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Screen time vs. scream time: Developmental interrelations between young children's screen time, negative affect, and effortful control

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ABSTRACT

This study aimed to examine developmental relations of screen time, negative affect and effortful control in children aged 12–36 months. Parents of 462 children up to 3 years of age at the start of the study ($M = 1.28$ years, $SD = 0.61$; 50% female) participated in four assessments within 10 months. Parents reported their children's screen time, negative affect, and effortful control at each assessment in a diary study. Results of multivariate Bayesian multilevel growth modeling revealed correlations between growth parameters of (1) children's screen time and their negative affect and (2) children's negative affect and their effortful control but not between growth parameters of (3) children's screen time and their effortful control. Overall, these results indicate that children's screen time may be associated with their negative affect independently of their effortful control. Hence, we found no evidence of displacement in the development of self-regulatory strategies in children of parents with higher levels of education. Future research on this topic should focus on children's excessive screen media use, considering contextual and content-related screen media factors and other factors in the child's immediate and broader environment.

1. Introduction

Screen media such as television, smartphones and tablets have become omnipresent in households and have been integrated seamlessly into modern family lifestyles (Livingstone & Blum-Ross, 2020). This increasing accessibility of screen media has led to children being exposed to screens from an early age (e.g., Ofcom, 2022; Paulus et al., 2021). Parents grant their young children screen time for a variety of purposes (e.g., Nevski & Siibak, 2016). One of these purposes is the regulation of a child's behavior (Coyne et al., 2022; Geurts et al., 2022; Gordon-Hacker & Gueron-Sela, 2020; Radesky et al., 2014, 2016), such as when a child expresses frustration or other kinds of negative affect. Because the first years of life are an important period for all aspects of development (Black et al., 2017; Britto et al., 2017; Jenni, 2021b), the practice of allowing young children screen time to regulate their behavior (e.g., Coyne et al., 2022) may displace opportunities for learning to deal with negative affect by developing active self-regulation strategies (e.g., Mutz et al., 1993; Roberts et al., 1993). Therefore, this study aimed to better understand the developmental interrelation of children's screen time, negative affect, and self-regulation measured by effortful control (Eisenberg, 2012) from 12 to 36 months of age.

1.1. Screen media in early childhood

The screen media landscape has changed dramatically in recent decades from the widespread adoption of television in the 1960s to the more recent widespread use of portable screen devices such as smartphones and tablets. Consequently, screen media use has become a ubiquitous aspect of modern childhood, with young children starting to use screens at increasingly earlier ages (e.g., Ofcom, 2022; Paulus et al.,

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2021). To provide guidance to parents of young children, international organizations such as the World Health Organization (2019) have issued recommendations for young children's exposure to screen media: Children younger than two years of age should not be exposed to screens at all, and for children 2–4 years old, daily sedentary screen time should not exceed 1 h (World Health Organization, 2019). However, many parents have not followed these recommendations. According to recent estimates from Germany, children aged 2–3 years spend an average of 59 min with a screen each day, and children aged 4–5 years an average of 75 min (Kieninger et al., 2021). Even higher estimates have been reported in other countries. For example, in Australia 40% of 500 18-month-old children had more than 2 h daily screen time (Chandra et al., 2016), and in the USA, the daily screen time of young children varies, with those under 2 years old spending an average of 49 min, and 2- to 4-year-olds an average of 2 h and 30 min (Rideout & Robb, 2020). The increasing amount of time that young children spend with screens (Feierabend et al., 2015; Kieninger et al., 2021; Ofcom, 2019, 2022; Rideout & Robb, 2020) has led to growing concerns (e.g., Bleckmann et al., 2022) about its potential impact on the crucial period of early child development (Black et al., 2017; Britto et al., 2017; Jenni, 2021b). The most prominent hypothesis supporting these concerns is the displacement hypothesis (Mutz et al., 1993; Roberts et al., 1993), according to which engagement with screen media displaces other activities (e.g., Motl et al., 2006; Wong et al., 2010). As parents increasingly integrate screen media into their daily lives and use them as a tool to regulate their children's behavior (Coyne et al., 2022; Geurts et al., 2022; Gordon-Hacker & Gueron-Sela, 2020; Gueron-Sela et al., 2023; Radesky et al., 2014, 2016), screens may displace learning opportunities that are essential for children to deal with negative affect by developing self-regulatory strategies.

1.2. Negative affect

Negative affect is an aspect of reactivity. Children exhibit interindividual differences in their tendency to experience negative emotions, such as anger, distress in response to limitations or frustration, sadness or fear (Putnam et al., 2014; Rothbart & Bates, 2006). Higher levels of negative affect are associated with a spectrum of emotional and behavioral difficulties (Eisenberg et al., 1996; Muris, 2006; Rothbart & Bates, 2006). In particular, it has been shown that negative affect contributes to later psychopathology (Osborne et al., 2022) and the development of problematic behaviors (Lilienfeld, 2003), including both internalizing (Behrendt et al., 2020; Jovanović, 2022; Luebbe et al., 2011; Muris et al., 2007) and externalizing (Moran et al., 2013; Muris et al., 2007; Singh & Waldman, 2010) behaviors in childhood (Behrendt et al., 2020; Luebbe et al., 2011; Moran et al., 2013; Muris et al., 2007) and adolescence (Jovanović, 2022; Muris et al., 2007). Born with restricted ability to regulate physiological and emotional states (Eisenberg et al., 2010; Tronick et al., 1978) young children are guided almost exclusively by their emotions (Jenni, 2021a) and thus may show higher levels of negative affect in their first years of life. As young children mature and develop better communication and regulation skills, their expression of negative affect typically decrease over the course of childhood (Jenni, 2021a; Rothbart & Bates, 2006). During this time of rapid learning as emotion regulation of negative affect processes develop, children rely greatly on external regulation provided by their parents (Kopp, 1989). Through such coregulation, parents assist their child in implementing particular techniques to regulate those emotions, such as practicing deep breathing, counting to calm down, taking a break, joint problem solving, or identifying mood boosters and expressing their emotions through words (Gottman et al., 1996; Morin, 2021).

1.3. Effortful control

Self-regulation is often referred to as effortful control (Eisenberg, 2012) and includes various self-regulatory skills (Rothbart & Bates, 2006). Effortful control is a facet of the regulatory aspect defined as the effectiveness of executive attention. Effortful control includes deliberate, voluntary control of attention, inhibitory control, and the capacity to regulate emotions (Rothbart & Bates, 2006). Thus, it includes self-regulatory skills such as the ability to direct attention, suppress impulsive reactions, and modulate emotional responses (Rothbart & Bates, 2006). Self-regulation begins in infancy (Eisenberg et al., 2010; Jenni, 2021a) and is a crucial skill that has long-term implications for relationships (Blair & Raver, 2015; Graziano et al., 2007; Harrington et al., 2020), resilience and coping (Shin & Kemps, 2020), behavior (Eisenberg et al., 2009; Graziano et al., 2007; Hill et al., 2006; Perry et al., 2017), academic performance (Blair & Raver, 2015; Blankson et al., 2017), and physical health (Calkins et al., 2019; Leung et al., 2014). In addition, higher levels of effortful control in young children are associated with lower levels of negative affect (Eisenberg et al., 1994, 2009; Kochanska et al., 1998; Kochanska & Knaack, 2003). During infancy as effortful control and self-regulation develops, parental co-regulation also plays an important role (Rothbart & Bates, 2006). Parents support their children's development of complex self-regulatory strategies by repeatedly interacting with their children in challenging situations (Kopp, 1989; Sameroff, 2010; Spinrad et al., 2007).

1.4. Regulation through screen media

When parents grant their children screen time to regulate their behavior (Coyne et al., 2022; Geurts et al., 2022; Gordon-Hacker & Gueron-Sela, 2020; Gueron-Sela et al., 2023; Radesky et al., 2014, 2016), the process of learning active self-regulation may well be disrupted. Coping with stressful situations through screens might replace the development of strategies involving parents' coregulation (e.g., Mutz et al., 1993; Roberts et al., 1993). For example, when a child experiences negative affect due to having to give a toy back to a friend, offering to distract them with screen media may well reduce negative affect in that instant. However, it may hinder social interaction and prevent exploring alternative strategies for regulating the negative affect experienced (e.g., Gordon-Hacker & Gueron-Sela, 2020). Such replacement reduces opportunities for children to learn more active regulation strategies such as self-soothing and redirected action, which can help them understand the root causes of their negative affect. As a result, children may maintain the expression of negative affect when screens are not available (e.g., Coyne et al., 2021). Moreover, children may learn to exhibit negative affect instrumentally to obtain more screen time (e.g., Coyne et al., 2022). This may lead to children expressing more negative affect when they want to have screen time, which in turn may eventually contribute to children's problematic screen media use (Coyne et al., 2021). Furthermore, when parents ask children to turn off the screen after spending some time in front of it, this may also cause children to express negative affect (Coyne et al., 2021; Hiniker et al., 2016).

