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Review

Effects of screen time on the development of children under 9 years old: a systematic review

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Abstract

Importance: This systematic review could serve as a comprehensive synthesis that would benefit parents, educators, therapists, policymakers, and researchers in identifying the advantages and disadvantages of screen time (ST) on key developmental outcomes of children, specifically socio-emotional functions (SEF), executive functions (EF), cognition, language, and motor skills.

Objectives: To comprehensively review the current state of literature to examine the association of the effects of ST on several developmental outcomes; to analyze the methodological quality of included studies to facilitate appraisal of evidence strength.

Methods: A systematic search across EBSCO, ScienceDirect, PubMed Central, and Scopus was accomplished to identify both peer-reviewed and gray literature that reported on the association between ST and varying developmental outcomes. A chronological restriction (studies published between January 2000 and March 2020) was implemented. Inclusion criteria were studies that had participants from 0 to 9 years old, measured duration of ST, explored the effects of any of the aforementioned outcomes, and were observational studies by design (i.e., cross-sectional, cohort, case-control). Meta-analysis was not done due to clinical heterogeneity.

Results: The narrative synthesis included 85 studies (from 16 countries) which had cross-sectional (n = 47), cohort (n = 36), and case-control (n = 2) designs. The majority of the studies had good (n = 16) to fair (n = 59) methodological quality. ST was generally associated with poorer SEF, EF, cognitive and motor development. Less than half of language studies supported the negative effect of ST. However, its positive effects were observed in certain conditions: (1) implementation of time limit on ST use, (2) parental co-viewing, and (3) exposure to educational content.

Conclusion and relevance: The findings support the reduction of ST in children and further substantiate the American Academy of Pediatrics recommendations. The results also highlight the roles of parents and caregivers

as it shows that digital media could be used as a tool to improve the development of children, given that certain conditions are met. Further research could be done on the positive effects of ST given the aforementioned conditions and the appropriate dosage of ST use.

Keywords

Screen time, development, children, socio-emotional functions, executive functions, cognition, language, motor skills.

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Introduction

Recently, there has been an explosion of technological devices, which has led to digital media becoming an essential part of everyday life and, among the populations that use these, children are one of the most frequent consumers [1-121]. The duration of digital media consumption or screen time (ST) has been observed to negatively affect socio-emotional functions (SEF) [3-9], executive functions (EF) [9-15], language acquisition [4, 16-18], cognition [11, 16-20], and motor skills [18, 21]. However, it has also been observed to have benefits depending on the content of the digital media [22-26] and the presence of an adult as a co-viewer and teacher [27, 28].

Previous systematic reviews tended to focus only on certain age groups [29], correlates [30], and select developmental outcomes [21, 25, 31-33]. No systematic review covered the effects of ST on a wide age range specific to the aforementioned developmental outcomes.

This review summarizes current literature examining the association of the effects of ST on several developmental outcomes. The researchers intend to analyze the methodological quality of several studies to facilitate appraisal of evidence strength. This research could serve as a comprehensive synthesis that would benefit parents, educators, therapists, policymakers, and researchers in identifying the advantages and disadvantages of ST on key developmental outcomes of children.

Methods

The systematic review was registered on PROSPERO (CRD42020172171; http://www.crd.york.ac.uk/prospero/) and reported using the PRISMA guidelines [34]. The COSMOS-E guideline was used to guide this systematic review [35].

EBSCO, ScienceDirect, PubMed Central, and Scopus were searched in March 2020. For studies to be included, these had to be written in English, peer-reviewed, and published from 2000 to March 2020. The ff. criteria had to be met as well: (a) population were children from 0 to 9 years old at baseline without diagnosed conditions, (b) duration and types of ST were reported, (c) associations between ST and aforementioned developmental outcomes were explored, and (d) design was observational (i.e., cross-sectional, cohort, case-control). Studies with mixed children and adolescents were excluded. Boolean terms were applied to the keywords (**Tab. 1**) as part of the search strategy.

Two reviewers searched the databases using the aforementioned search strategies (**Tab. 2**). Each unique study was then screened for review inclusion. Abstrackr [36], an online screening tool, was utilized to screen titles and abstracts, while an online spreadsheet was used to screen full-text articles. Any dispute during the screening process was settled through discussion and, when necessary, a third reviewer was involved.

Two reviewers independently extracted data from studies meeting the inclusion criteria on an online spreadsheet. Authors of the studies were contacted if more information was needed.

Table 1. Search strategy keywords.

1. "child*" OR "infant*" OR "preschool" OR "school-aged"
AND
2. "screen time" OR "computer*" OR "televis*" OR "tablet*" OR "mobile" OR "videogame*"
AND
3. "academic" OR "cognit*" OR "language" OR "vocabulary" OR "executive functions" OR "attention" OR "emotional" OR "socio-emotional" OR "motor" OR "developmental outcomes" OR "development"

Table 2. Search strategies.

