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The Association between Screen Time and Attention in Children: A Systematic Review

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ABSTRACT

Electronic media pervade modern life. Childhood is a crucial period for attentional development and the screen exposure time is increasing. This review aimed to understand the association between screen time and attention of children with typical development. A systematic review was conducted in compliance with Preferred Reporting Items for Systematic Reviews and Meta-Analyzes PRISMA being registered at Prospero under number CRD42021228721. A search was performed in January 2021 with the following keywords: "screen time," "children," and "attention," combined with the operator AND, on databases PubMed, and PsycINFO. Four hundred and ninety-eight articles were identified, and 41 papers were fully read, of which 11 were included in this review. Most studies found associations between screen time and attention in children. Only one study reported that children with more screen time performed better in an attention task. The findings suggest that exposure to excessive screen time in children can be associated with attention problems. Parents and teachers may be involved in controlling screen exposure, especially after the extensive exposition to online classes, due to the pandemic. Further studies are needed to assess the influence of this overexposure on care over time.

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Introduction

Electronic media pervade modern life. There are passive and interactive modalities of screen time, but both are almost omnipresent, being used for obtaining information and entertainment (Hale & Guan, 2015). The increasing inclusion of electronic devices and the internet in the current lifestyle has made the impact on children's daily experiences inevitable (Rocha & Nunes, 2020).

The recent recommendations from the World Health Organization (WHO) recommend no exposure of children with less than 2 years old to technology and a restriction of one hour use for children from 2 to 5 years of screen time a day to try to minimize the children's sedentary lifestyle (World Health Organization, 2019). Currently, researchers have evaluated on associating increased screen time with aspects of sedentarism, changes on socialization, cognitive, and language development, along with safety-related matter across several steps of children's development (Brazilian Society of Pediatrics-BSP, 2016; Guerra et al., 2019; Plitponkarnpim, Srikaew, Puranitee, & Vallibhakara, 2018). In children, some health outcomes have been associated with excessive screen time such as increased of overweight, sleep, and attention disorders. But there are some indirect screen effects such as taking the time that could be used in other activities, such as reading, "board games" or in outdoor activities that are less frequently evaluated (Rocha & Nunes, 2020).

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Children with psychiatric disorders may be particularly susceptible to the negative effects of increased screen exposure. Attention deficit hyperactivity disorder (ADHD) is a neurobiological disorder with high prevalence among young people worldwide, characterized by behavioral and cognitive symptoms including inattention. Children with this condition find it difficult to self-control and to regulate their impulses, limiting time spent on preferred activities, and maintain involvement in age-typical tasks, such as academic obligations (Ceranoglu, 2018).

Screen-based devices have also been increasingly utilized in the field of education. Currently, there is a growing effort in the educational field to provide students an active learning, based on problems, with quick feedback, and playfully (Muñoz, Villarreal, Morales, Gonzalez, & Nielsen, 2020). Aiming to support welfare, social abilities, and the inclusion of students with disabilities, the use of some sorts of games has also been considered an interesting approach to improve attention, effort, and motivation (Flynn & Colon, 2016; García-Redondo, García, Areces, Núñez, & Rodríguez, 2019). In this sense, educational games, properly designed, provide complex, challenging, collaborative environments that can support active learning and provide quick feedback. They require the development of skills that are in high demand in the new educational virtual reality such as critical thinking, collaborative, and communicative skills, as well as providing a basis for the assessment of such skills. In addition, players interact in an environment conducive to formulating new possibilities, testing new ideas as well as exploring social roles (Qian & Clark, 2016).

The growing implementation of technological resources, such as the tablet or smartphone in classrooms, is a way to promote the development of digital competence and the use of languages and resources familiar to students can improve participation and motivation while favoring meaningful learning. Some of the main technological trends in education for the coming years, according to experts, are Mobile Learning, Social Networks; Online Learning, Flipped classrooms, Cloud Computing, Gamification, and Virtual Reality (Prieto, Palma, Tobías, & León, 2019). However, some studies suggest that longstanding exposure to video games may be associated with impairments in the attentional sphere, with the possibility to evolve to a clinically important attention deficit and worsening in school performance (Peracchia & Curcio, 2018; Swing, Gentile, Anderson, & Walsh, 2010). A growing body of literature has been considered intellectual and ludic screen time as a sedentary time for research purposes (Sá, Pombo, Luz, Rodrigues, & Cordovil, 2020).

Attention is characterized by selecting information for preferential processing (Cohen, 2014). From the neuropsychological and clinical perspective, attention can be divided into selective (ability to distinguish between relevant and irrelevant stimuli), sustained (to keep the attentional focus on a certain stimulus for a set of time), alternated (to alternate focus between different stimuli) and divided (to divide attentional focus for the performing of two simultaneous tasks) (Lezak, Howieson, & Loring, 2004; Simão, Lima, Natalin, & Ciasca, 2010). Attentional development is observed since birth and might be modified in different periods. Regarding selective and sustained attention, fast improvement is present until 10 years old (Carreiro & Teixeira, 2012; Hazin et al., 2012). Screen time moderates attentional skills, especially when school and entertainment activities happen more and more through digital media (Sá et al., 2020; Tamana et al., 2019).

During social distancing and lockdown, the world's population amplified the use of digital technology at an unprecedented pace and scale. At a time like this, one cannot deny the benefit of electronic media to people's lives. Schools around the world were closed for different periods and many institutions made the transition to remote teaching, based on online classes, through meetings on digital platforms with the interaction between student and teacher/content made available virtually (Clark, Nong, Zhu, & Zhu, 2021; Gomes et al., 2021). In recent years, online learning pedagogy has been amplified, but there is still no consensus among researchers about its effectiveness. According to Clark et al. (2021), during the COVID-19 pandemic, children who studied online performed better academically than those who studied offline, however, the influence of this excessive exposure to screens on mental functions is still not evident. In addition, most studies in this area have focused on children with ADHD and these children are particularly susceptible to problematic media and internet use (He et al., 2021).

Attention is linked to school abilities (Fonseca, Lima, Ims, Coelho, & Ciasca, 2015) and attentional difficulties impact the learning and should be investigated (León, Rodrigues, Seabra, & Dias, 2013; Simão et al., 2010). Considering childhood as a crucial period for attentional development and the increasing screen exposure time, it becomes important to conduct a study aiming to better understand the association between screen time and attention in children. The results may help to design public policies targeting teachers who use screens for pedagogical purposes and families that deal with the screens at home. This review aimed to investigate the associations between screen time and children's attentional characteristics.

Method

This review was conducted in compliance with Preferred Reporting Items for Systematic Reviews and Meta-Analyzes – PRISMA (Shamseer et al., 2015) and was registered at PROSPERO, under number CRD42021228721. A search was performed in January 2021 with the following question: Is there an association between screen time and attention in children? For this, the following keywords were used: "screen time," "children," and "attention," combined with the operator AND on databases PubMed and PsycINFO. The search strategies for each database are detailed (see Table 1).

