley Scales of Infant Development and Communication DEALL Developmental Checklist). Rocha et al. (2021) assessed problem-solving with toys using the Brazilian Ages and Stages Questionnaire. McHarg et al. (2020) measured inhibition, working memory, and cognitive flexibility using three specific tasks (inhibition test, 3 boxes, and ball run) to assess executive functions specific to cognition. Stockdale et al. (2022) and Supanitayanon et al. (2020) evaluated cognition with the NIH Toolbox Cognition Battery and the Mullen Scales of Early Learning Composite, respectively. Li et al. (2017) assessed cognition using the Cognitive Adaptive Test/Clinical Linguistic & Auditory Milestone Scale. Myers et al. (2017) evaluated social contingency and synced behaviors, and Verma et al. (2018) considered cognitive milestones, but did not describe what or how milestones were assessed.

Study Findings

Rocha et al. (2021) and Varadarajan et al. (2021) used the WHO guidelines to split participants into groups based on screen time exposure. Children ages 0–2 years exposed to any screen time were placed in the excessive screen time group. Children >2 years of age and exposed to greater than one hour of screen time per day were also placed in the excessive screen time group. Lin et al. (2015) used the AAP guidelines of excessive screen time; children under 2 years exposed to any screen time were placed into the "tv" group, children older than 2 years exposed to >2 h of screen time per day were also placed into the "tv" group. All other children were placed into the control group. These three studies found that children exposed to more screen time had lower cognitive development scores than children in the control group.

Myers et al. (2017) placed participants into groups using matching. The mean age of the matched groups was 18.9 months. This study investigated whether social contingency facilitated learning in children under two years of age. Investigators placed children into two groups, FaceTime/real-time video chat, or pre-recorded video chat. Investigators evaluated children during the chat and one week after for signs of synced behaviors. Synced behaviors, which are an indication of contingency and cognitive learning, were significantly more frequent in the FaceTime group.

Four longitudinal studies conducted measurements at specific timepoints. McHarg et al. (2020) and Tomopoulos et al. (2010) collected data about infant screen exposure time at 4 months and 6 months, respectively. Cognitive development was measured in both studies at 14 months. Using propensity score analysis, McHarg et al. determined that the time of media exposure at 4 months was associated with lower inhibition but was not related to working memory or cognitive flexibility. Tomopoulos et al. (2010) found a correlation between longer duration of screen exposure and lower cognitive development; however, children with the longest screen time exposure had adjusted scores in the normal range. This suggests that after a period of time the screen exposure may cease to negatively impact cognitive development (Tomopoulos et al., 2010).

In a similar study, Stockdale et al. (2022) measured screen exposure in children over time, then assessed cognitive development at a later stage. Participants were recruited using a stratified sampling method through mailers, flyers, and referrals. Data was collected in waves, according to participants' ages: Wave 1 included children <1-year-old; Wave 2, children older than 1 year but <2 years; Wave 3, children between 2 and 3 years; and Wave 4 included children between 3 and 4 years. Television exposure time was measured in waves one through four. Wave two measured a variety of parental factors. Wave three measured child effort control, vocabulary, and parental factors. Wave four measured executive function and cognition. Although children at the final measurement were outside the parameters of this scoping review, the study was included since participants were within the age range of the review at the beginning of the study. Results of the study indicated that children with low television exposure performed best across all testing, and that there was a correlation between high television time and problematic cognitive development.

Supanitayanon et al. (2020) followed children from 6 months through 4 years of age. In this study, researchers collected infant screen time data at ages 6, 12, 18, and 24 months of age. Cognition was measured at 2, 3, and 4 years of age. This study was also included in the current scoping review because participants met the review's inclusion criteria during the initial data collection periods. This study correlated early screen exposure to cognitive outcomes. Researchers found that earlier age of screen exposure and more time of cumulative screen exposure in the first two years of life correlated to lower cognition later in preschool ages. In addition to screen exposure, researchers also found that higher exposure to media correlated to lower verbal interaction between parent and child. This may also impact the cognitive outcome.

