Association of screen use trajectories from early childhood with cognitive development in late childhood: The EDEN mother–child cohort

Shuai Yang, Lorraine Poncet, Muriel Tafflet, Sandrine Lioret, Hugo Peyre, Franck Ramus, Barbara Heude, Jonathan Y. Bernard

Abstract

Screen use has been related to children’s cognitive development, but more evidence from longitudinal studies is needed. We investigated the association of screen use trajectories from age 2 to 11–12 years and cognitive development at 11–12 years in 459 children from the EDEN cohort. Parents reported how frequently TV was on during family meals at age 2, 3, 5 and 8 years and children’s screen time at the same ages up to 11–12 years. Intellectual abilities were derived from subtests of the Wechsler Intelligence Scale for Children, and the Peabody Picture Vocabulary Test at 11–12 years. Trajectories of screen time and TV on during family meals were identified and examined in relation with intellectual abilities using multivariable linear regression models. Four screen time trajectories were identified: low (11%), average (50%), high (32%), and very high (6%) user. The three trajectories of TV on during family meals were never (41%), sometimes (34%), and often/always (25%). Screen time trajectories were not associated with intellectual abilities at 11–12 years. TV on sometimes (vs never), but not often/always, during family meals was associated with reduced non-verbal and general intellectual abilities. Future studies need to consider the context of screen use, not just the time.

1. Background

Screen time in children and adolescents has increased greatly with the rapid spread of handheld devices. In middle- and high-income countries, most children and adolescents exceed the recommended amount of screen time of 2 h per day (Bernard et al., 2021; Strasburger et al., 2013). An international study revealed that the average screen time of children aged 11–15 years was greater than 2 h per day in 30 countries (Bucksch et al., 2016). In the United States, a study reported that children aged 8–10 years spent approximately 8 h per day in front of screen (Rideout, 2015). In France, the 2015 Esteban survey found that adolescents aged 11–14 years spent 5 h per day on average in front of screen (SANTÉ et PUBLIQUE, 2014–2016). Concerns have been raised regarding the potential deleterious effect of screen time on child development (Kostyrka-Allchorne et al., 2017).

Published systematic reviews have indicated that excessive screen use may impede children’s development and psychological health (LeBlanc et al., 2012; Li et al., 2020; McNeill et al., 2019; Poitras et al., 2017; Tremblay et al., 2011). However, the cognitive developmental effects of screen use in children remain unclear.

A systematic review with meta-analysis revealed that increased screen time was associated with poorer language development in children under 5 years (Madigan et al., 2020). However, out of 38 studies included in the meta-analysis, 16 showed negative associations, while one reported positive associations and 21 presented null associations. There was significant heterogeneity of effect sizes between studies, and studies of smaller sample size tended to show larger effect sizes, suggesting publication bias (Madigan et al., 2020). Importantly, this systematic review focused on language development only, but a few studies also reported negative associations with other domains of cognition. For

Keywords:
Child
Birth cohort
EDEN
Screen time
TV
Smartphone
Video
Computer
Cognitive development
Intellectual ability
Latent profile analysis
Latent class analysis

Handling editor: Min Jou

ARTICLE INFO

A B S T R A C T

Screen use has been related to children’s cognitive development, but more evidence from longitudinal studies is needed. We investigated the association of screen use trajectories from age 2 to 11–12 years and cognitive development at 11–12 years in 459 children from the EDEN cohort. Parents reported how frequently TV was on during family meals at age 2, 3, 5 and 8 years and children’s screen time at the same ages up to 11–12 years. Intellectual abilities were derived from subtests of the Wechsler Intelligence Scale for Children, and the Peabody Picture Vocabulary Test at 11–12 years. Trajectories of screen time and TV on during family meals were identified and examined in relation with intellectual abilities using multivariable linear regression models. Four screen time trajectories were identified: low (11%), average (50%), high (32%), and very high (6%) user. The three trajectories of TV on during family meals were never (41%), sometimes (34%), and often/always (25%). Screen time trajectories were not associated with intellectual abilities at 11–12 years. TV on sometimes (vs never), but not often/always, during family meals was associated with reduced non-verbal and general intellectual abilities. Future studies need to consider the context of screen use, not just the time.

1. Background

Screen time in children and adolescents has increased greatly with the rapid spread of handheld devices. In middle- and high-income countries, most children and adolescents exceed the recommended amount of screen time of 2 h per day (Bernard et al., 2021; Strasburger et al., 2013). An international study revealed that the average screen time of children aged 11–15 years was greater than 2 h per day in 30 countries (Bucksch et al., 2016). In the United States, a study reported that children aged 8–10 years spent approximately 8 h per day in front of screen (Rideout, 2015). In France, the 2015 Esteban survey found that adolescents aged 11–14 years spent 5 h per day on average in front of screen (SANTÉ et PUBLIQUE, 2014–2016). Concerns have been raised regarding the potential deleterious effect of screen time on child development (Kostyrka-Allchorne et al., 2017).

Published systematic reviews have indicated that excessive screen use may impede children’s development and psychological health (LeBlanc et al., 2012; Li et al., 2020; McNeill et al., 2019; Poitras et al., 2017; Tremblay et al., 2011). However, the cognitive developmental effects of screen use in children remain unclear.

