



Universidade do Porto
Faculdade de Desporto

**Cross-sectional association between parental screen practices
and children's screen time: findings from the Sunrise Study in
Brazil**

Lucas Paiva Roxo
2026



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Orientadora: Professora Doutora Clarice Martins

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1. TEMPO DE ECRÃ 2. PRÉ-ESCOLARES 3. DINÂMICA FAMILIAR 4. EDUCAÇÃO DOS FILHOS 5. TEORIA BIOECOLÓGICA

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Resumo

Contexto e objetivo: A Organização Mundial da Saúde recomenda não mais do que 60 minutos por dia de utilização de ecrãs para crianças com idades compreendidas entre os 3 e os 4 anos. Considerando que a exposição precoce aos ecrãs é multifatorial este estudo teve como objetivo avaliar a associação entre as práticas de ecrã dos pais e o tempo de ecrã das crianças, tendo em conta as características sociodemográficas em crianças pré-escolares brasileiras. **Métodos:** O estudo incluiu 1,382 participantes (702 rapazes; $4,18 \pm 0,54$ anos de idade) das cinco regiões brasileiras, dos quais 1,325 forneceram dados válidos de tempo de exposição a ecrã. Os encarregados de educação preencheram um questionário no qual reportaram o tempo médio diário de exposição a ecrã por parte da criança e os seus comportamentos de utilização de ecrãs em diferentes situações. Foi realizada uma análise de regressão hierárquica no Stata (versão 19.0) para identificar os fatores associados à exposição total das crianças aos ecrãs, com os preditores introduzidos em blocos sucessivos sendo eles, fatores estruturais (região geográfica, área de residência), fatores individuais e familiares (idade e sexo da criança, idade e escolaridade dos encarregados de educação) e, por fim, comportamentos de utilização de ecrã pelos encarregados de educação no contexto familiar. **Resultados:** O tempo médio diário de exposição a ecrã foi de $120,5 \pm 97,2$ minutos. O modelo de regressão hierárquica ajustado explicou 16,3% da variância no tempo de exposição a ecrã. A região geográfica (entre -27,38 e -40,18 minutos/dia, consoante a região, em comparação com a região Norte) e a idade da criança (+19,06 minutos/dia por ano) foram fatores associados significativos; a utilização de ecrãs pelos encarregados de educação para entreter a criança (+16,51 minutos/dia por nível de frequência) e durante as refeições (+6,66 minutos/dia por nível de frequência) também demonstrou associação positiva com o tempo de exposição. **Conclusão:** Nos participantes avaliados, a exposição a ecrã excede o tempo recomendado. Embora diferenças geográficas e idade da criança sejam fatores relevantes, as práticas de ecrã dos pais, particularmente a utilização de dispositivos para entretenimento e durante as refeições, estão mais fortemente associados ao tempo de exposição de ecrã da criança.

Palavras-chave: Tempo de ecrã; Crianças em idade pré-escolar; Dinâmica familiar; Parentalidade; Teoria bioecológica.

Abstract

Background & aim: The World Health Organization recommends no more than 60 minutes per day of screen media use for children aged 3 and 4 years. Considering that early screen exposure is multifactorial, this study aimed to evaluate the association between parental screen practices and children's screen time, accounting for sociodemographic characteristics in Brazilian preschoolers. **Methods:** The study included 1,382 participants (702 boys; 4.18 ± 0.54 years old) from the five Brazilian regions, of whom 1,325 provided valid screen-time exposure data. Caregivers completed a questionnaire in which they reported the child's average daily screen exposure time and their own screen-use behaviors in different situations. A hierarchical regression analysis was conducted in Stata (version 19.0) to identify the factors associated with children's total screen exposure, with predictors entered in successive blocks: structural factors (geographic region, area of residence), individual and family factors (child age and sex, caregiver age and educational level), and, finally, caregivers' screen-use behaviors within the family context. **Results:** Mean daily screen exposure time was 120.5 ± 97.2 minutes. The adjusted hierarchical regression model explained 16.3% of the variance in screen exposure time. Geographic region (between -27.38 and -40.18 minutes/day, depending on the region, compared with the North region) and child age (+19.06 minutes/day per year) were significant associated factors; caregivers' screen use to entertain the child (+16.51 minutes/day per frequency level) and during meals (+6.66 minutes/day per frequency level) also showed a positive association with exposure time. **Conclusion:** Among the participants assessed, screen exposure exceeds the recommended time. Although geographic differences and child age are relevant factors, parental's screen practices, particularly device use for entertainment and during meals, are more strongly associated with the child's screen exposure time.

Keywords: Screen time; Preschool children; Family dynamics; Parenting; Bioecological theory.

List of abbreviations

Table 1 contains all abbreviations, acronyms and symbols used in this dissertation, including those present in the literature review table.

Table 1 – Abbreviations, acronyms and symbols used in this dissertation.

Abbreviation	Definition
%	Percentage
±	Plus/Minus (used with mean and standard deviation)
ABCD Study	Adolescent Brain Cognitive Development Study
BMI	Body Mass Index
CIAFEL	Research Centre in Physical Activity, Health and Leisure
FADEUP	Faculty of Sport, University of Porto
FCT	Fundação para a Ciência e Tecnologia, I.P.
IQR	Interquartile Range
kg/m²	Kilograms per Square Metre (Body Mass Index unit)
min/day	Minutes per Day
N	Total Sample Size
n	Subsample Size
p	Statistical Significance Level
PPCT	Process-Person-Context-Time (model)
R²	Coefficient of Determination
SD	Standard Deviation
SES	Socioeconomic Status
VIF	Variance Inflation Factor
WHO	World Health Organization

Note: Abbreviations are organized in alphabetical order, and symbols appear after them. Some symbols (e.g., R², N, n, p, ±, %) represent mathematical, statistical, or measurement units used throughout the dissertation. ABCD Study, BMI, N, SES, and WHO also appear in the literature review table.

1. Introduction

High screen exposure during early childhood has been associated with a range of adverse developmental outcomes (Liu et al., 2021; Yu-Ting et al., 2025). In response to these concerns, the World Health Organization (WHO) has established specific guidelines for children aged 3 to 4 years, recommending that screen time should not exceed 60 minutes per day (WHO, 2019). Despite these recommendations, recent global prevalence data indicate that a significant majority of preschoolers fail to meet these guidelines, with non-compliance rates frequently exceeding 70% (McArthur et al., 2022). Understanding why children's screen exposure remains so far above recommended levels requires looking beyond prevalence figures to the everyday family practices and situational contexts in which screen use actually occurs.

Early childhood is a particularly sensitive period, as screen-related routines are often established before children have the self-regulatory capacity to manage digital media use independently. Screen exposure at this age therefore reflects not only the child's behavior, but also the broader organization of the family environment. Studies suggest that children's screen time is multidimensional, shaped by a combination of individual, family, and contextual factors, such as age (Schmid et al., 2025), body mass index (Sivanesan et al., 2020), and sociodemographic conditions including living context and parental education (Määttä et al., 2017; McArthur et al., 2022).

Beyond these structural and individual factors, daily family dynamics also play a central role in preschoolers' screen exposure (Alves & Martins, 2021). Parental digital habits have been shown to influence children's own screen time, with more regulated parental approaches to device use being associated with lower exposure levels in children (Pyne et al., 2025). Overall, parental attitudes and interaction patterns appear closely related to children's lifestyle habits and well-being (Maia et al., 2025).