Scopus
(TITLE-ABS-KEY (child) OR TITLE-ABS-KEY (“infant”) OR TITLE-ABS-KEY (“preschool”) OR TITLE-ABS-KEY (“school-aged”) AND TITLE-ABS-KEY (“screen time”) OR TITLE-ABS-KEY (“mobile phone”) OR TITLE-ABS-KEY (“video game”) OR TITLE-ABS-KEY (“television”) AND TITLE-ABS-KEY (“developmental outcomes”) OR TITLE-ABS-KEY (“development”) OR TITLE-ABS-KEY (“academic”) OR TITLE-ABS-KEY (“cognition”) OR TITLE-ABS-KEY (“language”) OR TITLE-ABS-KEY (“vocabulary”) OR TITLE-ABS-KEY (“executive functions”) OR TITLE-ABS-KEY (“emotional”) OR TITLE-ABS-KEY (“socio-emotional”) OR TITLE-ABS-KEY (“motor skills”)) AND PUBYEAR > 1999 AND PUBYEAR < 2021 AND (LIMIT-TO (DOCTYPE , “ar”) OR LIMIT-TO (DOCTYPE , “cp”) OR LIMIT-TO (DOCTYPE , “re”) OR LIMIT-TO (DOCTYPE , “cr”))

EBSCO
(child OR “preschool” OR “school-aged” OR “infant”) AND (“screen time” OR “television” OR “computer” OR “video game” OR “mobile phone”) AND (“language” OR “motor skills” OR “emotional” OR “socio-emotional” OR “development” OR “developmental outcomes” OR “executive functions”)

ScienceDirect Databases
(preschool OR “school-aged”) AND “screen time” AND (cognition OR language OR vocabulary OR “executive functions” OR attention OR emotional OR “socio-emotional” OR motor OR “developmental outcomes” OR development)

PubMed Central (Filters applied: Meta-Analysis, Observational Study, Systematic Review, Child: birth-18 years, English, from 2000/1/1 to 2020/3/14)
((((((((((((((((child) OR (“infant”)) OR (“preschool”)) OR (“school-aged”)) AND (“screen time”)) OR (“video game”)) OR (“computer”)) OR (“mobile phone”)) OR (“television”)) AND (“development”)) OR (“developmental outcomes”)) OR (“academic”)) OR (“cognition”)) OR (“language”)) OR (“vocabulary”)) OR (“motor skills”)) OR (“emotional”)) OR (“socio-emotional”)

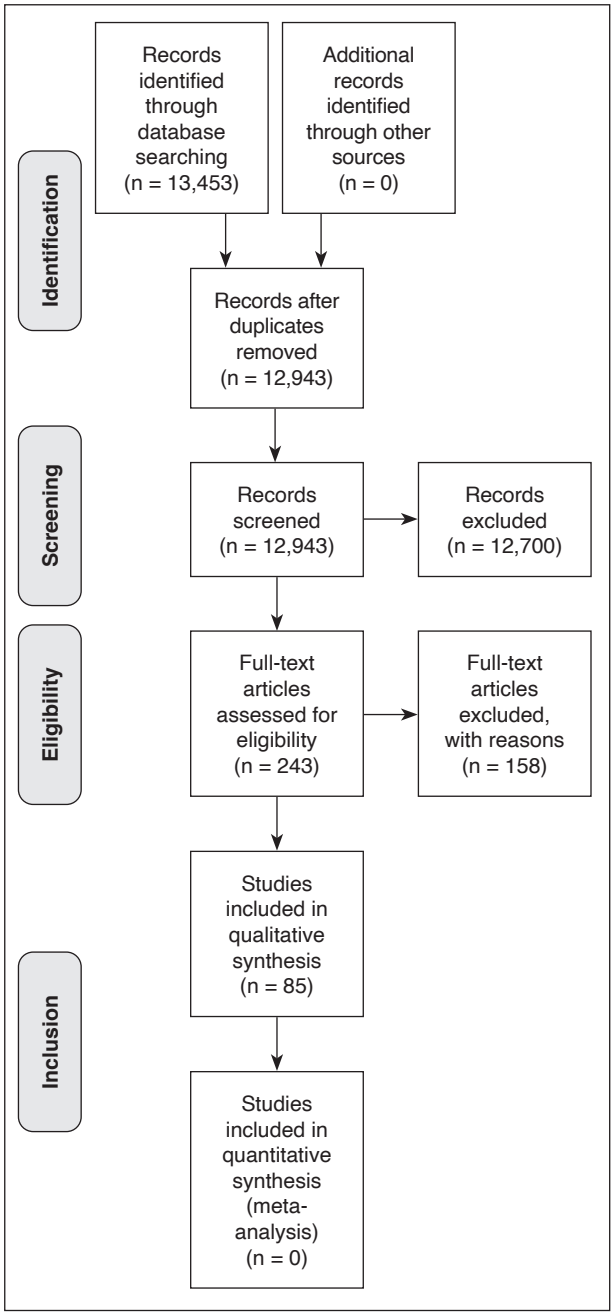

Figure 1. PRISMA 2009 Flow Diagram.
The PRISMA 2009 Flow Diagram is from: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med. 2009;6(6):e1000097. For more information, visit www.prisma-statement.org.

Included articles were also independently appraised by two reviewers for methodological quality and risk of bias using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies and the Quality Assessment of Case-Control Studies [37]. These tools were embedded in an online spreadsheet. Meta-analysis was not done due to clinical heterogeneity.

Results

Screening and inclusion

The overall search yielded 13,453 hits, with 510 of these being duplicates. Among the 12,943 unique studies, 243 passed title and abstract screening, and 85 passed full-text screening (**Fig. 1**, **Tab. 3**). Articles that passed full-text screening were observed to be from either EBSCO, ScienceDirect, or Scopus. Forty-seven (55.29%) of those that passed full-text screening were cross-sectional in nature, whereas 36 (42.35%) were cohort and 2 (2.35%) were case-control studies. Evidence was generally derived from academic journals from the fields of pediatrics, psychology, epidemiology, public health, nursing, occupational therapy, social science, and sports.

Table 3. Summary of included observational studies (continues on the next page).