We included studies that met the following criteria: (1) studies that involved associations between screen time (i.e the amount of time spent using a device with a screen such as a smartphone, computer, television, or video game console as entertainment, or educational use) and attention (i.e at least one dependent variable assessed); (2) studies with children (0 to 12 years old); (3) studies in English. Studies that involve children with attention problems such as previous diagnosis of Attention Deficit with Hyperactivity Disorder (ADHD), and do not present any measurement of attention were excluded.

The screening procedure was performed in pairs, including an initial search independently. After duplicate records were deleted, the titles and abstracts of each study were screened according to the inclusion and exclusion criteria. The articles eligible for full reading were selected and the two authors discussed the results and reached a consensus of articles to be included in the review. Any disagreements were resolved by consensus with the third author.

Data extraction

The following data were extracted according to a standard form that included: the first author, the date, the country of publication, study design, objectives, screen time exposure/procedures, study subject, measurement of attention, and main findings.

Quality Assessment

The Cochrane Collaboration's risk of bias tool was used by the same review authors to assess the risk of bias in each included study (Higgins & Green, 2011).

Results

A total of 498 articles were identified from the database using the search strategy. Fifty-six duplicates were removed, and 442 articles were assessed by title and abstract. After screening, 401 reports were excluded, because they did not meet the predetermined criteria. Hence, 41 papers were reviewed, of which 11 were included in this review (Figure 1)

Table 1. Search strategies.

Data Base	Search strategies
PubMed	All fields (((children) AND (screen time)) AND (screen time)) AND (attention)
PsycINFO	Any Field: children AND Any Field: screen time AND Any Field: attention AND Document Type: Journal Article

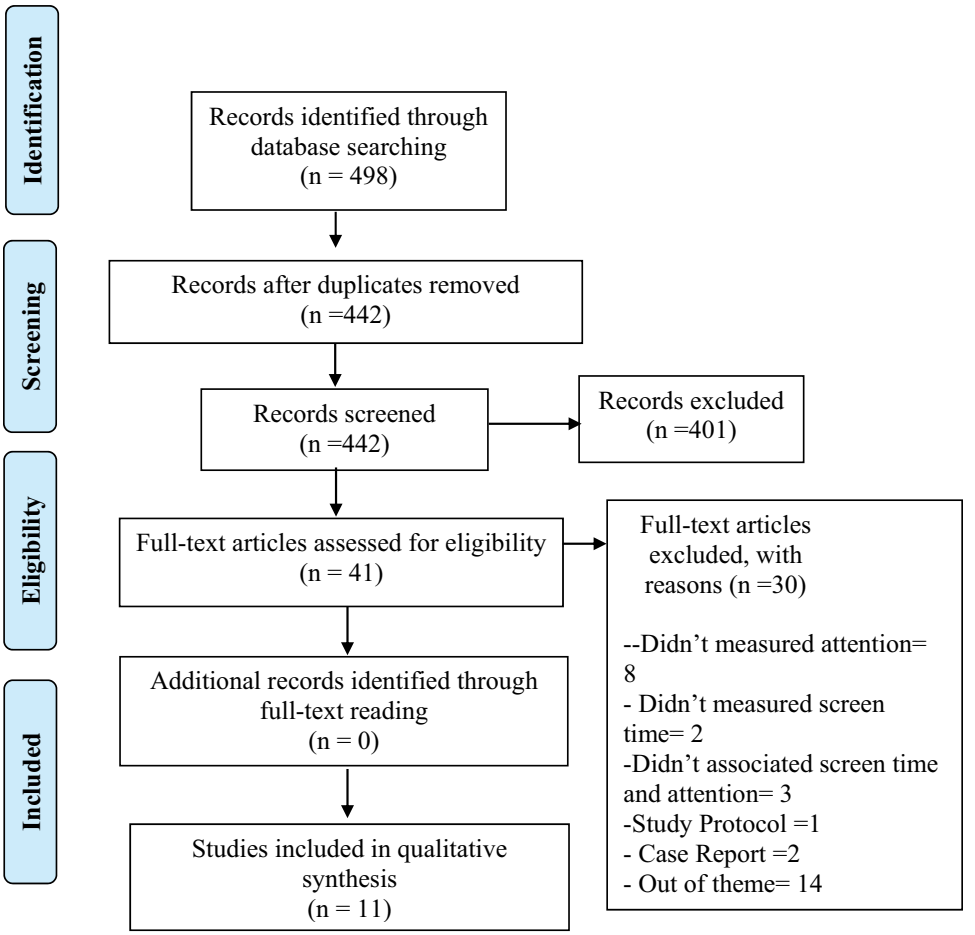

Figure 1 Flow Diagram

Study characteristics

A total of 8.637 children and adolescents aged between 18 months and 18 years old participated in studies, ranging from 30 (Zivan et al., 2019) to 1.897 individuals (Xie, Deng, Cao, & Chang, 2020). Two studies evaluated participants at three different times in early childhood, 18 to 26 months (Gueron-Sela & Gordon-Hacker, 2020), and in the school-age years (Barlett, Gentile, Barlett, Eisenmann, & Walsh, 2012). Two studies evaluated schoolchildren in just one moment (Altenburg, Chinapaw & Singh, 2015; Syväoja, Tammelin, Ahonen, Kankaanpää, & Kantomaa, 2014) and three studies evaluated preschoolers (Twait, Farah, Shamir, & Horowitz-Kraus, 2019; Xie et al., 2020; Zivan et al., 2019). The study by (Lin et al., 2020) evaluated young children aged 18 to 36 months, in a pediatric hospital and outpatient follow-up. The survey by (Hetherington, McDonald, Racine, & Tough, 2020) was conducted with the children's mothers, from prenatal consultations, until these children reached 5 years of age, and (Gueron-Sela & Gordon-Hacker, 2020) investigated children aged 18 to 26 months through a survey of mothers via an online platform. In addition to children, the evaluation of adolescents was included in two studies (Rosen et al., 2014; Swing et al., 2010).

The articles published between 2010 and 2020 and were from North America (Barlett et al., 2012; Hetherington et al., 2020); Europe (Altenburg et al., 2016; Swing et al., 2010; Syväoja et al., 2014); Asia (Lin et al., 2020; Rosen et al., 2014; Xie et al., 2020) and the Middle East (Gueron-Sela & Gordon-Hacker, 2020; Twait et al., 2019; Zivan et al., 2019).

About the study design, three articles reported randomized controlled trials (RCTs) (Altenburg et al., 2016; Twait et al., 2019; Zivan et al., 2019), two were longitudinal (Gueron-Sela & Gordon-Hacker, 2020; Hetherington et al., 2020), two were prospective studies (Barlett et al., 2012; Swing et al., 2010) and 4 were cross-sectional (Lin et al., 2020; Rosen et al., 2014; Syväoja et al., 2014; Xie et al., 2020). Table 2 summarized the included studies.