Knowledge of the relationship between children's screen time, negative affect, and effortful control in early childhood is still limited. Available evidence points to a concurrent and longitudinal relationship between more screen time and emotional (Gueron-Sela et al., 2023; Liu et al., 2021; Wu et al., 2017) and behavioral (Cheng et al., 2010; Fitzpatrick et al., 2023; Gueron-Sela et al., 2023; Liu et al., 2021; McDaniel & Radesky, 2020; McNeill et al., 2019) problems in young children. However, such associations have not always been confirmed longitudinally (Gordon-Hacker & Gueron-Sela, 2020; Gueron-Sela et al., 2023; McDaniel & Radesky, 2020). Additionally, no evidence has been found for the reverse effect: that behavioral problems in young children predict greater subsequent screen time (Fitzpatrick et al., 2023; Gordon-Hacker & Gueron-Sela, 2020). Furthermore, findings on the directionality and persistence of an association between screen use and poor regulatory control have been mixed. Some researchers report a concurrent and longitudinal relationship between young children's screen time and their self-regulation skills (Cliff et al., 2018; Lawrence et al., 2020;

McNeill et al., 2019; Munzer et al., 2018; Radesky et al., 2014). Other researchers have found bidirectional effects: more screen time has been associated with poorer self-regulation skills (Lawrence et al., 2020; McNeill et al., 2019; Munzer et al., 2018), less screen time led to higher self-regulation skills (Cliff et al., 2018), and vice versa, poorer self-regulation skills led to increased screen time (Cliff et al., 2018; Radesky et al., 2014) in young children. Others have reported that the concurrent and longitudinal bidirectional effects of increased screen time and poorer self-regulation skills were not always significant (Cliff et al., 2018; Lawrence et al., 2020).

The effect sizes for the associations found between children's screen time and self-regulation skills were often small or very small (Cliff et al., 2018; Gueron-Sela et al., 2023; Lawrence et al., 2020; McDaniel & Radesky, 2020; Munzer et al., 2018) and only occasionally small to moderate (Radesky et al., 2014).

1.5. The present study

Previous research has primarily emphasized bivariate analyses when examining the relationships between screen time, negative affect, and effort control, i.e., self-regulation, in young children. Consequently, there is a research gap in comprehensively examining the trivariate interplay between these variables in children younger than 36 months of age. While the display of negative affect is closely linked to the acquisition of self-regulation skills, it should not be equated with them. Effortful control is a critical component of self-regulation as well. An investigation of such interplay is of great importance for our understanding of the relationship of young children's screen time and their emotional development. To the best of our knowledge, a study has yet to address the intertwined correlations of trajectories of screen time, negative affect, and effortful control in this specific age cohort. Furthermore, very few studies have used longitudinal designs. To address these research gaps, we investigated the longitudinal, developmental interrelations between screen time, negative affect, and effortful control in children aged 12–36 months. We used growth models (Preacher et al., 2008) to model children's development on these three variables from 12 to 36 months within an accelerated longitudinal design (Galbraith et al., 2017). Growth models offer additional insights that go beyond conventional repeated measures approaches (Chen & Cohen, 2006). A key advantage of growth models is their ability to examine individual variation in developmental changes by defining an intercept and slope that represent the initial state and time course, respectively (Ghisletta et al., 2020). In addition, when growth curves of multiple constructs are modelled concurrently, correlations in the initial states and in the development of the different constructs can be examined. These advantages fit very well with the aim of our study, as we were interested in modeling the relations in developmental patterns across multiple constructs, namely screen time, negative affect, and effort control. We modelled each construct with an intercept to capture children's initial level at age 12–14 months, and how children differ therein. In addition, each construct received a slope to capture changes in the respective construct from age 12–36 months, as well as variation therein. We could then examine the interrelations between the intercepts and slopes of the different constructs, indication how individual variation in the initial levels and the developmental trends correlated across the three constructs. Because this approach has not been followed in any other study before, the following research questions are primarily exploratory, and isolated hypotheses are only formulated where guidance from previous research was available.

The specific research questions were.

RQ1. How are growth parameters (i.e., intercepts and slopes) for screen time and negative affect related in children aged 12–36 months? *H_1. More screen time at 12 to 14 months is associated with higher levels of negative affect at 12 to 14 months.*

RQ2. How are growth parameters (i.e., intercepts and slopes) for screen time and effortful control related in children aged 12–36 months? *H_2. More screen time at 12 to 14 months is associated with lower levels of effortful control at 12 to 14 months.*

RQ3. How are growth parameters (i.e., intercepts and slopes) of negative affect and effortful control related in children aged 12–36 months? *H_3. Higher levels of negative affect at 12 to 14 months are associated with lower levels of effortful control at 12 to 14 months.*

Due to the fact that other studies have not employed growth modeling, we were unable to generate any specific hypotheses for correlations between slopes that would have reflected changes over time.

2. Methods

2.1. Procedure

The current longitudinal study uses data collected from the research project "Children and Digital Media" (KiDiM-study), conducted in Switzerland. Four waves of data collection were conducted in March 2021 (T1), June 2021 (T2), September 2021 (T3), and January 2022 (T4). The study was reviewed and approved by the Ethics Committee of the University of Zurich. As incentives, parents were given the option to participate in a raffle, and they received personal activity and development data graphs for their child if they desired. All parents underwent a comprehensive informed consent procedure before participating.

At each measurement wave, a diary week was conducted. A diary week consisted of an initial questionnaire administered on Friday, followed by seven daily reviews covering children's activities and selected focus topics such as socio-emotional development from Saturday through Friday, and concluding with a final questionnaire the following Saturday. The LimeSurvey online software was used to administer the questionnaires. The primary diary week began on a Friday, and participants were notified via email two days in advance. For those who were unable to participate in the main week, a substitute diary week was held one week later. Each day at 6 p.m., parents were sent an individualized link to an online questionnaire, which they were asked to complete on the same day after their child went to bed. Participants who failed to complete the questionnaire by 10 a.m. the next day were reminded via email and asked to complete the questionnaire retrospectively for the previous day. Participants who did not complete the initial three questionnaires were removed from the primary diary week on the fourth day, Monday, and were offered the opportunity to participate in the substitute diary week starting the subsequent Friday. Further, a preliminary questionnaire was sent out either at the beginning of the study (T0, February) or immediately after study enrollment if this occurred later than February. A token system was used to merge the data from the four waves. The study was carried out in the German language.

2.2. Sample

The study sample comprised parents of children who were up to 36 months of age at the start of the study in February 2021 and from whom data were collected in a total of four measurement waves within a period of 10 months. This accelerated longitudinal approach allowed us to collect data from children across a wide age range from birth up to 46 months.

Recruitment was conducted between January and May 2021 with various partners in the field of early childhood, such as pediatricians, counseling centers for mothers and fathers, and day care centers. Parents who had multiple children were asked to focus their participation solely on the youngest child. Of a total of 474 registered participants, 12 did not participate in any of the four measurement waves and were therefore excluded from further analysis, yielding a final sample size of $N = 462$. The number of participants remained consistent across the four measurement waves, with $n = 406$, 454, 422, and 430 at T1, T2, T3, and T4, respectively. The increase in participants at T2 compared to T1 was due to the recruitment process only being completed in May 2021. Out of the 408 parents who registered prior to the first measurement wave, 366 (90%) actively participated in all four assessments, 20 (5%) participated in three assessments, 15 (4%) in two assessments, and 7 (2%) in just one assessment. Among the 54 parents who registered after the first measurement wave, 47 (87%) participated in three assessments, 3 (6%) in two, and 4 (7%) in one. Overall, 89% of participants fully completed the study. Further analysis showed that the participants who completed the study were not statistically different from those who did not in educational level, household income, children's screen time, negative affect, or effortful control at T1 or T2 (see Table S.1 in Supplement). Based on this observation, we assumed that missing data on the frequency of participation occurred at random. Further, roughly 70% of participants and about 59% of their partners have a university degree or higher. At baseline, most participants lived in Switzerland ($n = 455$), while a small number lived in Germany ($n = 5$), Georgia ($n = 1$), and Mexico ($n = 1$). Further details on the sample can be found in Table 1.