A systematic review with meta-analysis revealed that increased screen time was associated with poorer language development in children under 5 years (Madigan et al., 2020). However, out of 38 studies included in the meta-analysis, 16 showed negative associations, while one reported positive associations and 21 presented null associations. There was significant heterogeneity of effect sizes between studies, and studies of smaller sample size tended to show larger effect sizes, suggesting publication bias (Madigan et al., 2020). Importantly, this systematic review focused on language development only, but a few studies also reported negative associations with other domains of cognition. For

Keywords:
Child
Birth cohort
EDEN
Screen time
TV
Smartphone
Video
Computer
Cognitive development
Intellectual ability
Latent profile analysis
Latent class analysis

Handling editor: Min Jou

ARTICLE INFO

A B S T R A C T

Screen use has been related to children’s cognitive development, but more evidence from longitudinal studies is needed. We investigated the association of screen use trajectories from age 2 to 11–12 years and cognitive development at 11–12 years in 459 children from the EDEN cohort. Parents reported how frequently TV was on during family meals at age 2, 3, 5 and 8 years and children’s screen time at the same ages up to 11–12 years. Intellectual abilities were derived from subtests of the Wechsler Intelligence Scale for Children, and the Peabody Picture Vocabulary Test at 11–12 years. Trajectories of screen time and TV on during family meals were identified and examined in relation with intellectual abilities using multivariable linear regression models. Four screen time trajectories were identified: low (11%), average (50%), high (32%), and very high (6%) user. The three trajectories of TV on during family meals were never (41%), sometimes (34%), and often/always (25%). Screen time trajectories were not associated with intellectual abilities at 11–12 years. TV on sometimes (vs never), but not often/always, during family meals was associated with reduced non-verbal and general intellectual abilities. Future studies need to consider the context of screen use, not just the time.

1. Background

Screen time in children and adolescents has increased greatly with the rapid spread of handheld devices. In middle- and high-income countries, most children and adolescents exceed the recommended amount of screen time of 2 h per day (Bernard et al., 2021; Strasburger et al., 2013). An international study revealed that the average screen time of children aged 11–15 years was greater than 2 h per day in 30 countries (Bucksch et al., 2016). In the United States, a study reported that children aged 8–10 years spent approximately 8 h per day in front of screen (Rideout, 2015). In France, the 2015 Esteban survey found that adolescents aged 11–14 years spent 5 h per day on average in front of screen (SANTÉ et PUBLIQUE, 2014–2016). Concerns have been raised regarding the potential deleterious effect of screen time on child development (Kostyrka-Allchorne et al., 2017).

Published systematic reviews have indicated that excessive screen use may impede children’s development and psychological health (LeBlanc et al., 2012; Li et al., 2020; McNeill et al., 2019; Poitras et al., 2017; Tremblay et al., 2011). However, the cognitive developmental effects of screen use in children remain unclear.

A systematic review with meta-analysis revealed that increased screen time was associated with poorer language development in children under 5 years (Madigan et al., 2020). However, out of 38 studies included in the meta-analysis, 16 showed negative associations, while one reported positive associations and 21 presented null associations. There was significant heterogeneity of effect sizes between studies, and studies of smaller sample size tended to show larger effect sizes, suggesting publication bias (Madigan et al., 2020). Importantly, this systematic review focused on language development only, but a few studies also reported negative associations with other domains of cognition. For
instance, a study in 437 Singaporean children showed that those with greater screen time at 12 months were more likely to suffer from decreased attention and executive function at age 9 years (Law et al., 2023). Other research indicated that screen time was associated with poorer motor skills, (Felix et al., 2020) short-term memory, (Zimmerman & Christakis, 2005) non-verbal reasoning skills, (Beatty & Egan, 2020) working memory, (Zhang et al., 2021) and general cognitive development (Madigan et al., 2019; Yang et al., 2023). In contrast, other studies reported null, positive and mixed associations of screen time with cognitive development. A US cohort study in 872 children showed that early screen time, i.e., at age 6 months, 1 and 2 years, was not associated with their language and visual motor skills at age 3 years (Schmidt et al., 2009). A Brazilian study in 3625 adolescents indicated that TV viewing and video games at age 11 years and computer use at ages 11 and 15 years were positively associated with later working memory skill (Soares et al., 2021). A cross-sectional study in North American children aged 5–12 years showed that TV viewing was associated with lower cognitive development, including attention and executive function, language, memory/learning, social perception and visuospatial processing, whereas computer use was positively related to language, memory and learning, and social perception domains (Rosenqvist et al., 2016). In addition, in a previous study on 13,763 young children, we found that screen time was negatively associated with general cognitive development, but positively associated with non-verbal reasoning abilities (Yang et al., 2023). Hence, the epidemiological evidence regarding other cognitive domains remains scarcer with mixed findings, which warrants further investigation.