Bronfenbrenner's Bioecological Theory (Bronfenbrenner, 1977) offers a useful conceptual lens for organizing these structural, family, and individual influences hierarchically, according to their proximity to the child, rather than treating them as an unstructured list of covariates. Within this framework, proximal, repeated interactions between the child and their immediate environment are considered particularly influential for development, and screen-related routines may represent one such proximal practice,

through which broader social and environmental conditions are translated into children's behavior. It should be noted that the present study does not directly operationalize the Process-Person-Context-Time (PPCT) model in its complete form, nor does its cross-sectional design allow the temporal dimension of the theory to be captured; rather, Bronfenbrenner's framework is used here as a guiding, organizing structure for the hierarchical entry of variables, rather than as a fully tested explanatory model.

Evaluating these hierarchical associations specifically within the Brazilian context is particularly relevant. Brazil is a continental-scale, upper-middle-income country marked by pronounced regional inequalities in infrastructure and living conditions, alongside a digital landscape that has expanded rapidly but unevenly: national household survey data show that internet access in rural areas rose from 35.0% in 2016 to 81.0% in 2023, narrowing but not eliminating the gap relative to urban areas (IBGE, 2024). Most existing evidence on family digital practices and children's screen time, however, originates from high-income countries with comparatively homogeneous infrastructure and less pronounced regional disparities (Maia et al., 2025; Pyne et al., 2025; Radesky et al., 2023). Because the mechanisms linking structural conditions, family routines, and children's screen exposure may operate differently in a setting marked by regional and infrastructural heterogeneity, examining this hierarchy of associations within Brazil's specific socioeconomic and geographic context represents an important and, to date, underexplored contribution. However, previous literature has largely explored sociodemographic and parenting factors in isolation, without integrating them into a single explanatory model (Eirich et al., 2022; Lopez et al., 2025).

Therefore, this study investigates the association between parental screen practices and children's screen time. For that, a hierarchical structure of factors underlying screen time, geographic region and area of residence; child age and sex; parental age and educational level; and caregivers' screen-use behaviors to calm, entertain, and educate the child, and during meals, play, commuting, walking, and sleep routines was explored among Brazilian preschoolers.

2. Literature review

2.1 Conceptual definitions

2.1.1 Screen time

Screen time has been defined by the Sedentary Behavior Research Network as the time spent on screen-based behaviors, which may be performed while being either sedentary or physically active (Tremblay et al., 2017). The World Health Organization adopts a narrower construct in its recommendations, defining sedentary screen time as time spent passively watching screen-based entertainment and explicitly excluding active screen-based games that require physical movement; it is on this basis that the WHO advises that children aged 3 to 4 years should not exceed 60 minutes of sedentary screen time per day, while screen use is discouraged altogether for children younger than 2 years (WHO, 2019). Beyond the total duration of exposure, screen time is also shaped by the family context in which it occurs — particularly the daily practices and routines through which caregivers regulate, direct, or share their own device use with the child. It is this family-level dimension of screen exposure that constitutes the focus of the present dissertation.

2.1.2 Parental screen practices

Parental screen practices encompass the behaviors through which caregivers use screen devices themselves, either independently of the child or directed toward the child, within the family environment. Two such practices are particularly relevant to the present study. The first refers to caregivers' own personal use of screen devices in the child's presence, independent of any direct interaction with the child which may nonetheless shape the child's environment by modeling frequent screen use within the household (McDaniel & Radesky, 2018; Rudnova et al., 2023). The second refers to the instrumental use of screens as a caregiving strategy, in which caregivers actively direct screen devices toward the child for a specific purpose, particularly during moments of caregiver

unavailability or child distress (Radesky et al., 2023). Although conceptually distinct, these two practices are not mutually exclusive within the same household: a caregiver may, for instance, use their own smartphone extensively in the child's presence (personal use) while also frequently directing screens toward the child to calm them during tantrums (instrumental use).

As such, parental screen practices can be understood as proximal family behaviors that translate broader household digital habits into the child's pattern of screen exposure.

2.1.3 Rationale for a hierarchical analytical framework

Children's screen time has been consistently associated with multiple, co-occurring factors, ranging from broad structural and geographic conditions to individual and family-level characteristics. At the structural level, geographic region and area of residence have been linked to differences in screen exposure, reflecting broader infrastructural and socioeconomic disparities (Leão et al., 2025; McArthur et al., 2022). At the individual level, both age and body mass index have been associated with screen time, with exposure tending to increase progressively across early childhood (Schmid et al., 2025; Sivanesan et al., 2020). At the family level, parental characteristics such as age and educational attainment have similarly been associated with children's screen exposure, partly through their influence on household routines and rules (Ke et al., 2023; Määttä et al., 2017), while caregivers' own screen-related practices have been identified as proximal correlates directly shaping the child's exposure (Pyne et al., 2025; Radesky et al., 2023).

To organize the joint contribution of these different, co-occurring levels of influence within a single analytical framework, this dissertation draws loosely on Bronfenbrenner's Bioecological Theory (Bronfenbrenner, 1977), which conceptualizes child development as shaped by nested layers of environmental influence, ranging from distal structural conditions to proximal, everyday interactions. This framework is not directly tested in the present study; rather, it is used purely as an organizing analogy to justify the hierarchical entry of variables into the regression models, proceeding from the

most distal level (region and area of residence) to individual and family characteristics, and finally to the most proximal level — caregivers' screen-related routines within the household.

It should be noted that the frequency of caregivers' screen-related practices, entered in the final model, is treated here as a routine-level correlate of children's screen time, rather than as a direct measure of Bronfenbrenner's concept of proximal processes, which formally requires reciprocal, progressively complex, and enduring interactions that this single-occasion, frequency-based measure does not capture.

2.2 State of the art

2.2.1 Prevalence and patterns of screen time in early childhood

Global evidence indicates that compliance with WHO screen time guidelines among preschool-aged children remains low, with non-adherence rates frequently exceeding 70% (McArthur et al., 2022). Longitudinal data further show that, although screen exposure is already substantial among the youngest children, it tends to increase progressively with age (Leão et al., 2025; Schmid et al., 2025). Comparable patterns have been reported across distinct cultural contexts, including cross-sectional evidence from Brazilian (Gomes et al., 2024) and South Korean preschoolers (Han et al., 2023), suggesting that early and prolonged screen exposure represents a widespread phenomenon rather than a context-specific one. A recent systematic review synthesizing 36 studies conducted between 2010 and 2019 reinforced this picture, confirming that screen exposure is already considerable in children as young as six months of age and tends to intensify progressively throughout the preschool years, alongside the diversification of device types used, from stationary televisions to portable smartphones and tablets (Lee et al., 2024). This same review highlighted that healthy parental media-related habits and consistent limit-setting are among the most influential correlates of reduced screen exposure at this developmental stage, reinforcing the relevance of the

family environment as a proximal determinant of children's screen time patterns (Lee et al., 2024).

Table 2 summarizes key studies on the prevalence and patterns of screen time in early childhood, highlighting gaps that the present study addresses.

Table 2. Key studies on the prevalence and patterns of screen time in early childhood.

Reference	Design / Sample	Key Finding	Limitation
McArthur et al. (2022)	Systematic review & meta-analysis; 63 studies, N = 89,163, children ≤5y	Non-adherence to WHO screen time guidelines exceeds 70% globally	Aggregates data predominantly from high-income countries; limited representation from Latin America and other Global South contexts
Lee et al. (2024)	Systematic review; 36 studies, children aged 0–6y	Parental media habits and consistent limit-setting are the strongest correlates of reduced exposure	Reviews correlate individually, without testing their combined or hierarchical contribution to screen time
Leão et al. (2025)	Prospective cohort; Brazil (South region only), children aged 2 to 6–7y	Screen time increases with age; geographic disparities associated with higher exposure	Restricted to a single Brazilian region; does not extend to other regions or incorporate parental screen practices

Note: ABCD Study = Adolescent Brain Cognitive Development Study; BMI = Body Mass Index; WHO = World Health Organization.