2.3. Measures

2.3.1. Children's screen time

We used multiple data sources to measure children's screen time. We used online questionnaires that included a single item about children's screen time, as has been done in other studies (Benita et al., 2020; Dynia et al., 2021; Levelink et al., 2020; Lin et al., 2020; Liu et al., 2021) on different days throughout the diary week (e.g., Barr et al., 2020). We also supplemented activity-specific sub-questions to test for convergence of responses.

(1) In the initial questionnaire of the diary week, participants were asked about their child's average daily screen time in the previous week, with response options ranging from 0 to 12 h in increments of 0.25 h.

Table 1
Sample descriptives.

	T1	T2	T3	T4
Measurement wave	Mar 21	Jun 21	Sep 21	Jan 22
N	406	454	422	430
Children				
Mean Age Years *(SD)*	1.28 *(0.61)*	1.51 *(0.64)*	1.76 *(0.65)*	2.09 *(0.65)*
Sex (female)	50%	51%	50%	50%
Participants (caregivers)				
Mean Age Years *(SD)*	35.77 *(4.10)*	36.00 *(4.22)*	36.30 *(4.14)*	36.59 *(4.13)*
Sex (female)	93%	93%	93%	93%
Education (≥University)	71%	70%	69%	70%
Mean Annual Income *(SD)*	59′458 *(29′816)*	59′863 *(29′379)*	59′419 *(29′125)*	59′558 *(29′396)*
SSS Education *(SD)*	7.35 *(1.33)*	7.38 *(1.23)*	7.33 *(1.31)*	7.36 *(1.30)*
SSS Money *(SD)*	6.11 *(1.41)*	6.12 *(1.37)*	6.12 *(1.35)*	6.15 *(1.33)*
SSS Occupation *(SD)*	6.93 *(1.59)*	6.97 *(1.6)*	6.94 *(1.58)*	6.98 *(1.53)*
Partner (caregiver 2)				
Mean Age Years *(SD)*	37.76 *(5.09)*	37.95 *(5.11)*	38.22 *(5.09)*	38.51 *(5.00)*
Sex (female)	7%	7%	8%	7%
Education (≥University)	59%	59%	58%	59%
Mean Annual Income *(SD)*	92′416 *(32′426)*	91′808 *(32′622)*	90′939 *(31′676)*	91′618 *(32′137)*

Note. Sex assigned at birth; Income in CHF, mean of the annual household income; Subjective socio-economic status (SSS) was assessed using an adapted form of the German version of the MacArthur scale (Adler et al., 2000; Hoebel et al., 2015). This scale asks participants to position themselves on a 10-rung "social ladder" on the categories of education, money, and occupation.

(2) On days 1, 3, 5, and 7 of the daily reviews participants were asked about the duration of the child's screen usage on that day. The response format ranged again from 0 to 12 h in increments of 0.25 h. If a child had screen time of >0 h on a given day, participants were asked to specify up to three most frequent media content types consumed and the corresponding screen time for each. If participants had watched three media content types on a given day, we asked whether the child engaged with additional media content, and if so, participants were again required to indicate the child's screen time for that additional media content in minutes. Response options for children's content-related screen time ranged 0–120 min in 1-min increments. During data cleaning, the total screen time reported on the initial question was compared to the sum of time reported for each media content to ensure consistency. We expected these two sources of children's screen time to be similar. If a child had a difference of $\geq$0.25 h between these two sources, we used the sum of the child's content-related screen time because the per-minute response format for each media content was more precise. When the participant indicated that the media content and exact duration for each media content was unknown, we relied on that child's screen time from the initial question.

(3) The third source of data was provided by activity-related questions in the final questionnaire of the diary week. We asked participants about the average daily time their child spent (a) watching television or videos, (b) looking at digital photos, pictures, and picture books, and (c) playing with interactive apps during the diary week. Questions (b) and (c) were only asked if the child was over 3 months of age. The response format ranged again from 0 to 12 h in increments of 0.25 h. The average daily screen time was calculated by summing the duration of these three screen-related activities.

For all variables of children's screen time, outliers were checked during data cleaning, and suspiciously high values $\geq$ 4.5 h per day were checked against other days' data and defined as missing if there were strong inconsistencies: for instance, if the reported screen time within a diary week was always between 0 and 0.5 h and was 7 h on one day. Finally, data on children's screen time from these three sources were averaged into a final variable representing the final average daily screen time. Internal consistencies as indicated by McDonald's omega (which is more appropriate than Cronbach's Alpha, see Dunn et al., 2014) of children's screen time was $\omega_{T1/T2/T3/T4} = 0.79/.80/.90/.92$. An overview of the screen time measures can be found in Table A.1 in the Appendix.

2.3.2. Children's negative affect and effortful control

These concepts were assessed using the Negative Affect and Effortful Control subscales of the German version of the Infant Behavior Questionnaire–Revised–very short form (IBQ-R-VSF; Putnam et al., 2014), the Early Childhood Behavior Questionnaire–very short form (ECBQ-VSF; Putnam et al., 2006; 2010), and the Children's Behavior Questionnaire–very short form (CBQ-VSF; Putnam et al., 2006; Rothbart et al., 2001), depending on the child's age at each measurement time point: IBQ-R-VSF for children up to the age of 12 months[2]; ECBQ-VSF for children aged 12–36 months; and CBQ-VSF for children older than 36 months of age. However, for the present study, we used only the data

[2] The IBQ-R-VSF is intended for children between the ages of 3 and 12 months. In the present study, however, the IBQ-R-VSF was also presented to parents of children under 3 months of age, with the instruction that if a question seemed inappropriate, it should be answered with "I don't know" or "No answer."

from the ECBQ-VSF[3] because we examined the current research questions for children aged 12–36 months (n = 284).[4] These questionnaires are all designed to assess general patterns of behavior associated with temperament in early childhood. The negative affect and effortful control subscales are each composed of 12 items. An example of an item from the negative affect subscale is "While in a public place, how often did your child seem afraid of large, noisy vehicles?". An example of an item from the effortful control subscale is "When asked to wait for a desirable item [such as ice cream], how often did your child wait patiently?". Participants rated each question for the past month and by the frequency of certain behaviors from 1 (never) to 6 (always) on a six-point Likert scale. Higher scores indicate higher levels of negative affect or effortful control. Responses such as "I don't know" or "No answer," which were offered as response options for every question, were coded as missing. The response format was adjusted to match the response format used for other questions in the online questionnaires to facilitate completing the questionnaire. Both children's negative affect and effortful control (12 items) were averaged in each measurement wave. McDonald's omega of the ECBQ-VSF subscale negative affect was $\omega_{T1/T2/T3/T4}$ = 0.57/.65/.60/.59, indicating low to moderate internal consistency. The corresponding test–retest reliability, which can be interpreted as predictive validity, was $r_{T1,T2/T2,T3/T3,T4}$ = 0.64/.69/.65 ($p < .001$). The McDonald's omega of the ECBQ-VSF subscale effortful control was $\omega_{T1/T2/T3/T4}$ = 0.64/.62/.68/.69 and the test-retest reliability was $r_{T1,T2/T2,T3/T3,T4}$ = 0.69/.71/.69 ($p < .001$). Low to moderate internal consistencies are to be expected for both constructs because the items in both scales ask about a relatively broad range of behaviors. When capturing the breadth of a construct, moderate internal consistency should not be considered a limitation because construct validity requires that intercorrelations between measured items do not have excessively high values (Stadler et al., 2021; Steger et al., 2022; Taber, 2018). In addition, children develop greatly in their first years of life, which is why the answers to the questions may change over time (Fox et al., 2001).

2.3.3. Covariates

We considered three covariates in all subsequent analyses: participants' education level, gross household income, and number of siblings, all of which were measured at baseline (T0). Gross household income was calculated as the sum of the gross annual incomes of participants and their partners. All three covariates were considered as interval-scaled variables. Children's age was not considered because it is already accounted for in the eight newly generated age-specific variables.