A few hypotheses to explain the potentially detrimental effect of screen time on cognition have been proposed. A US study examined the effect of screen time at the brain’s structure level among 47 preschool children by diffusion tensor imaging, and found that longer screen time delayed brain development as reflected by lower microstructural organization and myelination of brain white matter known to support language, executive functions and literacy skills (Hutton et al., 2020). A more behavioral hypothesis has been also advanced, where screen time is considered as an activity that competes with and replaces time spent in other activities that are greatly favorable for brain functioning (e.g., social interaction, book reading) (Zhang et al., 2021). This latter hypothesis has yet rarely been examined in large epidemiological studies. Other limitations in study design and methodology have not allowed previous research to demonstrate a causal association between screen use and children’s cognitive development. First, most studies were cross-sectional and therefore unable to determine the temporal sequence between screen use and cognitive development (Masaelli & Billieux, 2022; Tremblay et al., 2011). Second, most studies failed to control adequately for core sociodemographic factors of the family, leaving their findings potentially attributable to residual confounding (Kostyrka-Allchorne et al., 2017; Zhao et al., 2022). In most studies that accounted for these factors, the association of screen use with cognitive development reduced toward the null after adjustment (Goh et al., 2016; Schmidt et al., 2009; Yang et al., 2023).

In our previous studies of children’s cognitive development, we found a negative effect of the context of screen use (e.g., TV during family meals), rather than an effect of screen time per se (Martino et al., 2021; Yang et al., 2023). A study focusing on children’s viewing content showed that viewing some specific programs (e.g., Dora the Explorer, Blue’s Clues, Arthur, Clifford, or Dragon Tales) contributed to children’s language development, while viewing other programs (e.g., Tele-ViBabies) was associated with poorer language development (Linebarger & Walker, 2005). It highlights the importance of considering and examining media content and the context of screen use.

Given that screen use habits are potentially modifiable, it is also crucial to investigate screen use trajectory within a longitudinal framework, employing repeated measures throughout childhood (Padmapiya et al., 2021). Studying screen use trajectory provides a more comprehensive perspective on the evolving nature of screen use habits (Zhao et al., 2022). However, few studies have explicitly identified screen use trajectories from early childhood to puberty and assessed its association with endpoint cognitive development (McArthur et al., 2020).

In this study, we leveraged repeated screen use data from a French mother–child cohort to (i) identify trajectories of screen time and the context of screen use (TV on during family meals) from age 2 to 11–12 years; and (ii) examined their associations with cognitive development at age 11–12 years, with adjustment for household sociodemographic characteristics, children’s movement behaviors and baseline cognition.

2. Methods

2.1. Study design and population

The Étude des Déterminants pré et postnataux précoce du développement et de la santé de l’Enfant (EDEN) study is an ongoing French mother–child cohort study aiming to examine the pre- and early post-natal determinants of child development and health. From 2003 to 2006, pregnant women presenting for prenatal appointments in the maternity units of Poitiers and Nancy university hospitals were invited to participate in the study. Women were eligible if they were pregnant for <24 weeks of gestation of a singleton fetus, had no history of diabetes before pregnancy, were able to write and speak French, and were not planning to leave the region within the next 3 years. A total of 2002 pregnant women were enrolled, and 1907 singleton newborns were included in the post-natal follow-up. The EDEN study received approval from the ethics research committee (Comité Consultatif de protection des personnes dans la recherche biomédicale) of Bicêtre Hospital and the Data Protection Authority (Commission Nationale de l’Informatique et des Libertés). More details regarding the EDEN study protocol have been published (Heude et al., 2016).

At inclusion, women signed informed written consent for their own participation. Consent for the offspring was obtained from both parents after delivery. Information concerning the parents and the child was obtained by questionnaires self-administered by the parents or by trained research staff during pregnancy, after delivery and when the child was aged 4 and 8 months and 1, 2, 3, 4, 5, 8 and 11–12 years. Obstetrical and clinical records were collected before and at birth. Children’s clinical and neuropsychological examinations occurred at ages 1, 3, and 5 years.

2.2. Assessment of screen use

Information on children’s screen time was collected by parent-completed questionnaires at ages 2, 3, 5, 8 and 11–12 years. At ages 2, 3 and 5 years, total screen time, including watching TV/DVDs, playing video games, and using a computer, was asked with a single question (“Currently, during a typical week, how much time does your child spend watching TV, playing video games or on a computer?”). At age 8 years, TV/DVD watching, playing video games, and using a computer were recorded by asking three separate questions (“Currently, during a typical week, excluding school holidays, how much time does your child spend watching TV? Using a computer? Playing video games?”). At age 11–12 years, there were two items queried: 1) watching TV/DVDs and 2) playing video games, using the Internet, and chatting/using social media regardless of the screen device (“Since the beginning of the academic year, during a typical week how much time on average does your child spend … 1) Watching TV or DVDs? 2) On video games, the Internet, chatting/using social media, on computer, tablet, phone or game console.”). All these questions were asked separately for different days of the week: At ages 2, 3, 5, and 8 years, parents were asked to report screen viewing time on a typical weekday (except Wednesday), on Wednesday (day off from school), and weekend days. At age 11–12 years, data were obtained from parents on a daily basis (from Monday to Sunday). Screen times were averaged (4 × weekday + Wednesday + 2 × weekend day)/7 at ages 2, 3, 5 and 8 years.
and (sum of screen time from Monday to Sunday)/7 at age 11–12 years to obtain a daily average screen time over the week. We combined screen times from the different devices/media into a single variable: total screen time.

Parents reported one particular context of screen exposure, TV on during family meals, by using a 4-point Likert scale (never, sometimes, often, or always) at ages 2, 3, 5, and 8 years (Martino et al., 2021).