2.2.2 Association between screen time and individual factors (age, BMI)

Beyond emotional and behavioral outcomes, screen time has also been associated with individual physical health indicators. Sivanesan et al. (2020) reported an association between higher screen exposure and adverse cardiometabolic risk markers, including elevated body mass index, in young children. Age itself also appears to be a relevant individual factor, given that screen exposure tends to increase progressively across early childhood (Schmid et al., 2025), suggesting a cumulative pattern of exposure as children grow older. This association between screen time and weight status has since been corroborated by larger-scale evidence: a dose-response meta-analysis pooling data from 45 individual studies found that children and adolescents in the highest categories of screen exposure had a significantly greater likelihood of developing obesity compared with those with lower exposure levels, with the risk increasing proportionally as screen time increased, in a clear dose-response pattern (Haghjoo et al., 2022). This dose-dependent relationship reinforces the plausibility of a cumulative biological pathway linking prolonged sedentary screen exposure to adverse metabolic outcomes from an early age, rather than a threshold effect restricted to already excessive levels of use.

Table 3 summarizes key studies on the association between screen time and individual factors.

Table 3. Key studies on the association between screen time and individual factors.

Reference	Design / Sample	Key Finding	Limitation
Sivanesan et al. (2020)	Cohort study; Canada, young children	Higher screen exposure associated with adverse cardiometabolic risk markers, including BMI	Focuses on physical health outcomes; does not examine parental or family-level correlates of exposure
Haghjoo et al. (2022)	Dose-response meta-analysis; 45 individual studies	Obesity risk increases proportionally with screen time	Aggregates dose-response evidence for weight outcomes only; does not consider caregivers' screen-related behaviors as predictors

Note: BMI = Body Mass Index.

2.2.3 Association between screen time and sociodemographic factors

Sociodemographic conditions appear to shape children's screen exposure in a consistent manner across studies. Living context has been associated with differential screen time levels, with geographic disparities linked to higher exposure (Leão et al., 2025). Parental education level has similarly been identified as a relevant determinant, with lower parental education frequently associated with home environments characterized by fewer rules limiting device use, an effect that appears to be mediated by broader features of the home environment itself (Määttä et al., 2017; McArthur et al., 2022). This pattern has also been confirmed outside Western contexts: a cross-sectional study of nearly 3,000 Chinese children and adolescents found that children whose parents had higher educational attainment were substantially more likely to meet screen time guidelines than those whose parents had lower education, with this association remaining significant even after accounting for other markers of family socioeconomic status (Ke et al., 2023). These findings suggest that the influence of parental education on children's screen exposure is not confined to specific cultural or geographic settings but instead reflects a broader structural mechanism through which socioeconomic disadvantage may translate into higher-risk digital environments for children, likely operating through differences in household rules, caregiver availability, and access to alternative, non-screen-based activities.

Table 4 summarizes key studies on the association between screen time and sociodemographic factors.

Table 4. Key studies on the association between screen time and sociodemographic factors.

Reference	Design / Sample	Key Finding	Limitation
Määttä et al. (2017)	Cross-sectional; Finland, 864 children aged 3–6y	Effect of parental education mediated by features of the home environment	Single high-income European country; sample considerably smaller than the present study
Ke et al. (2023)	Cross-sectional; China, ≈3,000 children and adolescents	Higher parental education associated with greater compliance with screen time guidelines	Assesses sociodemographic factors without jointly modeling caregivers' screen-related behaviors

2.2.4 Association between parental screen practices and children's screen time

Family dynamics and parental digital behaviors have been consistently identified as central determinants of children's screen exposure. Longitudinal evidence from Radesky et al. (2023) demonstrated a bidirectional relationship between parents' use of mobile devices to calm children and subsequent increases in children's emotional reactivity and media demand over time. Conversely, more regulated parental approaches to device use have been associated with lower levels of screen time in children (Pyne et al., 2025). Broader synthesis of this literature confirms that parental attitudes and interaction patterns are significantly related to multiple dimensions of children's lifestyle and well-being, including screen time, sleep, and dietary habits (Maia et al., 2025). Additional longitudinal evidence suggests that patterns of parental digital restriction may shape screen use trajectories not only in early childhood but also into adolescence (Lopez et al., 2025), while emerging findings point to potential downstream effects of screen time and parental mediation on children's linguistic and pragmatic development (Toth et al., 2026). Despite this growing body of evidence, previous literature has largely examined sociodemographic and parenting factors in isolation, without structurally quantifying their combined contribution across the different environmental levels proposed by Bronfenbrenner's model (Eirich et al., 2022; Lopez et al., 2025).

Table 5 summarizes key studies on the association between parental digital practices and children's screen time and identifies the central gap this dissertation addresses.

Table 5. Key studies on the association between parental digital practices and children's screen time.

Reference	Design / Sample	Key Finding	Limitation
Radesky et al. (2023)	Prospective cohort; United States, 422 children aged 3–5y	Bidirectional relationship between using devices to calm the child and emotional reactivity over time	Single high-income country; sociodemographic and structural factors not jointly modeled alongside parental practices
Pyne et al. (2025)	Systematic review; children $\leq 5y$	More regulated parental device use associated with lower child screen time	Synthesizes parenting factors narratively, without structurally quantifying their combined, hierarchical contribution
Eirich et al. (2022); Lopez et al. (2025)	Meta-analysis (children $\leq 12y$); longitudinal ABCD study (US adolescents)	Screen time associated with behavior problems; parental digital restriction shapes screen-use trajectories	<i>Sociodemographic and parenting factors examined in isolation, without structurally quantifying their combined contribution across environmental levels — the central gap this dissertation addresses</i>

Note: ABCD Study = Adolescent Brain Cognitive Development Study.

Based on the above, this study used the following hierarchical model to organize the entry of variables into the regression analysis (Figure 1).

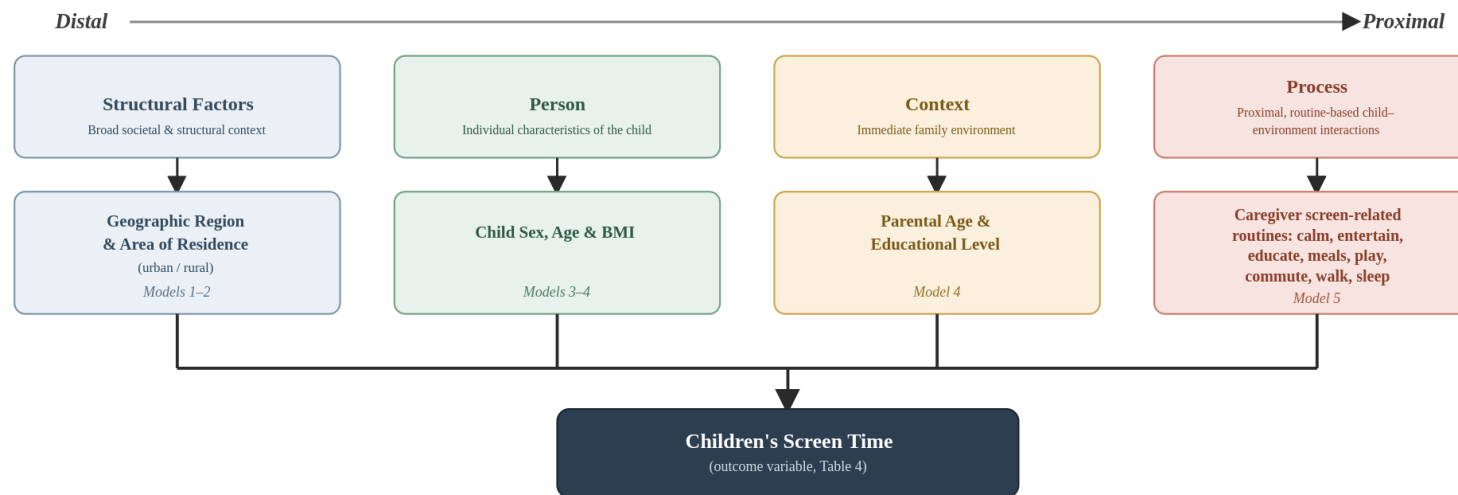


Figure 1. Theoretical model: Bronfenbrenner's Bioecological Framework applied to the hierarchical analysis of children's screen time.