Screen time assessment

Screen time was established in different ways by the studies in this review. Some surveys considered screen time as just watching television and playing video games (Gueron-Sela & Gordon-Hacker, 2020; Hetherington et al., 2020; Swing et al., 2010), Barlett et al. (2012), and Syväoja et al. (2014) also added the use of the computer. Xie et al. (2020) in addition to TV/DVD and video games, added the use of tablets and smartphones to expand the definition of screen time. In two studies, screen time was offered in the form of story video sessions with predefined content and time (Twait et al., 2019; Zivan et al., 2019). A single study specifically evaluated the average time of using a touchscreen device per day and the type of use such as playing games, watching movies, using educational programs, or others (Lin et al., 2020). Rosen et al. (2014) included the daily use of media and technology, such as using a computer for online or offline activity, talking on the phone, sending text messages, playing videos, playing games, and playing with technological toys, however, he did not refer the use of TV and Altenburg et al. (2016) did not include video games as screen time in her research.

Different patterns of screen time evaluation were observed. Five studies assessed screen time through questionnaires to parents (Gueron-Sela & Gordon-Hacker, 2020; Hetherington et al., 2020; Lin et al., 2020; Rosen et al., 2014; Swing et al., 2010), 3 others used reports provided by the children (Altenburg et al., 2016; Barlett et al., 2012; Syväoja et al., 2014) and one evaluated using an accelerometer (Xie et al., 2020). In contrast, two articles used protocols during their experiments to measure exposure to screen time (Twait et al., 2019; Zivan et al., 2019).

Attention assessment

Other outcomes were evaluated in addition to the attention skills; however, we focused the details on the evaluations related to the attentional dimensions carried out in the studies. It was not a priority of all studies included to measure each type of attention separately, however, associations were observed between screen time and focused attention in Gueron-Sela and Gordon-Hacker (2020) and Hetherington et al. (2020), selective attention in Altenburg et al. (2016), visual attention in Twait et al. (2019) and Zivan et al. (2019), the flexibility of attention in Syväoja et al. (2014) and simultaneous attention (Swing et al., 2010).

Two investigations assessed attention through reports of the professor (Barlett et al., 2012; Swing et al., 2010). Four studies assessed attention through questionnaires based on parents'report, such as CBCL (Lin et al., 2020; Xie et al., 2020), the Behavior Assessment System for Children (BASC-2) that assesses self-regulatory skills, including focusing attention (Hetherington et al., 2020), the school version of the Attention Deficit and Hyperactivity Disorder Assessment Scale of 18 items (Rosen et al., 2014) and the Behavior Questionnaire for Childhood Focusing subscale Short Form (ECBQ-SF), which assesses focused attention skills (Gueron-Sela & Gordon-Hacker, 2020). In Twait et al. (2019) and Zivan et al. (2019) the parents answered the questionnaire (CONNERS) but the children also performed the Sky Search test that investigates selective attention, and EEG measures were obtained. Altenburg et al. (2016), however, evaluated only children, applying the Sky Search subtest, of the selective attention test in children (TEA-CH). The study by Syväoja et al. (2014) also directly evaluated children using two tests that measure attention: reaction time (RTI) and rapid visual information processing (RVP). The RTI measures the speed of response to a visual target, whereas the RVP provides measures of sustained attention.

Table 2. Descriptive characteristics of included studies.

	First author	Year	Country	Study design	Objectives	Exposure/ Procedures	Study subject	Measurement of attention	Main findings
1	Swing	2010	USA	Cohort study	Investigate if there are associations of television and video game exposures with attention problems different in middle childhood compared with late adolescence/ early adulthood.	Exposure to television and video games were based on the participants' responses to the average time spent on weekdays and weekends.	N= 1323 Female=53% Male= 43% Age: 6-12	Attention problems were assessed by teacher report ("This child: has difficulty staying on task; has difficulty paying attention; often interrupts other children's work") on a 5-point scale, with responses ranging from "never true" to "almost always true".	Total screen media exposure (television and video games combined) was associated with greater subsequent attention problems (B = 0.83, p < .05). When associated separately, video game exposures was a more predictor of attention problems when compared with television exposures.
2	Barlett	2012	Canada	Cohort study	To examine the relations between media exposure and multiple health-related outcomes, including aggression, attention, and body mass index (BMI) with a prospective study, specifically testing sleep as a mediator	Children reported the number of hours they watched TV, played video games, and spent time on the computer. Total screen time = weekly totals for TV, video games, and computer time.	N= 1.288 children Age= 9.6 years mean (range 6–12 years of age). 1.196 (93%) at baseline 1.156 (90%) at Time 2 1.110 (86%) at Time 3	Attention problems were assessed by teacher report ("This child: has difficulty staying on task; has difficulty paying attention; often interrupts other children's work") on a 5-point scale, with responses ranging from "never true" to "almost always true".	Media exposure at Time 1 was indirectly related to greater attention problems, physical aggression, and Body Mass Index at Time 3 (13 months later), mediated by sleep at Time 2.

(*Continued*)

Table 2. (Continued).

	First author	Year	Country	Study design	Objectives	Exposure/ Procedures	Study subject	Measurement of attention	Main findings
3	Rosen	2014	China	Cross-sectional	To examine the impact of technology on four areas of ill-being: physical problem symptomology, psychological symptom manifestation, attention problems, and home and classroom behaviors, among children (aged 4–8), preteens (9–12), and teenagers (13–18)	Parents were asked questions about their own and their child 's technology usage (going online, using a computer for other than being online, sending and receiving e-mail, I Ming/ chatting, talking on the telephone, texting, playing video games, listening to music, and playing with technological toys) on a scale including not at all, less than an hour, 1 h, 2 h, 3 h, 4–5 h, 6–8 h, 9– 10 h and more than 10 h per day. Total Technology Use = hours per day for all ten queried forms of media.	N=338 (aged 4-8) N=316 (aged 9-12) N=376 (aged 13-18) Males (51%) and Females (49%).	Included the 18-item Attention Deficit Hyperactivity Disorder Rating Scale–IV– Also, a parent and child attention symptomology checklist was included.	Those children who used more technology demonstrated more attention problems
4	Syvaoja	2014	Finland	Cross-Sectional	To examine how objectively measured and selfreported physical activity and sedentary behavior are associated with cognitive functions in school-aged children.	Self-reported screen time was evaluated with the question: ''About how many hours a day do you usually a) watch television (including videos), b) play computer or video games, or c) use a computer (for purposes other than playing games, for example, emailing, chatting, or surfing the Internet or doing homework). Total daily screen time averages = summing of hours (weekdays and weekends together).	N=224 Female =56% Male =44% Mean age =12,2 year	The tests assessing attention were Reaction Time (RTI) and Rapid Visual Information Processing (RVP). RTI measures children's reaction time and speed of response to a visual target. RVP is similar to the Continuous Performance Task measuring sustained attention.	Boys reported more total screen time than girls, especially they spent more time playing computer or video games than girls. In cognitive tests, boys were faster than girls in the reaction time test - RTI, ($p < 0.001$). The time of use of the self-reported computer was negatively associated with the change and flexibility of attention.

(*Continued*)

Table 2. (Continued).

