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Associations of screen use with cognitive development in early childhood: the ELFE birth cohort

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Background: The associations of screen use with children's cognition are not well evidenced and recent, large, longitudinal studies are needed. We aimed to assess the associations between screen use and cognitive development in the French nationwide birth cohort. **Methods:** Time and context of screen use were reported by parents at ages 2, 3.5 and 5.5. Vocabulary, non-verbal reasoning and general cognitive development were assessed with the MacArthur-Bates Communicative Development Inventory (MB) at age 2, the Picture Similarities subtest from the British Ability Scales (PS) at age 3.5 and the Child Development Inventory (CDI) at ages 3.5 and 5.5. Outcome variables were age-adjusted and standardized (mean = 100, *SD* = 15). Multiple imputations were performed among children (N = 13,763) with ≥1 screen use information and ≥1 cognitive measures. Cross-sectional and longitudinal associations between screen use and cognitive development were assessed by linear regression models adjusted for sociodemographic and birth factors related to the family and children, and children's lifestyle factors competing with screen use. Baseline cognitive scores were further considered in longitudinal analysis. **Results:** TV-on during family meals at age 2, not screen time, was associated with lower MB scores at age 2 (β [95% CI] = −1.67 [−2.21, −1.13]) and CDI scores at age 3.5 (−0.82 [−1.31, −0.33]). In cross-sectional analysis, screen time was negatively associated with CDI scores at ages 3.5 (−0.67 [−0.94, −0.40]) and 5.5 (−0.47 [−0.77, −0.16]), and, in contrast, was positively associated with PS scores (0.39 [0.07, 0.71]) at age 3.5. Screen time at age 3.5 years was not associated with CDI scores at age 5.5 years. **Conclusions:** Our study found weak associations of screen use with cognition after controlling for sociodemographic and children's birth factors and lifestyle confounders, and suggests that the context of screen use matters, not solely screen time, in children's cognitive development. **Keywords:** Child; birth cohort; ELFE; screen time; TV; smartphone; video; computer; cognitive development; language; non-reasoning skill.

Background

There has been extensive concern that early excessive screen use may hinder children's development (Stiglic & Viner, 2019; Tremblay et al., 2011), but there is no clear consensus to date (Madigan, McArthur, Anhorn, Eirich, & Christakis, 2020). Screen time was frequently reported as negatively associated with lower cognition, especially language development (Madigan et al., 2020; Walsh, Barnes, Tremblay, & Chaput, 2020). In contrast, some studies found that high-quality programmes (e.g. 'Sesame Street') and contexts (e.g. co-viewing with parents) of screen use may offset the overall negative effects introduced by screen time, suggesting that not only screen time matters (Fisch, 2014; Kostyrka-Allchorne, Cooper, & Simpson, 2017; Linebarger & Walker, 2005; Madigan et al., 2020).

The quality of the evidence remains, however, limited as there are many methodological gaps in the literature. First, systematical reviews show that past studies were primarily cross-sectional, which does not discard potential reverse causation (Kostyrka-Allchorne et al., 2017; Madigan et al., 2020; Tremblay et al., 2011). Second, language ability has been extensively examined, but less attention has been given to other domains of cognitive development (Kostyrka-Allchorne et al., 2017; Madigan et al., 2020; Tremblay et al., 2011). Moreover, confounding by third factors is likely, given that both screen use and cognitive development are linked to family socioeconomic factors (Bernard et al., 2017; Duch, Fisher, Ensari, & Harrington, 2013; Goh et al., 2016). Yet, many observational studies were not able to accurately account for such confounders.

Conflict of interest statement: No conflicts declared.

It has also been hypothesized that negative effects of screen time on child cognition are rather due to time displacement by other activities that are more beneficial for cognitive development (Anderson & Subrahmanyam, 2017; Horowitz-Kraus & Hutton, 2018; Walsh et al., 2020). This calls for studies considering modifiable lifestyle factors that compete with screen use (e.g. physical activity, parent–child interactions and sleep) (Aishworiya et al., 2019; Schmidt, Rich, Rifas-Shiman, Oken, & Taveras, 2009; Walsh et al., 2020).

We aimed to assess the cross-sectional and longitudinal associations of screen use with cognitive development in children aged 2–5.5 years enrolled in a large, nationwide French birth cohort study, accounting for the sociodemographic and birth factors related to the family, the parents and the children and children's lifestyle factors.

Methods

Study design and population

The *Étude Longitudinale Française depuis l'Enfance* (ELFE) study is the French national birth cohort study launched in 2011 in 349 randomly selected maternity hospitals. The study design and detailed protocol have been published (Charles et al., 2020). Briefly, newborns were recruited through four enrolment waves distributed across the four seasons. The main inclusion criteria were gestational age at birth ≥33 weeks, mothers aged ≥18 years, not planning to leave metropolitan France within the next 3 years and the ability to read/understand French, Arabic, Turkish or English. Fifty-one per cent of eligible parents agreed to participate, and 18,329 children were enrolled. Informed consent was signed by the parents or the mother alone, with the father being informed of his right to deny the consent for his child's participation. The ELFE study was approved by the Advisory Committee for Treatment of Health Research Information (Comité Consultatif sur le Traitement des Informations pour la Recherche en Santé), the National Data Protection Authority (CNIL) and the National Statistics Council.

Baseline characteristics of the parents and children were obtained by questionnaire after birth during the maternity stay. Phone interviews with the parents were conducted when the children were aged 2 months, 1, 2, 3.5 and 5.5 years. Home visits were additionally conducted at 3.5 years. Demographic, socioeconomic and lifestyle information on the parents and the child was collected at each survey wave.

Assessment of screen use

Screen use was obtained for five types of screens (TV, smartphone, video game console, tablet and computer) at ages 2 (in 2013), 3.5 (2014–2015) and 5.5 years (2016). Parents were asked to report the average time their child spent on each screen during a typical weekday and weekend day. The average daily screen use over the week was weighted from the times on weekdays and weekends as follows: ([weekday*5] + [weekend*2])/7. Parents were only asked to indicate whether they turn the TV on during family meals (yes or no) at age 2 years.

Cognitive development

Child cognition was assessed by the parents or assessed by trained interviewers at 2, 3.5 and 5.5 years; the assessment tools were selected for meeting the following criteria: (a) capturing different aspects of cognitive development at the target ages, including language ability, non-verbal reasoning and overall development; (b) being validated, internationally recognized or used in previous cohorts, and available in French; and (c) offering a balance between cost and feasibility in a nationwide setting, participants' burden and scientific validity. At age 2 years, parents evaluated children's language development with the French version of the MacArthur-Bates Communicative Development Inventory (MB). It consists of a list of 100 words, where parents report those that their child happens to pronounce spontaneously; the score ranges from 0 to 100 points (Kern, Langue, Zesiger, & Bovet, 2010). At ages 3.5 and 5.5, general cognitive development was assessed by the parents with the Child Development Inventory (CDI), a parental questionnaire adapted and validated in French (Duyme & Capron, 2010). It assesses the development and learning of children aged 15–72 months in eight subdomains: social, self-help, gross motor, fine motor, expressive language, language comprehension and letter and numeracy knowledge (Ireton, 1992). During the 3.5-year home visit, children's non-verbal reasoning was evaluated by a trained investigator with the Picture Similarities subtest (PS) from the British Ability Scales (Bradshaw & Corbett, 2013). The child was shown a row of four pictures and given a card with a fifth picture, and was asked to place the card over the picture which shares an element or concept with the card. A total of 33 sets of cards were used. The PS score reflects inductive reasoning, visual perception and analysis (Bradshaw & Corbett, 2013). All these constructs were designed for specific target ages and do not have age-normed values. The pairwise correlations of cognitive scores are presented in Table S1.