Note. Bronfenbrenner's framework was used as a guiding, organizing structure for the hierarchical entry of variables into the regression models (Table 3), not as a fully and directly tested causal model. The framework captures the Person and Context components, and a partial, cross-sectional approximation of Process through recurrent caregiver-child screen-related routines. The Time component was not operationalized in this study.

3. Methods

This dissertation follows an alternative design comprising an original scientific paper in the Results section. Therefore, this Methods chapter presents an expanded overview of the study design and population, complementing the more concise methodological description provided within the article itself, and follows the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) recommendations for the reporting of cross-sectional studies (von Elm et al., 2007).

This cross-sectional study was conducted across 82 preschools (30 urban and 52 rural) geographically distributed across the five Brazilian regions, selected by convenience: 8 in the North, 21 in the Northeast, 16 in the Midwest, 5 in the Southeast, and 32 in the South (Figure 2). Data collection took place between July 2024 and September 2025. The study was approved by the Research Ethics Committee of the School of Arts, Sciences and Humanities, University of São Paulo (CAAE: 76402523.9.1001.5390) on 15 January 2024, and written informed consent was obtained from the legal guardian of each participating child prior to data collection.

Eligible participants were children aged 3 to 4 years, defined as those who had not yet reached 60 months of age (36–59 completed months) at the end of the data collection period at each preschool, whose legal guardians provided written consent. To ensure the feasibility of objective measurements, children were also required to be capable of independent locomotion and free from severe physical or developmental impairments that would prevent habitual physical activity or the continuous wear of an accelerometer. Following the application of these criteria, the final sample consisted of 1,382 children (702 boys).

No formal a priori sample size calculation was performed for this specific analysis. Instead, the sample comprised all eligible children across the 82 participating preschools who were enrolled during the data collection period. This is consistent with the broader SUNRISE International Study protocol, within which the present data collection was conducted, which targets approximately 1,000 children per participating country in its main study phase, sufficient to achieve a margin of error of at most 5% for the 95% confidence interval around an estimated 21% prevalence of guideline compliance (Okely et al., 2021).

Children's anthropometric measurements (stature and body mass, used to calculate BMI) were collected following standardized WHO procedures, using a portable stadiometer (SECA 213) and a calibrated digital scale (SECA 876) (WHO, 2008).

Children's screen time and parental screen practices were assessed through a structured telephone interview with the caregiver, based on a subset of items from the standardized questionnaire of the SUNRISE International Study (Okely et al., 2021). The instrument was directly translated from the original English version into Brazilian Portuguese and adapted in a pilot study comprising 100 children. Only the items assessing total daily screen time and the frequency of parents' digital practice across specific daily routines were used in the present analysis; Data were analyzed using hierarchical multiple linear regression models with robust standard errors, ranging from structural (region, area of residence) to individual and family-level factors, in order to examine their combined contribution to children's screen time.



Figure 2. Geographic distribution of participating preschools and children across the five Brazilian regions.

4. Results

Cross-sectional association between parental screen practices and children's screen time: findings from the Sunrise Study in Brazil

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Lucas Roxo: Conceptualization, Data curation, Investigation, Visualization, Writing – Original draft, Writing – review & editing

Vicente Romo-Pérez: Formal Analysis

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Enrique Pintos-Toledo: Investigation

Clarice Martins: Conceptualization, Data curation, Investigation, Project administration, Resources, Supervision, Formal analysis, Writing – Review & Editing, Funding acquisition

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Conflict of interest statement

The authors declare no conflicts of interest.

Abstract

Background & aim: The World Health Organization recommends no more than 60 minutes per day of screen media use for children aged 3 and 4 years. Considering that early screen exposure is multifactorial, this study aimed to evaluate the association between parental screen practices and children's screen time, accounting for sociodemographic characteristics in Brazilian preschoolers. **Methods:** The study included 1,382 participants (702 boys; 4.18 ± 0.54 years old) from the five Brazilian regions, of whom 1,325 provided valid screen-time exposure data. Caregivers completed a questionnaire in which they reported the child's average daily screen exposure time and their own screen-use behaviors in different situations. A hierarchical regression analysis was conducted in Stata (version 19.0) to identify the factors associated with children's total screen exposure, with predictors entered in successive blocks: structural factors (geographic region, area of residence), individual and family factors (child age and sex, caregiver age and educational level), and, finally, caregivers' screen-use behaviors within the family context. **Results:** Mean daily screen exposure time was 120.5 ± 97.2 minutes. The adjusted hierarchical regression model explained 16.3% of the variance in screen exposure time. Geographic region (between -27.38 and -40.18 minutes/day, depending on the region, compared with the North region) and child age (+19.06 minutes/day per year) were significant associated factors; caregivers' screen use to entertain the child (+16.51 minutes/day per frequency level) and during meals (+6.66 minutes/day per frequency level) also showed a positive association with exposure time. **Conclusion:** Among the participants assessed, screen exposure exceeds the recommended time. Although geographic differences and child age are relevant factors, parental's screen practices, particularly device use for entertainment and during meals, are more strongly associated with the child's screen exposure time.

Keywords: Screen time; Preschool children; Family dynamics; Parenting; Bioecological theory.

Introduction

High screen exposure during early childhood has been consistently linked to emotional and behavioral difficulties (Liu et al., 2021). Children with higher screen time tend to show higher levels of depression, aggression, oppositional behaviors, and social withdrawal, with boys and girls showing potentially distinct patterns of vulnerability (Yu-Ting et al., 2025). In response to these risks, the World Health Organization (WHO) has established specific guidelines for children aged 3 to 4 years, recommending that screen time should not exceed 60 minutes per day (WHO, 2019). Despite these recommendations, recent global prevalence data indicate that a significant majority of preschoolers fail to meet these guidelines, with non-compliance rates frequently exceeding 70% (McArthur et al., 2022). This widespread and prolonged exposure remains associated with adverse cognitive and psychosocial outcomes, such as emotional dysregulation and attention deficits (Paulus et al., 2023).

Early childhood is a particularly sensitive period because screen-related routines are often established before children have the self-regulatory capacity to manage digital media use independently. Therefore, screen exposure at this age reflects not only the child's behavior, but also the organization of the family environment. Children's screen time seems to be multidimensional and shaped by a set of individual, family, and contextual factors. Studies indicate that while exposure levels among the youngest children are already concerning, digital device use tends to progressively increase with age (Schmid et al., 2025). Also, body mass index (BMI) is frequently associated with greater exposure (Sivanesan et al., 2020), and broader sociodemographic factors, such as living contexts and parental education level may play an important role in determining screen exposure (McArthur et al., 2022). For instance, geographic disparities are associated with higher levels of screen time (Leão et al., 2025), whereas lower parental education is frequently linked to family environments with fewer rules limiting device use (Määttä et al., 2017).