	First author	Year	Country	Study design	Objectives	Exposure/ Procedures	Study subject	Measurement of attention	Main findings
5	Altenburg	2015	Holland	Randomized Controlled Trial (RCT)	To examine the acute effect of one or two 20-minute sessions of moderate exercise in the sustained attention of children	TV viewing (min/day) and computer use (min/day) were assessed using items from a child questionnaire	N=56 Female= 30 Male=26 Age= 10-13 years	Selective attention was measured by the 'Sky Search' subtest of the 'Test of Selective Attention in Children' (TEA-Ch)	Group with higher screen time values had lower scores on attention tests
6	Twait	2019	Israel	Randomized Controlled Trial (RCT)	To examine the effect of dialogic reading compared to screen-exposed intervention on executive functions.	Both the dialogic reading and screen-based groups participated in 18 sessions for six weeks, three meetings per week, for 30 minutes each session.	N=32 Female=40% Male= 60% Age=4-6 years	Attention/ hyperactivity measured by the Conners rating scale. Visual and auditory attention were measured by the 'Sky Search' subtest of the 'Test of Selective Attention in Children' (TEA-Ch). EEG	Significant improvement in visual attention after the dialogic reading intervention, compared to the control group that received screen-based exposure.
7	Zivan	2019	Israel	Randomized Controlled Trial (RCT)	To determine the effect of 6-weeks screen-based stories-listening exposure compared to a story-telling intervention delivered by an interactive human presenter on attention abilities in 4–6-year-old children.	Storytelling interventions were performed either using a screen for stories listening by the screen group or administered by an interactive experimenter to the storytelling group. two intervention groups - screen-based stories listening (n = 14) and live-presented interactive storytelling (n = 16).	N= 30 Age= 4 -6 years screen: 50% females, storytelling: 43.8% females	Attention measured by the Conners rating scale, BRIEF,'Sky Search' subtest of the 'Test of Selective Attention in Children' (TEA-Ch). EEG	Greater visual attention abilities after the storytelling intervention, but not after screen exposure. Screen exposure was related to EEG patterns previously related to altered attention abilities.

(*Continued*)

Table 2. (Continued).

	First author	Year	Country	Study design	Objectives	Exposure/ Procedures	Study subject	Measurement of attention	Main findings
8	Xie	2020	China	Cross-Sectional	To establish if there exists a correlation between behavioral outcomes and screen time of preschoolers.	The screen time was recorded in minutes and different weights were given to weekdays and weekends to calculate the accumulated screen time. Preschoolers were grouped based on screen time of less 60 min or over 60min.	N=1897 Age=3-6 years	Parents completed the Child Behavior Checklist (CBCL) preschool version, which contains 99 items. Children's behaviors were divided into 7 categories, including emotionally reactive, anxiousness/ depression, aggressive behavior, attention problems, somatic complaints, withdrawn symptom and sleep problems.	Children with screen time > 60 minutes had higher scores on attention problems (total problem: $p = 0.024$, externalizing: $p = 0.016$).
9	Lin	2206	Taiwan	Cross-Sectional	Address associations of touchscreen device exposure emotional and behavioral problems with symptoms children between the ages of 18 and 36 months	Caregivers answered for children aged 18 to 36 months in the clinic of the medical center. Quiz about screen and touch time.	N= 161 Age= mean of 25,63 months	Parents completed the Child Behavior Checklist for Ages 1½–5 (CBCL 1½–5).	Children aged 18–36 months who spent more time on touch screen devices tended to have more attention problems ($\beta = .300$, $p < .001$, 95 % CI: .432–1.267).
10	Hetherington	2020	Canadá	cohort study	The objectives of this study were to determine risk factors and moderators associated with the three elements of self-regulation (i.e., inattention, emotional control, or behavioral control) as well as overall self-regulation, among children at age 5.	Screen time was measured by maternal report of how much time they estimated their child spent watching television, movies, or playing videogames per day. Responses ranged from less than 1 h to over 5 h and were dichotomized according to national guidelines for this age group (1 h or less compared to more than 1 h per day).	N=1644 children In months =61,52 mean	The outcome measure was self-regulation skills at age 5, which was measured by parent report on the Behavior Assessment System for Children (BASC-2).	Excess screen time (>1 h per day) was associated with poor self-regulation in Model inattention.

(*Continued*)

Table 2. (Continued).

	First author	Year	Country	Study design	Objectives	Exposure/ Procedures	Study subject	Measurement of attention	Main findings
11	Gueron-Sela & Gordon-Hacker	2020	Israel	Cohort study	Examining the links between a cumulative index of media use and children's focused attention abilities at three time points in toddlerhood: 18 (T1), 22 (T2), and 26 (T3) months of children's age.	Screen time was assessed using maternal report of average child screen time (i.e., watching television, watching videos/playing games on a handled device) during a typical weekday and weekend day. The measure of Cumulative Media Use (CMU) was constructed.	N= 199 mothers of children aged 17–19 months (60% male; 40% female)	Children's focused attention abilities were measured using the Attentional Focusing subscale from the Early Childhood Behavior Questionnaire Short Form (ECBQ-SF).	The exposition of multiple (rather than single) aspects of media use was related to decreased subsequent focused attention abilities during toddlerhood.

Associations between screen time and attention

Attentional behavioral changes in children

Most studies have observed associations between screen time and children's attention. Regarding younger children and preschoolers, screen time was predictive of the attention problems later (Barlett et al., 2012; Gueron-Sela & Gordon-Hacker, 2020; Lin et al., 2020; Xie et al., 2020). Even the time using touch screen devices was related to an increase in propensity for attention problems in young children (Lin et al., 2020).

The Council on Communication and Media, (2013) of the American Academy of Pediatrics (AAP), recommends school-age children should not spend more than 2 hours a day with television and video games combined. Children exceeding daily recommendation for television exposure or use of technological toys seems more likely to be above average in attention problems (Hetherington et al., 2020; Rosen et al., 2014; Swing et al., 2010).

Early grades' children were more prone to attention problems and videogames were more related with later attention problems than television (Swing et al., 2010). In the study by Rosen et al. (2014), the use of technology in daily basis was associated with attention problems for children aged 4 to 8 years, regardless of the type of media. For pre-adolescents (9 to 12 years old), the daily use of the total technology was not related to attention problems, being associated only foreseen when considering the use of video games and technological toys, separately (Rosen et al., 2014).

In the study by Hetherington et al., 2020, the screen time of up to 1 hour daily was considered excessive for children with a mean age of 5 years. A significant relationship between excessive screen time and inattention was observed, including a possible increase in inattention for each additional hour of screen time, but children were compared only for time of exposure but not for the kind of electronic media. These studies provided information about children's attention through reports from parents and teachers, who mentioned difficulties in focusing attention and staying on task (Hetherington et al., 2020; Rosen et al., 2014; Swing et al., 2010).

Attentional alterations in experimental studies and cortical electrical activity

Experiments screen-based observed differences in performance in tests of visual attention when comparing control to screen-exposed group. Children who received dialogic reading and storytelling interventions showed improvement in visual attention after the intervention, compared to the control group that received screen-based exposure (Twait et al., 2019; Zivan et al., 2019). Only one study reported that children with more screen time performed better in an attention task Rapid Visual Information Processing (RVP) (Syväoja et al., 2014).