As each cognitive assessment was conducted at varying ages around the target age, we adjusted the raw score for the child's exact age using linear regression and retrieved the model's residuals. The model's residuals were defined as age-adjusted cognitive scores then. As the age-adjusted cognitive scores ranged on different metric scales and were not directly comparable to each other, we standardized (i.e. rescaled) them with a mean of 100 and a standard deviation of 15, so that it matches the distribution of the widely used intelligence quotient.

Covariates

Potential confounders were determined a priori based on the literature and selected using directed acyclic graphs (Figure 1) (Tennant et al., 2020). They were classified into two groups: (a) sociodemographic and birth factors related to the family, the parents and the child, and (b) lifestyle factors occurring during early childhood and susceptible to compete with screen use.

Sociodemographic and birth factors. This group included child sex (male, female), gestational age at birth (in weeks), birth weight *z*-score, recruitment waves (Spring, Summer, Fall, Winter), maternal age (in years), parental education level (in five categories from less than high school graduation to postgraduate level) and employment status (full time, part time, other), maternal TV time during pregnancy (in hr/day), monthly household income, parental separation (yes, no), sibling number (0, 1, ≥2), language spoken at home (French only, French and another language, other).

Lifestyle factors. This group of covariate included the frequency of activities of the child with either the mother or the father at age 1; child arrangement (parents, grandparents, licensed childminder, day care/nursery school or others) at age 2; patterns of non-screen-based activities and play at age 2; preschool attendance at age 3.5 (full vs. part time); leisure activities shared with the parents at ages 3.5 and 5.5; time spent in outdoor activities at age 3.5 and 5.5 (in hr/day); and

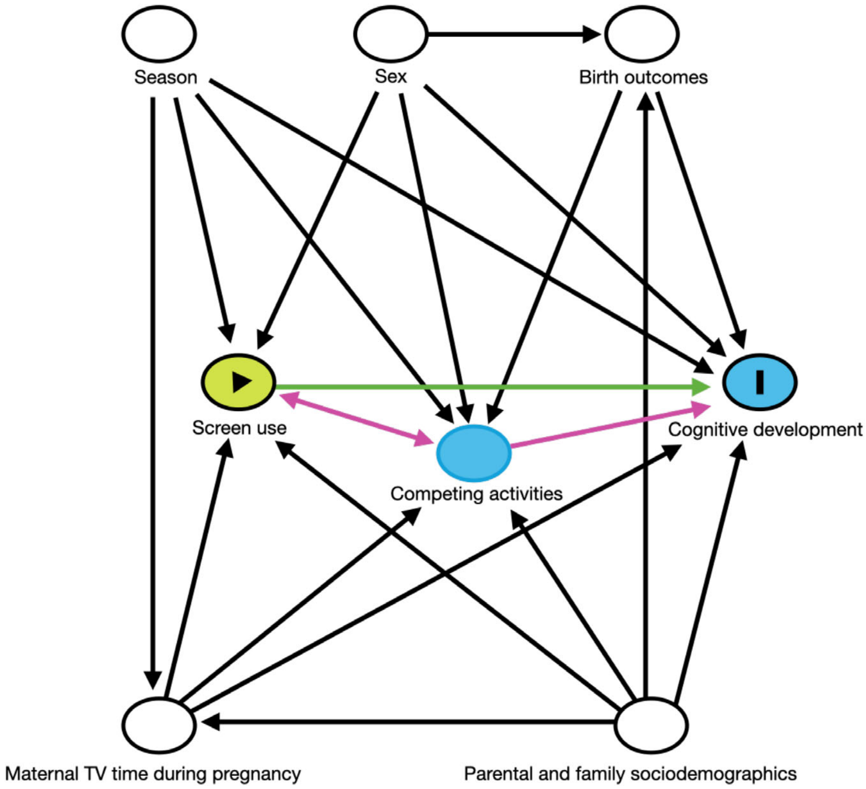

Figure 1 Directed acyclic graph of the assumed relationships between screen use, cognitive development and other covariates. Birth outcomes include children's birth weight and gestational weeks; competing activities include children's non-screen-based activities and play, parent–child interactions, children's sleep and outdoor activities time, child arrangement at age 2 years and pre-school attendance at age 3.5 years; parental and family sociodemographics include parental age, education level, employment status and separation, family incomes, language spoken at home and family composition

sleep duration at ages 2, 3.5 (including nap time, in hr/day) and 5.5 (night sleep, in hr/day).

Patterns of non-screen-based activities and play at age 2 were derived from variables measuring the frequency (everyday, often, sometimes or never) with which the child engaged in 11 non-screen-based activities and play. These items included playing with a ball, drawing/painting, stacking toys (cubes, etc.), slotting bricks (Lego, etc.), doing puzzles, playing with cuddly toys, playing with dolls, playing with cars, playing with water games, promenading outside and doing physical activities. Polychoric principal component analysis with varimax rotation provided a solution with three factors that loaded with (a) fine motor/construction/puzzle play, (b) physical activities and play and (c) sex-typed play (Table S2); the first two factors were included in our models since they are susceptible to compete with screen use.

Leisure activities shared (yes or no) with the parents at ages 3.5 and 5.5 were measured with 7 and 13 binary items, respectively (e.g. painting/drawing/colouring, reading stories, playing memory games, singing or listening to music etc.). At both ages, tetrachoric principal component analyses with varimax rotation provided a first component loading positively with all items, that we used in our models as a proxy for parents' overall engagement in leisure activities with their child (Table S3).

Preschool attendance was only considered at age 3.5 since, in France, most children enter preschool within the year of their third birthday; 2-year-olds have childcare arrangements other than preschool, and 5.5-year-olds generally attend preschool full time.

Statistical analyses

We examined the associations between screen use (TV-on during family meals at age 2 years; screen time at 2, 3.5 and 5.5 years) and cognitive development outcomes (MB at 2 years, PS at 3.5 years, CDI at 3.5 and 5.5 years) by linear regression models conducted using both cross-sectional (screen use and cognitive development assessed at the same age) and longitudinal (screen use measured before cognitive development) designs. Separate regression analyses were run for each cognitive score as the dependent variable. We report all cross-sectional and longitudinal models implemented with effect estimates on the standard scale (mean = 100, *SD* = 15) of the cognitive scores; therefore, the reported effect sizes are mean differences in the cognitive score when the independent variable is TV-on during family meals (yes vs. no), and change in the mean cognitive score for a 1-hr/day increase when the independent variable is screen time. Models assessing screen use at age 2 were performed with and without mutual adjustment for both TV-on during family meals and screen time to evaluate potential confounding by each other. We also tested the interaction between them but found none. To investigate the shape of the associations between screen time and cognitive development, we performed sensitivity analyses with screen time as categorical variables (0, 1–30, 31–60, 61–120 and >120 min/day at 2 years; at 3.5 and 5.5 years, the categories '0' and '1–30' were combined as only 3.3% and 2.5% of children had no screen time at all respectively). Given the literature showing sex differences in both screen use and cognition (Duch et al., 2013; Peyre et al., 2019), we tested whether child sex moderated the associations by testing the multiplicative interaction *screen use***sex* in the models; then, we performed fully adjusted analyses stratified by sex.