Reference	Study design	Country	Population	Exposure	Outcome measure(s)	Developmental outcome(s)
Intusomaa, et al., 2013	Retrospective cohort	Thailand	4,157 children	Parent report on TV viewing duration	Modified Infant-Toddler Social and Emotional Assessment (MITSEA)	SEF
Mistry et al., 2007	Prospective cohort	USA	2,707 children Males = 49.00%	Parent report on TV viewing and presence of TV in the bedroom	Child Behavior Checklist (CBCL) and Social Skills Rating System	SEF and EF
McHarg et al., 2020	Prospective cohort	UK, USA, and Netherlands	416 children Males = 50.96%	Parent report on electronic screen-based exposure	Prohibition task, Three Boxes task and Ball Run task	EF
Mundy, 2017	Cross-sectional	Australia	976 children Males = 41.09%	Parent report on electronic media use	Strengths and Difficulties Questionnaire (SDQ)	SEF
Hu et al., 2020	Cross-sectional	China	558 children Males = 51.40%	ST assessed by a parent survey	Test of Children Mathematics Achievement (TCMA), Life Science Assessment (LiS), Earth and Physical Science Assessment (EPS) and Heads-Toes-Knees-Shoulders task (HTKS), Peabody Picture Vocabulary Test – Revised (PPVT-R) and Social Skills Improvement System – Rating Scales	Cognition and SEF
Schmidt et al., 2009	Prospective cohort	USA	1,579 mother-child pairs	Parent report on TV viewing	Peabody Picture Vocabulary Test – 3rd edition (PPVT-III) and Wide Range Assessment of Visual Motor Abilities (WRAVMA)	Cognitive and Visual-Motor skills
Jusiené et al., 2020	Cross-sectional	Lithuania	190 children Males = 44.21%	Parent report on screen media device use	Shape School task, Missing Scan task and Head and Feet task	EF
Lee and Carson, 2018	Cross-sectional	South Korea	1,774 children Males = 51.40%	Parent report on TV viewing and reading	Bayley Scales of Infant Development and Ages and Stages Questionnaire (ASQ)	SEF
Duch et al., 2013	Cross-sectional	USA	119 children Males = 38.10%	Parent report on ST use and duration	Ages & Stages Questionnaires – 3rd edition (ASQ-3)	Language
Hutton et al., 2020	Cross-sectional	USA	47 children Males = 43.00%	Screen Q survey to assess access to screens, frequency of use, content viewed, and interactivity or co-viewing	Expressive Vocabulary Test – 2nd edition (EVT-2), Comprehensive Test of Phonological Processing – 2nd edition (CTOPP-2) and Get Ready to Read! (GRTR)	Language
Nathanson et al., 2014	Cross-sectional	USA	107 preschooler-parent pairs	Parent report on TV viewing	Grass/Snow task, Whisper task, Backward Digit Span task and Tower task	EF
Li and Atkins, 2004	Cross-sectional	USA	122 children Males = 46.72%	Parent report on early computer experience	Bender Visual Motor Gestalt Test (Bender), The Boehm Test of Basic Concepts – 3rd edition – Preschool (Boehm-3 Preschool), Test of Gross Motor Development – 2nd edition (TGMD-2), Wechsler Preschool and Primary Scale of Intelligence – Revised (WPPSI-R)	Cognition and Gross Motor skills
del Pozo-Cruz et al., 2019	Retrospective cohort	Australia	4,164 children, B-cohort 3,974 children, K-cohort	Recorded child activities for all waking hours	Paediatric Quality of Life Inventory (PedsQL) and Strengths and Difficulties Questionnaire (SDQ)	SEF
Skaug et al., 2018	Prospective cohort	Norway	953 children	Parent report on TV viewing	Biringen's Emotional Availability (EA) Scales manual – 4th edition	SEF
Barnett et al., 2012	Cross-sectional	Australia	53 children	Parent report on engagement in computer games	Test of Gross Motor Development (TGMD-2)	Gross Motor skills
Ribner et al., 2017	Cross-sectional	USA	807 children	Parent report on TV viewing and duration	Woodcock-Johnson III Tests of Achievement, Dimensional Change Card Sort task (DCCS), Raven's Progressive Matrices test	EF

Table 3. Summary of included observational studies (continues from the previous page and on the next page).

Reference	Study design	Country	Population	Exposure	Outcome measure(s)	Developmental outcome(s)
Linebarger et al., 2014	Cross-sectional	USA	1,156 respondents	Parent report on their child's TV exposure, music, and book reading	Behavior Assessment System for Children (BASC-2)	EF
Castles et al., 2013	Cross-sectional	Australia	1,539 children Males = 50.62%	Parent report on TV viewing and computer use	Kaufman Brief Intelligence Test – 2nd edition, Clinical Evaluation of Language Fundamentals – Preschool – 2nd edition (CELF), Goldman Fristoe Test of Articulation and Sutherland Phonological Awareness Test	Cognition and Language
Parkes et al., 2013	Prospective cohort	UK	11,014 children Males = 51.10%	Parent report on TV viewing and electronic games playing	Strengths and Difficulties Questionnaire (SDQ)	SEF
Skalická et al., 2019	Prospective cohort	Norway	999 parents	Parent report on TV viewing and gaming	Test of Emotion Comprehension (TEC)	SEF
Hudon et al., 2013	Cross-sectional	Canada	85 children Males = 43.53%	Television Habits Questionnaire to assess a variety of television habits, ranging from frequency of hours watched per week to the type of TV programming	Communicative Development Inventory (CDI)	Language
Ruangdaraganon et al., 2009	Prospective cohort	Thailand	260 children	Parent report on TV viewing and duration	Clinical Linguistic Auditory Milestone Scale (CLAMS)	Language
Okuma et al., 2009	Cross-sectional	Japan	378 children	Parent report on TV viewing	Denver Developmental Screening Test (Denver-II)	Language
Xie et al., 2020	Cross-sectional	China	3,742 parent-child dyads	Parent report on ST	Child Behavior Checklist (CBCL)	SEF
Mendelsohn et al., 2010	Prospective cohort	USA	575 parent-child dyads	Parent report on ST	Preschool Language Scale – 4 (PLS-4)	Language
Pagani et al., 2013	Prospective cohort	Canada	1,999 children	Parent report on TV exposure	Peabody Picture Vocabulary Test (PPVT), Number Knowledge Test, Test of gross motor development, Classroom engagement (teacher rating) and Social Behavior Questionnaire	Cognition, Language, SEF and Motor skills
Swing et al., 2010	Prospective cohort	USA	1,323 children	Parent report on TV and video game exposure Self-report on TV and video game exposure were completed (late adolescent/early adult sample)	Adult ADHD Self-Report Scale (ASRS), Brief Self-Control Scale (BSCS), and Barratt Impulsiveness Scale (BIS)	EF
Guxens et al., 2019	Cross-sectional	Netherlands	3,102 children	Residential presence of RF-EMF indoor sources Parent report on mobile phone, cordless phone calls and ST exposure	Strengths and Difficulties Questionnaire (SDQ)	SEF
Madigan et al., 2019	Prospective cohort	Canada	2,441 respondents	Parent report on electronic media use	Ages and Stages Questionnaire – 3rd edition (ASQ-3)	SEF, Gross/Fine Motor skills, Language and EF