2.4. Analysis strategy

The aim of the current analyses was to better understand the interplay between children's screen time, negative affect, and effortful control during the second and third years of life. To achieve this overall aim, data analyses were prepared and conducted as follows.

2.4.1. Data structure

The original data structure included a total of four measurement waves over a 10-month period with data from children who were up to 36 months of age at the start of the study. This data structure was disaggregated in an accelerated longitudinal study approach (Galbraith et al., 2017) by dividing the study variables into age categories from 12 to 36 months in 3-month increments: 12–14, 15–17, 18–20, 21–23, 24–26, 27–29, 30–32, and 33–35 months. This resulted in eight new variables each for children's screen time, negative affect, and effortful control, and the data collected on children's screen time, negative affect, and effortful control was assigned to these age categories according to the child's age at the time of measurement.

2.4.2. Missing data

This disaggregation of the data structure and the exclusion of data points on screen time, negative affect, and effortful control of children younger than 12 months and older than 36 months resulted in an average of 60% missing values in each of the newly formed variables for the 12- to 36-month age range (see Table S.2 in Supplement). This proportion of missing data stems mostly from the accelerated longitudinal design and can easily be handled with methods such as multiple imputation (van Buuren, 2018), as other research in this field has already demonstrated (e.g., Gueron-Sela et al., 2023). Working on the assumption that data for frequency of participation were missing at random, we used multiple imputation (van Buuren, 2018) to account for the missingness in the disaggregated data structure. Missing data were imputed using the mice package (van Buuren & Groothuis-Oudshoorn, 2011) in R (R Core Team, 2022) and the predictive mean matching method, which accommodates deviations from normality. All variables used later in the analyses were considered in the imputation (see Table S.2 in the Supplement). The number of imputations was set to 20: This number both accommodates the relatively high percentage of missing values in the data and was feasible for the statistical procedure and model calculation (see below). Convergence was reached in all data imputations. Convergence plots of the data imputation and graphs of the trajectories of children's screen time, negative affect, and effortful control before and after data imputation can be found in the Supplementary File (Figs. S.1 to S.4.2).

2.4.3. Multivariate bayesian multilevel growth model

To evaluate our research questions statistically and answer the corresponding hypotheses, we used Bayesian estimation (McElreath, 2020), which has been recently used for research within this area (Gueron-Sela et al., 2023). Our decision to use Bayesian estimation was due to its advantage over frequentist estimation methods in avoiding estimation problems (König & van de Schoot, 2018), and its ability to integrate and interpret multilevel parameters more accurately (Kéry & Schaub, 2012). We chose a multivariate Bayesian multilevel growth model because individual-level data about children in our sample are nested either within repeated measures or within the newly created age categories. Incorporating this nesting structure into multilevel models avoids potential biases in model estimates that would result from nesting if either of these factors were ignored (Barr et al., 2013; Kéry & Schaub, 2012; McElreath, 2020). The model was set up in six steps.

(1) For each of the three study variables, children's screen time, negative affect, and effortful control, we defined a separate model in which we included a random intercept for the participants. The random intercepts showed an intraclass correlation coefficient (ICC[5]) of .41 for children's screen time, 0.38 for children's negative affect, and 0.36 for children's effortful control, indicating that 36–41% of variance depended on systematic differences between individuals.
(2) Further, we added correlated random slopes to each of the models. The slopes capture changes in the outcome variables across age. Estimating random slopes accounted for

[3] The IBQ-R-VSF and CBQ-VSF measurement instruments were mentioned here because missingness (missing at random; see Table S.1 in Supplement) due to participation frequency was verified from the information of children's negative affect and effortful control provided by all three constructs at baseline.

[4] Of the children who participated at T1 (n = 406), n = 253 were between 12 and 36 months old at T1. Of the children enrolled after T1 (n = 55), n = 31 were between 12 and 36 months old at T2. Data were then imputed for the full sample (N = 462).

[5] Multiple imputation of the missing data created 20 complete data sets. The ICC reported for each study variable is the average of the ICC of all 20 data sets.

interindividual differences in children's development in these variables across age. We used linear slope parameters following graphical inspections of the data (see Figs. S.2.1 to S.4.2 in Supplement).

(3) Our research questions related to correlations between children's initial levels and developmental changes in these variables. Accordingly, the random intercepts and random slopes of the three variables were all allowed to covary within the multivariate model.

(4) We regressed the intercepts and slopes of each of the three study variables on the three mean-centered covariates: parents' educational level, income, and number of siblings.

(5) To account for the distribution of the residuals of the response variables, we extended each model with an appropriate distribution. For children's screen time, we used a hurdle-lognormal distribution. A lognormal distribution is generally an appropriate option for modeling time variables, which often have a long tail and visible right-skewness (e.g., van der Linden, 2006). In addition to the lognormal part, we also added a hurdle part to the distribution to capture those children with a screen time of 0. The variable screen time contained many zeros, which is because particularly among younger children, many yet have no screen time. The hurdle part in the hurdle-lognormal model accounts for many zeros in the data (Heiss, 2022). A comparison of a lognormal model and a hurdle-lognormal model indicated that the latter fitted the observed data appropriately and much better than the former (see Appendix Figure A.1 and Supplement Figs. S.5). The hurdle model provides separate parameter estimates for both the hurdle (zero) and the nonhurdle (nonzero) parts of the screen time variable. By estimating and predicting the hurdle part of the model, we can model how many children have no screen time and how this depends on their age and the background variables. By estimating and predicting the nonhurdle part of the model, we can model which variables predict variation in average screen time per day in minutes among those children who already have screen time. For the negative affect and effortful control variables, we assumed a Gaussian distribution of the residuals, which fitted the data well (Figure A.1).

(6) Finally, we combined these three models into one multivariate model. This process involved pooling the 20 separate data sets that were created to impute missing values.

The model was implemented in R (R Core Team, 2022) using the brms package (Bürkner, 2017). Within Bayesian estimation, multiply imputed data can easily be accommodated by combining the posterior draws resulting from the imputed data sets. Within this package, we applied Hamiltonian Monte Carlo estimation using four chains of 4000 draws, 1000 of which were designated as warm-up period, with a high target acceptance rate of 0.95 to ensure convergence.

The convergence of the model was confirmed by Rhat estimates of population-level and group-level parameters (see Figs. S.6 in Supplement). The Rhat estimates for the random effects were one each of 1.06, 1.05, and 1.04, while all others were 1.03 and under. Further, the absence of divergent transitions during estimation, effective sample sizes exceeding 400, and inspection of posterior trace plots indicated appropriate mixing (Bürkner, 2017). In general, parameter estimates from models that include multilevel structures may differ from descriptive statistics. Parameter estimates are reported and interpreted as medians of posterior distributions (McElreath, 2020). Because the parameter estimates of the screen time variable were logarithmized within the model, they were back-transformed for interpretations.

Unlike traditional frequentist estimation, Bayesian estimation does not provide *p* values. Bayesian *credible intervals* are used as an informative alternative for statistical inference (Wagenmakers et al., 2022). Credible intervals determined by the 90% highest density interval of posterior distributions (HDI; McElreath, 2020) were interpreted by considering an estimated credible interval of a model parameter not including zero as evidence that the corresponding effect deviates from zero. For model parameters whose estimated credibility interval includes zero, we interpreted the associated range but did not exclude the possibility that the corresponding parameter is zero (Sorensen & Vasishth, 2016). Because there is no universal range of credible intervals (McElreath, 2020), we decided to use 90% credible intervals to present our results because this approach provides a relatively high degree of confidence (90%) that the unobserved parameters are within the interval. This simple and intuitive interpretation cannot be achieved with traditional frequentist confidence intervals (e.g., Morey et al., 2016). One advantage of using 90% credible intervals is that their limits are generally estimated with greater accuracy than wider credible intervals such as 95% (McElreath, 2020).

2.5. Data reporting plan

The univariate relationships provide important information for understanding the bivariate results. Therefore, the results of both univariate and bivariate analyses are considered. For ease of the readership, we report the univariate and bivariate analyses in two parts, followed by a general discussion.

3. Part 1: univariate analyses

Here, we address descriptive statistics of the study variables: screen time, negative affect, and effortful control. We then present the growth parameters for each study variable separately.