Models were built in three steps: unadjusted models; models adjusted for sociodemographic and birth factors related to the family, the parents and the child (Models 1); models further adjusted for children's lifestyle factors susceptible to compete with screen use (Models 2). In adjusted models, only covariates that were measured before or concomitantly to the screen variables of interest were included, to account for the temporal sequence of potential confounding. Longitudinal models were further adjusted for baseline cognition (e.g. models examining the effect of screen use at age 2 years were adjusted for MB score at age 2 years, and models examining the effect of screen use at age 3.5 years were adjusted for CDI score at age 3.5 years). For CDI scores at ages 3.5 and 5.5 years, we also examined the eight subdomains, with baseline adjustment when appropriate.

Missing data for screen use, cognitive development and covariates were imputed by using the fully conditional specification method in the sample of participants with at least one measure of screen use and one cognitive outcome between ages 2 and 5.5 (Figure 2). Five data sets were generated and estimates resulting from each data set were pooled using Rubin's rule. We performed sensitivity analyses on complete-case samples. We did not adjust our analyses for multiple comparisons (Rothman, 1990). Statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC).

Results

Of the 18,329 newborns included in the cohort, 13,763 (75%) children were followed up to 2, 3.5 or 5.5 years with ≥1 screen use data and ≥1 cognitive measurement (Figure 2). The characteristics of the study sample are described in Table 1. Table 2 shows descriptive statistics on children's screen use, cognitive development and other lifestyle characteristics. In total, 41.4% of 12,989 children were exposed to TV during family meals at age 2. Mean (±*SD*) daily screen times increased from 0.82 (±0.97) to 1.41 (±1.11) hours between ages 2 and 5.5 years. Cognitive development scores before age-adjusted standardization were 72.5 (±25.2) for MB at age 2, 67.5 (±15.8) for PS and 53.1 (±5.5) for CDI at age 3.5 and 65.3 (±3.0) for CDI at age 5.5.

Table 3 provides the regression coefficients for unadjusted models, models 1 (adjusted for sociodemographic and birth factors) and models 2 (further adjusted for children's lifestyle factors). Separate regression analyses were run for each cognitive score as dependent variable. All dependent variables (i.e. cognitive scores) are expressed on a standard scale with mean = 100 and *SD* = 15; the coefficients therefore represent the change in standard scores. The independent variables were

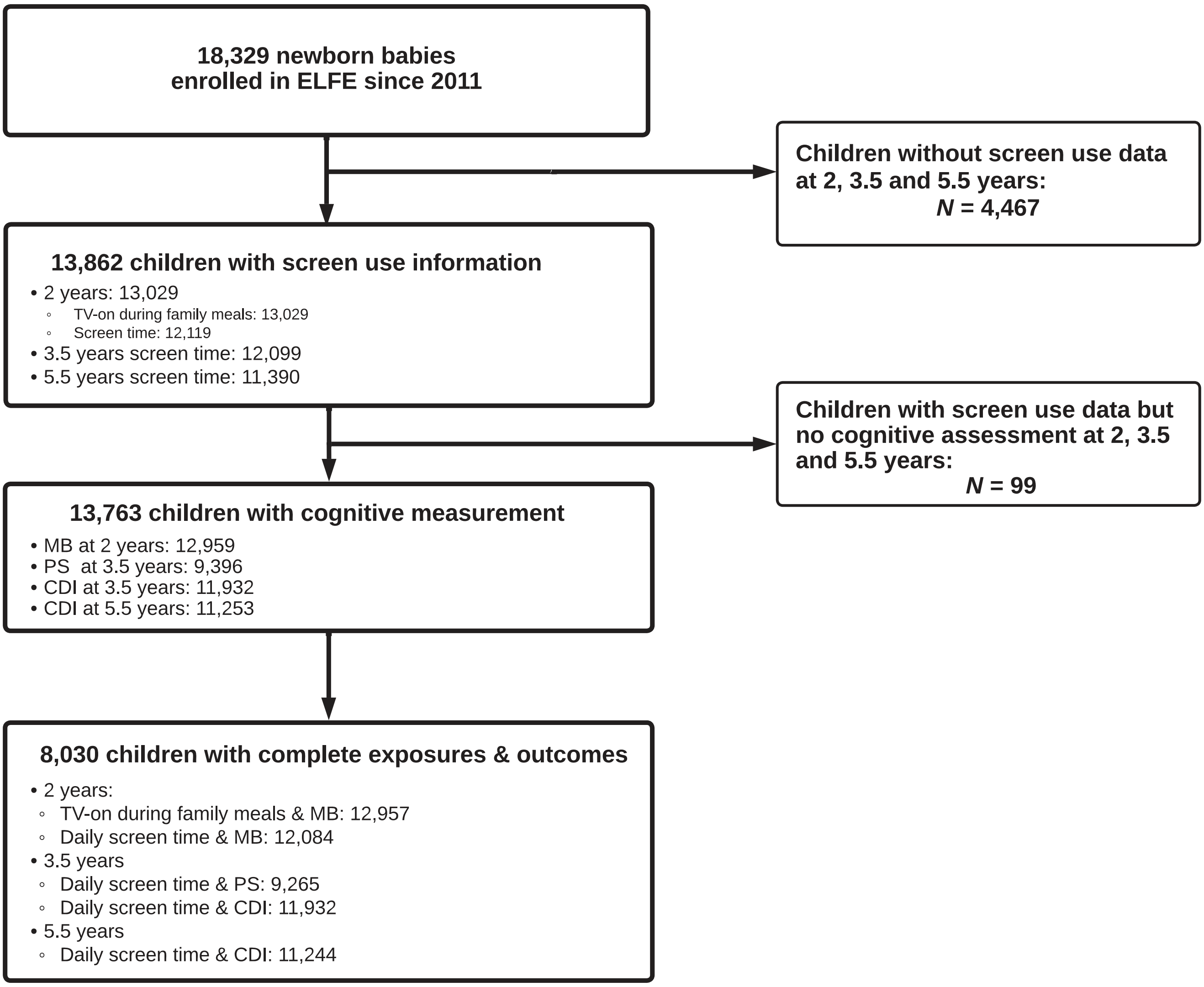

Figure 2 Flowchart of the ELFE children analysed in the study. CDI, Child Development Inventory; MB, MacArthur-Bates Communicative Development Inventory; PS, Picture Similarities subtest from the British Ability Scale

Table 1 Children, parents and household characteristics at birth or age 2 years in the ELFE cohort (*N* = 13,763)

