JAMA Pediatrics | Original Investigation

Association Between Screen Time and Children's Performance on a Developmental Screening Test

Sheri Madigan, PhD; Dillon Browne, PhD; Nicole Racine, PhD; Camille Mori, BA; Suzanne Tough, PhD

IMPORTANCE Excessive screen time is associated with delays in development; however, it is unclear if greater screen time predicts lower performance scores on developmental screening tests or if children with poor developmental performance receive added screen time as a way to modulate challenging behavior.

OBJECTIVE To assess the directional association between screen time and child development in a population of mothers and children.

DESIGN, SETTING, AND PARTICIPANTS This longitudinal cohort study used a 3-wave, cross-lagged panel model in 2441 mothers and children in Calgary, Alberta, Canada, drawn from the All Our Families study. Data were available when children were aged 24, 36, and 60 months. Data were collected between October 20, 2011, and October 6, 2016. Statistical analyses were conducted from July 31 to November 15, 2018.

EXPOSURES Media.

MAIN OUTCOMES AND MEASURES At age 24, 36, and 60 months, children's screen-time behavior (total hours per week) and developmental outcomes (Ages and Stages Questionnaire, Third Edition) were assessed via maternal report.

RESULTS Of the 2441 children included in the analysis, 1227 (50.2%) were boys. A random-intercepts, cross-lagged panel model revealed that higher levels of screen time at 24 and 36 months were significantly associated with poorer performance on developmental screening tests at 36 months (β, −0.06; 95% CI, −0.10 to −0.01) and 60 months (β, −0.08; 95% CI, −0.13 to −0.02), respectively. These within-person (time-varying) associations statistically controlled for between-person (stable) differences.

CONCLUSIONS AND RELEVANCE The results of this study support the directional association between screen time and child development. Recommendations include encouraging family media plans, as well as managing screen time, to offset the potential consequences of excess use.

JAMA Pediatr. 2019;173(3):244-250. doi:10.1001/jamapediatrics.2018.5056
Published online January 28, 2019. Corrected on March 25, 2019.

Supplemental content

Author Affiliations: Department of Psychology, University of Calgary, Calgary, Alberta, Canada (Madigan, Racine, Mori); Department of Paediatrics, Alberta Children's Hospital Research Institute, Calgary, Alberta, Canada (Madigan, Racine, Mori, Tough); Department of Psychology, University of Waterloo, Waterloo, Ontario, Canada (Browne).

Corresponding Author: Sheri Madigan, PhD, Department of Psychology, University of Calgary, 2500 University Ave, Calgary, AB T2N 1N4, Canada (sheri.madigan@ucalgary.ca).

By school entry, 1 in 4 children shows deficits and delays in developmental outcomes such as language, communication, motor skills, and/or socioemotional health.[1,2] Thus, many children are beginning school inadequately prepared for learning and academic success. Gaps in development tend to widen vs shrink over time without intervention,[3] creating a burden on education and health systems in the form of greater government and public expenditures for remediation and special education.[4,5] Consequently, there have been efforts to identify factors, including children's screen time,[6] that may create or exacerbate disparities in early child development.

Digital media and screens are now ubiquitous in the lives of children. Approximately 98% of US children aged 0 to 8 years live in a home with an internet-connected device and, on average, spend over 2 hours a day on screens.[7] This amount exceeds the recommended pediatric guideline that children spend no more than 1 hour per day viewing high-quality programming.[8,9] Although some benefits of high-quality and interactive screen time have been identified,[10-13] excessive screen time has been associated with a number of deleterious physical, behavioral, and cognitive outcomes.[14-21] While it is possible that screen time interferes with opportunities for learning and growth, it is also possible that children with delays receive more screen time to help modulate challenging behaviors. For example, toddlers who struggle with self-regulation have been shown to receive more screen time than those without difficulties.[22] However, most studies have used cross-sectional methods, limiting conclusions regarding the directionality of associations.

Greater clarity on the directionality of associations may be informative for pediatricians and other health care practitioners seeking to guide parents on developmentally appropriate screen exposure as well as the potential consequences of excessive screen use. Using a 3-wave, random-intercepts, cross-lagged panel model including 2441 children followed up at age 24, 36, and 60 months, we investigated whether higher screen time affects performance on developmental screening tests and whether children with lower scores on those tests received more screen time.

Key Points

Question Is increased screen time associated with poor performance on children's developmental screening tests?

Findings In this cohort study of early childhood development in 2441 mothers and children, higher levels of screen time in children aged 24 and 36 months were associated with poor performance on a screening measure assessing children's achievement of development milestones at 36 and 60 months, respectively. The obverse association (ie, poor developmental performance to increased screen time) was not observed.

Meaning Excessive screen time can impinge on children's ability to develop optimally; it is recommended that pediatricians and health care practitioners guide parents on appropriate amounts of screen exposure and discuss potential consequences of excessive screen use.