Table 3. Summary of included observational studies (continues from the previous page and on the next page).

Reference	Study design	Country	Population	Exposure	Outcome measure(s)	Developmental outcome(s)
Wu et al., 2017	Cross-sectional	China	8,900 children Males = 52.92%	Parent report on ST	Strengths and Difficulties Questionnaire (SDQ) and Clancy Autism Behaviour Scale (CABS)	SEF
Tomopoulos et al., 2010	Prospective cohort	USA	259 parent-child dyads	Parent report on electronic media exposure	Bayley Scales of Infant and Toddler Development – 3rd edition (Bayley-III) and Preschool Language Scale – 4 (PLS-4)	Cognitive and Language
Zimmerman et al., 2007	Cross-sectional	USA	384 children	Parent report on general time use	Child's normed score on the short-form Communicative Development Inventory (CDI)	Language
Nayena et al., 2015	Prospective cohort	USA	263 children	Parent report on TV viewing	Peabody Picture Vocabulary Test – 3rd edition (PPVT-III) and Animal Stroop task (Stroop) and Kaufman Assessment Battery for Children (K-ABC)	Language and EF
Cheng et al., 2010	Prospective cohort	Japan	302 children Males = 50.66%	Parent report on TV viewing	Strengths and Difficulties Questionnaire (SDQ)	SEF
Griffiths et al., 2010	Cross-sectional analysis of cohort	UK	13,470 children Males = 51.10%	Parent report on electronic media use	Strengths and Difficulties Questionnaire (SDQ)	SEF
Carson et al., 2019	Prospective cohort	Canada	251 parent-child dyads	Accelerometers to assess sedentary time and physical activity. Parent report on ST use	Adaptive Social Behavior Inventory (ASBI)	SEF
Séguin and Klimek, 2016	Cross-sectional	Canada	52 children Males = 51.92%	Parent report on electronic media use	Preschool Behavior Questionnaire (PBQ)	SEF
Taylor et al., 2018	Cross-sectional	UK	131 children Males = 46.56%	Parent report on media exposure	UK Communicative Development Inventory (UK-CDI) and UK Communicative Development Inventory Toddlers	Language
Radesky et al., 2014	Retrospective cohort	USA	7,450 children Males = 51.10%	Parent report on TV viewing	Infant Toddler Symptom Checklist (ITSC)	SEF and EF
Conners-Burrow et al., 2011	Cross-sectional	USA	95 children	Parent report on TV exposure, TV and video viewing	Head Start Family and Child Experiences Survey (FACES 2000)	SEF
Cadoret et al., 2016	Retrospective cohort	Canada	113 children Males = 45%	Parent report on electronic media use	Bruininks-Oseretsky Test of Motor Proficiency – 2nd edition (BOTMP)	Motor skills
Stevens and Mulsow, 2006	Cross-sectional	USA	2,500 children	Parent report on TV and video viewing	Social Skills Rating Scale	EF and SEF
Przybylski and Weinstein, 2019	Cross-sectional	USA	19,957 children Males = 50%	Parent report on electronic media use	Questionnaire drafted by Developmental Specialists	SEF
Linebarger and Walker, 2005	Prospective cohort	USA	51 children Males = 45.10%	Parent report on TV viewing	Bayley Scale of Infant Development and MacArthur Communicative Development Inventory	Language
Poulain et al., 2019	Cross-sectional	Germany	553 children Males = 55%	Parent report on personal and child's electronic media use	Strength and Difficulties Questionnaire (SDQ)	SEF and EF
Özmert et al., 2002	Cross-sectional	Turkey	689 children Males = 49.78%	Parent report on TV viewing and habits	Child Behavior Checklist	Cognition and SEF
Byeon and Hong, 2015	Cross-sectional	South Korea	1,778 children	Parent report on TV viewing	Korean – Ages and Stages Questionnaire (K-ASQ)	Language

Table 3. Summary of included observational studies (continues from the previous page and on the next page).