Moreover, daily family dynamics play a central role in preschoolers' screen time (Alves & Martins, 2021). Recent longitudinal findings from a prospective cohort study of 422 children from the United States aged 3 to 5 years demonstrate that parents' habits are directly linked to the amount of time children spend using screens, showing a

bidirectional relationship over time where using devices as a calming tool reinforces higher levels of media demand and emotional reactivity (Radesky et al., 2023). In contrast, a more regulated approach to device use is associated with lower screen time (Pyne et al., 2025). Overall, parental attitudes and their interaction patterns are significantly related to children's lifestyle habits and well-being (Maia et al., 2025).

According to Bronfenbrenner's Bioecological Theory (Bronfenbrenner, 1977), child development occurs within a complex system of environmental layers that are organized from the broadest level to the one closest to the child. Within this framework, proximal processes — the repeated interactions between the child and the immediate environment — are expected to be particularly influential. In the context of screen time, daily routines such as using screens during meals, before sleep, or as entertainment may represent proximal family practices through which broader social and environmental conditions are translated into children's behavior. Despite the growing number of studies, previous literature has explored these sociodemographic factors and parenting behaviors in isolation, showing gaps by not structurally quantifying the combined weight of these different environmental levels (Eirich et al., 2022; Lopez et al., 2025).

Therefore, this study aimed to explore the hierarchical association between parental screen practices and children's screen time in Brazilian preschoolers. By integrating structural determinants, family characteristics, parental digital behaviors, and individual attributes, this research seeks to provide a broader understanding of the factors associated with screen exposure in early childhood.

Methodology

Study design

The present study was conducted within the framework of the SUNRISE International Study, designed to examine 24-hour movement behaviors (sedentary behavior, physical activity, and sleep) in young children across countries with different income levels (Okely et al., 2021). Although the broader SUNRISE study evaluates 24-hour movement behaviors, the present analysis focuses specifically on screen time and its individual, sociodemographic, and family-routine correlates. Data collection took place

between July 2024 and September 2025. The study was approved by the Research Ethics Committee of the School of Arts, Sciences and Humanities, University of São Paulo (CAAE: 76402523.9.1001.5390), on 15 January 2024.

Brazil is a country with five regions (north, northeast, midwest, southeast, and south), and a total of 82 preschools (30 urban and 52 rural) were conveniently selected across these five regions: 8 in the north, 21 in the northeast, 16 in the midwest, 5 in the southeast and 32 in the south. Because preschools were selected by convenience, the sample should be interpreted as geographically diverse rather than nationally representative.

For data analysis and presentation throughout this study, these regions are coded as follows: North, Midwest, Northeast, South, and Southeast. Preliminary contact was made with the preschools to explain the project and invite them to participate. Next, meetings were held with the participants' parents to explain the project objectives and study procedures. Data collection lasted approximately one week at each preschool, during which children were assessed for anthropometric measurements, accelerometry, motor skills, and executive functions. During this period, the research team made phone calls to interview parents, seeking answers to a questionnaire about movement and feeding behaviors.

Participants

Eligible participants for this study were children aged 3 to 4 years, defined as those who had not yet reached 60 months of age (36–59 completed months) at the end of the data collection period at each preschool, whose legal guardians provided written consent. Age was calculated as the difference between each child's date of birth and the date of data collection (encompassing both accelerometry placement and in-person testing). Because data collection at each preschool extended over several days, children who turned 5 years (60 months) at any point during this period were excluded from testing, whereas children who had not yet reached this age by the end of the data collection window remained eligible, even if their fifth birthday was imminent. To ensure the feasibility of objective measurements, children were also required to be capable of independent locomotion and free from severe physical or developmental impairments that would prevent habitual physical activity or the continuous wear of an accelerometer.

Following the application of these criteria, a total of 1,382 children were enrolled in the study (702 boys), with an overall mean age of 4.1 ± 0.5 years. Of these, 1,325 children (95.9%) provided fully valid screen time data and were retained for the present analysis; the remaining 57 children were excluded due to incomplete or missing screen time data.

Anthropometrics

Stature and body mass were assessed using a portable stadiometer (SECA 213, SECA, Hamburg, Germany) and a calibrated digital scale (SECA 876, SECA, Hamburg, Germany), respectively, in accordance with standardized WHO methodologies (WHO, 2008). Body mass was measured to the nearest 0.01 kg, with the child wearing light clothing, while stature was measured in the Frankfort horizontal plane to the nearest 0.01 m. All measurements were taken twice, and a third measure was taken if the difference between the first two measures exceeded 0.25 kg or 0.5 cm; the recorded value corresponded to the average of the two measures, or the median if three measures were taken. Body mass index was calculated as body mass divided by stature squared (kg/m^2).

Parental screen practices

Parents' digital habits and screen-related mediation behaviors were assessed using the standardized parent questionnaire of the SUNRISE International Study (Okely et al., 2021). The questionnaire was answered by the child's parent or legal guardian, and was administered directly to the caregiver via a structured telephone interview conducted by a trained researcher, in order to minimize the risk of missing data. The instrument was translated directly from the original English version into Brazilian Portuguese, without a formal back-translation or cross-cultural validation procedure.

Children's total daily screen time was derived from a single item, in which caregivers reported the average daily time (in hours and minutes) the child spent using any electronic screen device (e.g., smartphone, tablet, video game console, television, computer) while sitting or lying down, referring to a full week (7 days) prior to the interview. Because this item captures all screen-based devices within a single aggregate estimate, no summing across devices was performed and double counting was therefore not possible. Responses were converted into total minutes per day (e.g., 2 h 30 min = 150 min) and analyzed as a continuous variable. No a priori plausibility thresholds were

applied to the reported values, and only participants with complete screen time data were retained for analysis.

Caregivers' screen-related behaviors were assessed through eight individual items, each referring to a distinct daily context and analyzed separately, in order to identify which specific behaviors were most strongly associated with children's screen time. Three items addressed the frequency with which the caregiver used screen devices (television, computer, tablet, or smartphone) as a tool directed at the child — namely, to educate the child, to calm the child when upset, and to keep the child entertained while the caregiver carried out other activities. The remaining five items addressed the frequency with which the caregiver used their own smartphone (to make calls, send messages, check emails, or watch videos) in the child's presence, specifically during meals, while playing with the child, while commuting with the child, while walking with the child, and during the child's sleep routine. Each item was answered using a standardized 5-point ordinal scale: (1) Never, (2) Less than once a week, (3) Once a week, (4) Almost every day, and (5) Every day. An additional "I don't know" response option was available and was treated as missing data. Each item was entered separately into the statistical models as an ordinal predictor, rather than combined into a composite score.

Statistical Analysis

Descriptive analyses were performed to characterize the study sample. Continuous variables were reported as mean $\pm$ standard deviation and median with interquartile range, whereas categorical variables were presented as absolute and relative frequencies. Screen time was analyzed as a continuous outcome expressed in minutes per day. Differences in screen time according to region, area of residence, and child sex were explored using descriptive statistics. Hierarchical multiple linear regression models with robust standard errors were then fitted to examine factors associated with children's screen time. Variables were entered in blocks according to a conceptual framework: region in Model 1, area of residence in Model 2, child sex in Model 3, child and family characteristics in Model 4, and screen-use context variables in Model 5. The hierarchical order of blocks was theoretically guided by Bronfenbrenner's Bioecological Theory, proceeding from the most distal, structural level of the system (geographic region) to the most proximal,

routine-based level (frequency of screen use across daily contexts), with area of residence, child sex, and child and family characteristics entered as intermediate levels of increasing proximity to the child. This sequence allowed the incremental contribution of each ecological level to be examined net of the levels entered previously. The final model included region, zone, child sex, age and BMI, parental age and schooling level, and the frequency of screen use across different daily contexts. Model fit was assessed using R^2 and adjusted R^2 . Statistical significance was set at $p < 0.05$. Because models were fitted using listwise deletion, the analytic sample size decreased across successive blocks as variables with missing values were introduced (Models 1–3, $n = 1,325$; Model 4, $n = 1,289$; Model 5, $n = 1,271$). Consequently, R^2 and adjusted R^2 values are not directly comparable across models, as later models were estimated on a progressively smaller and potentially non-equivalent subsample; these statistics should therefore be interpreted as indicative of the explanatory power within each model rather than as a strictly incremental decomposition of variance.