	N	% (*N*) or Mean ± *SD*
Season at birth	13,763	
Spring		15.3 (2,113)
Summer		25.6 (3,521)
Fall		28.5 (3,921)
Winter		30.6 (4,208)
Child characteristics		
Child sex	13,763	
Males		51.0 (7,018)
Females		49.0 (6,745)
Birth weight *z*-score	13,228	−0.0 ± 1.0
Gestational age at birth (weeks)	13,552	39.6 ± 1.5
Parents' characteristics		
Maternal age (years)	13,147	32.8 ± 4.7
Paternal age (years)	12,705	35.4 ± 5.8
Maternal education	13,446	
Less than high school graduation		18.3 (2,459)
High school graduation		17.8 (2,399)
Some higher education		23.1 (3,103)
Bachelor's degree		19.1 (2,563)
Master's degree and above		21.7 (2,922)
Paternal education	12,238	
Less than high school graduation		26.1 (3,191)
High school graduation		21.0 (2,459)
Some higher education		18.8 (2,298)
Bachelor's degree		11.8 (1,444)
Master's degree and above		23.3 (2,846)
Maternal employment status	13,232	
Full time		79.2 (10,473)
Part-time		8.0 (1,060)
Others		13.0 (1,699)
Paternal employment status	12,794	
Full time		92.6 (11,713)
Part-time/others		7.4 (936)
Maternal TV time during pregnancy (hr/day)	12,066	2.2 ± 1.6
Household characteristics		
Number of siblings at age 2 years	13,309	
0		38.1 (5,020)
1		41.1 (5,413)
>1		20.7 (2,728)
Parental separation at age 2 years	13,221	
Yes		6.0 (791)
No		94.0 (12,430)
Language spoken at home	11,393	
French only		94.3 (10,746)
French and another language		4.3 (496)
Other languages but French		1.3 (151)
Monthly household income per household member at age 2 years	12,394	
<€1,100		18.6 (2,304)
€1,110–1,430		16.5 (2,045)
€1,430–1,670		15.1 (1,874)
€1,670–2,000		16.2 (2,011)
€2,000–2,330		13.0 (1,606)
€2,330–2,700		8.4 (1,045)
>€2,700		12.2 (1,509)

either binary (TV on vs. off during family meals) or continuous (screen time in hours/day). Thus, the regression coefficients for the binary variable represent a mean difference in standard scores between the two groups (i.e. TV on vs. off). The regression coefficients for the continuous variable (or B for beta coefficient) represent the change in the cognitive measure in standard scores for one unit increase (i.e. 1 hr/day) in screen time. In addition, we translate effect sizes into Cohen's *d* (i.e. change in *SD*). In all unadjusted models, screen use was negatively associated with cognitive development. After adjusting for sociodemographic and birth factors related to the family, the parents and the child (models 1) and for children's lifestyle factors (models 2), the effect sizes reduced substantially. The largest adjusted effect size was found for TV-on during family meals on MB. Compared to children having the TV off during family meals at age 2 years, those having the TV on scored 1.67

Table 2 Description of children's screen use (context and time), cognitive development and lifestyle factors in the ELFE cohort (*N* = 13,763)

	Total *N*	% (*n*) or mean ± *SD*	Median (interquartile range)
Screen use			
TV-on during family meals at age 2 years	12,989	41.4 (5,378)	
Screen time at age 2 years (hr/day)	12,099	0.82 ± 0.97	0.57 (0.19–1.13)
Screen time at age 2 years (categories)	12,099		
0 min/day		15.5 (1,870)	
0–30 min/day		32.6 (3,943)	
31–60 min/day		24.9 (3,018)	
61–120 min/day		18.4 (2,228)	
> 120 min/day		8.6 (1,040)	
Screen time at age 3.5 years (hr/day)	12,056	1.17 ± 1.01	0.96 (0.50–1.54)
Screen time at age 3.5 years (categories)	12,056		
0 min		3.3 (398)	
0–30 min/day		23.8 (2,863)	
31–60 min/day		28.5 (3,440)	
61–120 min/day		29.8 (3,595)	
> 120 min/day		14.6 (1,760)	
Screen time at age 5.5 years (hr/day)	11,377	1.41 ± 1.11	1.14 (0.64–1.86)
Screen time at age 5.5 years (categories)			
0 min/day	11,377	2.5 (284)	
0–30 min/day		16.0 (1,818)	
31–60 min/day		16.0 (2,962)	
61–120 min/day		34.4 (3,911)	
>120 min/day		21.1 (2,402)	
Cognitive score			
Raw MB score at age 2 years	12,959	72.5 ± 25.2	81 (58–93)
Standardized MB score at age 2 years	12,959	100.0 ± 15	105 (92–112)
Raw PS score at age 3.5 years	9,396	67.5 ± 15.8	70 (59–76)
Standardized PS score at age 3.5 years	9,299	100.0 ± 15	101 (92–109)
Raw CDI score at age 3.5 years	11,932	53.1 ± 5.5	54 (51–57)
Standardized CDI score at age 3.5 years	11,932	100.0 ± 15	102 (93–110)
Raw CDI score at age 5.5 years	11,253	65.3 ± 3.0	66 (64–67)
Standardized CDI score at age 5.5 years	11,253	100.0 ± 15	103 (95–109)
Lifestyle factors			
Child arrangement at age 2 years	13,110		
Parents		28.6 (3,744)	
Grandparents		4.4 (577)	
Licensed Childminder		41.2 (5,399)	
Day care/nursery school		22.1 (2,893)	
Others		3.8 (497)	
Preschool attendance at age 3.5 years	12,128		
Full time		71.7 (8,698)	
Part-time		28.3 (3,430)	
Outdoor activities time (hr/day)			
3.5 years	10,572	1.7 ± 1.1	1.5 (1.0–2.2)
5.5 years	10,576	1.6 ± 1.0	1.3 (0.9–1.9)
Total sleep time (hr/day)			
2 years	12,596	13.0 ± 1.1	13.0 (12.4–13.6)
3.5 years	11,008	12.3 ± 0.8	12.3 (11.8–12.8)
5.5 years	10,898	10.8 ± 0.5	10.8 (10.5–11.1)

standard points lower on MB at age 2 years (95% CI: −2.21, −1.13) and 0.82 standard points lower on CDI at age 3.5 years (95% CI: −1.13, −0.33), which corresponds to a decrease of 0.11 and 0.05 *SD* respectively. There was, however, no longitudinal associations of TV on during family meals at age 2 years with PS score at age 3.5 years and CDI score at age 5.5 years. Screen time at age 3.5 years was positively associated with PS score: a 1-hr/day increase was associated with a 0.39 standard points increase (95% CI: 0.07, 0.71), which corresponds to an increase of 0.03 *SD*. Contrariwise, screen time was negatively associated with CDI score at age 3.5 years (B [95% CI]: −0.67 [−0.94, −0.40] standard points per hour/day, corresponding to a decrease of 0.04 *SD*), and not associated with CDI score at age 5.5 years (−0.31 [−0.74, 0.13] standard points per hour/day, corresponding to a decrease of 0.02 *SD*). At age 5.5 years, screen time was cross-sectionally associated with CDI score (−0.47 [−0.77, −0.16] standard points per hour/day, corresponding to a decrease of 0.03 *SD*). The variance in cognitive scores explained by the adjusted models shown in Table 3 ranged from 9% to 40% depending on the outcomes; screen use contributed for up to 2% of the total variance.