Methods

Study Design and Population

Participants included mothers and children from the All Our Families study, a large, prospective pregnancy cohort of 3388 mothers and children from Calgary, Alberta, Canada.[23,24] In this cohort, pregnant women were recruited between May 13, 2008, and December 13, 2010, through local primary health care offices, community advertising, and the local blood laboratory service. Inclusion criteria for the study were (1) age 18 years or older, (2) able to communicate in English, (3) gestational age less than 24 weeks, and (4) receiving local prenatal care. Mothers were followed up at 34 to 36 weeks' gestation and when their child was aged 4, 12, 24, 36, and 60 months. The 24-, 36-, and 60-month points were used in the present study when screen time variables were collected. Demographics and study characteristics can be found in **Table 1**, with further details reported elsewhere.[23,24] All procedures were approved by the University of Calgary Conjoint Health Research Ethics Board, Calgary, Alberta, Canada. Mothers provided written informed consent; there was no financial compensation.

Measures

Developmental Screener

When the children were 24, 36, and 60 months, mothers completed the Ages and Stages Questionnaire, Third Edition (ASQ-3).[25] The ASQ-3 is a widely used, parent-reported screening measure.[26,27] The ASQ-3 identifies developmental progress in 5 domains: communication, gross motor, fine motor, problem solving, and personal-social. The questionnaire includes 30 items scored as yes, sometimes, or not yet on questions asking about a child's ability to perform a task.

Consistent with previous research,[28] a summed ASQ-3 score across all domains was used (higher scores indicate better development). The concurrent validity of the ASQ-3 with standardized testing of developmental (Bayley Scales of Infant Development[29]) and intellectual (Stanford-Binet Intelligence Test–4th Edition[30]) skills have been demonstrated.[31] The ASQ-3 has been recommended for pediatric screening and has good psychometric properties.[32] The ASQ-3 has moderate to high sensitivity (0.70-0.90) and specificity (0.76-0.91). Test-retest reliability is high (0.94-0.95) as is interrater reliabilities between parents and professionals (0.94-0.95).[31,33,34]

Screen Time

Mothers indicated the range of time their child spent using particular electronic mediums on a typical weekday and weekend day. Mothers reported on the following devices and/or mediums: watch television programs; watch movies, videos, or stories on a VCR or DVD player; use a computer, gaming system, or other screen-based devices. A weighted weekly average of weekday and weekend screen time across mediums was calculated to yield screen time use in hours/week.

Covariates

Child sex was coded as female (1) or male (0), and maternal and child age were recorded in years and months, respectively. When the child was 12 months, mothers indicated whether they "look at or read children's books to my child," coded as not very often (1), sometimes (2), or often (3). When the child was 24 months, mothers indicated the amount of time that the child engaged in physical activity on a typical weekday, ranging from none (1) to 7 hours or more (7), and completed the Center for Epidemiologic Depression Scale.[35] When the child was 36 months, maternal educational level was collected using a scale of 1 (some elementary or high school) to 6 (completed graduate school), income was reported in increments of $10 000 CAD (1, ≤10 000 CAD$; 11, ≥$100 000 CAD$), maternal positive interactions were assessed using the National Longitudinal Survey of Children and Youth Parenting Scales,[36] and the number of hours of sleep the child receives in a typical 24-hour period was recorded. At 60 months, mothers responded to "Has your child been in nonparental childcare or daycare on a regular basis before this year?" as either no (0) or yes (1).

Statistical Analysis

The longitudinal associations between child hours of screen time and developmental outcomes were examined using a random-intercepts, cross-lagged panel model (RI-CLPM), as defined by Hamaker and colleagues[37] (**Figure**). Compared with the standard CLPMs, the RI-CLPM addresses problems associated with residual confounding by statistically isolating the

Table 1. Sample Demographics and Study Characteristics

Characteristic	Value
Maternal race/ethnicity, No. (%)	
White	2636 (77.8)
Black/African North American	50 (1.5)
Indigenous	32 (0.1)
Asian	293 (8.6)
Latin American	79 (2.3)
Mixed/other	263 (7.8)
Missing	35 (1.0)
Marital status, No. (%)	
Single	45 (1.3)
Single with partner	125 (3.7)
Married	2777 (82.0)
Common law	388 (11.5)
Divorced	9 (0.3)
Separated	9 (0.3)
Missing	35 (1.0)
Maternal educational level at T1, No. (%)	
Some elementary school or high school	119 (3.5)
Graduated high school	248 (7.3)
Some college or university	479 (14.1)
Graduated college or university	1980 (58.4)
Some graduate school	90 (2.7)
Completed graduate school	439 (13.0)
Missing	33 (1.0)
Household income at T1, No. (%), $	
≤39 999	298 (8.8)
40 000-79 999	717 (21.2)
≥80 000	2236 (66.0)
Missing	137 (4.0)
Child sex	
Male	1622 (47.9)
Female	1467 (43.3)
Missing	299 (8.8)
Maternal age, y at T1, mean (SD)	30.60 (4.55)
Weekly screen time at 24 mo, mean (SD)	17.09 (11.99)
Weekly screen time at 36 mo, mean (SD)	24.99 (12.97)
Weekly screen time at 60 mo, mean (SD)	10.85 (5.33)
ASQ-3 total score at 24 mo, mean (SD)	51.25 (6.50)
ASQ-3 total score at 36 mo, mean (SD)	52.67 (6.38)
ASQ-3 total score at 60 mo, mean (SD)	54.93 (5.52)