Reference	Study design	Country	Population	Exposure	Outcome measure(s)	Developmental outcome(s)
Nathanson and Fries, 2014	Cross-sectional	USA	107 children Males = 50.50%	Parent report on TV viewing	Theory of Mind Measures, Grass/Snow task, Whisper task and Backward Digit Span task	Cognition and EF
Alloway et al., 2013	Cross-sectional	UK (Britain)	30 children Males = 57%	Parent report on TV and video viewing	Picture Vocabulary Scale, Digit Recall and Dot Matrix – Short	Language and EF
Stenseng et al., 2020	Prospective cohort	Norway	699 children	Parent report on video gaming	Preschool Age Psychiatric Assessment/Child and Adolescent Psychiatric Assessment	EF and SEF
Choi and Park, 2020	Cross-sectional	South Korea	1,031 children Males = 50.8%	Parent report on electronic media use	Scale developed by Song (2014) and scale developed by the Korean Institute of Child Care and Education (2015)	SEF, Cognition and Language
Hinkley et al., 2016	Prospective cohort	Australia	567 children Males = 53%	Parent report on electronic media use	Emotional Quotient Inventory – Youth Version (EQi-YV)	SEF
Yang et al., 2017	Cross-sectional	China	119 children Males = 49%	Parent report on TV viewing	Backward Digit Span task, Boy-Girl Stroop task, and Tower of Hanoi task	EF
Raman et al., 2017	Cross-sectional	USA	210 children Males = 51%	Parent report on ST	Ages and Stages Questionnaire	SEF
Dadson et al., 2020	Cross-sectional	Australia	25 children Males = 36%	Parent report on ST	The Test of In-Hand Manipulation-Revised (TIHM-R), Bruininks-Oseretsky Test of Motor Proficiency – 2nd edition (BOT-2), and Beery Buktenica Developmental Test of Visual-Motor Integration – 6th edition (Beery VMI)	Motor skills
Foster and Watkins, 2010	Retrospective cohort	USA	1,159 children	Parent report on TV viewing	Behavior Problems Index	EF
Poulain et al., 2018	Prospective cohort	Germany	527 children Males = 51.61%	Parent report on electronic media use	Strengths and Difficulties Questionnaire (SDQ)	SEF and EF
Patterson, 2002	Cross-sectional	USA	64 children Males = 50%	Parent report on TV viewing	Spanish-English Vocabulary Checklist (SEVC)	Language
Hosokawa and Katsura, 2018	Cross-sectional	Japan	1,642 children Males = 51.22%	Parent report on mobile phone use	Strengths and Difficulties Questionnaire (SDQ)	SEF and EF
Ferguson and Donnellan, 2014	Cross-sectional	USA	392 children	Parent report on media exposure	Communicative Development Inventory	Language
Zimmerman and Christakis, 2005	Retrospective cohort	USA	1,797 children	Parent report on TV viewing	Peabody Individual Achievement Test (PIAT), Memory for Digit Span assessment from the Wechsler Intelligence Scale for Children	Cognition
Mills, 2015	Cross-sectional	USA	9,777 children	Parent report on TV viewing	The dependent variable in this study was operationalized with third grade theta reading scores	Cognition and Language
Tamana et al., 2019	Retrospective cohort	Canada	3,455 children	Parent report on total ST	Child Behavior Checklist	SEF and EF

Table 3. Summary of included observational studies (continues from the previous page and on the next page).

Reference	Study design	Country	Population	Exposure	Outcome measure(s)	Developmental outcome(s)
Hu et al., 2020	Cross-sectional	China	579 children Males = 50.26%	Parent report on active and passive ST	Peabody Picture Vocabulary Test – Revised (PPVT-R), Test of Children Mathematics Achievement, Life Science Assessment (LiS) and Earth and Physical Science Assessment, Head-Toes-Knees-Shoulders (HTKS) task and Social Skills Improvement System – Rating Scales	Cognition, Language, EF and SEF
Chonchaiya et al., 2015	Prospective cohort	Thailand	194 children Males = 50.5%	Parent report on TV exposure	Child Behaviour Checklist, Infant Temperament Questionnaire	SEF
Hinkley et al., 2018	Cross-sectional	Australia	575 children Males = 54%	Parent report on 1. television/DVD/ video viewing, 2. computer/electronic game/hand held device use, and 3. outdoor play time	Adaptive Social Behaviour Inventory	SEF
Divan et al., 2008	Cross-sectional	Denmark	13,159 children	Cell phone use among children, as well as among mothers during pregnancy	Strengths and Difficulties Questionnaire (SDQ)	SEF and EF
Fitzpatrick et al., 2012	Retrospective cohort	Canada	1,786 children	Parents report on TV and film viewing with "lots of violence in them"	Social Behavior Questionnaire	SEF, EF and Cognition
Huang and Lee, 2009	Retrospective cohort	USA	2,770 children Males = 50%	Parent report on TV viewing	Basic Personality Inventory (BPI)	SEF
Wright et al., 2001	Prospective cohort	USA	236 children	Parent report on TV viewing	Woodcock-Johnson Tests of Achievement, Peabody Picture Vocabulary Test – Revised (PPVT-R) and School Readiness Scale of the Bracken Basic Concepts Scales	Cognition and Language
Allen et al., 2015	Retrospective cohort	Australia	3,956 children Males = 51.5%	Parent report on TV viewing and electronic games playing	School-aged Temperament Inventory	SEF
Twenge and Campbell, 2018	Cross-sectional	USA	40,337 children Males = 49.8%	Parent report on electronic media exposure	National Survey of Children's Health (NSCH)	SEF
Kühhirt and Klein, 2020	Retrospective cohort	UK (Scotland)	2,678 children	Parent report on TV viewing	Strengths and Difficulties Questionnaire (SDQ) and naming vocabulary	SEF, EF and Language
Cliff et al., 2018	Retrospective cohort	Australia	4,606 children	Parent report on ST	Survey items (Moffitt et al.)	SEF
Lin et al., 2014	Cross-sectional	Taiwan	150 children Males = 62.1%	Parent report on media use and exposure	Bayley Scales of Infant Development – 2nd edition (BSID-II) and Peabody Developmental Motor Scales – 2nd edition (PDMS-2)	Cognition, Language and Motor skills
Lee et al., 2017	Cross-sectional	South Korea	1,890 children Males = 51.1%	Parent report on TV viewing and reading	Denver Developmental Screening Test – II, Early Lab, Bayley's Scales of Development, MacArthur-Bates Communicative Development Inventories – Korean, Ages and Stages Questionnaire, Vineland Adaptive Behaviour Scales and Wechsler Preschool and Primary Scale of Intelligence (WPPSI)	Cognition and Language

Table 3. Summary of included observational studies (continues from the previous page).