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Table 3 Cross-sectional and longitudinal associations of screen use with cognitive development in the ELFE birth cohort (N = 13,763)

Outcome	Exposure	Unadjusted models	Models 1	Models 2	Adjusted R^2 explained by exposure in Model 2	Total variance explained in model 2
MacArthur-Bates (2 years)	TV-on during family meals at 2 years (ref: no)	−3.30 (−3.83, −2.78)***	−2.27 (−2.81, −1.72)***	−1.67 (−2.21, −1.13)***	.01	.13
	Screen time at 2 years (hr/day)	−0.98 (−1.25, −0.71)***	−0.29 (−0.56, −0.01)*	−0.10 (−0.37, 0.17)	.008	
Picture similarities (3.5 years)	TV-on during family meals at 2 years (ref: no)	−1.21 (−1.98, −0.44)**	0.01 (−0.67, 0.70)	0.06 (−0.67, 0.79)	.002	.09
	Screen time at 2 years (hr/day)	−0.21 (−0.48, 0.07)	0.26 (−0.04, 0.56)	0.27 (−0.06, 0.60)	.0008	
	Screen time at 3.5 years (hr/day)	−0.47 (−0.74, −0.19)**	0.30 (−0.03, 0.62)	0.39 (0.07, 0.71)*	.001	.09
CDI (3.5 years)	TV-on during family meals at 2 years (ref: no)	−3.03 (−3.58, −2.49)***	−1.14 (−1.63, −0.65)***	−0.82 (−1.31, −0.33)***	.01	.31
	Screen time at 2 years (hr/day)	−0.58 (−0.85, −0.30)***	−0.01 (−0.25, 0.24)	−0.01 (−0.25, 0.23)	.005	
	Screen time at 3.5 years (hr/day)	−1.84 (−2.09, −1.59)***	−1.04 (−1.30, −0.77)***	−0.67 (−0.94, −0.40)***	.02	.16
CDI (5.5 years)	TV-on during family meals at 2 years (ref: no)	−2.08 (−2.64, −1.51)***	−0.48 (−1.03, 0.07)	−0.26 (−0.81, 0.30)	.004	.14
	Screen time at 2 years (hr/day)	−0.52 (−0.82, −0.22)***	−0.01 (−0.31, 0.28)	−0.02 (−0.33, 0.29)	.003	
	Screen time at 3.5 years (hr/day) with adjustment for CDI score at 3.5 years	−1.37 (−1.64, −1.11)***	−0.06 (−0.31, 0.19)	0.06(−0.21, 0.32)	.001	.40
	Screen time at 5.5 years (hr/day)	−1.41 (−1.68, −1.15)***	−0.80 (−1.08, −0.52)***	−0.47 (−0.77, −0.16)**	.01	.09

All estimates are based on the standard scales (mean = 100, SD = 15). Models 1 were adjusted for confounders including season at birth, sex, gestational age at birth, birth weight z-score, maternal age, education, employment status and TV time during pregnancy, paternal education and employment status, parental separation at age 2 years, number of siblings at age 2 years, language spoken at home and monthly household income at age 2 years; Models 2 were model 1 further adjusted for children's lifestyle factors at the age of exposure assessment (e.g. child arrangement at age 2 years, preschool attendance of the child at age 3.5 years, frequency of activities with mother and father at age 1 year, non-screen-based activities and play at age 2 years, parent–child interactions at age 3.5 and 5.5 years, daily outdoor activities time of child at age 3.5 and 5.5 years and sleep durations at age 2, 3.5 and 5.5 years); models with screen exposure at 2 years were mutually adjusted for TV-on during family meals and screen time. Longitudinal models were adjusted for baseline cognitive scores. To help visualization, cross-sectional analyses have grey background, and longitudinal analyses have white background. CDI, Child Development Inventory.
*p-value < .05; **p-value < .01; ***p-value < .001.