Abbreviations: ASQ-3, Ages and Stages Questionnaire, Third Edition; T1, time of first measure, <24 weeks' gestation.

variance in repeated outcome measures that is stable (ie, between-person and time-invariant) vs dynamic (ie, within-person and time-varying). Simulation studies have indicated that this approach reduces bias in directional estimates of association and more closely approximates causal inference.[38]

Analyses took place in 2 steps. First, the standard RI-CLPM was estimated; then, the contribution of covariates was examined. In the RI-CLPM, between-person (stable) factors were extracted from the repeated-measures of screen time and the ASQ-3, and these factors were permitted to covary. The covariance among the between-person factors reflects the association between screen time and development that is constant (not dynamic) over time. The covariance also isolates the contribution of any between-person and/or time-invariant confounders that are associated with both screen time and the ASQ-3 (eg, child sex, living in a lower socioeconomic status home across all waves of the study) from the within-person component of the model, in which direction of associations are considered. The within-person component comprises 3 types of estimates: (1) autoregressions (ie, lags) capture the within-person, rank-order stability in constructs over time; (2) within-time covariances capture the strength and direction of associations between screen time and ASQ-3 within persons at 1 time point; and (3) the cross-lags capture the longitudinal and directional associations between screen time and the ASQ-3 within persons (Figure). This model was fit with and without constraining cross-lags to equality over time. This did not substantially affect our conclusions. Therefore, the constrained model is presented. After fitting the standard RI-CLPM, covariates (measured at the between-person level) were treated as predictors of the stability factors in an exclusively between-person model.

Missing Data

The subsample used in the present study (n = 2441) completed questionnaires for at least 1 point at either 24, 36, or 60 months. Attrition rates and a comparison of demographic characteristics for families that remained vs dropped out of the study are provided in the eTable in the Supplement. To estimate the effects of missing data, models were run with full information maximum likelihood estimation.[39] Analyses were run with participants with complete data at 36 months, and participants with complete data at 60 months. Results were substantively similar across these model iterations. Findings were considered significant at the $P < .05$, 2-tailed level. All analyses were conducted in Mplus, version 7.0.[40] Statistical analyses were conducted from July 31 to November 15, 2018.

Results

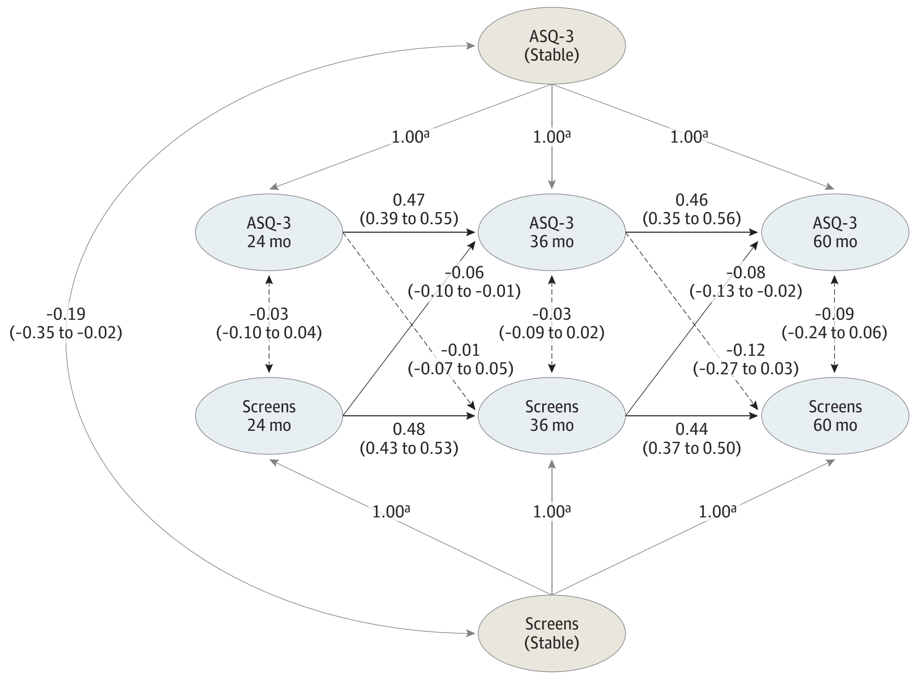
Descriptive Statistics

Descriptive statistics are presented in Table 1. Children were viewing screens a mean (SD) of 17.09 (11.99) (median, 15) hours per week at 24 months, 24.99 (12.97) (median, 23) hours per week at 36 months, and 10.85 (5.33) (median, 10.5) hours per week at 60 months.