### 2.3. Intellectual abilities at age 11–12 years

Children’s intellectual abilities were assessed by computer-assisted tests at age 11–12 years. All tests were implemented at home on a Web interface; parents were instructed to provide a quiet environment without external distraction and to not interfere with their child during the test. Written and pre-recorded verbal instructions were given simultaneously.

We used parts of the French version of the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) to measure general intellectual abilities of children. The WISC-IV was designed to measure the intellectual abilities of children aged 6–16 years. In our study, participants were assessed with three subtests of the WISC-IV (Picture Concepts, Matrix Reasoning, and a multiple-choice version of Comprehension) and the French version of the Peabody Picture Vocabulary Test (Dunn et al., 1993). These WISC-IV subtests were selected in order to only use receptive tests requiring multiple-choice answers, better suited to online testing conditions. Raw scores from each test were adjusted for the child’s grade in three categories: 4th/5th grade, 6th grade, and 7th/8th grade.

Verbal, non-verbal, and general intellectual abilities were derived with a three-step strategy using factor analysis: 1) verbal abilities were obtained by factor analysis of the grade-adjusted scores of Vocabulary and Comprehension subtests; 2) non-verbal abilities were obtained by factor analysis of the grade-adjusted scores of Matrix Reasoning and Picture Concepts subtests; and 3) general intellectual abilities were obtained by factor analysis of verbal and non-verbal abilities. Verbal, non-verbal and general intellectual abilities factor scores were re-scaled with a mean of 100 and an SD of 15.

### 2.4. Covariates

Potential confounders were determined a priori from the literature. Covariates included the study center (Nancy or Poitiers); sociodemographic factors related to the child, parents, and family at baseline and age 11–12 years; baseline cognition at ages 2 and 5–6 years; and children’s movement behaviors at age 11–12 years.

#### 2.4.1. Sociodemographic factors

These included child sex (male, female), gestational age at birth (in weeks), maternal pre-pregnancy body mass index (BMI), maternal age at delivery (in years), first child at birth (yes, no), average of both parents’ education (in years), child exact age at testing at age 11–12 years (in months), paternal employment status at 11–12 years (yes, no/do not know), paternal employment status at 11–12 years (full-time, part-time, no) and monthly household income at age 11–12 years (in five categories).

#### 2.4.2. Baseline child cognition measures at ages 2 and 5–6 years

To model the change in intellectual abilities that can be directly attributed to screen use over the time period, we accounted for baseline cognition by adjusting for measures at age 2 or 5–6 years. At age 2 years, language ability was evaluated with the short form of the MacArthur Bates Communicative Development Inventory (MB-CDI), (Penson et al., 1993) adapted in French in 2003 (Kern, 2003). The MB-CDI scale contains 100 items with a total score of 0–100. Motor development was assessed with 22 motor-related items from the French Psychomotor Developmental Scale for Early Childhood, (Josse, 1997) leading to a score of 0–22. More details have been published (Bernard et al., 2016).

At age 5–6 years, cognition was assessed with the French version of the WISC-III (Wechsler, 2002) by two trained psychologists (one in each study center). The core subtests of the scale were used (i.e., information, vocabulary, word reasoning, block design, matrix reasoning, picture concepts, and coding) to obtain age-adjusted composite scores for verbal, non-verbal, and general intelligence abilities (Bernard et al., 2017).

#### 2.4.3. Child movement behaviors

Sleep, sedentary behavior, and physical activity have been collectively referred to as movement behaviors (Tremblay et al., 2016). In our study, we considered sleep time (in hours) and outdoor activities time (in hours) at age 11–12 years. Parents reported the times the child went to bed at night and woke up in the morning on a typical weekday and weekend. Then, sleep time was calculated as follows: (5 × weekday + 2 × weekend day)/7. Parents also reported the time their child usually spent playing outdoor activities (gardens, parks, etc.) during the seven days of a typical week. The daily average outdoor activities time at age 11–12 years was calculated as follows: (sum of time child spent on playing outdoor activities time from Monday to Sunday)/7.

### 2.5. Statistical analyses

Latent profile analysis (LPA) is a data-driven classification approach used to derive latent trajectories within a population based on pattern of responses to multiple observed variables. It has received great interest in social science and psychological research in recent years (Spurk et al., 2020). Assumption underlying LPA is that the variance within a population can be minimized by introducing a categorical latent variable. This latent variable effectively divides the population into two or more subgroups that exhibit greater homogeneity in their patterns of variable means and covariances. The primary benefits of employing LPA over traditional, non-latent cluster methods (e.g., hierarchical cluster analysis and K-means clustering) are: 1) LPA is based on a probabilistic framework, allowing for the estimation of posterior probabilities of membership in latent profiles. This provides a more nuanced understanding of individuals’ cluster memberships, accommodating fractional or partial memberships; 2) LPA explicitly models unobserved heterogeneity within the data, allowing for the identification of latent structures that traditional clustering methods might overlook; 3) LPA offers versatility in analyzing different types of data, including continuous, categorical (nominal or ordinal), counts, or any combination of these (Magidson & Vermunt, 2002).