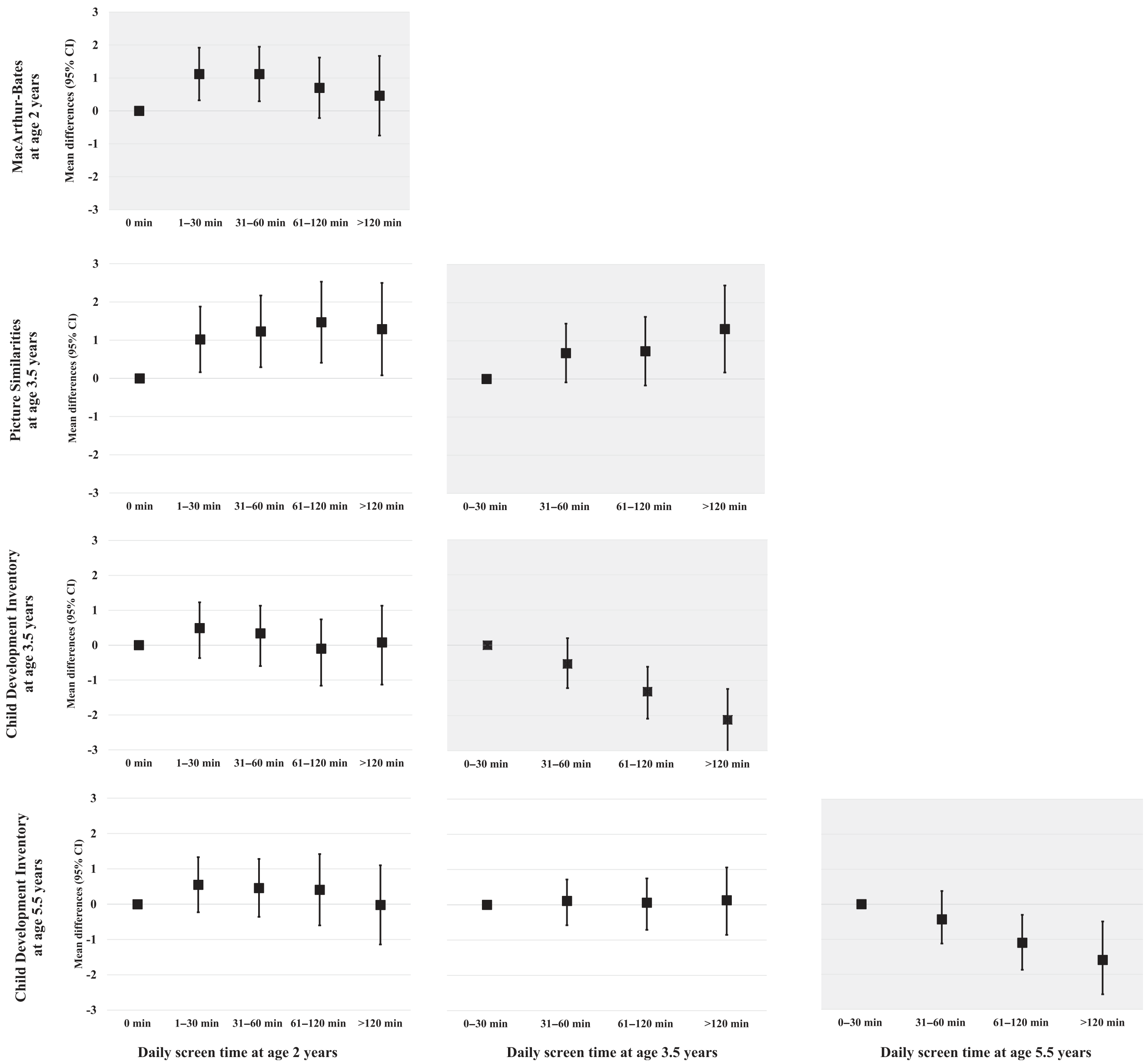

Figure 3 Adjusted cross-sectional (grey background) and longitudinal (white background) associations of screen use with cognitive development in the ELFE birth cohort (N = 13,763) using categorical screen time (X-axis: 5 categories at age 2 years, 4 categories at ages 3.5 and 5.5 years). All effect sizes are expressed on the standard scale (cognitive score with mean = 100 and SD = 15) on the Y-axis. All models were adjusted for the season at birth, sex, gestational age at birth, birth weight z-score, maternal age, education, employment status and TV time during pregnancy, paternal education and employment status, parental separation at age 2 years, number of siblings at age 2 years, language spoken at home, monthly household income at age 2 year and children's lifestyle factors at the age of exposure assessment (e.g. child arrangement at age 2 years, preschool attendance of the child at age 3.5 years, frequency of activities with mother and father at age 1-year, non-screen-based activities and play at age 2 years, parent–child interactions at age 3.5 and 5.5 years, daily outdoor activities time of child at age 3.5 and 5.5 years and sleep durations at age 2, 3.5 and 5.5 years. Models with screen use at age 2 years as independent variable were further adjusted for TV on during family meals. Longitudinal models were further adjusted for baseline cognitive scores (i.e. models with screen use at age 2 years were further adjusted for MB score; models with screen use at age 3.5 years were further adjusted for CDI score at 3.5 years)

To help visualize the shape of the relationships, Figure 3 shows the mean difference in standard scores for the cognitive measures (y-axis) for groups differing in screen time (x-axis). Overall, it shows that the shape of the associations, when any, was linear, which was the case in cross-sectional models (plots with grey background) at ages 3.5 and 5.5 years. Compared to children watching screens for 0–30 min per day at 3.5 years, those watching screens for >120 min scored 1.31 (95% CI: 0.14, 2.49) standard points higher on PS and 2.12 (95% CI: −3.03, −1.20) standard points lower on CDI at 3.5 years, which corresponds to changes of 0.09 and 0.14 SD respectively. Children in intermediate groups (31–60 and 61–120 min) had intermediate scores. Similarly, at 5.5 years, children watching screens for >120 min scored 1.59 (95% CI: −2.66, −0.53) standard points lower on CDI than children

Table 4 Fully adjusted cross-sectional and longitudinal associations of screen use with specific domains of cognitive development measured by CDI subscales in children aged 3.5 and 5.5 years in the ELFE birth cohort (N = 13,763)

Outcomes (CDI subscales)	Exposure	Outcomes at age 3.5 years	Outcomes at age 5.5 years
Social	TV-on during family meals at 2 years (ref: no)	0.07 (−0.49, 0.63)	−0.10 (−0.72, 0.53)
	Screen time at 2 years	0.02 (−0.26, 0.31)	−0.11(−0.42, 0.20)
	Screen time at 3.5 years	−0.44 (−0.72, −0.16)**	0.09 (−0.21,0.39)
	Screen time at 5.5 years	n.a	−0.09 (−0.37, 0.20)
Self help	TV-on during family meals at 2 years (ref: no)	−0.02 (−0.63, 0.59)	−0.34 (−0.97, 0.29)
	Screen time at 2 years	−0.23 (−0.57, 0.11)	−0.30 (−0.61, 0.00)*
	Screen time at 3.5 years	−0.43 (−0.70, −0.16)**	−0.62 (−0.96, −0.27)**
	Screen time at 5.5 years	n.a	−0.79(−1.14, −0.44)***
Gross motor	TV-on during family meals at 2 years (ref: no)	−0.18 (−0.74, 0.38)	0.07 (−0.54, 0.67)
	Screen time at 2 years	0.13 (−0.21, 0.48)	−0.11 (−0.38, 0.16)
	Screen time at 3.5 years	−0.17 (−0.46, 0.13)	−0.15 (−0.49, 0.19)
	Screen time at 5.5 years	n.a	0.04 (−0.21, 0.3)
Fine motor	TV-on during family meals at 2 years (ref: no)	−0.95 (−1.53, −0.37)**	−0.31 (−1.09, 0.48)
	Screen time at 2 years	0.00 (−0.29, 0.30)	0.17 (−0.1, 0.44)
	Screen time at 3.5 years	−0.43 (−0.70, −0.17)**	0.22 (−0.21, 0.64)
	Screen time at 5.5 years	n.a	0.07 (−0.30, 0.43)
Expressive language	TV-on during family meals at 2 years (ref: no)	−0.54 (−1.04, −0.03)*	−0.20 (−0.84, 0.44)
	Screen time at 2 years	−0.37 (−0.63, −0.12)**	−0.36 (−0.75, 0.03)
	Screen time at 3.5 years	−0.75 (−1.01, −0.48)***	−0.02 (−0.32, 0.27)
	Screen time at 5.5 years	n.a	−0.29 (−0.55, −0.03)*
Language comprehension	TV-on during family meals at 2 years (ref: no)	−1.29 (−1.81, −0.78)***	−0.72 (−1.34, −0.11)*
	Screen time at 2 years	0.06 (−0.19, 0.32)	−0.01 (−0.32, 0.30)
	Screen time at 3.5 years	−0.55 (−0.83, −0.27)***	−0.08 (−0.34, 0.19)
	Screen time at 5.5 years	n.a	−0.33 (−0.65, −0.01)*
Letter knowledge	TV-on during family meals at 2 years (ref: no)	−0.34 (−1.00, 0.32)	0.25 (−0.32, 0.82)
	Screen time at 2 years	0.12 (−0.25, 0.50)	0.15 (−0.15, 0.44)
	Screen time at 3.5 years	−0.28 (−0.67, 0.12)	−0.24 (−0.53, 0.06)
	Screen time at 5.5 years	n.a	−0.58 (−0.86, −0.30)***
Number knowledge	TV-on during family meals at 2 years (ref: no)	−0.37 (−0.91, 0.18)	0.09 (−0.50, 0.68)
	Screen time at 2 years	0.55 (0.26, 0.84)***	0.20 (−0.31, 0.71)
	Screen time at 3.5 years	0.06 (−0.26, 0.37)	0.10 (−0.23, 0.44)
	Screen time at 5.5 years	n.a	−0.15 (−0.44, 0.15)

All estimates are based on the standard scales (mean = 100, SD = 15). Models were adjusted for season at birth, sex, gestational age at birth, birth weight z-score, maternal age, education, employment status and TV time during pregnancy, paternal education and employment status, parental separation at age 2 years, number of siblings at age 2 years, language spoken at home, monthly household income at age 2 years, and also children's lifestyle factors at the age of exposure assessment (e.g. child arrangement at age 2 years, preschool attendance child at age 3.5 years, frequency of activities with mother and father at age 1 year, non-screen-based activities and play at age 2 years, parent–child interactions at age 3.5 and 5.5 years, daily outdoor activities time of child at age 3.5 and 5.5 years and sleep durations at age 2, 3.5 and 5.5 years. n.a., not applicable. Longitudinal models were adjusted for baseline cognitive scores. To help visualization, cross-sectional analyses have grey background, and longitudinal analyses have white background.
*p-value < .05; **p-value < .01; ***p-value < .001.

watching screens for 0–30 min. At age 2 years, however, a nonlinear shape was observed: children watching screens for 1–30 and 31–60 min scored 1.12 (95% CI: 0.35,1.90) and 1.12 (95% CI: 0.30,1.94) standard points higher than children watching no screens; children with greater screen times (61–120 min and above) scored in between. In longitudinal models (plots with white background), no associations were observed at the exception of the model for screen time at 2 years on PS at 3.5 years.