Random-Intercepts, Cross-Lagged Panel Model

The standard RI-CLPM was estimated (Figure), and fit indices revealed that the model was a good fit to the observed data ($\chi^2_1 = 1.45$; $P = .49$; root mean square error of approximation [RMSEA] = 0.00; 95% CI, 0.00-0.04; Tucker-Lewis Index [TLI] = 1.00; standardized root mean square residual [SRMR] = 0.005). In the between-person part of the model, there were statistically significant variances (ie, random intercepts) for both poor performance on the developmental screener ($\sigma^2 = 14.64$; 95% CI, 10.95-18.34) and screen time ($\sigma^2 = 17.18$; 95% CI, 11.59-22.76), revealing important individual differences in the person-level means of both outcomes. That is, some children have higher levels of screen time and child developmental outcomes, on average, than other chil-

Figure. Random-Intercepts, Cross-Lagged Panel Model Illustrating Within-Person Association Between Developmental Outcomes (Ages and Stages Questionnaire, Third Edition [ASQ-3]) and Screen Time (Hours per Week) From Ages 24 to 60 Months, Controlling for Between-Person Differences



Standardized estimates (95% CIs) are presented. Solid lines represent estimates where 95% CIs do not include zero. The central, blue-tinted part of the model connected by black solid and dashed lines is the within-person (dynamic) part, and the outer, tan-tinted part of the model connected by gray lines is the between-person (stable) component.

[a] Pathways constrained to 1.00 to isolate between-person factor (n = 2441).

dren. In addition, a statistically significant and negative covariance between the between-person components suggests that children with higher levels of screen time exhibit poorer performance on developmental screening tests, on average, and across all study waves.

In the time-variant component of the model, statistically significant autocorrelations for every estimated lag indicate substantial within-person stability in constructs over time. As detailed in the Figure, after accounting for this within-person stability, there were significant and negative cross-lags linking screen time exposure at 24 months with lower scores on developmental screening tests at 36 months (β, −0.06; 95% CI, −0.10 to −0.01), and also with screen time exposure at 36 months associated with lower scores on developmental screening tests at 60 months (β, −0.08; 95% CI, −0.13 to −0.02). The obverse direction of lower scores on developmental screening tests being associated with higher levels of later screen time was not observed. Also, within-time covariances were not significant. Taken together, these findings suggest that higher levels of screen exposure relative to a child's average level of screen time were associated with significantly poorer performance on developmental screening tests at the next study wave relative to a child's average level of developmental milestones but not vice versa.

Between-Person Predictors of Average Screen Time and Developmental Outcomes

Covariates were treated as predictors in a multivariate regression, whereby the between-person factors were regressed onto all variables simultaneously. The forced entry of all of these covariates resulted in a poorer-fitting model, although the permission of a covariance matrix among all covariates yielded a model that fit moderately well on fit indexes, with the exception of the TLI (χ^2_{53} = 521.04; P < .001; RMSEA = 0.06; 95% CI, 0.05-0.06; TLI = 0.78; SRMR = 0.067). As detailed in **Table 2**, higher person-level means on the ASQ-3 were observed for girls and when mothers reported lower maternal depression and higher household income, maternal positivity, levels of child physical activity, child exposure to reading, and hours of sleep per day. These predictors accounted for 15% of the variance. Lower person-level means of screen time were

Table 2. Between-Person Predictors of Average Screen Time and Developmental Milestones

	Standardized Estimate (β), 95% (CI)	
Predictor	Developmental Outcomes	Screen Time
Child age	0.04 (−0.01 to 0.09)	−0.02 (−0.07 to 0.03)
Maternal age	0.00 (−0.06 to 0.07)	0.03 (−0.03 to 0.09)
Female child	0.23 (0.18 to 0.27)[a]	−0.06 (−0.11 to −0.02)[a]
Income	0.11 (0.06 to 0.16)[a]	−0.10 (−0.15 to −0.04)[a]
Educational level	0.03 (−0.02 to 0.08)	−0.19 (−0.25 to −0.14)[a]
Physical activity	0.07 (0.01 to 0.12)[a]	−0.01 (−0.07 to 0.04)
Maternal positivity	0.13 (0.08 to 0.18)[a]	−0.03 (−0.08 to 0.02)
Reading to child	0.12 (0.06 to 0.18)[a]	−0.08 (−0.13 to −0.02)[a]
Maternal depression	−0.06 (−0.11 to −0.01)[a]	0.08 (0.03 to 0.13)[a]
Sleep (h/night)	0.11 (0.06 to 0.16)[a]	−0.14 (−0.19 to −0.10)[a]
Child in care	0.02 (−0.03 to 0.06)	−0.03 (−0.09 to 0.00)
R^2	0.15 (0.12 to 0.19)[a]	0.12 (0.08 to 0.15)[a]

[a] Estimates in which 95% CIs do not include 0.

observed for girls and when mothers reported lower maternal depression and higher levels of income, education, child exposure to reading, and hours of sleep per night. These predictors accounted for 12% of the variance. When these variables were included, the standardized covariance (correlation) of the between-person stability factors was $\sigma = -0.13$ (95% CI, −0.19 to −0.08), suggesting the existence of a stable association between screen time and the ASQ-3 that is not accounted for by these predictors.