The hierarchical entry of variables was conceptually guided by Bronfenbrenner's Bioecological Theory. For categorical predictors, indicator coding was applied, with North region, urban area, boys, and basic education set as reference categories. Multicollinearity among the independent variables was assessed using the variance inflation factor (VIF). The assumptions of the linear regression model were further assessed through residual analysis. Homoscedasticity was examined using the Breusch–Pagan/Cook–Weisberg and White tests, supplemented by graphical inspection of residuals versus fitted values. Residual normality was evaluated using the joint skewness and kurtosis test and the Shapiro–Wilk test, together with a quantile–quantile plot and a histogram with a superimposed normal curve. Given the evidence of heteroskedasticity, the final models were estimated using robust standard errors. All statistical analyses were performed using Stata (version 19.0; StataCorp, College Station, TX, USA).

Results

Sample Characteristics

The sample included 1,382 children, of whom 1,325 had valid screen-time data. Mean daily screen time (120.5 ± 97.2 min) exceeded WHO recommendations, and the sample was geographically diverse and balanced by sex, with most caregivers reporting secondary education (Table 1). Missing data across variables were low (0–4.20%); a descriptive summary of missing cases is presented in Supplementary Table 1.

Table 1. Sample characteristics.

Variable	N	Mean $\pm$ SD or n (%)
<i>Continuous variables</i>		
Screen time (min/day)	1,325	120.5 ± 97.2
Child age (years)	1,340	4.18 ± 0.54
Parental age (years)	1,324	32.86 ± 8.70
BMI (kg/m²)	1,339	16.33 ± 2.45
<i>Categorical variables</i>		
Region	1,382	
North		305 (22.1%)
Midwest		233 (16.9%)
Northeast		374 (27.1%)
South		247 (17.9%)
Southeast		223 (16.1%)
Area of residence	1,380	
Urban		792 (57.4%)
Rural		588 (42.6%)
Child sex	1,380	
Boy		702 (50.9%)

Variable	N	Mean ± SD or n (%)
Girl		678 (49.1%)
Parental education	1,327	
Basic		286 (21.6%)
Secondary		1,041 (78.5%)

Note: The geographical areas correspond to the official Brazilian regions.

Screen Time by Sociodemographic Factors

Descriptive screen time patterns across region, area of residence, and child sex are presented in Supplementary Table 2; the largest descriptive differences were observed across geographic regions, consistent with the adjusted associations reported in the hierarchical regression models (Table 3)

The presence of a region $\times$ zone interaction was additionally tested in a supplementary model; this interaction was not statistically significant, $F(4, 1248) = 0.49$, $p = 0.7445$, indicating that differences between urban and rural areas did not vary significantly across regions. Predicted margins from this supplementary model are presented in Supplementary Figure 1.

Screen-Use Contexts

Screen use for entertainment was the most frequently reported practice occurring almost every day (28.34%) or every day (22.00%). Caregivers' personal smartphone use during the child's sleep routine was also frequent (18.82% almost every day; 20.18% every day), as was screen use directed at the child to educate (21.36% almost every day; 16.23% every day). In contrast, caregivers' personal smartphone use while walking with the child was uncommon, with 82.01% reporting never doing so in this context (Table 2).

Table 2. Frequency of screen use across daily contexts.

Context	Never (%)	Less than once a week (%)	Once a week (%)	Almost every day (%)	Every day (%)
Educate	476 (35.92)	126 (9.51)	225 (16.98)	283 (21.36)	215 (16.23)
Calm	561 (42.40)	128 (9.67)	160 (12.09)	258 (19.50)	216 (16.33)
Entertain	343 (25.93)	137 (10.36)	177 (13.38)	375 (28.34)	291 (22.00)
Meals	827 (62.42)	125 (9.43)	83 (6.26)	166 (12.53)	124 (9.36)
Play	780 (58.96)	148 (11.19)	122 (9.22)	206 (15.57)	67 (5.06)
Commute	792 (59.82)	165 (12.46)	142 (10.73)	155 (11.71)	70 (5.29)
Walk	1085 (82.01)	87 (6.58)	64 (4.84)	59 (4.46)	28 (2.12)
Sleep	659 (49.81)	77 (5.82)	71 (5.37)	249 (18.82)	267 (20.18)

** Note: n and percentages are calculated among valid responses; "I don't know" responses were treated as missing data and excluded from the denominator for each item.*

Factors Associated with Children's Screen Time

Model diagnostics indicated the presence of heteroskedasticity and non-normality of residuals, which were addressed using robust standard errors; no evidence of multicollinearity or of a region $\times$ zone interaction was found (see Supplementary Results for full diagnostic statistics).

In the hierarchical regression models (Models 1–5), region was a consistent predictor of screen time across all models. In Model 5 (the fully adjusted model), compared with North, children from Midwest had 27.38 fewer min/day, those from Northeast had 40.18 fewer min/day, and those from South had 32.49 fewer min/day; Southeast, however, was no longer significant in Model 5. Child age was positively associated with screen time: each additional year was associated with 19.06 more min/day. Rural residence, sex, parental education, and BMI were not significant predictors in Model 5 (Table 3).

Among screen-use contexts, entertainment showed the strongest association with screen time: each one-level increase in reported frequency was associated with 16.51

more min/day (95% CI: 12.90, 20.12). Screen use during meals was also positively associated with screen time (6.66 more min/day; 95% CI: 2.56, 10.76). Model 5 explained 16.3% of the variance in the final analytic sample (Table 3).

Table 3. Hierarchical linear regression models for factors associated with children's screen time.

Predictor	Model 1 Coeff. (95% CI)	Model 2 Coeff. (95% CI)	Model 3 Coeff. (95% CI)	Model 4 Coeff. (95% CI)	Model 5 Coeff. (95% CI)
Midwest	-40.36*** (-57.92, - 22.80)	-39.86*** (-57.42, - 22.30)	-39.91*** (-57.50, - 22.32)	-37.77*** (-55.47, - 20.07)	-27.38** (-44.00, - 10.76)
Northeast	-52.31*** (-67.72, - 36.90)	-53.68*** (-69.26, - 38.10)	-53.87*** (-69.51, - 38.23)	-45.95*** (-62.00, - 29.90)	-40.18*** (-55.61, - 24.75)
South	-49.40*** (-66.35, - 32.45)	-48.82*** (-65.71, - 31.93)	-49.16*** (-66.19, - 32.13)	-44.38*** (-61.82, - 26.94)	-32.49*** (-49.13, - 15.85)
Southeast	-28.64** (-47.75, - 9.53)	-28.57** (-47.68, - 9.46)	-28.69** (-47.80, - 9.58)	-26.18** (-45.17, - 7.19)	-14.02 (-32.25, 4.21)
Rural	—	-7.79 (-18.45, 2.87)	-7.95 (-18.65, 2.75)	-10.76 (-22.03, 0.51)	-7.05 (-18.05, 3.95)
Girl	—	—	-3.88 (-14.23, 6.47)	-5.00 (-15.37, 5.37)	-4.65 (-14.51, 5.21)
Child age	—	—	—	17.80*** (7.96, 27.64)	19.06*** (9.57, 28.55)
Parents' age	—	—	—	-0.64* (-1.19, -0.09)	-0.36 (-0.89, 0.17)
Secondary education	—	—	—	10.26 (-2.56, 23.08)	8.38 (-4.36, 21.12)
BMI	—	—	—	1.59 (-1.04, 4.22)	1.08 (-1.39, 3.55)
Calm	—	—	—	—	3.84* (0.00, 7.68)
Entertain	—	—	—	—	16.51*** (12.90, 20.12)