Table 4 presents the fully adjusted associations of screen use with different subdomains of cognitive development as measured by the CDI subscales at ages 3.5 and 5.5 years. Several negative associations were found with self-help, fine motor, expressive language and language comprehension. Table 5 shows sensitivity analysis using the complete cases. The observed associations of screen use with cognitive development were, overall and statistical significance put apart, consistent with the imputed samples. Indeed, the magnitude of the effect sizes was mostly unchanged.

Table S4 shows fully adjusted associations of screen use with cognitive development stratified by sex (male vs female). Overall, associations were similar in males and females, although a few estimates were stronger in males than females.

Discussion

In this nationwide birth cohort study of 13,763 children aged 2–5.5 years old, we found that TV-on during family meals at age 2 years was negatively associated with expressive language at age 2 years

Table 5 Cross-sectional and longitudinal associations of screen use with cognitive development in the ELFE birth cohort: complete case analyses

Outcome	Exposure	N[a]	Unadjusted models	Models 1	Models 2
MacArthur-Bates (2 years)	TV-on during family meals at 2 years (ref: no)	12,082/ 8,422/ 7,761	−3.29 (−3.85, −2.73)***	−1.99 (−2.68, −1.3)***	−1.33 (−2.04, −0.62)**
	Screen time at 2 years (hr/day)		−0.97 (−1.25, −0.68)***	−0.34 (−0.69, 0.00)	−0.18 (−0.54, 0.19)
Picture Similarities (3.5 years)	TV-on during family meals at 2 years (ref: no)	8,622/ 6,435/ 6,024	−1.41 (−2.08, −0.74)***	−0.11 (−0.92, 0.71)	−0.07 (−0.92, 0.77)
	Screen time at 2 years (hr/day)		−0.22 (−0.57,0.13)	0.40 (−0.03, 0.82)	0.40 (−0.05, 0.86)
	Screen time at 3.5 years (hr/day)	9,265/ 6,623/ 5,810	−0.55 (−0.86, −0.24)***	0.17 (−0.25, 0.59)	0.41 (−0.05, 0.87)
CDI (3.5 years)	TV-on during family meals at 2 years (ref: no)	10,827/ 7,828/ 7,284	−3.08 (−3.67, −2.49)***	−1.18 (−1.79, −0.56)***	−0.81 (−1.44, −0.18)*
	Screen time at 2 years (hr/day)		−0.69 (−0.99, −0.38)***	−0.18 (−0.50, 0.13)	−0.26 (−0.59, 0.07)
	Screen time at 3.5 years (hr/day)	11,939/ 8,117/ 6,970	−1.93 (−2.20, −1.67)***	−1.43 (−1.78, −1.08)***	−1.15 (−1.53, −0.78)***
CDI (5.5 years)	TV-on during family meals at 2 years (ref: no)	10,299/ 7,554/ 7,035	−2.10 (−2.71, −1.49)***	−0.70 (−1.41, 0.01)	−0.54 (−1.29, 0.21)
	Screen time at 2 years (hr/day)		−0.73 (−1.06, −0.41)***	0.08 (−0.30, 0.45)	0.01 (−0.40, 0.42)
	Screen time at 3.5 years (hr/day)	10,624/ 7,545/ 6,945	−1.54 (−1.83, −1.24)***	0.07 (−0.24, 0.38)	0.11 (−0.22, 0.43)
	Screen time at 5.5 years (hr/day)	11,248/ 7,814/ 7,285	−1.59 (−1.84, −1.35)***	−1.16 (−1.50, −0.82)***	−0.88 (−1.24, −0.52)***

All estimates are based on the standard scales (mean = 100, *SD* = 15). Models 1 were adjusted for confounders including season at birth, sex, gestational age at birth, birth weight *z*-score, maternal age, education, employment status and TV time during pregnancy, paternal education and employment status, parental separation at age 2 years, number of siblings at age 2 years, language spoken at home and monthly household income at age 2 years; Models 2 were model 1 further adjusted for children's lifestyle factors at the age of exposure assessment (e.g. child arrangement at age 2 years, preschool attendance child at age 3.5 years, frequency of activities with mother and father at age 1 year, non-screen-based activities and play at age 2 years, parent–child interactions at age 3.5 and 5.5 years, daily outdoor activities time of child at age 3.5 and 5.5 years and sleep durations at age 2, 3.5 and 5.5 years); In models with screen exposure at 2 years were mutually adjusted for TV-on during family meals and screen time. Longitudinal models were adjusted for baseline cognitive scores. To help visualization, cross-sectional analyses have grey background, and longitudinal analyses have white background. CDI, Child Development Inventory.
[a]The number of children with complete data in each model (from left to right).
**p*-value < .05; ***p*-value < .01; ****p*-value < .001.

and general cognitive development at age 3.5 years, but not associated with non-verbal reasoning at age 3.5 years nor with general cognitive development at age 5.5 years. In cross-sectional analyses, screen time was associated with lower general cognitive development at ages 3.5 and 5.5 years, particularly fine motor, language and self-help, but greater non-verbal reasoning at age 3.5 years. The associations were importantly reduced in magnitude when adjusting for sociodemographic and birth factors related to the family, the parents and child, and children's lifestyle factors susceptible to compete with screen use and became of small magnitude at the clinical level (up to 0.11 *SD*). Additionally, we found that the associations between screen time and cognitive development were non-linear when considering screen time at age 2 years, and linear when considering screen time at ages 3.5 and 5.5 years.

In our study, the associations of screen use with cognitive development were generally negative and of small magnitude, although they varied by age and domains of cognitive development.

Screen use explained up to 2% of the total variance of the models, which is relatively important for such a complex trait determined by numerous genetic, biological, environmental and psychosocial factors (Guez, Peyre, Williams, Labouret, & Ramus, 2021). This finding is consistent with recent studies that found negative associations of screen time with cognitive development (Aishworiya et al., 2019; Madigan et al., 2020; Martinot et al., 2021;