Reference	Study design	Country	Population	Exposure	Outcome measure(s)	Developmental outcome(s)
López-Vicente et al., 2017	Prospective cohort	Spain	1,400 children Males = 50.79%	Parent report on TV viewing	Computerized n-back task	EF
Lin et al., 2020	Cross-sectional	Taiwan	161 children Males = 53.41%	Parent report on screen device use	Child Behavior Checklist for Ages and Communication and Language Screening Test	SEF, EF and Language
Webster et al., 2018	Cross-sectional	USA	126 children Males = 46.03%	Parent report on TV and video viewing	Test of Gross Motor Development – 3rd edition (TGMD-3), Movement Assessment Battery for Children – 2nd edition (MABC-2)	Motor skills
Carson et al., 2017	Cross-sectional	Canada	100 children Males = 47%	Parent report on ST	Nebraska Barnyard task, Fish-Shark Go/No-Go task and Peabody Picture Vocabulary Test 4th edition (PPVT-4)	EF and Language
Allen and Vella, 2015	Retrospective cohort	Australia	3,956 children, B cohort Females = 48.5% 3,862 children, K cohort Females = 48.9%	Parent report on TV viewing and electronic games playing	Strengths and Difficulties Questionnaire (SDQ)	SEF and EF
McNeill et al., 2019	Prospective cohort	Australia	185 children Males = 60.54%	Parents report on electronic media behaviors	Early Years Toolbox and Strengths and Difficulties Questionnaire (SDQ)	EF
Zhao et al., 2018	Cross-sectional	China	20,234 children Males = 52.7%	Parent report on ST	Strengths and Difficulties Questionnaire (SDQ)	SEF and EF
Chonchaiya and Pruksananonda, 2008	Case-control	Thailand	56 children, case group 110 children, control group	Parent report on TV viewing and home environment	Denver Developmental Screening Test (Denver-II)	Language
Collet et al., 2019	Case-control	France	167 children, case group Males = 70.7% 109 children, control group Males = 50.5%	Parent report on ST	Parental questionnaires	Language

EF: executive functions; SEF: socio-emotional functions; ST: screen time.

Location

Countries in which the studies were conducted included the USA (n = 30), Australia (n = 11), Canada (n = 9), China (n = 6), the UK (n = 6), Thailand (n = 4), South Korea (n = 4), Japan (n = 3), Norway (n = 3), the Netherlands (n = 2), Germany (n = 2), Taiwan (n = 2), Denmark (n = 1), Lithuania (n = 1), Spain (n = 1), Turkey (n = 1), and France (n = 1).

Risk of bias

Articles that were included in the review were assessed for risk of bias using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies and the Quality Assessment of Case-Control Studies [37]; 18.82% (n = 16) was found to be of good quality rating, 69.41% (n = 59) was fair, and 11.76% (n = 10) was poor.

Associations between screen time and socio-emotional functioning

Among the developmental outcomes studied, 44 examined the association of ST and SEF. Of these studies, 13, 24, and 7 were of good, fair, and poor methodological quality, respectively.

Common outcome measures used to assess SEF included Strengths and Difficulties Questionnaire and Child Behavior Checklist. There were varying associations between ST and SEF. However, most studies (n = 35; **Fig. 2**) found that excessive ST had a detrimental effect on a child's SEF, including but not limited to their social skills [15], emotions [38], prosocial behavior [6], emotional understanding [39], conduct [40], self-regulation [41], and psychological well-being [42]. Some studies (n = 6) claimed that ST is not associated with SEF at all, specifically social skills [9], child responsiveness [43], mental health [44, 45], and emotional and behavioral problems [46]. Few studies determined the positive effects of ST in relation to emotional skills [47], positive affect and caregiver attachment [48], and intrapersonal and stress management skills [8]. Lastly, 1 study found that sedentary electronic games were beneficial to intrapersonal skills and total emotional quotient while computer and internet use was detrimental to interpersonal skills [8].

Associations between screen time and executive functions

Thirty studies investigated the correlation between ST and EF. Among these, 4, 24, and 2 studies were classified as having good, fair, and poor methodological quality, respectively. Frequently used EF measures included grass/snow task, whisper task, and backward digit span task. Majority of the studies (n = 19) found that increased screen exposure was correlated with problems in inhibition [49], attention [18, 40, 50-56], and self-regulation [27]. Some studies (n = 9) demonstrated no association between ST and EF. Yang et al. [57] and Linebarger et al. [58] reported that child-directed education programs had a positive association with EF. Conversely, background TV was seen as a deterrent to EF development [58].