Studies that compared the effects of human interaction through dialogic reading and interactive storytelling, with exposure to screen time in attentional processes, also have done electroencephalogram (EEG) measurements (Twait et al., 2019; Zivan et al., 2019). In the study by Twait et al. (2019), a dialogic reading intervention was carried out. Intervention consisted of 18 reading sessions of different age-appropriate books, accompanied by researchers who interacted with the children during the process, repeating, questioning, and expanding what the child said, to create or to reinforce associations. Twait et al. (2019) considered two subcomponents of attention control, the first one related to external stimuli, that is, based on the reception of information to central neuroanatomical substrates, also called ascending processes or guiding attention, reflected in the P300 component and a second component, focused on information processing and response, motivated by internal processes and notably slower, reflected in the N200 Component of the EEG. Significant differences were observed between intervention groups, with greater amplitudes of P300 and N200 in the screening group and smaller in the dialogic reading group. Better scores in visual attention tasks and processing speed were correlated with smaller differences between the P300 and N200 amplitudes, respectively (Twait et al., 2019).

To investigate whether screen exposure correlates with changes in basic attention mechanisms, in Zivan et al. (2019), the EEG was used focusing on bands related to this outcome. The study compared the effect of screen exposure and interactive storytelling on attention skills and brain electrical activity

in the theta and beta bands, whose frequencies were used statistically as measures of functional connectivity. The results showed an increase in functional connectivity in areas that configure a pattern previously related to attention difficulties in the control group, exposed to the screen, concerned the group that participated in the interactive storytelling intervention. In the post-intervention visual attention tests, the best scores were observed in the experimental group, compared to the screen exposure group.

Risk of bias

Most studies showed a low or unclear risk of bias for the items evaluated (see Figure 2 and Figure 3). In addition, 'Risk of bias' summaries were reported in detail to allow accurate assessment of domains of randomization, allocation, and blinding for those studies that were not randomized controlled trials.

Discussion

The purpose of this review was to analyze the literature on the associations between screen time and children's attention. The results suggest that the child's exposure to excessive screen time can be associated with attention problems. Although there is the prospect of educational potential of screen media for young children, there is also concern about the development and health of these children. However, children are growing up in environments with a varied offer of media, such as videos, mobile, and interactive technologies, in addition to television. In this perspective, the AAP sought a more current approach to the issue, through the Council and Communications and Media, 2016, but remaining with time limitations in the use of digital media for children aged 2 to 5 years for no more than 1 hour a day. For children under 2 years old, the document makes the use of video calling with responsive adults more flexible, as a way to facilitate interaction with distant relatives. Excessive exposure for children over five years old, is defined by the AAP as total time greater than two hours a day using screens of any types, such as television, video games, smartphones, computers, and tablets.

To the best of our knowledge, this is the first systematic review that aimed to identify studies that analyzed the correlations between screen time and children's attention. Most studies analyzed found associations between exposure to different types of screen-based devices and attention in children (Altenburg et al., 2016; Barlett et al., 2012; Gueron-Sela & Gordon-Hacker, 2020; Hetherington et al., 2020; Lin et al., 2020; Rosen et al., 2014; Swing et al., 2010; Twait et al., 2019; Xie et al., 2020; Zivan et al., 2019).

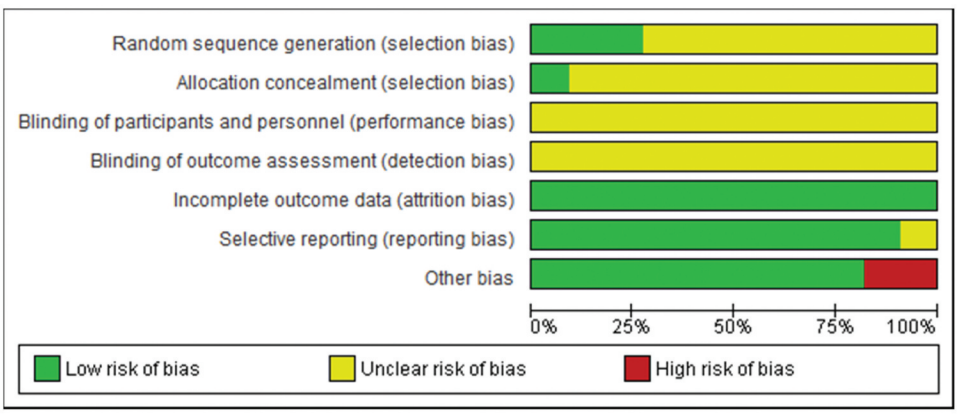

Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

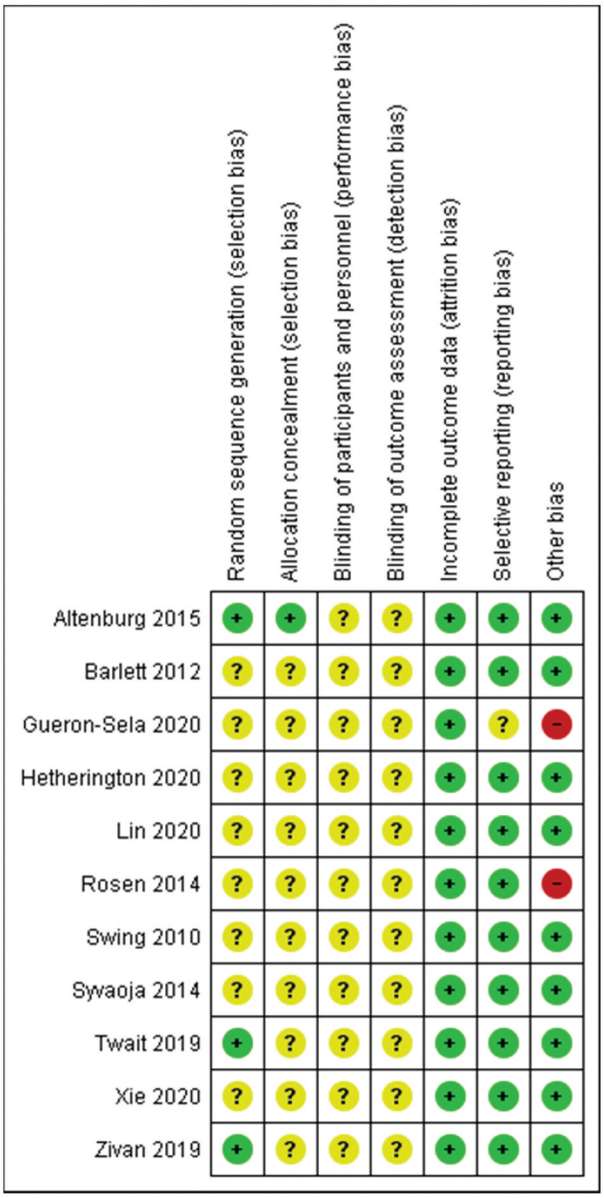

Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

Watching television and playing video games similarly were correlated with attention outcomes in children from 4 to 8 years old and late in adolescence (Swing et al., 2010). We found results that suggest a decrease in attention skills in young children when considering the total screen time exposure (Gueron-Sela & Gordon-Hacker, 2020). However, results of a survey conducted with Japanese children (Sugawara, Matsumoto, Murohashi, Sakai, & Isshiki, 2015), contrast with our data, concluding that screen time was not related to attention problems. This study analyzed the relationships between exposure to television and other media by children aged 0 years and externalizing problems such as attention, at 5 years of age. Each year, families received a 1-week diary to record the use of television and other screens (i.e., videos/DVDs, video games, and home computers) by the assessed child. This exposure generally increased from age 0 to 1 and decreased at age of 5 years. Some