Nichols, 2022; Zimmerman & Christakis, 2005). Together with these studies, our study shows that, among various cognitive domains, language seems to be the most consistently related to screen use. As the first years of life are crucial for children's development and maturation, excessive screen time may replace time for other beneficial activities and social interactions, which may indirectly impede children's language. In ours, we also focused on the context of screen use, that is, TV during family meals, and found that it was associated with lower development, especially language, which is also in agreement with a previous study we conducted in another French birth cohort (Martinot et al., 2021). In the present study, the effect of watching TV during meals on the MB score was more than 10 times higher than the effect of a 1-hr increase in screen time daily. The main explanation for this finding is that background TV interferes with the quality and quantity of parent–child interactions, which is crucial for language acquisition in early childhood (Anderson & Subrahmanyam, 2017; Kirkorian, Pempek, Murphy, Schmidt, & Anderson, 2009). Indeed, auditory and visual stimulation from background TV may increase distractions within the family setting, limiting both ways verbal interactions between children and parents. This can pose challenges for a child in deciphering phonological and syntactical sounds amidst the background noise in the home and limit verbal comprehension and expression (McMillan & Saffran, 2016; Riley & McGregor, 2012). Our study, in cross-sectional designs, also revealed negative associations of screen use with general cognitive development at ages 3.5 and 5.5 years. This finding is in line with extant studies that showed that excessive daily screen time had a deleterious effect on cognitive development (Domingues-Montanari, 2017; Felix et al., 2020; Madigan et al., 2020; Madigan, Browne, Racine, Mori, & Tough, 2019; Walsh et al., 2020). However, the cross-sectional design in our study does not allow us to discard the potential reverse causation that children with lower cognitive scores were more spontaneously attracted by screens, or more disruptive children were disciplined using screens. In the longitudinal model adjusting for CDI score at age 3.5 years, the negative association of screen use at age 3.5 with CDI score at age 5.5 disappeared, which may suggest that the true causal effect of screen use on cognitive development are likely to be small. Indeed, the largest fully adjusted effect size we highlight in the present study (see Table 3) corresponds to a standardized effect size, that is, Cohen's *d*, of .11. Together with the fact that effects are inconsistent across cognitive measures, the small size of the effects is unlikely to have major implications for children's cognitive development at the individual level. However, it does justify some degree of vigilance. Just like small streams make large rivers, small effects remain relevant at the population level, especially given that screen time steadily increases with children's age, with potentially cumulative effects from early childhood to adolescence, and that these trends seem to be increasing year after year. Longitudinal studies examining more long-term consequences are warranted to confirm such cumulative effects.

An unexpected finding of our study is the positive cross-sectional association between screen time and non-verbal reasoning at age 3.5 in model 2 where the lifestyle factors competing with screen use were further adjusted. However, this finding was not observed in our sensitivity analysis of the complete case and contrary to a nationwide Irish cohort study with non-verbal reasoning skills also measured by PS (Beatty & Egan, 2020). In the Irish study, screen use >3 hr/day was negatively, although weakly, associated with non-verbal reasoning skills, compared to those exposed to screen for 1–2 hr. Also, it only accounted for a few family factors, which raises concern about residual confounding. Studies also revealed that screen viewing promoted brain and cognitive development in some content, especially visual processing skills (Moon et al., 2019; Walsh et al., 2020), but positive associations are rarely reported in real-life settings. Studies assessing the associations of screen use with non-verbal reasoning skills in children are needed.

The association of screen time at age 2 years with cognitive development at age 2 years had an inverted-U shape but was linear at ages 3.5 and 5.5 years. More specifically, we found that children without screen exposure had lower cognition scores than those exposed to less than 1 hr/day, which is partly in line with our previous study (Martinot et al., 2021). A possible explanation for this sporadic U-shape association is that children aged 2 years with intermediate screen time could be exposed to screens under the supervision of their parents and more likely to watch high-quality content (e.g. educational programmes or some training video games), which may promote their language and general cognitive development. This U-shape association does not seem to last beyond 2 years.

A few differences in the associations were found in our study in analyses stratified by sex, but, overall, they were consistent with the findings on the imputed sample when focusing on the magnitude of effect sizes instead of the statistical significance. Males are typically lagging in early language acquisition and a study reported observed associations of screen use with cognition varied by sex (Peyre et al., 2019; Walsh et al., 2020).

Our study has many strengths. First, it adds to the very few studies that examined the associations of screen use with cognitive development in early childhood using both cross-sectional and longitudinal design on a nationally representative sample. Second, our daily screen time variable included five types of devices (e.g. TV, smartphone, video game console, tablet and computer) and focused on various domains of cognitive development, not only language. Third, our study controlled for a wide range of confounders, including sociodemographic and birth factors related to the family, the parents and the child, and children's lifestyle factors susceptible to compete with screen use, and we observed the magnitude of associations reduced substantially once controlling for these confounders. Although residual confounding may remain, it is unlikely that it would change drastically our conclusions. Several limitations should be mentioned, however. First, the baseline cognitive scores adjusted in the longitudinal analyses were not optimal because we did not have repeated measures for all cognitive constructs; adjusting test scores for the tests taken at earlier times provided the next best control in such circumstance, even though this prevents us from fully tackling potential reverse causation. Second, we could not examine device-specific associations because time spent using screens other than television was limited at these stages and lacked variability in our sample. Third, we could not examine the content of media use or co-viewing in the ELFE cohort, limiting us in determining whether they confound or modulate the observed associations. Last, as in most observational studies, screen use was reported by the parents. This method is known to be poorly accurate and suffers from biases such as social desirability. Similar limitations apply to our cognitive measures, which were reported by the parents except for non-verbal reasoning skills measured by a trained investigator. The CDI score also had a ceiling effect and lacked variability at the right end of the distribution, not allowing us to discriminate cognitive development within children of normal development.

Implications

The current evidence base on the impact of screen use on cognition appears intricated. There is sufficient evidence to conclude that, overall and in the real context of use, greater screen time is associated with lower language development in early childhood; the magnitude of such an effect remains small at the individual level and mostly holds after controlling for sociodemographic factors and children's lifestyle factors. However, there are hints suggesting that, in particular settings, the relationship of screen use with cognitive development may not be linear, modulated by third factors and differentially associated with other subdomains of cognition. Although the magnitude of effects is small and not relevant at the clinical level (Cohen's d not greater than 0.11 once adjusted for confounders), public health experts and decision makers must consider screen use as a significant issue at the population level, given the important raise and accumulation of screen use over childhood, especially in the post-Covid-19 era. Longitudinal follow-ups are warranted to determine whether associations observed in early childhood remain in later childhood. Given that health-related behaviour adopted in early childhood tends to track over the life course (Jones, Hinkley, Okely, & Salmon, 2013), developing adequate screen use habits in early life remains necessary.

Conclusions

Our study shows negative associations between screen use and language ability and general cognitive development in early childhood, even after controlling for key confounders and children's lifestyle factors susceptible to compete with screen use. However, screen use was not consistently associated with all examined outcomes and was even positively associated with children's non-verbal reasoning skills. These associations were of small magnitude at the individual level but need consideration at the population level. Future studies need to better account for the context of screen use, not only screen time.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Table S1. Pairwise correlations between children's cognitive scores at ages 2, 3.5 and 5.5 years in the ELFE birth cohort.

Table S2. Factor loadings from the principal component analysis of children's non-screen-based activities and play at age 2 years in the ELFE birth cohort (n = 13,028).

Table S3. Factor loadings from principal component analyses of children's leisure activities shared with parents at ages 3.5 (n = 12,071) and 5.5 (n = 11,263) years in the ELFE birth cohort.

Table S4. Fully adjusted cross-sectional and longitudinal associations of screen use with cognitive development in the ELFE birth cohort according to child sex (N = 13,763).

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Key points

- Negative associations of screen use with child cognition were frequently reported; however, the evidence remains weak because of methodological gaps.
- Based on a nationwide French birth cohort, this study examined the associations of screen use with cognition from 2 to 5.5 years, accounting for a wide range of confounders, including children's lifestyle factors competing with screen use.
- TV-on during family meals at age 2 was negatively associated with language development at age 2 and general development at age 3.5. In cross-sectional analyses, screen time was negatively associated with general development at ages 3.5 and 5.5, but positively with non-verbal reasoning at age 3.5.
- This study suggests that the context, not solely the screen time, matters in children's cognitive development.

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