Discussion

Screen time is common in the lives of modern families. Moreover, it is on the rise as technology becomes increasingly integrated across all domains of life. The consequences of excessive screen time have garnered considerable attention in research, health, and public debate over the past decade.[7,41,42] But what comes first: delays in development or excessive screen time viewing? One of the novelties of the current longitudinal, 3-wave study is that it can address this question using repeated measures. Results suggest that screen time is likely the initial factor: greater screen time at 24 months was associated with poorer performance on developmental screening tests at 36 months, and similarly, greater screen time at 36 months was associated with lower scores on developmental screening tests at 60 months. The obverse association was not observed.

On average, children aged 24, 36, and 60 months in our study were watching approximately 17, 25, and 11 hours of television per week, which amounts to approximately 2.4, 3.6, and 1.6 hours of screen time per day, respectively. The amount of screen time in this sample is consistent with a recent report[7] that suggests that children across the United States are watching, on average, 2 hours and 19 minutes of programming per day. Although the reduction in screen time at 60 months would not affect cross-lag analyses as they pertain to rank-order stability vs mean change, this reduction is noteworthy. It may be a reflection of the children in our cohort commencing primary school, as well as before- and after-school care, which begins at age 5 years, resulting in less time at home and a natural reduction in screen time.

Child development unfolds rapidly in the first 5 years of life. The present study examined developmental outcomes during a critical period of growth and maturation, revealing that screen time can impinge on children's ability to develop optimally. When young children are observing screens, they may be missing important opportunities to practice and master interpersonal, motor, and communication skills. For example, when children are observing screens without an interactive or physical component, they are more sedentary and, therefore, not practicing gross motor skills, such as walking and running, which in turn may delay development in this area. Screens can also disrupt interactions with caregivers[43-45] by limiting opportunities for verbal and nonverbal social exchanges, which are essential for fostering optimal growth and development.[46]

Consistent with theoretical models articulating the multiple influences on development in a multilevel ecologic system,[47] we observed that both screen time and performance on developmental screening tests were associated with a variety of person-level and contextual factors, including family income, maternal depression, child sleep, the child being read to regularly, and the child being female. Taken together, these findings suggest that many factors may influence a child's propensity for excessive screen time. It is possible, however, that not all children are equally and putatively influenced by screen time. Factors may exist that buffer the negative effects of screen time on child development. Future longitudinal research examining the differential susceptibility[48] of children to screen time exposure, as well as risk and protective factors,[49] will be necessary to identify when and for whom screen time is particularly problematic for child development.

Several practice implications and recommendations emerge from this study. First, practitioners should emphasize that screen time should be used in moderation and that one of the most effective methods for enhancing child development is through high-quality caregiver-child interactions without the distraction of screens.[44] Second, pediatricians and health care professionals are encouraged to develop personalized media plans with families or direct families to resources to develop media plans[50] to ensure that screen time is not excessive or interfering with face-to-face interactions or family time. Media plans can be customized to help meet each family's needs. The plans provide guidance on setting and enforcing rules and boundaries regarding media use based on child age, how to devise screen-free zones and device curfews in the home, and how to balance and allocate time for online and offline activities to ensure that physical activity and family interactions are prioritized.

Limitations

Longitudinal research designs are necessary for drawing conclusions regarding directionality and patterning of associations over time and across development. However, one of the most significant hurdles in longitudinal research involving screens is that technology development is rapidly evolving and outpacing research.[51] In our large, prospective cohort monitoring children between the ages of 24 and 60 months, data were collected between October 20, 2011, and October 6, 2016. It is possible that screen time behaviors may have shifted over this time period owing to advances in technologies. Another potential limitation is that the first assessment of study variables was at 24 months. It may be beneficial in future research to include an additional lag of data at 12 or 18 months to add further support to the pattern of results observed herein. The addition of an earlier lag of data may be especially pertinent given recent reports suggesting that screen time in infancy is on the rise.[7,17]

A third limitation is the unidimensional focus on screen time. Future research should disaggregate the effect of media content quality (eg, online streaming of videos vs educational apps) on children's development. One further limitation is that the assessment of screen time and child development was taken from maternal reports. The advantage of collecting maternal reports via questionnaire measures in large samples of participants is that it reduces research burden on other family members and, accordingly, can minimize attrition. However, within-informant approaches introduce the potential for common-method variance bias. The interobserver reliabilities between parents and professionals on the ASQ-3 are high.[31] Thus, the ASQ-3 is likely an effective assessment method for screening for developmental delays. In future research, collecting maternal and paternal assessments of early child outcomes could reduce the potential for reporter bias. To corroborate the present findings using a multi-informant approach, future research could also use tracking apps on devices to objectively monitor screen time behavior.