Predictor	Model 1 Coeff. (95% CI)	Model 2 Coeff. (95% CI)	Model 3 Coeff. (95% CI)	Model 4 Coeff. (95% CI)	Model 5 Coeff. (95% CI)
Meals	–	–	–	–	6.66** (2.56, 10.76)
Play	–	–	–	–	-1.56 (-5.50, 2.38)
Commute	–	–	–	–	0.91 (-3.19, 5.01)
Walk	–	–	–	–	-0.69 (-5.88, 4.50)
Sleep	–	–	–	–	1.76 (-1.42, 4.94)
Educate	–	–	–	–	0.95 (-2.32, 4.22)
Constant	154.50*** (141.45, 167.55)	157.95*** (143.86, 172.04)	160.06*** (144.42, 175.70)	70.89* (6.60, 135.18)	-21.70 (-86.01, 42.61)
N	1,325	1,325	1,325	1,289	1,271
R ²	0.043	0.044	0.045	0.057	0.163
Adjusted R ²	0.040	0.041	0.041	0.050	0.151

*Note: The geographical areas correspond to the official Brazilian regions. Reference categories: Region = North; Zone = Urban; Child sex = Boy; Parental education = Basic education. Coefficients are unstandardized; values in parentheses denote 95% confidence intervals. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Standard errors used to derive confidence intervals were heteroskedasticity-robust. Models 1 to 3 were estimated on the full analytic sample with valid screen-time data ($n = 1,325$); due to listwise deletion of missing values on variables entered in subsequent blocks, Model 4 was estimated on $n = 1,289$ and Model 5 on $n = 1,271$. Consequently, R^2 and adjusted R^2 values are not strictly comparable across models, as later models are based on progressively smaller, non-identical subsamples; this is acknowledged as a limitation of the hierarchical modelling approach (see Discussion).*

Discussion

The present study aimed to evaluate the relative association of different ecological levels with the screen time of Brazilian preschoolers aged 3 to 4 years, guided by Bronfenbrenner's Bioecological Theory. The main findings reveal that the average daily screen time among the sample (120.5 minutes) substantially exceeds the World Health Organization's recommendation of a maximum of 60 minutes per day. Furthermore, our hierarchical regression model showed that while macro-level geographic factors (region) and individual attributes (child's age) are significant predictors, the micro-level daily routines, specifically the frequent use of screens for entertainment and during meals, emerge as the factors most strongly associated with higher screen time. Conversely, sociodemographic factors such as area of residence (urban and rural), child's sex, and parental education did not show significant associations in the fully adjusted model.

Aligned with the hierarchical regression model, factors closest to the child, such as daily entertainment routines and device use during meals, were most strongly associated with screen time. The finding that screen use for entertainment is the strongest predictor, associated with an average of 16.5 additional minutes per frequency level, strongly corroborates evidence that the use of screens as a primary tool for distraction is closely associated with higher overall exposure (Radesky et al., 2023). Similarly, the significant association of screen use during meals aligns with recent literature, which highlights mealtime media use as a habit strongly associated with prolonged daily screen time and the displacement of crucial family interactions (Gomes et al., 2024; Han et al., 2023). Taken together, these results reiterate that, beyond macro-level structural factors, the daily family dynamic and the contextual boundaries set by parents are closely associated with a preschooler's digital lifestyle (Alves & Martins, 2021).

Interestingly, while geographic region remained a predictor of screen time, that may reflect broader structural inequalities across Brazil (Leão et al., 2025), the distinction between urban and rural living zones lost its statistical significance in the fully adjusted model. Although this attenuation cannot be directly explained by the present data, one plausible hypothesis is that the traditionally lower technology access in rural areas may

be narrowing: national household survey data indicate that internet access among rural Brazilian households rose from 35.0% in 2016 to 81.0% in 2023, reducing the urban-rural gap from over 40 percentage points to approximately 13 percentage points over the same period (IBGE, 2024). Whether this broader trend in connectivity translates into comparable increases in young children's screen time, however, remains to be directly tested in future research.

Despite the associations found, it is important to consider that the final model explained 16.3% of the variance in screen time ($R^2 = 0.163$; adjusted $R^2 = 0.151$, accounting for the number of predictors included). This remaining unexplained variance indicates that digital media use by preschoolers is a highly complex and multifactorial phenomenon, only partially captured by the structural, sociodemographic, and routine-based variables examined in this study. Existing literature suggests that unmeasured psychosocial variables may account for this gap. Parental factors such as psychological distress, elevated parenting stress, and maternal depression have been associated with a greater reliance on screens as a coping or pacifying mechanism within the household (Niiranen et al., 2024). At the individual level, a child's behavioral traits, such as a difficult temperament or poor self-regulation skills, have been associated with increased parental use of devices to manage tantrums (Radesky et al., 2023). Furthermore, the specific quality and type of digital content consumed represent critical unmeasured factors that may be associated with the duration and developmental impact of screen use (Toth et al., 2026). Therefore, future research must go beyond sociodemographic and routine-based associations, incorporating psychological, parental, and content-related variables to construct more comprehensive predictive models.

An important methodological feature of this research is the large sample encompassing preschools across all five regions of Brazil, which allowed structural, family, and individual factors to be examined jointly within a single hierarchical framework. Furthermore, the use of a hierarchical regression model grounded in a robust theoretical framework allowed for a clear structural analysis of macro- and micro-level factors associated with screen time. However, certain limitations must be acknowledged. Preschools were selected by convenience rather than through probabilistic sampling, resulting in a markedly uneven distribution across regions; the resulting sample should

therefore be interpreted as geographically diverse rather than nationally representative, and caution is warranted when generalizing these findings to the broader Brazilian preschool population.. Children were also clustered within 82 preschools, and the analytic models did not account for this clustering (e.g., through multilevel modelling), which may have resulted in underestimated standard errors and an increased risk of Type I error for predictors correlated within schools. The cross-sectional design precludes any causal inferences between the evaluated contexts and screen time. Additionally, screen exposure and family routines were assessed through parental self-report, which is susceptible to recall bias and social desirability bias, meaning that the already concerning levels of screen time reported might still be an underestimation of the true daily exposure. Furthermore, because the response categories of the ordinal scale used to assess caregivers' screen-related practices do not necessarily correspond to equal underlying intervals, the corresponding regression coefficients should be interpreted as the average change in screen time associated with a one-category increase in each predictor, rather than as evidence of a linear dose-response relationship. Finally, because participation depended on caregiver consent and preschool cooperation, the sample may be subject to selection bias, potentially under- or over-representing families with particular engagement or screen-use patterns.

Conclusion

In this geographically diverse Brazilian sample, mean screen exposure exceeded the 60 minutes per day recommended by current health guidelines. Among the parental screen practices examined, the use of devices for entertainment children and caregivers' screen use during mealtimes were positively associated with children's screen time. These findings highlight the relevance of routine-based family practices, alongside geographic and individual factors, in understanding screen time exposure during early childhood.