children had longer screen contact time since the beginning of the study but showed no significant differences in attention problems compared to groups with the shorter contact time, showing that screen time and its trajectories of change at ages of 1 at 5 years does not influence externalization problems, such as attention, at 5 years. These data were obtained from a longitudinal study beginning in 2002, later Foster and Watkins (2010) also found no significant correlation between maternal reports of watching television at ages 1 and 3 and attention problems at 7 years old. Longitudinal studies are important to definitively establish if the exposure was or not related to the outcome, so mere studies are still necessary in different cultures and conditions to be certain about the effects of screen on children development.

Children who spent more time on touchscreen devices were more likely to have precocious attention problems (Lin et al., 2020). These data reinforce recent research, in which the use of devices based on touch screens for the long term has been associated with differences in speed and control of the attention allocation on the visual scene. This study compared children who used touch screen devices for a short with those who used them for a long time. Children who used the touch screen for a longer time were faster in one of the stages of the Visual Search Reaction Time test. However, the authors considered that there could be an interference of the salience in the execution of the task, instead of quick learning within the task. The authors add that transferring this to the child's daily life would be the same as saying, for example, which the child may have difficulty concentrating on their activity in the middle of a busy classroom (Portugal, Bedford, Cheung, Gliga, & Smith, 2021). Also, according to Li, Cheng, Sha, Cheng, and Yan (2020), when the device with a touch-sensitive screen is removed, children may not be able to concentrate on activities without strong stimulation.

In young children, the association between attention and screen time (quantity versus quality) appears to be stronger when sleep was considered together (Barlett et al., 2012). In a recent review by Li et al. (2020), the meta-analysis elucidated that more use of screen media was related to more sleep problems, but the evidence regarding cognitive or attentional development in this population was unclear. The presence of neurodevelopmental disorders is known to affect sleep and attention in children, such as described for ADHD (van der Heijden, Stoffelsen, Popma, & Swaab, 2018). Although this review found associations between screen time and the presence of ADHD symptoms, a conclusive relationship could not be established. The children included in the studies reviewed did not have a previous diagnosis of ADHD, however, they show alterations in the scores of the instruments that suggest the presence of an undiagnosed condition or recent development of symptoms and even related disorder (Xie et al., 2020).

The underlying mechanisms linking attention skills and screen time exposure are still not well established. The current review found a significant improvement in children's visual attention after interventions that involved interaction with people, compared to exposure to screens (Twait et al., 2019; Zivan et al., 2019). These data agree with a previous MRI study, which evaluated the connectivity between the language-related area and other brain regions, in children aged 8 to 12 years, who report reading and screen times. It was concluded that the time spent on reading was positively correlated with greater functional connectivity between regions related to language and visual and cognitive processing and control of the brain, while the screen time group was related to less connectivity in these regions (Horowitz-Kraus & Hutton, 2017). Although the study by Zivan et al. (2019) observed an increase in connectivity in the group exposed to the screen, this increase was detected in regions previously related to attention difficulties. Another study showed that screen exposure decreased gray matter integrity (Paulus et al., 2019). However, these studies mainly addressed visual processing regions in a population aged 8 years and over, differing from the experimental records in this review (Twait et al., 2019; Zivan et al., 2019), which they examined the relationship between screen exposure and neurobiological correlates of brain attention skills in preschool children.

Young children and preschoolers, however, might be particularly affected by excessive screen time, as at this age the brain has great plasticity (Dumuid, 2020; Thompson & Nelson, 2001). The American Academy of Pediatrics (AAP) advises against the use of electronic devices until the age of 2 years, although recognizing potential benefits, this exposure may cause greater harm to children (AAP

Council on Communications and Media, 2016). A study conducted with children aged 3 to 5 years Hutton, Dudley, Horowitz-Kraus, DeWitt & Holland, (2019), has found magnetic resonance evidence of harmful associations between screen time and microstructural integrity of the white matter tracts, implicated in executive functions and literacy, results that support the findings of the present review about young and preschool children, in which screen time was also related to later attention problems (Barlett et al., 2012; Gueron-Sela & Gordon-Hacker, 2020; Lin et al., 2020, 2020; Xie et al., 2020).

Attention skills have neurobiological foundations, but children's experiences also play a key role in this development (Colombo & Salley, 2015). In this sense, cultural aspects can be considered. Studies carried out in culturally distinct populations may not find differences in the attention of children exposed to screen time, either due to the influence of discipline, naturally developed in children (Sugawara et al., 2015) or even due to the lack of provision of recommendations guidelines of on-screen media use by young children American Academy of Pediatrics (2016), as in the UK, (Taylor, Monaghan & Westermann, 2018). Added to these differences are countries, such as France, for example, which approved the ban on smartphones in schools, until the 9th grade, or Taiwan, in which the Law for the Protection of the Rights and Welfare of Children and Youth started to recommend nothing more 30 minutes of use of electronic devices each time, for children older than 2 years (Lin et al., 2020).

Xie et al. (2020) conclude the screen time on TV/DVD, on tablets, smartphones, and video games should be reduced to less than 1 hour per day. For preschoolers, Hetherington et al. (2020) add as a concern, the prediction of greater inattention in children whose screen times exceed one hour a day. Although previous AAP statements have advised specific screen time limits (Council on Communications and Media, 2016), recent guidelines suggest that families manage this exposure individually, without a specific universal limit. Although excessive screen time may be related to health risks, given the pandemic scenario by COVID-19, increases in screen time seem inevitable, leading to the creation of family strategies to take advantage of benefits and an attempt to minimize losses (Nagata, Abdel Magid, & Pettee Gabriel, 2020).

Limitations

Some studies have assessed the impact of screen time on attention as a secondary outcome, such as evaluating sedentarism, school and eating behavior, cognition, sleep, interaction with parents, and learning or development of skills.

Another important and delicate point is the report of screen time. Currently, screen time has become a more complex concept, with a great variety and availability of electronic media devices, so the report for parents or for child might be inaccurate about both the quantity and quality. There is a potential underestimation of the amount of time spent on electronic media.

About the assessment of attention, the studies in this review were mostly composed of an indirect evaluation of attention using the behavioral questionnaires answered by parents, which might not capture the real behaviors in diverse scenarios.