Conclusions

One-quarter of children are not developmentally ready for school entry.[1,2] Although educational curriculums and programs have continued to progress, no improvements have been seen in student academic performance over the past decade,[52] which parallels the period in which technology use and screen time have rapidly increased.[53,54] Excessive screen time has been associated with various negative outcomes, including cognitive delays and poorer academic performance.[55,56] To our knowledge, the present study is the first to provide evidence of a directional association between screen time and poor performance on development screening tests among very young children. As technology use is entrenched in the modern-day lives of individuals, understanding the directional association between screen time and its correlates, and taking family-based steps to engage with technology in positive ways may be fundamental to ensuring developmental success of children growing up in a digital age.

ARTICLE INFORMATION

Accepted for Publication: November 25, 2018.

Correction: This article was corrected on March 25, 2019, to fix numeric errors in the Abstract, Results, and figure.

Published Online: January 28, 2019. doi:10.1001/jamapediatrics.2018.5056

Author Contributions: Drs Madigan and Browne had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Madigan, Browne, Racine, Tough.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Madigan, Browne.
Critical revision of the manuscript for important intellectual content: Browne, Racine, Mori, Tough.
Statistical analysis: Madigan, Browne, Racine.
Obtained funding: Tough.
Administrative, technical, or material support: Browne, Tough.
Supervision: Tough.

Conflict of Interest Disclosures: Dr Tough reported grants from the Alberta Childrens Hospital Foundation, Alberta Innovates Health Solutions, the MaxBell Foundation, CanFASD, and the Canadian Institutes for Health Research during the conduct of the study. No other disclosures were reported.

Funding/Support: The All Our Families study was supported by Alberta Innovates Health Solutions Interdisciplinary Team grant 200700595. The principal investigator of the All Our Families Study is Dr Tough. Research support was provided by the Alberta Children's Hospital Foundation and the Canada Research Chairs program (Dr Madigan).

Role of the Funder/Sponsor: The funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Additional Contributions: The authors acknowledge the contributions of the All Our Families research team and thank the participants who took part in the study.

REFERENCES

1. Janus M, Offord DR. Development and psychometric properties of the Early Development Instrument (EDI): a measure of children's school readiness. *Can J Behav Sci*. 2007;39(1):1-22. doi:10.1037/cjbs2007001

2. Browne DT, Wade M, Prime H, Jenkins JM. School readiness amongst urban Canadian families: risk profiles and family mediation. *J Educ Psychol*. 2018;110(1):133-146. doi:10.1037/edu0000202

3. Stanovich KE. Matthew effects in reading—some consequences of individual-differences in the acquisition of literacy. *Read Res Q*. 1986;21(4):360-407. doi:10.1598/RRQ.21.4.1

4. Browne DT, Rokeach A, Wiener J, Hoch JS, Meunier JC, Thurston S. Examining the family-level and economic impact of complex child disabilities as a function of child hyperactivity and service integration. *J Dev Phys Disabil*. 2013;25(2):181-201. doi:10.1007/s10882-012-9295-z

5. Heckman JJ. Skill formation and the economics of investing in disadvantaged children. *Science*. 2006;312(5782):1900-1902. doi:10.1126/science.1128898

6. Radesky JS, Christakis DA. Increased screen time: implications for early childhood development and behavior. *Pediatr Clin North Am*. 2016;63(5):827-839. doi:10.1016/j.pcl.2016.06.006

7. Common Sense Media. The Common Sense census: media use by kids age zero to eight 2017. Common Sense Media website. https://www.commonsensemedia.org/research/the-common-sense-census-media-use-by-kids-age-zero-to-eight-2017. Accessed August 30, 2018.

8. American Academy of Pediatrics. American Academy of Pediatrics announces new recommendations for children's media use. http://www.aap.org/en-us/about-the-aap/aap-press-room/Pages/American-Academy-of-Pediatrics-Announces-New-Recommendations-for-Childrens-Media-Use.aspx. Published October 21, 2016. Accessed August 30, 2018.

9. Radesky J, Christakis D, Hill D, et al; Council on Communications and Media. Media and young minds. *Pediatrics*. 2016;138(5):e20162591. doi:10.1542/peds.2016-2591

10. Kirkorian HL, Choi K, Pempek TA. Toddlers' word learning from contingent and noncontingent video on touch screens. *Child Dev*. 2016;87(2):405-413. doi:10.1111/cdev.12508

11. Staiano AE, Calvert SL. Exergames for physical education courses: physical, social, and cognitive benefits. *Child Dev Perspect*. 2011;5(2):93-98. doi:10.1111/j.1750-8606.2011.00162.x

12. Sweetser P, Johnson DM, Ozdowska A, Wyeth P. Active versus passive screen time for young children. *Aust J Early Child*. 2012;37(4):94-98.