In this study, we applied LPA to identify screen time trajectories from age 2 to 11–12 years using (continuous) screen times at ages 2, 3, 5, 8 and 11–12 years. The identified trajectories can be defined by means and variances (Oberski, 2016). We conducted the LPA in two steps. First, we ran LPA models with two to six trajectories without controlling for covariates. We retained the final latent model based on the best fit, the interpretability of trajectories and their sample size. Statistical fit was assessed with log-likelihood, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and sample-size adjusted BIC (SABIC), the lower value indicating a better fit; bootstrapped likelihood ratio test (BLRT) for statistical significance; and higher posterior probability and entropy ($≥$0.80). Second, the final model was built by fixing the measurement parameters obtained from the first step.

Latent class analysis (LCA) is a model-based cluster analysis designed specifically for categorical data, and applies the expectation-maximization algorithm to identify qualitatively different trajectories within a population that share certain characteristics (Oberski, 2016). The underlying assumption of LCA is that the membership within latent unobserved trajectories can be elucidated by examining the profile of assessment indicators (e.g., TV on during family meals in this study) (Weller et al., 2020). The advantages of applying LCA over traditional cluster analysis (e.g., hierarchical cluster analysis and K-means clustering) are: 1) in contrast to other types of cluster analysis which...
primarily rely on distance-based methods, LCA is model-based and has more formal criteria for choosing the final model; 2) traditional cluster analysis methods typically assign individuals to clusters in a binary, all-or-none manner. Conversely, LCA permits individuals to have varying degrees of membership in each latent trajectory, allowing for fractional trajectory membership, which is quantified through posterior probabilities (Hagenaars & McCutcheon, 2002).

In our study, we used LCA to identify the trajectory of TV on during family meals from ages 2–8 years using the (categorical) variables indicating how frequently TV was on during family meals at ages 2, 3, 5 and 8 years. First, we explored models with two to six trajectories without controlling for covariates. The model with the optimal number of trajectories was selected according to statistical fit (lowest AIC and BIC) and interpretability and sample size of the trajectories.

The association of trajectories of screen time and TV on during family meals from age 2 to 11–12 years and intellectual abilities at age 11–12 years was examined by linear regression, with adjustment for all covariates and baseline cognition at age 2 years. Models were built using four sets of covariate adjustment: unadjusted models; Model 1: adjusting for sociodemographic factors related to the family, the parents, and the child at baseline and at age 11–12 years; Model 2: model 1 with further adjustment for baseline cognition at age 2 years (model related to verbal and non-verbal intellectual abilities was adjusted for language and motor development at age 2 years, respectively; model related to general intellectual abilities was adjusted for both language and motor development at age 2 years); and Model 3: model 2 with further adjustment for children’s movement behavioral factors susceptible to compete with screen use.

In this study, we included children with at least one measure of screen use from age 2 to 11–12 years and one cognitive score at age 11–12 years (n = 459, see Fig. 1). We further compared the baseline characteristics between the included and excluded children. Missing data for screen use, intellectual abilities, and covariates were imputed using the random forest method for those included children (Shah et al., 2014). LPA, LCA and linear regression analysis were performed on the imputed dataset.

To examine the robustness of the findings, additional analyses were performed to assess the association of screen time and TV on during family meals at each age separately (i.e., without deriving trajectories) and verbal, non-verbal and general intellectual abilities, with adjustment for all covariates. In these additional analyses, models related to screen use at age 2 and 3 were adjusted for baseline cognition at age 2 years and models related to screen use at age 5, 8 and 11–12 years were adjusted for baseline cognition at age 5–6 years; sensitivity analyses were conducted on complete cases.

Data analysis involved using SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Random forest imputation, LPA, LCA and linear regression analysis were performed with RStudio (2022) (RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA), package “missForest” for random forest imputation, package “tidyLPA” for LPA and package “poLCA” for LCA.

3. Results

3.1. Study population

As compared with excluded children, included children had older mothers with lower pre-pregnancy BMI and parents with higher education and income; they also spent less time in front of screens and had higher language ability at age 2 years (Table 1). Mean (SD) daily screen time was 0.7 (0.7), 1.0 (0.7), 1.2 (0.8), 1.8 (1.1), and 1.9 (1.2) hour at age 2, 3, 5, 8 and 11–12 years, respectively (Supplemental Table 1). More than 40% of included families never had TV on during family meals and the proportion consistently decreased from “sometimes” to

Fig. 1. Flowchart of the EDEN children in the study.
“always” from age 2–8 years. **Supplemental Table 1** shows other socio-demographic factors, children’s movement behaviors, and cognitive development at age 2 years.

### 3.2. Screen use trajectories

As compared with other models, the LPA model with four profiles was identified as both the most interpretable and the most parsimonious screen-time trajectory (age 2 to 11–12 years) in terms of goodness of fit (lower AIC and BIC, and higher entropy, **Supplemental Table 2**). The characteristics of the four identified trajectories are presented in **Fig. 2 a**. The latent trajectories and proportion of participants in each trajectory are in **Supplemental Table 3**. The trajectories were labelled “very high user” (6% of the sample), “high user” (32%), “average user” (50%, reference group) and “low user” (11%).

The LCA model with three classes was identified as the most parsimonious trajectory of TV on during meals in terms of goodness of fit and interpretability (see, **Supplemental Table 4**). The characteristics of the three identified trajectories are in **Fig. 2 b**. These trajectories were named according to the original response: “never” (41% of the sample, reference group), “sometimes” (34%) and “often/always” (25%).