The number of studies included in this review and the heterogeneity in measures and outcomes, such as samples at different stages of child development, contexts, and methodologies made difficult to generalize the results shown here.

Conclusion

The cognitive function of attention is related to the child's adequate performance in their activities, especially at school. This review contributes to highlight the associations between screen-based media exposure and children's attention. The studies argue that the screen-use has the benefit of children's entertainment and can also complement school and learning activities. However, the potential benefit was not possible to capture in all studies, suggesting changes in the ability to pay attention after exposure to screens. Generally, the reviewed data suggest the need to control screen time use to avoid attentional problems. The associations between overexposure and attention manifest themselves, and

we will be challenged to evaluate to what extent are attention problems associated with the time or type of screen-use or would be beneficial as a resource for learning. More studies with objective measures of attention in controlled environments of exposure to screen time will be needed to answer this question.

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References

Altenburg, T. M., Chinapaw, M. J., & Singh, A. S. (2016). Effects of one versus two bouts of moderate-intensity physical activity on selective attention during a school morning in Dutch primary school children: A randomized controlled trial. *Journal of Science and Medicine in Sport*, *19*(10), 820–824. doi:10.1016/j.jsams.2015.12.003

American Academy of Pediatrics -AAP. Council on Communications and Media. (2013). Children, adolescents, and the media. *Pediatrics*, *132*(5), 958–961. doi:10.1542/peds.2013-2656

American Academy of Pediatrics -AAP, Council on Communications and Media. (2016). Media and young minds. *Pediatrics*, *138*(5), e20162591. doi:10.1542/peds.2016-2591

Barlett, N. D., Gentile, D. A., Barlett, C. P., Eisenmann, J. C., & Walsh, D. A. (2012). Sleep as a mediator of screen time effects on US children's health outcomes: A prospective study. *Journal of Children and Media*, *6*(1), 37–50. doi:10.1080/17482798.2011.633404

Brazilian Society of Pediatrics -SBP. (2016). The health of children and adolescents in the digital age. Department of Adolescence, editor. Guidance Manual. [accessed March 2, 2021]. Available at: https://www.sbp.com.br/fileadmin/user_upload/2016/11/19166d-MOrient-Saude-Crian-e-Adolesc.pdf

Carreiro, L. R. R., & Teixeira, M. C. T. V. (2012). Attention Assessment. In C. S. Hutz (Ed.), *Advances in psychological and neuropsychological assessment of children and adolescents II* (Vol. 1, pp. 57–92). São Paulo, SP: Casa do Psicólogo.

Ceranoglu, T. A. (2018). Inattention to problematic media use habits: interaction between digital media use and attention-deficit/hyperactivity disorder. *Child and Adolescent Psychiatric Clinics of North America*, *27*(2), 183–191. doi:10.1016/j.chc.2017.11.009

Clark, A. E., Nong, H., Zhu, H., & Zhu, R. (2021). Compensating for academic loss: Online learning and student performance during the COVID-19 pandemic. *China Economic Review*, *68*, 101629. doi:10.1016/j.chieco.2021.101629

Cohen, R. A. (2014). *The neuropsychology of attention*. New York USA: Springer.

Colombo, J., & Salley, B. (2015). Biopsychosocial perspectives on child care development. In S. D. Calkins (Ed.), *Handbook of child biopsychosocial development* (pp. 71–96). New York, NY: Guilford Press.

Dumuid, D. (2020). Screen time in early childhood. *The Lancet. Child & Adolescent Health*, *4*(3), 169–170. doi:10.1016/S2352-4642(20)30005-5

Flynn, R. M., & Colon, N. (2016). Solitary active videogame play improves executive functioning more than collaborative play for children with special needs. *Games for Health Journal*, *5*(6), 398–404. doi:10.1089/g4h.2016.0053

Fonseca, G. U. S., Lima, R. F., Ims, R. E., Coelho, D. G., & Ciasca, S. M. (2015). Validity evidence for instruments of attention and executive functions and relationship with school performance. *Temas em Psicologia*, *23*(4), 843–858. doi:10.9788/TP2015.4-04

Foster, E. M., & Watkins, S. (2010). The value of reanalysis: TV viewing and attention problems. *Child Development*, *81*(1), 368–375. doi:10.1111/j.1467-8624.2009.01400.x

García-Redondo, P., García, T., Areces, D., Núñez, J. C., & Rodríguez, C. (2019). Serious games and their effect improving attention in students with learning disabilities. *International Journal of Environmental Research and Public Health*, *16*(14), 2480. doi:10.3390/ijerph16142480

Gomes, J., Almeida, S. C., Kaveri, G., Mannan, F., Gupta, P., Hu, A., & Sarkar, M. (2021). Early childhood educators as covid warriors: adaptations and responsiveness to the pandemic across five countries. *International Journal of Early Childhood*, 1–22. Advance online publication, doi:10.1007/s13158-021-00305-8

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*, 569222. doi:10.3389/fpsyg.2020.569222

Guerra, P. H., Filho, V. C. B., Almeida, A., Silva, L. S., Pinto, M. T. V., Leonel, R. M., . . . Florindo, A. A. (2019). Systematic review of physical activity and sedentary behavior indicators in south-American preschool children. *Revista Paulista de Pediatria*, *38*, 10.1590/\1984–0462/2020/38/2018112.

Hale, L., & Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: A systematic literature review. *Sleep Medicine Reviews*, *21*, 50–58. doi:10.1016/j.smrv.2014.07.007

Hazin, I., Falcão, J. T. R., Garcia, D., Gomes, E., Cortez, R., Maranhão, S., . . . Dias, M. G. B. B. (2012). Dados normativos do Teste de Atenção por Cancelamento (TAC) em estudantes do ensino fundamental. *Psico*, *43*(4), 428–436.

He, S., Shuai, L., Wang, Z., Qiu, M., Wilson, A., Xia, W., . . . Zhang, J. (2021). Online learning performances of children and adolescents with attention deficit hyperactivity disorder during the COVID-19 pandemic. *Inquiry: A Journal of Medical Care Organization, Provision, and Financing*, *58*, 469580211049065. doi:10.1177/00469580211049065

Hetherington, E., McDonald, S., Racine, N., & Tough, S. (2020). Longitudinal predictors of self-regulation at school entry: findings from the all our families cohort. *Children*, *7*(10) MDPI AG. Retrieved from, 186. 10.3390/children7100186.

Higgins, J. P., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., & Oxman, A. D.; Cochrane Statistical Methods Group. (2011). The Cochrane collaboration's tool for assessing the risk of bias in randomized trials. *BMJ (Clinical Research Ed.)*, *343*, d5928. doi:10.1136/bmj.d5928

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 (Oslo, Norway: 1992)*, *107*(4), 685–693. doi:10.1111/apa.14176

León, C. B. R., Rodrigues, C. C., Seabra, A. G., & Dias, N. M. (2013). Executive functions and school performance in children aged 6 to 9 years. *Revista Psicopedagogia*, *30*(92), 113–120.

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological assessment*. New York: Oxford University Press.