Verma et al. (2018) divided infants into two groups; one group of infants who had been exposed to electronic gadgets during feeding for a minimum of 4 h per day ($n = 25$), and one group of infants who had not been exposed to electronic gadgets ($n = 75$). Time of exposure to electronics varied for each infant. The researchers reported that 18 of the 25 infants in the exposed group displayed delayed cognitive milestones. The authors also reported that after the withdrawal of gadgets, infants in this group displayed gradual improvements in cognitive milestones during a 2-month follow-up. Unfortunately, the authors did not describe the method used for measuring the cognitive milestones of the participants in this study.

Li et al. (2017) conducted a retrospective chart review to explore the effect of children's educational content and touchscreen devices on cognition. Specific data collection methods were not provided. Findings of this study indicated that there was no correlation between touchscreen device usage, educational content, and cognitive development. While educational content was outside the parameters of this scoping review, it is interesting to note that touchscreen device exposure did not result in any changes in cognitive developmental scores.

Discussion

Stage five of Anderson and Pempek (2005) framework is the collating, summarizing, and reporting of results. We will discuss the studies in this review in relation to the study question "What evidence exists about screen exposure and cognitive development in children ages birth to 24 months?"

Screen Exposure

To account for the amount of screen exposure an infant experienced, seven of the eight studies relied upon single point-in-time estimates of screen time based on parental recall, self-report, or documentation of screen time diaries. One study collected screen time duration by parent report annually for four years (Stockdale et al., 2022). In each study, the researchers extrapolated the reported screen viewing into minutes or hours per day. However, the studies that explored screen time exposure hours are observational and are subject to the limitations of observational studies. Screen exposure and other confounding variables cannot be controlled by the researcher, resulting in correlational outcomes lacking the directionality needed to demonstrate causation. AAP and WHO recommendations are based on observational studies and causation should not be implied. Three of the researchers placed their samples into study groups that followed AAP and WHO guidelines (Lin et al., 2015; Rocha et al., 2021; Varadarajan et al., 2021). Infants whose screen time viewing exceeded AAP and WHO guidelines were placed into screen exposure groups and assessed, resulting in potential threats to construct validity due to experimenter expectancies or biases, known as the Rosenthal effect (Grove & Gray, 2019).

Screen Exposure Context

Research has indicated that viewing context can have both positive and negative effects on an infant's cognitive development. Viewing context includes exposure to foreground screen media (purposeful infant screen exposure), background screen media (being in the room when screen media is playing), and co-viewing (watching screen media with a caregiver). Of the studies examining screen time context, Varadarajan et al. (2021) surveyed parents about when they allowed children to view screens. Parents used screen time to entertain children when they were ill, eating, having a tantrum, out at an event, traveling, and at bedtime. Parents also used screens to distract children when they were doing chores or needing a break. Supanitayanon et al. (2020) surveyed parents who talked to and interacted with infants while watching television (co-viewing). Co-viewing was positively correlated with positive parenting behaviors, early learning composite (ELC) scores and fewer months of high screen media exposure. Stockdale et al. (2022) surveyed the screen viewing habits of parents, finding no correlations between parental viewing habits on screen exposure or cognition.

Confounding Variables

Six of the studies analyzed potentially confounding variables. Variables for infants were sex, birth order, body weight, height, preschool attendance, types of care providers, and child temperament. Variables for parents were marital status, nationality, education level, employment status, primary language spoken, ethnicity, couple's satisfaction, self-efficacy in the nurturing role, social support, subjective social status, family monthly income, TV watching, depression, stress, media concerns, and positive parenting behaviors. One study included the home environment as a confounding variable. Lower maternal education and increased maternal screen consumption were predictive of lower scores on cognitive development tests. Supanitayanon et al. (2020) found higher maternal education was associated with a later age of onset and less duration of screen media exposure.

Cognition

One in six children in the United States has one or more developmental delays (Centers for Disease Control and Prevention, 2022). Known developmental delay risk factors include male sex, lower socioeconomic status, perinatal risk factors, and maternal education (Vitrikas et al., 2017). Many of the samples in this study were drawn from populations described as having low economic status, with one study finding associations between high and moderate screen exposure and economic status (Stockdale et al., 2022).