### Table 1

<table>
<thead>
<tr>
<th>Characteristics of children (and families) in the EDEN cohort who were included in and excluded from the study.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Included children</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td><strong>Study center</strong></td>
</tr>
<tr>
<td>Poitiers</td>
</tr>
<tr>
<td>Nancy</td>
</tr>
<tr>
<td><strong>Parental characteristics</strong></td>
</tr>
<tr>
<td>Maternal age at birth (years)</td>
</tr>
<tr>
<td>Paternal age at birth (years)</td>
</tr>
<tr>
<td>Maternal pre-pregnancy BMI (kg/m²)</td>
</tr>
<tr>
<td>Family income at age 2 years (Euros)</td>
</tr>
<tr>
<td>&lt;1500</td>
</tr>
<tr>
<td>16.9 (73)</td>
</tr>
<tr>
<td>28.1 (272)</td>
</tr>
<tr>
<td><strong>Child characteristics</strong></td>
</tr>
<tr>
<td>Child sex</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Gestational age at birth (weeks)</td>
</tr>
<tr>
<td>Birth weight (kg)</td>
</tr>
<tr>
<td>Screen use at age 2 years (hour/day)</td>
</tr>
<tr>
<td>Never</td>
</tr>
<tr>
<td>Sometimes</td>
</tr>
<tr>
<td>Often</td>
</tr>
<tr>
<td>Always</td>
</tr>
<tr>
<td>Language development at age 2 years</td>
</tr>
<tr>
<td>Motor development at age 2 years</td>
</tr>
</tbody>
</table>

*Continuous variables were analyzed by Student t-test and categorical variables by chi-squared test.*

![Fig. 2. Trajectories for children from the EDEN cohort study (n = 459). a) Profiles of screen time trajectories. b) Description of trajectories of TV on during family meals. Trajectory 1: sometimes (n = 154, 34%); trajectory 2: never (n = 189, 41%); trajectory 3: often/always (n = 116, 25%). The red bar indicates the conditional probability of being in the category of TV on during family meals at age 2, 3, 5 and 8 years given the latent trajectory.](image)
Table 2

<table>
<thead>
<tr>
<th>Screen-time trajectories (age 2–11–12 years)</th>
<th>General intellectual abilities at age 11–12 years</th>
<th>Non-verbal intellectual abilities at age 11–12 years</th>
<th>Verbal intellectual abilities at age 11–12 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unadjusted models</td>
<td>1.0 (0.8, 1.1)</td>
<td>5.7 (4.5, 6.9)</td>
<td>1.1 (0.9, 1.3)</td>
</tr>
<tr>
<td>Models further adjusted for movement behaviors at age 11–12 years</td>
<td>0.7 (0.5, 1.0)</td>
<td>4.7 (3.5, 5.9)</td>
<td>0.8 (0.6, 1.0)</td>
</tr>
</tbody>
</table>

We found substantial changes in the model estimates when we adjusted for sociodemographic factors (Model 1) but no considerable changes when further adjusting for baseline cognition at age 2 years (Model 2) and children’s movement behaviors at age 11–12 years (Model 3). Overall, we found no associations between screen time trajectories and verbal, non-verbal and general intellectual abilities in the fully adjusted models (Model 3) (see Table 2). As compared with the children in the average user trajectory, those in the very high user trajectory scored up to 6.3 (95% CI: 0.0, 13.0) points higher in verbal intellectual abilities (Model 1); in Models 2 and 3, this difference was reduced to 5.6 points and became non-significant.

Regarding the trajectories for TV on during family meals, children sometimes exposed to it (vs never) had lower non-verbal (β [95% CI]: (−4.9 [−8.4, −1.4]) and general intellectual abilities (−3.8 [−7.1, −0.4]) but not verbal intellectual abilities. These associations were not dose-responsive because of no association for children often/always exposed to TV during family meals (vs never).

Association of screen time and TV on during family meals at each age separately with intellectual abilities at age 11–12 years.

Supplemental Table 5 presents the results of the additional analyses on the association of screen time and TV on during family meals at each age separately with verbal, non-verbal and general intellectual abilities. Screen time across ages was not associated with intellectual abilities at age 11–12 years, except for a cross-sectional association with reduced non-verbal intellectual abilities at age 11–12 years (β [95% CI]: (−1.3 [−2.8, −0.3]). As compared with children never exposed to TV during family meals, those who were sometimes but not often or always exposed to TV during family meals at ages 2–8 years had lower non-verbal and general intellectual abilities at age 11–12 years.

3.3. Association of screen use trajectories with intellectual abilities at age 11–12 years

The observed associations between screen use trajectories from age 2 to 11–12 years and intellectual abilities at age 11–12 years for complete cases were consistent with the imputed samples, even though the magnitude of the estimates were consistently smaller (Supplemental Table 6).

4. Discussion

In this study of the EDEN mother–child cohort, we identified four screen time trajectories from age 2 to 11–12 years (low, average, high and very high user) and three stable trajectories of TV on during family meals (never, sometimes, and often/always) from age 2–8 years. Overall, screen time trajectories were not associated with intellectual abilities at age 11–12 years. However, the trajectory of TV on sometimes (vs never) during family meals was associated with reduced non-verbal and general intellectual abilities at age 11–12 years.