Associations between screen time and language

Twenty-nine articles explored the association between ST and language. Among these, 27 were cross-sectional in nature, while 2 were case-control studies. For their methodological quality, 3, 24, and 2 had good, fair, and poor ratings, respectively. Frequently used language tests included Communicative Development Inventory, Peabody Picture Vocabulary Test – Revised, Clinical Evaluation of Language Fundamentals – Preschool, Clinical Linguistic Auditory Milestone Scale, and Preschool Language Scale. Less than half of the studies (n = 13) observed that increased ST was associated

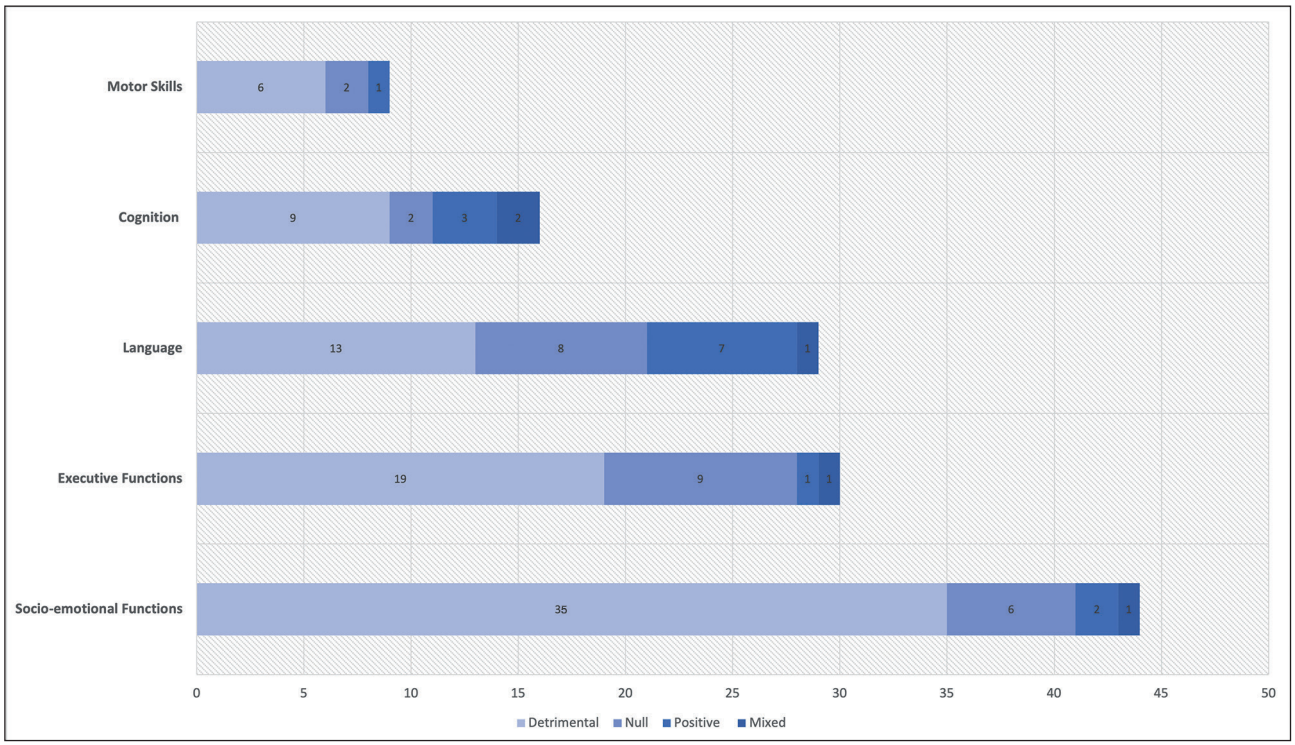

Figure 2. Types of associations between screen time (ST) and different developmental outcomes.

with poorer language development, including communication [59] and vocabulary [47, 60]. According to both case-control studies, children with greater media exposure were 6 times more likely to develop language delays or disorders [61, 62]. Eight studies found that ST had no significant correlation to language and vocabulary at all. Seven studies discovered that ST may be beneficial for language as long as caregivers were involved [63, 64], educational programs were consumed [65, 66], active ST was engaged in [67], or children were language minority students [68]. In addition, 1 study reported that the effects of media exposure on language performance depend on the content viewed [69]. Engagement in child-audience informative programs predicted higher performance in vocabulary tests, while general-audience programs had the opposite effect.

Associations between screen time and cognition

Sixteen studies analyzed the association between ST and cognition. Among these studies, 3, 10, and 3 were seen to have good, fair, and poor methodological quality, respectively. Outcome measures usually utilized included Wechsler Preschool and Primary Scale of Intelligence – Revised, Kaufman Brief Intelligence Test, Bayley Scales of Infant and Toddler Development, and Peabody Individual Achievement Test. More than half of the studies (n = 9) found that ST had a negative correlation with cognitive development, such as in math skills [21, 67] and school achievement [54, 70, 71]. Two studies posited that television viewing [72] and early computer exposure [73] had no effect on children's cognitive outcomes. Some studies proposed the benefits of media exposure in terms of reading achievement [68] and letter knowledge [74]. Participating in television viewing with caregivers was associated with higher cognitive development as well [63]. Lastly, 2 cognition studies had mixed results. Similar to ST and language association, child educational programs were seen to predict higher academic achievement than general-audience programs [69]. Another study differentiated the effects of passive and active ST on cognition. The researchers found that passive ST was negatively associated with math skills, while active ST was positively associated with science knowledge [67]. This study attributes the detrimental effect of passive ST to the time being spent in an inactive and dull activity (e.g., TV viewing), instead of active learning.

Associations between screen time and motor skills

Nine studies were seen to have measured the association between ST and motor skills. Of these, 2, 6, and 1 were categorized as having good, fair, and poor methodological quality, respectively. Commonly utilized outcome measures quantifying motor skills included Test of Gross Motor Development, Movement Assessment Battery for Children, the Test of In-Hand Manipulation-Revised, Bruininks-Oseretsky Test of Motor Proficiency, and Beery Buktenica Developmental Test of Visual-Motor Integration. Two-thirds of the studies (n = 6) found that greater ST was associated with poorer performance in gross motor skills [21], motor proficiency [75], visual-motor integration, and bilateral coordination [76]. Less than a third of the studies (n = 2) found no association between ST and visual-motor skill development [72, 73]. Lastly, 1 study found that children who spent more time playing interactive electronic games were more adept in terms of object control skills [77].