Cognitive delays may be caused by preterm birth, brain injuries, illness, or genetic abnormalities. In many cases the cause of the cognitive delay is unknown (Centers for Disease Control and Prevention, 2022). Cognition is addressed as a component of executive function in three of the studies measuring working memory, inhibition, attention, cognitive flexibility, and social contingency. Findings indicated screen viewing was associated with lower inhibition (McHarg et al., 2020), no effect on inhibition with moderate viewing (Stockdale et al., 2022), and positive social contingency with new knowledge acquisition (Myers et al., 2017). Speculation about the effect of screen exposure on executive function is circular. Most studies relate screen exposure to a lack of inhibition control, but outcomes are unclear regarding which comes first; innate problems of executive function or the lack of inhibition due to screen exposure.

Only two studies were interventional in nature to determine the effects of screen exposure on cognitive development (Myers et al., 2017; Verma et al., 2018). However, only one of those studies clearly described the methodology and outcome measurements (Myers et al., 2017).

Limitations

The quality of the research reported in this review was not evaluated which is a limitation of the scoping review methodology approach. Despite attempts to be thorough, this review may not have identified all published articles. Another limitation is that the scope of this review was intended to restrict the subjects to infants <2 years of age; however, study design and sampling methods skewed the results by following the child beyond infancy. The focus on cognition as the sole variable of development could also be a limitation. Cognition is only one component of development and there were no standard definitions prominent in the studies reviewed or in the background literature. Additionally, there were no standard tools to measure cognition used in the studies included in this review.

Future direction

While randomized controlled trials are upheld as the gold standard for demonstrating causation, they are not feasible or ethical when investigating screen time exposure involving infants and children. Most of the studies in this review are based on screen time recommendations from the WHO or AAP which recommend no screen time for infants under 24 months of age other than video chatting. These recommendations imply screen time is harmful to infants, yet they are not based on studies demonstrating causal association between screen time and child development. Recommendations for no screen time are based on assumptions that greater screen time results in greater harm. These recommendations do not take into account other factors impacting screen exposure such as maternal education, co-viewing and economic status which, in turn, affect screen time quality and duration. Many of the studies in this review correlated higher duration of screen exposure to poor cognitive outcomes without exploring the context in which the child is placed in front of a screen. When context was explored, infants who had no screen time, per parent report, had the best cognitive outcomes. However, Supanitayanon et al. (2020) reported that children who had moderate screen exposure and co-viewed screens with caregivers had better cognitive outcomes than children who view alone. Myers et al. (2017) also found that video chatting positively influenced infants' acquisition of new knowledge.

Screens are a ubiquitous part of our society. To shield infants from any screen exposure is impractical at best. Future studies focusing on the context of screen exposure, parenting behaviors, maternal education and economic status could provide new insights into screen viewing risks and benefits especially since maternal education and socioeconomic status are also known risk factors for developmental delays in children. The risks and benefits of caregiver co-viewing screens with children should also be explored.

Infancy is a time of rapid cognitive development and environmental adaptation. Current studies suggest excessive screen exposure may impact some children; however, the majority of children do not demonstrate cognitive delays that correlate to screen exposure. Future studies might apply standard operational definitions for cognitive development related to screen exposure. Consistent methodologies and measurements may make additional research more robust. Future research may be better focused on identifying risk factors for developmental deficiencies related to screen exposure, including maternal education and parenting behaviors related to viewing. This scoping review did not explore the needs of hospitalized children or children with chronic illnesses. Many acute care facilities utilize screens as distraction and comfort strategies. Additional research might investigate the risks and benefits of screen technologies in these environments.

CRediT authorship contribution statement

Carin Adams: Conceptualization, Writing – original draft, Writing – review & editing. **Laura Kubin:** Conceptualization, Writing – original draft, Writing – review & editing. **John Humphrey:** Methodology, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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