Li, C., Cheng, G., Sha, T., Cheng, W., & Yan, Y. (2020). The relationships between screen use and health indicators among infants, toddlers, and preschoolers: A meta-analysis and systematic review. *International Journal Environmental Research and Public Health*, *17*(19), 7324. doi:10.3390/ijerph17197324

Lin, H. P., Chen, K. L., Chou, W., Yuan, K. S., Yen, S. Y., Chen, Y. S., & Chow, J. C. (2020). Prolonged touch screen device usage is associated with emotional and behavioral problems, but not language delay, in toddlers. *Infant Behavior & Development*, *58*, 101424. doi:10.1016/j.infbeh.2020.101424

Muñoz, L., Villarreal, V., Morales, I., Gonzalez, J., & Nielsen, M. (2020). Developing an interactive environment through the teaching of mathematics with small robots. *Sensors (Basel Switzerland)*, *20*(7), 1935. doi:10.3390/s20071935

Nagata, J. M., Abdel Magid, H. S., & Pettee Gabriel, K. (2020). Screen time for children and adolescents during the coronavirus disease 2019 pandemic. *Obesity (Silver Spring, Md.)*, *28*(9), 1582–1583. doi:10.1002/oby.22917

Paulus, M. P., Squeglia, L. M., Bagot, K., Jacobus, J., Kuplicki, R., Breslin, F. J., Tapert, S. F. (2019). Screen media activity and brain structure in youth: evidence for diverse structural correlation networks from the ABCD study. *NeuroImage*, *185*, 140–153. doi:10.1016/j.neuroimage.2018.10.040

Peracchia, S., & Curcio, G. (2018). Exposure to video games: Effects on sleep and post-sleep cognitive abilities. A systematic review of experimental evidence. *Sleep Science (Sao Paulo, Brazil)*, *11*(4), 302–314. doi:10.5935/1984-0063.20180046

Plitponkarnpim, A., Srikaew, C., Puranitee, P., & Vallibhakara, A. S. (2018). ICT exposure in children younger than 2 years: rates, associated factors, and health outcomes. *Journal of the Medical Association of Thailand*, *101*(3), 345–349.

Portugal, A. M., Bedford, R., Cheung, C. H. M., Gliga, T., & Smith, T. J. (2021). Saliency-driven visual search performance in toddlers with low– vs high–touch screen use. *JAMA Pediatrics*, *75*(1), 96–97. doi:10.1001/jamapediatrics.2020.2344

Prieto, M., Palma, L., Tobías, P., & León, F. (2019). Student assessment of the use of kahoot in the learning process of science and mathematics. *Educ. Sci*, *9*, 55. doi:10.3390/educsci9010055

Qian, M., & Clark, K. R. (2016). Game-based Learning and 21st-century skills: A review of recent research. *Comput. Hum. Behav*, *63*, 50–58. doi:10.1016/j.chb.2016.05.023

Rocha, B., & Nunes, C. (2020). Benefits and damages of the use of touchscreen devices for the development and behavior of children under 5 years old-a a systematic review. *Psicologia Reflexão e Critica*, *33*(1), 24. doi:10.1186/s41155-020-00163-8

Rosen, L. D., Lim, A. F., Felt, J., Carrier, L. M., Cheever, N. A., Lara-Ruiz, J. M., Rokkum, J. (2014). Media and technology use predicts ill-being among children, preteens, and teenagers independent of the negative health impacts of exercise and eating habits. *Computers in Human Behavior*, *35*, 364–375. doi:10.1016/j.chb.2014.01.036

Sá, C. D. S. C., Pombo, A., Luz, C., Rodrigues, L. P., & Cordovil, R. (2020). Covid-19 social isolation in Brazil: Effects on the physical activity routine of families with children. *Revista Paulista de Pediatria*, *39*, e2020159. doi:10.1590/1984-0462/2021/39/2020159

Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., , . . . Whitlock, E. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA) 2015: Elaboration and explanation. *BMJ (Online)*, *349* 9647 .

Simão, A. N. P., Lima, R. F., Natalin, J. C., & Ciasca, S. M. (2010). Comparison of student performance in instruments of attention and executive functions. *Revista Psicopedagogia*, *27*(83), 171–180.

Sugawara, M., Matsumoto, S., Murohashi, H., Sakai, A., & Isshiki, N. (2015). Trajectories of early television contact in Japan: Relationship with preschoolers' externalizing problems. *Journal of Children and Media*, *9*(4), 453–471. doi:10.1080/17482798.2015.1089298

Swing, E. L., Gentile, D. A., Anderson, C. A., & Walsh, D. A. (2010). Television and video game exposure and the development of attention problems. *Pediatrics*, *126*(2), 214–221. doi:10.1542/peds.2009-1508

Syväoja, H. J., Tammelin, T. H., Ahonen, T., Kankaanpää, A., & Kantomaa, M. T. (2014). The associations of objectively measured physical activity and sedentary time with cognitive functions in school-aged children. *PloS one*, *9*(7), e103559. doi:10.1371/journal.pone.0103559

Tamana, S. K., Ezeugwu, V., Chikuma, J., Lefebvre, D. L., Azad, M. B., Moraes, T. J., Mandhane, P. J. (2019). Screen-time is associated with inattention problems in preschoolers: results from the CHILD birth cohort study. *PloS one*, *14*(4), e0213995. doi:10.1371/journal.pone

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. 10.1080/17482798.2017.1365737

Thompson, R. A., & Nelson, C. A. (2001). Developmental science and the media. Early brain development. *The American Psychologist*, *56*(1), 5–15. doi:10.1037/0003-066x.56.1.5

Twait, E., Farah, R., Shamir, N., & Horowitz-Kraus, T. (2019). Dialogic reading vs screen exposure intervention is related to increased cognitive control in preschool-age children. *Acta Paediatrica (Oslo, Norway: 1992)*, *108*(11), 1993–2000. doi:10.1111/apa.14841

van der Heijden, K. B., Stoffelsen, R. J., Popma, A., & Swaab, H. (2018). Sleep, chronotype, and sleep hygiene in children with attention-deficit/hyperactivity disorder, autism spectrum disorder, and controls. *European Child & Adolescent Psychiatry*, *27*(1), 99–111. doi:10.1007/s00787-017-1025-8

World Health Organization. (2019). Guidelines on physical activity, sedentary behavior and sleep for children under 5 years of age. *World Health Organization* 20 09 2021, License: CC BY-NC-SA 3.0 IGO https://apps.who.int/iris/handle/10665/311664

Xie, G., Deng, Q., Cao, J., & Chang, Q. (2020). Digital screen time and its effect on preschoolers' behavior in China: Results from a cross-sectional study. *Italian Journal of Pediatrics*, *46*(1), 9. doi:10.1186/s13052-020-0776-x

Zivan, M., Bar, S., Jing, X., Hutton, J., Farah, R., & Horowitz-Kraus, T. (2019). Screen-exposure and altered brain activation related to attention in preschool children: An EEG study. *Trends in Neuroscience and Education*, *17*, 100117. doi:10.1016/j.tine.2019.100117