13. Radesky JS, Schumacher J, Zuckerman B. Mobile and interactive media use by young children: the good, the bad, and the unknown. *Pediatrics*. 2015;135(1):1-3. doi:10.1542/peds.2014-2251

14. Hancox RJ, Milne BJ, Poulton R. Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *Lancet*. 2004;364(9430):257-262. doi:10.1016/S0140-6736(04)16675-0

15. Przybylski AK, Weinstein N. Digital screen time limits and young children's psychological well-being: evidence from a population-based study [published online December 13, 2017]. *Child Dev*. doi:10.1111/cdev.13007

16. Zimmerman FJ, Christakis DA. Children's television viewing and cognitive outcomes: a longitudinal analysis of national data. *Arch Pediatr Adolesc Med*. 2005;159(7):619-625. doi:10.1001/archpedi.159.7.619

17. Christakis DA, Ramirez JSB, Ferguson SM, Ravinder S, Ramirez J-M. How early media exposure may affect cognitive function: a review of results from observations in humans and experiments in mice. *Proc Natl Acad Sci U S A*. 2018;115(40):9851-9858. doi:10.1073/pnas.1711548115

18. Paavonen EJ, Pennonen M, Roine M, Valkonen S, Lahikainen AR. TV exposure associated with sleep disturbances in 5- to 6-year-old children. *J Sleep Res*. 2006;15(2):154-161. doi:10.1111/j.1365-2869.2006.00525.x

19. Zimmerman FJ, Christakis DA, Meltzoff AN. Associations between media viewing and language development in children under age 2 years. *J Pediatr*. 2007;151(4):364-368. doi:10.1016/j.jpeds.2007.04.071

20. Chonchaiya W, Pruksananonda C. Television viewing associates with delayed language development. *Acta Paediatr*. 2008;97(7):977-982. doi:10.1111/j.1651-2227.2008.00831.x

21. Duch H, Fisher EM, Ensari I, et al. Association of screen time use and language development in Hispanic toddlers: a cross-sectional and longitudinal study. *Clin Pediatr (Phila)*. 2013;52(9):857-865. doi:10.1177/0009922813492881

22. Radesky JS, Silverstein M, Zuckerman B, Christakis DA. Infant self-regulation and early childhood media exposure. *Pediatrics*. 2014;133(5):e1172-e1178. doi:10.1542/peds.2013-2367

23. Tough SC, McDonald SW, Collisson BA, et al. Cohort profile: the All Our Babies pregnancy cohort (AOB). *Int J Epidemiol*. 2017;46(5):1389-1390. doi:10.1093/ije/dyw363

24. McDonald SW, Lyon AW, Benzies KM, et al. The All Our Babies pregnancy cohort: design, methods, and participant characteristics. *BMC Pregnancy Childbirth*. 2013;13(suppl 1):S2. doi:10.1186/1471-2393-13-S1-S2

25. Squires J, Twombly E, Bricker D, Potter L. *ASQ-3 Users' Guide*. Baltimore, MD: Brookes; 2003.

26. Richter J, Janson H. A validation study of the Norwegian version of the Ages and Stages Questionnaires. *Acta Paediatr*. 2007;96(5):748-752. doi:10.1111/j.1651-2227.2007.00246.x

27. Heo KH, Squires J, Yovanoff P. Cross-cultural adaptation of a pre-school screening instrument: comparison of Korean and US populations. *J Intellect Disabil Res*. 2008;52(pt 3):195-206. doi:10.1111/j.1365-2788.2007.01000.x

28. Alvik A, Grøholt B. Examination of the cut-off scores determined by the Ages and Stages Questionnaire in a population-based sample of 6 month-old Norwegian infants. *BMC Pediatr*. 2011;11(1):117. doi:10.1186/1471-2431-11-117

29. Bayley N. *Manual for the Bayley Scales of Infant Development*. San Antonio, TX: Psychological Corp; 1969.

30. Thorndike RL, Hagen EP, Sattler JM. *Stanford-Binet Intelligence Scale*. 4th ed. Itasca, IL: Riverside Publishing Co; 1986.

31. Squires J, Bricker D, Potter L. Revision of a parent-completed development screening tool: Ages and Stages Questionnaires. *J Pediatr Psychol*. 1997;22(3):313-328. doi:10.1093/jpepsy/22.3.313

32. Schonhaut L, Armijo I, Schönstedt M, Alvarez J, Cordero M. Validity of the Ages and Stages Questionnaires in term and preterm infants. *Pediatrics*. 2013;131(5):e1468-e1474. doi:10.1542/peds.2012-3313

33. Gollenberg AL, Lynch CD, Jackson LW, McGuinness BM, Msall ME. Concurrent validity of the parent-completed Ages and Stages Questionnaires, 2nd ed, with the Bayley Scales of Infant Development II in a low-risk sample. *Child Care Health Dev*. 2010;36(4):485-490. doi:10.1111/j.1365-2214.2009.01041.x