4.1. Screen use trajectory

In our study, the four latent trajectories identified were parallel to each other, so screen time was quite stable throughout childhood (Bernard et al., 2023). Although more recently published studies have identified joint trajectories of screen use and physical activity, we focused solely on screen use (O’Souza et al., 2020). The number of trajectories identified in studies of screen time trajectories across different ages is not consistent and varied by region and sample size. A birth cohort study in Taiwan identified three trajectories, one of which intersected with the other two (Chiu et al., 2017). A study in Western Canada identified a high-persistent trajectory in early childhood, (McArthur et al., 2020) and another Chinese study of screen time from age 6 months–72 months identified early and later increasing
4.2. Screen use and intellectual abilities

We found no consistent associations of trajectories of screen time from age 2 to 11–12 years with intellectual abilities at age 11–12 years. This finding contradicts with most but not all previous studies (Aishworiya et al., 2019; McArthur et al., 2020; Zhao et al., 2022). However, some studies had important limitations: only a few accounted for sociodemographic characteristics, and almost no children’s movement behaviors were accounted for (Madigan et al., 2020; Tremblay et al., 2011). Our results suggest that children with very high screen use may have up to 6 points greater verbal and general intellectual abilities than those with average use, which however remains difficult to ascertain because of the small sample size of this group. In addition, most studies focused solely on screen time, without considering the context of screen use.

On the other hand, one potential reason for the null associations in our study is that there might be certain unmeasured protective factors, such as the viewing of educational content, co-viewing with parents, or a later initiation to screen use, which could have mitigated any potential negative impact of screen use on cognitive development (Yang et al., 2017). These protective factors are probably found among families of high socioeconomic position, who are numerous in our study sample. Moreover, some studies revealed device-specific associations, (Zhang et al., 2021) and positive associations were more often found in studies on video games (O’Connell, 2018; Yang, 2012). In our cohort study, children’s time devoted to each device was not collected, limiting further comparison. Overall, the adverse impact introduced by certain devices, contexts or media content might be offset by potential positive effects from other devices.

In line with a previous study of the EDEN cohort, we found that TV on sometimes during family meals was associated with reduced non-verbal and general intellectual abilities at age 11–12 years (Martinot et al., 2021). The most likely explanation is that background TV (e.g., TV on during family meals) may impede the quantity and quality of the parent-child interaction (Kirkorian et al., 2009; McCormick et al., 2020). Parent-child interactions are crucial for children’s cognitive development, and family meals are, at least in our study setting, privileged times for such interactions; having the TV on during family meals (particularly with adult-directed or age-inappropriate content) might impede such interactions with parents. The observed negative effect would therefore reflect a replacement of positive factors rather than TV being a negative factor per se (Kirkorian et al., 2009; McCormick et al., 2020). Authors have suggested alternative explanations, including brain mechanisms, based on the fact that environmental stimuli actively engage children’s cognitive processing, fostering the establishment of functional connections between the prefrontal cortex and other brain regions crucial for cognitive development (Cole et al., 2013; Diamond & Lee, 2011). Screen use, such as background TV, predominantly involves passive processing, potentially hindering the development of these cognitive control networks and leading to lower cognitive proficiency (Huston et al., 1981). This neurobiological explanation remains speculative and future studies are warranted to further demonstrate biological mechanisms underlying epidemiological evidence.

We found no dose–response association between TV on during family meals and intellectual abilities. One potential explanation for this finding could be that families sometimes turning on the TV during meals may encounter more difficulties regulating screen use at home and adopt clear and fixed rules regarding screen use. However, we do not have data on parenting style and cannot explore this hypothesis further.

This negative association between TV on sometimes during family meals was found for non-verbal but not verbal intellectual abilities at age 11–12 years, which contrasts with evidence that screen use is a risk factor for language development in early childhood (Madigan et al., 2020). This finding might be explained by verbal intellectual abilities being measured in our study at age 11–12 years: the negative impact of screen use on language development could be limited to early childhood when language develops rapidly. In addition, a recent study showed that the associations observed between screen time and developmental delay differed across various cognitive domains (Takahashi et al., 2023). More studies are warranted to decipher the complex relations between screen use and the development of various cognitive abilities in children.

4.3. Strengths and limitations

The first strength is that this is the first longitudinal study to identify screen use trajectories with repeated measurements over such a long-time span, from age 2 to 11–12 years. Second, this study examined the context of screen use and various other household characteristics and children’s movement behaviors. Third, we focused on different domains of intellectual abilities at age 11–12 years. Finally, models were adjusted for a large number of known confounders and further adjusted for baseline cognition, which allowed us to tackle potential reverse causation when interpreting our findings.