3.1. Results

3.1.1. Descriptive statistics

The descriptive statistics of the variables included in this study are shown in Table 2 for both the complete cases data set and the imputed data set. Bivariate correlations of the study variables from the imputed data set can be found in Table S.3 in the Supplement. The following information refers exclusively to the imputed data set.

Children's daily average screen time and the corresponding standard deviation increased from 6.60 min ($SD = 12.60$) for the youngest to 27.00 min ($SD = 22.80$) for the oldest children. The data also showed a constant slight increase in negative affect from $M = 2.36$ ($SD = 0.58$) for children aged 12–14 months to $M = 2.71$ ($SD = 0.57$) for children aged 30–32 months, with a constant standard deviation over time. Thereafter, however, negative affect remains constant or declines. Finally, a steady increase in effortful control was observed from $M = 3.80$ ($SD = 0.54$) for the youngest children to $M = 4.24$ ($SD = 0.54$) for the oldest, again with a constant standard deviation over time.

3.1.2. Bayesian multilevel growth model

Here, we present the intercepts and slopes representing the initial values and the developmental growth over time for each of the three study variables.

3.1.2.1. Screen time. Because of the hurdle-lognormal distribution of the screen time variable, the model estimates were reported separately for both the number of children with no screen time, hurdle part, *hu*, and the distribution of screen times for children with screen time, nonhurdle part, *mu*. Thus, we describe estimates for the hurdle and nonhurdle parts of children's screen time separately below, followed by a compilation of the two parts. All screen-time-related parameters described, their estimates, and their relationship to the covariates can be found in Table 3 and graphically represented in Figure A.2 in the Appendix.

The hurdle part of children's screen time, *hu*, showed an estimated intercept of 44% ($b = -0.26$), indicating that 44% of children do not yet have any screen time at 12–14 months of age. The slope for the hurdle

Table 2
Descriptive statistics of the study variables.

Variable	Complete cases dataset						Imputed dataset					
	n	*M*	*SD*	*Md*	Min	Max	*n*	*M*	*SD*	*Md*	Min	Max
Children's screen time (in minutes)												
12–14 months	197	6.26	12.77	0.62	0.00	89.38	462	6.60	12.60	0.60	0.00	89.40
15–17 months	199	8.21	14.76	3.33	0.00	100.00	462	7.80	13.80	4.20	0.00	100.20
18–20 months	204	13.18	17.73	7.07	0.00	110.83	462	13.20	17.40	7.20	0.00	111.00
21–23 months	215	17.96	22.77	12.00	0.00	140.00	462	17.40	21.60	12.00	0.00	139.80
24–26 months	176	19.80	21.97	13.57	0.00	104.29	462	19.20	21.00	13.80	0.00	104.40
27–29 months	132	23.49	28.07	17.50	0.00	203.57	462	22.80	23.40	17.40	0.00	203.40
30–32 months	93	25.78	25.52	18.33	0.00	110.71	462	26.40	24.60	19.80	0.00	111.00
33–35 months	49	28.96	29.09	19.29	0.00	145.00	462	27.00	22.80	21.00	0.00	145.20
Children's negative affect												
12–14 months	197	2.34	0.58	2.25	1.00	4.18	462	2.36	0.58	2.26	1.00	4.18
15–17 months	199	2.38	0.53	2.36	1.09	4.08	462	2.40	0.52	2.38	1.09	4.08
18–20 months	204	2.57	0.55	2.50	1.08	4.14	462	2.56	0.53	2.52	1.08	4.14
21–23 months	216	2.54	0.52	2.50	1.44	4.00	462	2.53	0.51	2.49	1.44	4.00
24–26 months	176	2.62	0.50	2.58	1.42	4.17	462	2.59	0.48	2.58	1.42	4.17
27–29 months	132	2.64	0.51	2.73	1.17	3.83	462	2.66	0.50	2.74	1.17	3.83
30–32 months	93	2.73	0.60	2.67	1.75	4.17	462	2.71	0.57	2.68	1.75	4.17
33–35 months	49	2.61	0.54	2.50	1.67	3.75	462	2.66	0.52	2.69	1.67	3.75
Children's effortful control												
12–14 months	197	3.80	0.55	3.82	2.36	5.33	462	3.80	0.54	3.82	2.36	5.33
15–17 months	199	3.86	0.54	3.91	2.57	5.20	462	3.84	0.53	3.88	2.57	5.20
18–20 months	204	3.93	0.52	3.92	2.27	5.25	462	3.94	0.51	3.93	2.27	5.25
21–23 months	216	4.05	0.53	4.00	2.75	5.33	462	4.07	0.51	4.04	2.75	5.33
24–26 months	176	4.08	0.47	4.08	2.73	5.17	462	4.08	0.46	4.08	2.73	5.17
27–29 months	132	4.11	0.46	4.11	2.64	5.18	462	4.11	0.45	4.13	2.64	5.18
30–32 months	93	4.18	0.53	4.17	2.83	5.18	462	4.18	0.52	4.20	2.83	5.18
33–35 months	49	4.28	0.56	4.42	3.00	5.92	462	4.24	0.54	4.33	3.00	5.92

Note. Md = median; For the imputed dataset, the figures show the average values of the descriptive statistics of all 20 imputed datasets; The 33–35 months age group includes the final 3 months up to 36 months of age.

Table 3
Fixed population-level effects of the multivariate Bayesian multilevel growth model for Children's screen time, negative affect, and effortful control.

Parameters	*Md*	*SE*	HDI-90%
Screen time (*hu*)			
Intercept	−0.26	0.10	*−0.43; -0.09*
Slope	−0.35	0.04	*−0.41; -0.29*
Education	0.06	0.06	−0.04; 0.16
Income	−0.10	0.18	−0.35; 0.17
Siblings	0.07	0.07	−0.05; 0.20
Screen time (*mu*)			
Intercept	−2.26	0.06	*−2.37; -2.16*
Slope	0.18	0.02	*0.16; 0.20*
Education	−0.06	0.04	−0.12; 0.01
Income	0.16	0.11	−0.02; 0.32
Siblings	0.00	0.06	−0.09; 0.09
Negative affect			
Intercept	2.39	0.03	*2.34; 2.44*
Slope	0.05	0.01	*0.04; 0.06*
Education	−0.01	0.02	−0.04; 0.03
Income	0.06	0.06	−0.03; 0.17
Siblings	0.04	0.04	−0.02; 0.09
Effortful control			
Intercept	3.81	0.03	*3.76; 3.86*
Slope	0.06	0.01	*0.05; 0.07*
Education	0.00	0.02	−0.03; 0.03
Income	−0.03	0.05	−0.11; 0.05
Siblings	0.08	0.03	*0.02; 0.14*

Note. Md = median. Screen time (*hu*) = hurdle part of children's screen time (untransposed values); Screen time (*mu*) = nonhurdle part of children's screen time (untransposed values); Education = participants' educational level; Income = gross household income; All covariates were centered; HDI-90% = 90% highest density interval. *Italic* figures represent coefficients where 90%-HDI did not include zero.

part of children's screen time showed a decrease over time of, meaning that the proportion of children with zero screen time decreased over time from 44% at age 12–14 months to 6% at age 33–35 months.

The nonhurdle part of children's screen time, *mu*, showed an estimated intercept of 0.10 h, indicating that those children aged 12–14 months who have screen time spend a daily average of 6 min in front of a screen. The slope of the nonhurdle part of children's screen time was positive on the lognormal scale across each age category, which meant that the screen time increased by an average of 18% each 3 months, an increase from 6 to 22 min over the course of the second and third years of life. The correlation results in Table 4, Fig. 1a, and Fig. A.3 in the Appendix confirm that children's screen time at age 12–14 months was negatively correlated with change in screen time from age 12–36 months, indicating a strong effect (Cohen, 1988). In other words,

Table 4
Group-level effects of the multivariate Bayesian multilevel growth model; correlations for Children's screen time, negative affect, and effortful control.