34. Limbos MM, Joyce DP. Comparison of the ASQ and PEDS in screening for developmental delay in children presenting for primary care. *J Dev Behav Pediatr*. 2011;32(7):499-511. doi:10.1097/DBP.0b013e31822552e9

35. Radloff LST. The CES-D scale: the self report depression scale for research in the general population. *Appl Psychol Meas*. 1977;1:385-401. doi:10.1177/014662167700100306

36. NLSCY. *Overview of Survey Instruments for 1994-1995*. Ottawa, ON: Statistics Canada & Human Resources Canada; 1995.

37. Hamaker EL, Kuiper RM, Grasman RPPP. A critique of the cross-lagged panel model. *Psychol Methods*. 2015;20(1):102-116. doi:10.1037/a0038889

38. Berry D, Willoughby MT. On the practical interpretability of cross-lagged panel models: rethinking a developmental workhorse. *Child Dev*. 2017;88(4):1186-1206. doi:10.1111/cdev.12660

39. Graham JW. Missing data analysis: making it work in the real world. *Annu Rev Psychol*. 2009;60:549-576. doi:10.1146/annurev.psych.58.110405.085530

40. Muthén L, Muthén B. *Mplus Statistical Modeling Software: Release 7.0*. Los Angeles, CA: Muthén & Muthén; 2012.

41. American College of Pediatricians. The impact of media use and screen time on children, adolescents, and families. http://www.acpeds.org/the-college-speaks/position-statements/parenting-issues/the-impact-of-media-use-and-screen-time-on-children-adolescents-and-families. Published November 2016. Accessed September 4, 2018.

42. Bolhuis K, Verhoeff ME, Hillegers M, Tiemeier H. Psychotic-like symptoms in preadolescence: what precedes the precursory symptoms of severe mental illness? *J Am Acad Child Adolesc Psychiatry*. 2017;56(10):S243. doi:10.1016/j.jaac.2017.09.258

43. Radesky J, Miller AL, Rosenblum KL, Appugliese D, Kaciroti N, Lumeng JC. Maternal mobile device use during a structured parent-child interaction task. *Acad Pediatr*. 2015;15(2):238-244. doi:10.1016/j.acap.2014.10.001

44. Kirkorian HL, Pempek TA, Murphy LA, Schmidt ME, Anderson DR. The impact of background television on parent-child interaction. *Child Dev*. 2009;80(5):1350-1359. doi:10.1111/j.1467-8624.2009.01337.x

45. Pempek TA, Kirkorian HL, Anderson DR. The effects of background television on the quantity and quality of child-directed speech by parents. *J Child Media*. 2014;8(3):211-222. doi:10.1080/17482798.2014.920715

46. Hoff E. The specificity of environmental influence: socioeconomic status affects early vocabulary development via maternal speech. *Child Dev*. 2003;74(5):1368-1378. doi:10.1111/1467-8624.00612

47. Bronfenbrenner U. *The Ecology of Human Development: Experiments by Nature and Design*. Cambridge, MA: Harvard University Press; 1979.

48. Belsky J, Bakermans-Kranenburg MJ, van Ijzendoorn MH. For better *and* for worse: differential susceptibility to environmental influences. *Curr Dir Psychol Sci*. 2007;16(6):300-304. doi:10.1111/j.1467-8721.2007.00525.x

49. Masten AS, Garmezy N. *Risk, Vulnerability, and Protective Factors in Developmental Psychopathology: Advances in Clinical Child Psychology*. New York: Springer; 1985:1-52.

50. American Academy of Pediatrics. Family media plan. http://www.healthychildren.org/English/media/Pages/default.aspx?gclid=EAIaIQobChMIoq2F-eiA3QIVUFuGCh3e0gDnEAAYBCAAEgJqNPD_BwE. Accessed August 30, 2018.

51. Radesky JS, Eisenberg S, Kistin CJ, et al. Overstimulated consumers or next-generation learners? parent tensions about child mobile technology use. *Ann Fam Med*. 2016;14(6):503-508. doi:10.1370/afm.1976

52. Chu M-W. Why Canada fails to be an education superpower. https://theconversation.com/why-canada-fails-to-be-an-education-superpower-82558. Accessed August 30, 2018.

53. Lenhart A. *Teens and Mobile Phones Over the Past Five Years: Pew Internet Looks Back*. Washington, DC: Pew Internet & American Life Project; 2009.

54. Anderson M, Jiang J. Teens, social media & technology. http://assets.pewresearch.org/wp-content/uploads/sites/14/2018/05/31102617/PI_2018.05.31_TeensTech_FINAL.pdf. Published May 31, 2018. Accessed August 30, 2018.

55. Hancox RJ, Milne BJ, Poulton R. Association of television viewing during childhood with poor educational achievement. *Arch Pediatr Adolesc Med*. 2005;159(7):614-618. doi:10.1001/archpedi.159.7.614

56. Zimmerman FJ, Christakis DA. Associations between content types of early media exposure and subsequent attentional problems. *Pediatrics*. 2007;120(5):986-992. doi:10.1542/peds.2006-3322