Discussion

This systematic review mainly synthesizes an abundance of evidence that supports the negative correlation between ST and all aforementioned outcomes, except for language development which had less than half of its included studies supporting this claim. All outcome types had studies that reported favorable, null, and mixed associations with ST as well (apart from motor skills outcomes, for which there were no studies reporting mixed associations).

Time-displacement

Among the cited theories for ST's negative effects, time-displacement was the most popular. In this theory, it is posited that excessive engagement in digital media consumption replaces time that could have otherwise been spent on more developmentally enriching activities [78]. A case-control study found that infants who spent > 2 hours per day watching TV were 6 times more likely to develop language delays [61]. The study credits this phenomenon to the infant's lack of engagement in more beneficial activities, such as play and social interaction. In another research, even background TV exposure is cited as a possible factor that could interfere with children's interactions with toys and family members [79]. Hence, this could disrupt the process of language development as this is

supported by early interactions with caregivers [61]. These studies show the limited and schedule-driven nature of time wherein engagement in one activity could lead to less time for another.

Time limit

In general, studies included in the review reported that more than 2-3 hours of ST per day could be detrimental to children across varying age groups. It was suggested to be harmful for their SEF [6, 15, 53], EF [15, 27, 80], and language [15, 61]. Other studies proposed that > 1 hour of media exposure is already significantly linked with poorer cognitive development for infants [17] and lower psychological well-being [41], conduct problems, hyperactivity, and inattention [39] for children above 2 years old. These findings are in line with the American Academy of Pediatrics (AAP) recommendations wherein children under 2 are recommended not to spend any ST on devices, while those over 2 should be limited to 1-2 hours per day. However, a cross-sectional study posits that instead of counting the hours spent on screen exposure per day, the number of daily activities with a screen are considered [81]. Children who had > 5 daily routines occurring with an active screen were 5.8 times more likely to experience socio-emotional delay compared to children with < 5 routines taking place with a screen [81]. This is supported by another study wherein children who were (a) exposed to digital media in the morning before school and (b) had the contents of these media rarely discussed by their parents were 6 times more likely to develop language disorders than children who did not have these 2 features [62].

Social and physical environment

Co-viewing digital content and placing limits on ST are among the recommended practices by experts [82] and researchers [63, 67]. In a study with toddlers and preschool children, it was found that children who frequently participated in TV viewing with their caregivers had improved cognition and language [63]. Furthermore, children whose parents enforced restrictions on their viewing time had positive associations with social skills development [67]. Meanwhile, a neglectful parenting style was seen as the strongest risk factor associated with language delay due to the lack of interaction between child and caregiver [61]. The findings of this review highlight the role of parents and caregivers as potential mediators for several developmental outcomes in relation to ST. However, the role of the physical environment in a child's development must be looked at as well. For example, the presence of a bedroom TV was related to heavier TV exposure, and this may possibly result in (a) parents having less control over the amount of TV a child watches and (b) more solitary viewing, which causes fewer interactions [39].

Content

In addition to how children are exposed to digital media (i.e., environment), the content they are exposed to is also seen as an important variable. In children between 2 and 3 years old, those who frequently viewed educational programs were seen to have better academic performance than those who frequently viewed general-audience programs instead [69]. The study attributes this effect to the comprehensible and appealing presentation of educational content based on research and curriculum development, unlike most entertainment programs. In addition, educational programs were also noted to be beneficial for expressive language [83] and EF [57]. However, a systematic review suggests that only young children may benefit from these types of programs as they primarily learn from repetitions, which is inherent to these programs [22]. In contrast, cartoons and violent TV content were suggested to have null or negative associations with child development, respectively. In a cross-sectional study, cartoons were observed to have no benefits for children's vocabulary skills [84]. This effect was attributed to the content and pacing of these programs as high rates of action and loud sound effects present in cartoons may cause levels of arousal incompatible with learning [85]. Violent TV viewing was associated with distractibility, inattention, and negative affect symptoms [54]. This type of content was suggested to have predisposed children towards developing feelings of anxiety, trauma, and depression [86].

Limitations

More than half of the studies had cross-sectional designs, which means that findings should be interpreted with caution as causation may be more difficult to interpret compared to prospective studies. Most studies also primarily relied on parent and caregiver reports to measure

the ST of children. Hence, irregularities (e.g., overestimation, underestimation) may have occurred during their data collection. Further, results that had mixed data with children above 9 years old were excluded from the review. Thus, the findings presented in the review are an incomplete snapshot of current literature.

Although literature was collected from 17 countries across 4 continents, the majority of the studies included came from the West. Thus, cultural differences from other parts of the world that affect ST and child development may not have been accounted for. In addition, not all studies considered confounding variables.

Future studies could focus on the positive effects of ST as there is already an abundance of research on the harmful effects of these conditions on child development. There is also a need for additional research that looks into the appropriate dosage of ST use by children.

Conclusion

Although ST is generally associated with poorer SEF, EF, language, cognitive, and motor development, its positive effects were observed in certain conditions: (1) implementation of time limit on ST use, (2) parental co-viewing, and (3) exposure to educational content. Hence, the findings support the reduction of ST in children and further substantiate the AAP recommendations. The results also highlight the role of parents and caregivers in the ST use of children as it shows that digital media could be used as a tool to improve the development of children as long as the aforementioned conditions are properly regulated.

Declaration of interest

The Authors have no conflicts of interest or financial ties to disclose regarding this research.

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