Parameter	1	2	3	4	5	6
1. ST intercept	–					
2. ST slope	*−.65 [-0.85, -0.36]*	–				
3. NA intercept	*.29 [0.15, 0.44]*	−.14 [-0.46, 0.22]	–			
4. NA slope	*−.24 [-0.49, -0.03]*	.22 [-0.21, 0.69]	*−.66 [-0.82, -0.53]*	–		
5. EC intercept	−.08 [-0.27, 0.10]	.02 [-0.41, 0.48]	*−.21 [-0.33, -0.08]*	.18 [-0.03, 0.49]	–	
6. EC slope	.01 [-0.20, 0.25]	−.08 [-0.53, 0.37]	.11 [-0.14, 0.32]	*−.26 [-0.53, 0.00]*	*−.70 [-0.80, -0.53]*	–

Note. ST = screen time (nonhurdle part); NA = negative affect; EC = effortful control. Values in square brackets indicate the 90% highest density interval (HDI) for each correlation. *Italic* figures represent correlations where 90% HDI did not include zero, except for the correlation between the slope of negative affect and the slope of effortful control, where the 90% HDI barely included 0.

a

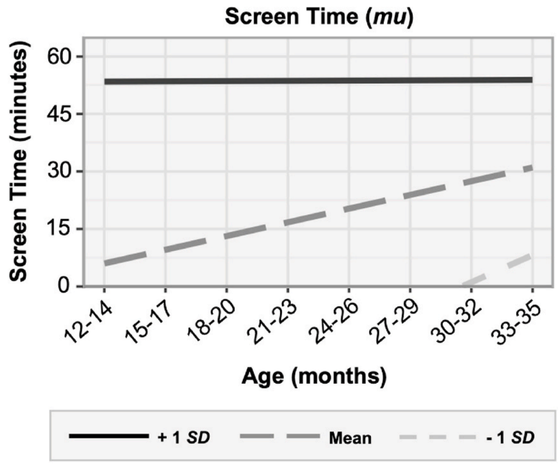

Fig. 1a. Development of Screen Time for Children Depending on Their Initial Levels at Age 12–14 Months
Note. For example, three lines in the plot "Screen Time (*mu*)" show the development of screen time across age for children with initially low (-1SD, bright grey short-dashed line), average (mean, middle grey long-dashed line), and high (+1SD, black full line) initial screen time at age 12–14 months. Interpretation: Children with initially more screen time (approx. 53 min) show a flatter change over time than children with less initial screen time.

children who spent more screen time at age 12–14 months of age had less increase in screen time between 12 and 36 months of age. The trajectories for initial low, medium, and high screen times are illustrated in Fig. 1a.

Finally, the conditional effects plots (see Figure A2 in the Appendix) show that the combined hurdle and nonhurdle proportions of children's screen time (*hu* + *mu*) was 5 min at 12–14 months and increased to 30 min at 33–35 months.

3.1.2.2. Negative affect. Table 3 and Fig. A.4 in the Appendix show the estimated intercept of children's negative affect was 2.39. The corresponding slope indicated a slight increase during the second and third years up to 2.72 at age 33–35 months. Further, correlation results showed that higher negative affect in children aged 12–14 months was negatively associated with change in children's negative affect from age 12–36 months, indicating a strong effect (Cohen, 1988). This means that children who show higher levels of negative affect as early as 12–14 months of age had a less pronounced increase and for some children even a decrease in negative affect between 12 and 36 months of age (see Table 4, Fig. 1b, and Fig. A.3 in the Appendix). The trajectories of initial low, medium, and high levels of negative affect are illustrated in Fig. 1b.

3.1.2.3. Effortful control. A similar pattern emerged for children's effortful control. A slight increase also occurred in the slope of children's effortful control from 3.81 up to 4.25 when children were aged 33–35 months (see Table 3 and Fig. A.2 in the Appendix). In addition, correlation results showed that the effortful control of children aged 12–14 months was negatively associated with an increase in effortful control of children aged 12–36 months, indicating a strong effect (Cohen, 1988). In other words, children who showed higher levels of effortful control at age 12–14 months showed a less pronounced increase and for some children even a decrease in effortful control from age 12–36 months (see Table 4, Fig. 1c, and Fig. A.3 in the Appendix). The trajectories of initial low, medium, and high levels of effortful control are illustrated in Fig. 1c.

3.2. Discussion

Part 1 of this study explored descriptive data and univariate

b

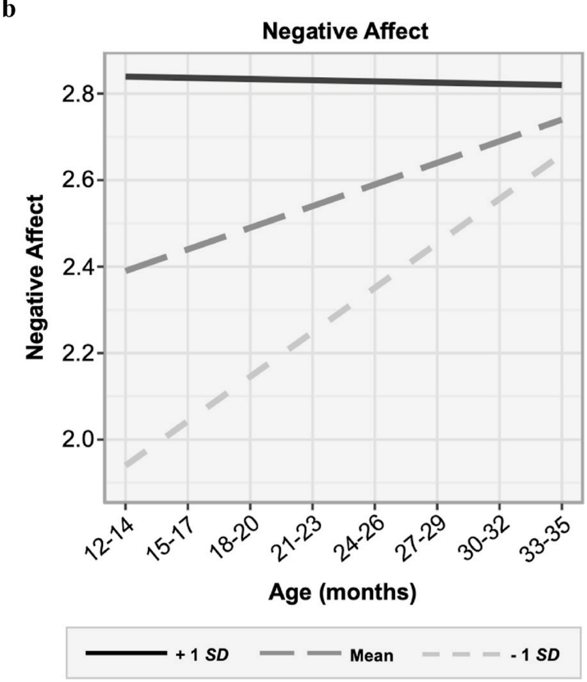

Fig. 1b. Development of Negative Affect for Children Depending on Their Initial Levels at Age 12–14 Months
Note. Negative affect (y-axe) ranges from 1 (*never*) to 6 (*always*).

c

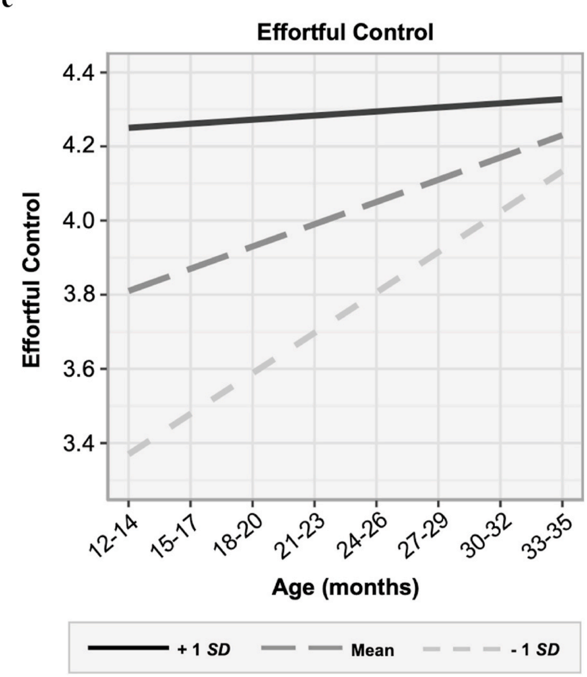

Fig. 1c. Development of Effortful Control for Children Depending on Their Initial Levels at Age 12–14 Months
Note. Effortful control (y-axe) ranges from 1 (*never*) to 6 (*always*).

relationships of growth parameters of screen time, negative affect, and effortful control in children aged 12–36 months. In the following section, we discuss the descriptive data and the observed trajectories for each of the study variables.

3.2.1. Screen time

As the descriptive results show (see Table 2), children's screen time increased steadily between 12 and 36 months, from a daily average of 6.60 min (SD = 12.60) at age 12–14 months to 27.00 min (SD = 22.80) at age 33–35 months. This increase was also confirmed by the Bayesian multilevel growth model, where we found a decrease in the zero part (hu) and an increase in the nonzero part (mu) of young children's screen time.[6] An increase in young children's screen time is generally in line with other studies (Kieninger et al., 2021; Rideout & Robb, 2020). However, the daily screen time of children in our sample, 27 min at 33–35 months of age, was lower than in a recent study in Germany (Kieninger et al., 2021), which reported a daily screen time of 59 min for children aged 2–3 years. There are several possible explanations for this discrepancy between our results and those of the German study: First, our sample consisted mainly of highly educated participants, and young children from families with lower education level and household income are often reported to spend more time in front of screens (Duch et al., 2013; Levine et al., 2019). However, Kieninger et al. (2021) also noted a bias towards a higher educational level in their sample. In addition, as our results did not show any definite correlations between children's screen time and participants' educational level, a plausible explanation for this discrepancy is difficult to formulate. Because there are no representative studies on the daily screen time of children under the age of 36 months in Switzerland to date, our findings cannot be compared with or discussed against representative figures. Furthermore, our results also indicated that children with an initially greater amount of screen time showed a flatter increase in screen time in their second and third years of life. One explanation for this pattern may be that parents limit their children's daily screen time in different ways (e.g., Chiu et al., 2017; Tang et al., 2018). For example, some children initially spend less time with screens because their parents set consistent limits. Parents then adjust these rules over time so that screen time increases with the age of the child. In contrast, parents of children with more initial screen time may have established a set limit that did not change over time or may not have established limits initially and later imposed screen time restrictions on their children, resulting in some children having more daily screen time both initially and over time than other children with the mean amount or less than daily screen time (e.g., Chiu et al., 2017). From a methodological perspective, such negative correlations between intercept and slope are typical in growth models, an effect referred to as regression to the mean. This is because, for example, children who have less screen time at the beginning have much more scope to expand it than children who already have more screen time at the beginning.