5. Final consideration

This dissertation aimed to explore the hierarchical relationships between structural, family, and individual factors underlying screen time behaviors in Brazilian preschool-aged children, across all five Brazilian regions simultaneously, applying a hierarchical modelling strategy that explicitly reflects the nested structure of environmental associations on early childhood behavior. Beyond the specific findings discussed in the preceding article, this dissertation offers a broader contribution to the scientific, educational, and social understanding of early childhood screen exposure in Brazil.

From a scientific standpoint, by organizing predictors hierarchically according to their proximity to the child, this dissertation offers a methodological structure that future studies on movement and screen behaviors in early childhood, in Brazil and in other large, regionally diverse countries, may adapt and build upon.

From an educational standpoint, these findings suggest a possible implication for future intervention efforts. Rather than relying solely on broad awareness campaigns targeting sociodemographic groups, working directly with families on concrete daily routines, such as mealtime and entertainment practices, may represent a more proximal and potentially more modifiable target for early childhood education professionals, pediatricians, and family-support programs. However, because the present study is cross-sectional and associative in nature, this implication should be regarded as a hypothesis to be directly tested in future intervention studies, rather than as an established recommendation.

From a social and public health standpoint, this dissertation contributes to a still limited body of evidence on children's digital habits in the Global South, and specifically in a middle-income, continental-scale country such as Brazil, where regional inequalities coexist with a rapidly expanding digital infrastructure. These findings may inform future public health guidance and policy discussions on early childhood screen exposure that are sensitive to Brazil's particular geographic and socioeconomic context, rather than relying solely on evidence generated in high-income countries.

Future research should build on this work through longitudinal designs capable of establishing temporal and potentially causal pathways between family digital practices and children's screen time, as well as through the incorporation of psychological, parental,

and content-related variables not captured in the present study. Future studies should also employ validated measures of parental digital practices, distinguish measures by device type and content, and, ideally, incorporate objective methods or diary-based measures of use, rather than relying solely on single-item, retrospective self-report. Extending this hierarchical approach to nationally representative samples would also allow these findings to be generalized with greater confidence.

In summary, this dissertation contributes to the literature not only through its specific empirical findings, but by offering an integrated, theoretically grounded lens through which structural, family, and individual correlates of early childhood screen exposure can be jointly examined. This contribution is intended to be of value to researchers, early childhood educators, and policymakers engaged with children's digital environments in Brazil and beyond.

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Supplementary Material

Supplementary Table 1. Data completeness of the study variables.

Variable	N valid	N missing	% missing
Region	1,382	0	0.0%
Area of residence (zone)	1,380	2	0.14%
Child sex	1,380	2	0.14%
Child age	1,340	42	3.04%
BMI	1,339	43	3.11%
Parental age	1,324	58	4.20%
Parental education	1,327	55	3.98%
Screen time	1,325	57	4.13%

Note: Percentages of missing data are calculated relative to the total enrolled sample (N = 1,382).

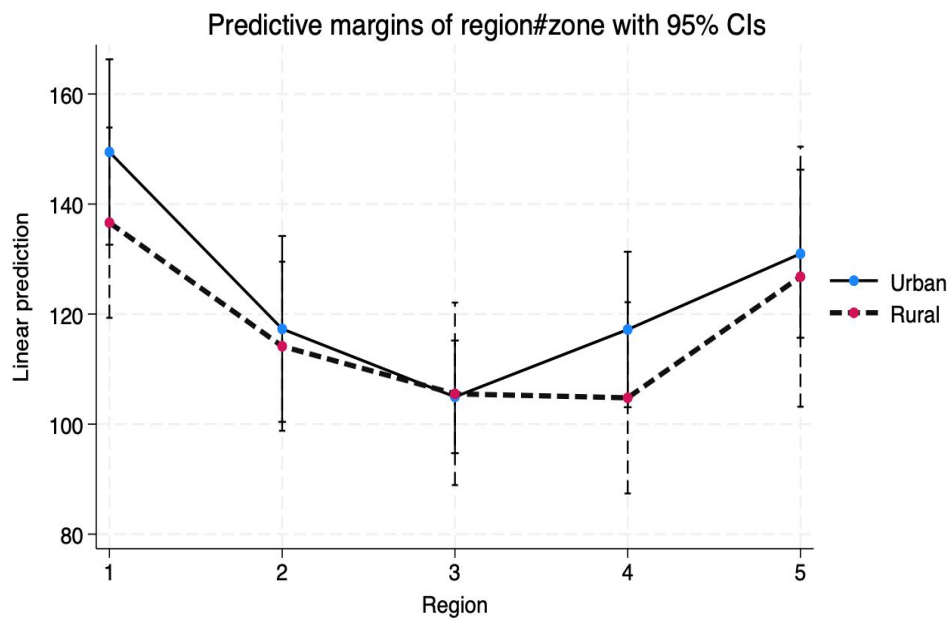
Supplementary Table 2. Screen time according to region, zone, and child sex.

Variable	N	Mean $\pm$ SD	Median (IQR)
North	303	154.5 $\pm$ 115.9	120 (60-240)
Midwest	227	114.1 $\pm$ 90.3	90 (50-180)
Northeast	342	102.2 $\pm$ 77.1	90 (45-120)
South	240	105.1 $\pm$ 85.4	90 (60-120)
Southeast	213	125.9 $\pm$ 104.0	120 (60-180)
Urban	765	122.7 $\pm$ 94.7	120 (60-180)
Rural	560	117.5 $\pm$ 100.4	90 (60-180)
Boy	675	121.4 $\pm$ 100.0	90 (60-180)
Girl	650	119.6 $\pm$ 94.2	90 (60-180)
Total	1,325	120.5 $\pm$ 97.2	90 (60-180)

**Note: The geographical areas correspond to the official Brazilian regions.*

Supplementary Results: Model Diagnostics

Diagnostic tests indicated that the homoscedasticity assumption was not met: the Breusch–Pagan/Cook–Weisberg test was statistically significant, $\chi^2(18) = 152.24$, $p < 0.001$, as was the White test, $\chi^2(176) = 253.46$, $p < 0.001$. Likewise, the residuals showed a statistically significant deviation from the normal distribution according to both the joint skewness and kurtosis test, $\chi^2(2) = 297.23$, $p < 0.001$, and the Shapiro–Wilk test, $W = 0.907$, $p < 0.001$. Consequently, to reduce the effect of heteroskedasticity on statistical inference, the final models were estimated using robust standard errors. No multicollinearity problems were observed in the final model: the highest VIF was 1.82, corresponding to the Northeast region category, and the mean VIF was 1.23. In a supplementary fully adjusted model including the region $\times$ zone interaction, no evidence of an interaction between region and area of residence (zone) in relation to children's screen time was observed, $F(4, 1248) = 0.49$, $p = 0.7445$, indicating that differences between urban and rural areas did not vary significantly across regions (Supplementary Figure 1).



Supplementary Figure 1. Predicted margins of children's screen time by region and area of residence (zone).

**Note: The geographical areas correspond to the official Brazilian regions: Region 1 = North; Region 2 = Midwest; Region 3 = Northeast; Region 4 = South; Region 5 = Southeast. Predicted margins were estimated from a supplementary fully adjusted model that included the region $\times$ zone interaction and the same covariates as Model 5 (Table 3); this interaction model is therefore distinct from the main-effects Model 5 presented in Table 3. The overall region $\times$ zone interaction was not statistically significant, $F(4, 1248) = 0.49$, $p = 0.7445$.*