However, our study has limitations. First, our sample size was limited by high loss to follow-up at age 11–12 years, which limits the statistical power of our analyses; furthermore, as compared with children who did not participate at age 11–12 years, those who did participate had lower screen time at age 2 years and came from families with more favorable socioeconomic position, which can introduce selection bias, limit the diversity of the identified screen time trajectories, and in turn limit our ability to generalize our findings to the entire population. Second, we did not include children’s time devoted to handheld devices in the questionnaires conducted at age 2, 3, 5 and 8 years. Handheld devices were much less widespread at the period of data collection (2006–2014). However, TV viewing was and remains the main source of screen time in children of this age (Bernard et al., 2023; Agence nationale de sécurité sanitaire de l’alimentation, 2017; Agence Française de Sécurité Sanitaire des Aliments, 2009). Also, at the time of the study, the access to the Internet and social media was primarily accessed through a computer, and this use was therefore covered by the item “Computer” in our questionnaire (Agence nationale de sécurité sanitaire de l’alimentation, 2017; Agence Française de Sécurité Sanitaire des Aliments, 2009). Third, we did not measure more information on screen use, such as media content and co-viewing, which thus limits our understanding of the mechanisms potentially at play. However, we adjusted for important family socioeconomic status factors, which could affect and reflect the context and content of screen use. Finally, as in most observational studies, parents reported their children’s screen use. This method is known to be relatively inaccurate and implies biases such as recall and social desirability, although a recent study supported the use of subjective screen use data in research designs with psychological outcomes (Steele et al., 2022).

5. Implications

Currently, research on screen use trajectories is rare, and the association of screen use trajectories with cognition in later childhood is not well documented. Our study shows that screen use behaviors maintained throughout childhood, such as the context of screen use, apart from screen time, were associated with reduced cognition in later childhood. Although our study was underpowered, we highlighted associations of high magnitude (i.e., up to 5 IQ points), which is considerable and relevant at both the clinical and population level. Public health experts and decision-makers must consider the effects of screen use with a more nuanced approach and target the specific conditions for which screen use is an important issue. It includes limiting low-quality or age-inappropriate content, unsupervised screen viewing and background TV, supporting more favorable educational practices, while targeting...
populations the most at-risk of inappropriate screen use. Also, given that health-related behaviors, including sedentary screen time, adopted in early childhood track importantly over the life course, (Jones et al., 2013) interventions aiming to improve screen use should be implemented in early childhood to be more cost-effective.

6. Conclusions

In our longitudinal study, using data from the EDEN cohort, we identified four screen time trajectories from age 2 to 11–12 years and three trajectories of TV on during family meals from age 2–8 years, which demonstrates the high tracking of screen use during childhood. TV sometimes on during family meals but not screen time was associated with reduced intellectual abilities at age 11–12 years. Future studies examining health outcomes associated with screen use need to better account for the context of screen use, not just the time.

Poster presentation

The International Society of Behavioral Nutrition and Physical Activity (ISBNPA) conference held in June 2023 in Uppsala, Sweden.

Ethics

The EDEN study received approval from the ethics research committee (Comité Consultatif de protection des personnes dans la recherche biomédicale) of Bicêtre Hospital and the Data Protection Authority (Commission Nationale de l’Informatique et des Libertés).

Data sharing statement

Researchers who are interested in accessing the EDEN data are free to submit their research project to the EDEN unit.

Author’s contributions

Design of the cohort study: FR, BH. Design of the present analysis: SY, FR, BH, JYB. Data management and analysis: SY, MT, HP, JYB. Draft of the manuscript: SY, LP, JYB. Critical appraisal of the manuscript: all Final approval of the version to be published: all.

Funding

This study was funded by grants from the Agence Nationale de la Recherche (ANR) (ANR-12-DSSA-0005-01 [DYSEDEN project] and ANR-20-CE36-0001 [ISCAN project]). HP and FR were further supported by the grants ANR-10-IDEX-0001-02 and ANR-17-EURE-0017. The EDEN cohort study was supported by the Foundation for Medical Research (FRM), National Agency for Research (ANR), National Institute for Research in Public Health (IRESP: TGIR cohorte santé–youth, 2008 pro), French Ministry of Health (DGS), French Ministry of Research, Inserm Bone and Joint Diseases National Research (PRO-A) and Human Nutrition National Research Programs, Paris–Sud University (now Université Paris-Saclay), Nestlé, French National Institute for Population Health Surveillance (InVS), French National Institute for Health Education (INPES), the European Union FP7 programmes (FP7/2007–2013, HELIX, ESCAPE, ENRIECO, Medall projects), Diabetes National Research Program (through a collaboration with the French Association of Diabetic Patients (AFD)), French Agency for Environmental Health Safety (now ANSES), Mutuelle Générale de l’Education Nationale (MGEN), French National Agency for Food Security, and the French-speaking association for the study of diabetes and metabolism (ALFE-DIAM). Funders had no influence of any kind on statistical analyses, result interpretation or decision to submit the manuscript for publication.

Declaration of competing interest

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

Data availability

The authors do not have permission to share data.

Acknowledgments

We are extremely grateful to all the families who took part in this study, the midwives and psychologists who recruited and followed them, and the whole EDEN team, including research scientists, engineers, technicians, and managers and especially Josiane Sahuquillo and Edith Lesieux for their commitment and their role in the success of the study. We also acknowledge the commitment of the members of the EDEN Mother-Child Cohort Study Group: I Annesi-Maesano, J Y Bernard, J Botton, M-A Charles, P Dargent-Molina, B de Lauzon-Guillain, P Ducimetière, M De Agostini, B Foliouet, A Forhan, X Fritel, A Germa, V Goua, R Hankard, B Heude, M Kaminiski, B Larroque, N Lelong, J Lepreux, G Magnin, I Marchand, C Nabes, F Pierre, R Slama, J-M Saurel-Cubizolles, M Schweitzer, O Thiebaugeorges. We greatly thank Laura Smales for proofreading the language.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2023.108042.

References