3.2.2. Negative affect

Both the descriptive results and the trajectory derived from the Bayesian multilevel growth model showed a slight increase in negative affect from 12 to 36 months of age, a pattern in early childhood that is also confirmed by other longitudinal studies (Bridgett et al., 2009; Fitzpatrick et al., 2023; Komsi et al., 2006; Lipscomb et al., 2011). However, compared to other studies in which children's level of negative affect was M = 3.90 (SD = 1.23) at age 18 months and M = 3.88 (SD = 1.19) at age 26 months (Gordon-Hacker & Gueron-Sela, 2020), children's levels of negative affect in our study appeared to be lower, with an initial level of M = 2.36 (SD = 0.58) and a final level of M = 2.66 (SD = 0.52). Because children's negative affect is also temperament-based (Rothbart & Bates, 2006), one explanation for this discrepancy may be that our sample predominantly consisted of children with generally lower negative affect. However, parents with higher levels of education tend to report lower levels of children's negative affect (Gordon-Hacker & Gueron-Sela, 2020), so that the reason for the lower levels of children's negative affect in our sample may also be our highly educated sample. Furthermore, although children typically progressively reduce their negative affect expressions throughout childhood as they learn more effective self-regulatory strategies (Jenni, 2021a; Rothbart & Bates, 2006), the slight increase observed here in early childhood may be related to the development of autonomy that occurs during the second year of life, when the child develops an awareness that they are able to control their own actions, exert influence, assert themselves in conflicts, and cope with problems successfully (Jenni, 2021c). Indeed, encountering resistance or experiencing failure at this developmental stage of autonomy can trigger the expression of negative affect (Jenni, 2021c), such as acts of defiance and frustration. However, it is also possible that children with a higher level of negative affect face a different set of challenges from their immediate environment compared to children with a lower level of negative affect, such as different family risks (e.g., Sticca et al., 2023) or parental stress (e.g., Diener & Swedin, 2020). In addition, our results indicated that children with initially high levels of negative affect showed flatter or, for some children, even decreased trajectories of negative affect over time. This finding could be interpreted as indicating that parents of children who initially exhibit high levels of negative affect are already using a broader range of regulatory techniques that also help shape the child's tendencies toward negative affect, as argued by others (e.g., Gordon-Hacker & Gueron-Sela, 2020). However, from a methodological perspective, such a negative correlation between intercept and slope were expected.

3.2.3. Effortful control

Both descriptive results and the trajectory of effortful control from the Bayesian multilevel growth model showed a continuous increase between ages 12–36 months. An increase in young children's self-regulatory skills is consistent with another longitudinal study (Cliff et al., 2018). This finding was expected because effortful control develops rapidly in early years (Eisenberg, 2012): Between the ages of 9 and 18 months, infants begin to exhibit attentional control, although this remains relatively limited (Ruff & Rothbart, 1996). During this period, infants acquire the ability to resolve conflicts, correct errors, and plan new actions, leading to advancements in attentional control (Posner & Rothbart, 1998). Notably, children demonstrate significant enhancements in attentional switching and inhibitory behavior by 30 months of age, and by 36–38 months of age, they exhibit high accuracy in performing such skills (Eisenberg, 2012; Gerardi-Caulton, 2000; Posner & Rothbart, 1998). Moreover, our results indicate that children with initially high levels of effortful control showed a flatter increase or, for some children, even a decrease in effortful control over time. An explanation for this pattern could be that children who already show a higher level of effortful control at the beginning, perhaps due to temperament, may encounter fewer learning opportunities to further develop their effortful control. For example, a child who has poorer self-regulatory skills at the beginning may more often encounter challenging situations in which the ability to self-regulate may develop. However, this argument should be interpreted with caution because, as mentioned above, this correlation may well arise from aspects of our methodology.

4. Part 2: bivariate analyses

Here, we address the research questions and present the results on both the concurrent and longitudinal relationships among the three study variables (see Table 4, Fig. 2 and Fig. A.4 in the Appendix) and discuss these bivariate results.

4.1. Results

4.1.1. RQ1. How are growth parameters of screen time and negative affect related in children aged 12–36 months?

As shown in Table 4, the intercepts of children's screen time and negative affect were positively related, indicating a moderate effect

[6] The parameter estimates of models that include multilevel structure may differ from the descriptive statistics (McElreath, 2020).

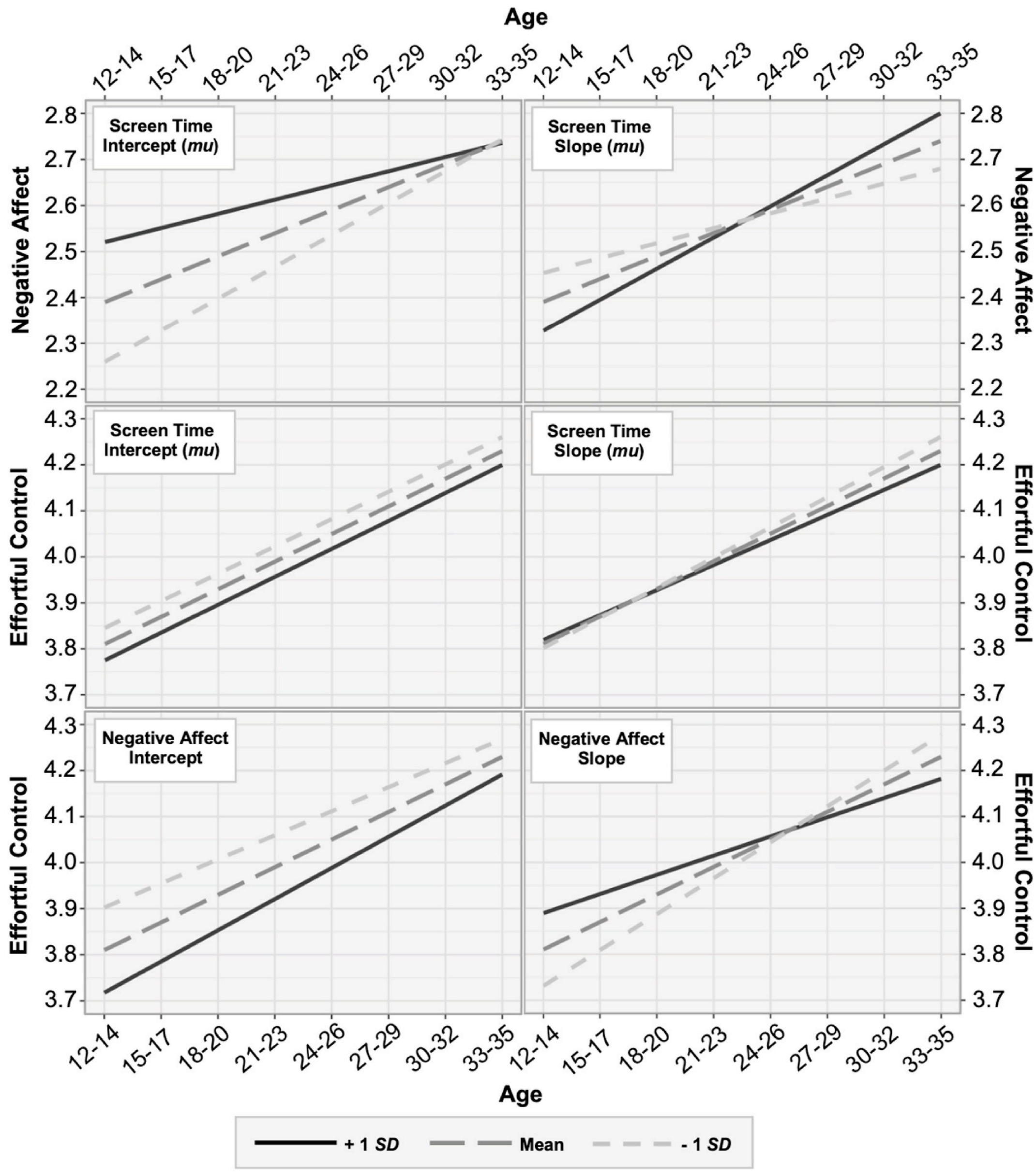

Fig. 2. Development of Study Variables Over Time Depending on Children's Initial Levels and Development on the Other Study Variables
Note. Y-axis of negative affect and effortful control range from 1 (*never*) to 6 (*always*). Children's age is in months. For example, the plot "Screen Time Intercept (*mu*)" shows the correlation between screen time intercept (*mu*) and negative affect (intercept, $r = 0.29$ and slope, $r = -0.24$), each with a different level of negative affect (+1 *SD*, *Mean*, - 1 *SD*). Interpretation: Children with initially more screen time show higher levels of initial negative affect (approx. 2.52) than children with initially less screen time (approx. 2.26). In addition, children with initially more screen time show a flatter increase in negative affect over time (from approx. 2.52 at age 12–14 months up to approx. 2.72 at age 33–35 months) than children with initially less screen time (from approx. 2.26 at age 12–14 months up to approx. 2.72 at age 33–35 months).

(Cohen, 1988). In other words, the more screen time at 12–14 months of age, the more their negative affect at 12–14 months of age. Results hint at a positive association between change in children's screen time and change in children's negative affect over time. However, the HDI included zero, such that we did not assume any certain correlation. Results showed a negative relationship between children's screen time at age 12–14 months and change in children's negative affect from age 12–36 months, with a low to moderate effect (Cohen, 1988). This implies that increased screen time in children aged 12–14 months was associated with a less pronounced increase and for some children even a decrease in negative affect from age 12–36 months (see Figure A.4 in the Appendix). Furthermore, results for the relationship between change in children's screen time from age 12–36 months and children's negative affect at age 12–14 months indicated a negative association. However, HDI included zero. Thus, we assume no certain correlation here. Overall, there was an association between negative affect and screen time concurrently in the expected direction (see hypothesis H_1). However, this pattern is not in the expected direction longitudinally because those with initially less screen time increase in negative affect more rapidly over time than those with consistently more screen exposure. However, the graphical representation in Fig. 2 shows how although children with more initial screen time tend to show a less pronounced increase over time, overall, they consistently show higher levels of negative affect than children with less initial screen time.

4.1.2. RQ_2. How are growth parameters of screen time and effortful control related in children aged 12–36 months?

Correlations showed that children's screen time and children's effortful control at age 12–14 months were very weakly negatively related. However, HDI included zero, and therefore we assume no certain correlation. Further, results show that change in children's screen time from age 12–36 months was again weakly negatively related to change in children's effortful control from age 12–36 months. However, because HDI included zero, we cannot assume any certain correlation. The relationship between children's screen time at age 12–14 months and change in children's effortful control from age 12–36 months also showed no certain correlation because HDI included 0. Furthermore, the relationship between children's effortful control at age 12–14 months and change in children's screen time from age 12–36 months exhibited no certain correlation, because the corresponding HDI included zero. Overall, no certain correlations were found between effortful control and screen time, either concurrently or longitudinally. All bivariate interrelations with high, medium, and low patterns are visualized in Fig. 2.

4.1.3. *RQ$_3$. How are growth parameters of negative affect and effortful control related in children aged 12–36 months?*

The intercepts of children's negative affect and children's effortful control were negatively related, indicating a low to moderate effect (Cohen, 1988). In other words, children who initially showed higher levels of negative affect initially showed lower levels effortful control, and vice versa. Changes in children's negative affect correlate negatively with their effortful control over time, indicating a small to moderate effect (Cohen, 1988), with the HDI barely including zero (see Table 4). Children who exhibited a greater increase in negative affect during the second and third years of life underwent a less pronounced increase in effortful control or even a decrease during this time. Conversely, children who experienced a greater increase in effortful control between 12 and 36 months of age underwent a less pronounced increase in negative affect or even a decrease during this time. Children's negative affect at age 12–14 months correlated positively with change in children's effortful control from age 12–36 months results. However, the corresponding HDI included zero, and thus this correlation is assumed to be uncertain. Finally, results for the relationship between children's effortful control at age 12–14 months and change in children's negative affect from age 12–36 months indicated a positive correlation; however, the HDI included zero again. All bivariate interrelations with high, medium, and low patterns are visualized in Fig. 2. Overall, both concurrent and longitudinal associations were found between effortful control and negative affect.

4.2. *Discussion*

Here, we discuss bivariate relations of growth parameters of screen time, negative affect, and effortful control in children aged 12–36 months.

4.2.1. *RQ1. How are growth parameters of screen time and negative affect related in children aged 12–36 months?*

In accordance with our hypothesis H_1, we found that children with more initial screen time showed higher levels of negative affect, and vice versa. This finding suggests that children with higher levels of negative affect were granted more screen time to regulate their behavior, which is supported by other research (Coyne et al., 2022; Geurts et al., 2022; Gordon-Hacker & Gueron-Sela, 2020; Gueron-Sela et al., 2023; Radesky et al., 2014, 2016). Conversely, it may also indicate that screen time was a reward for children when expressing negative affect (e.g., operant conditioning; Skinner, 1953; Thorndike, 1911). This finding could also indicate that children who spend more time in front of screens also show more negative affect because they consume content from which they learn negative affect (e.g., social learning theory; Bandura, 1977, 1986; Huesmann, 1986). Although other studies have hypothesized that content-related factors may play a role in shaping children's regulatory dimension in behavior (Cliff et al., 2018), it remains unclear whether content differences can explain these associations because the content of screen media was not the subject of the current study.

Further, for children who had more initial daily screen time, the development of negative affect from age 12–36 months was flatter and even decreased for some children (see Fig. A.4 in Appendix). However, children with initially higher levels of negative affect also showed consistently higher levels of negative affect over time than children who had mean or low initial levels and showed greater increases over time. Given that young children with a high level of negative affect tend to be given more screen media to regulate their behavior than children with a low level of negative affect (Coyne et al., 2021), one explanation for this finding might be that screen media were used by parents as an effective external regulatory strategy (e.g., Coyne et al., 2021) to reduce the child's negative affect right from the beginning. This hypothetical scenario would reflect a vicious cycle, as this regulatory strategy appears to be effective in the short term but could displace the development of other, more active regulatory strategies (e.g., Mutz et al., 1993; Roberts et al., 1993). In the long term, this may lead to children regulating their negative affect primarily with the support of screen media because other regulatory strategies have been insufficiently developed. This in turn could lead to increased or even excessive children's screen time (e.g., Coyne et al., 2021), as early screen time patterns are habit-forming and persist into later life (Certain & Kahn, 2002; Chiu et al., 2017). In contrast, parents of children who initially spent less time on screens may have used other effective regulatory strategies to reduce the child's negative affect over time. However, the results of the present study also suggest that these children who initially spent less time in front of screens also exhibited lower levels of negative affect, both initially and over time, which could also simply be due to their temperament.

Further, we did not find a relationship between children's initial level of negative affect and change in children's screen time in the second and third years of life, indicating that the direction of effects may be reversed: The initial screen time may influence the change in negative affect, but not vice versa. This assumption would be in line with prior longitudinal research, which found that young children's screen media use is associated with later behavioral and emotional problems (Cheng et al., 2010; Fitzpatrick et al., 2023; Liu et al., 2021; McDaniel & Radesky, 2020). However, both our finding and those from prior research (e.g., McDaniel & Radesky, 2020) point to a small to moderate effect at most. However, because the present findings are correlative in nature, such directional interpretations can only be made with great caution.

Finally, we found no certain correlation between change in children's screen time and change in children's negative affect over time. This finding indicates that the relationship may be largely concurrent and only partly longitudinal so that, for instance, children's initial screen time is associated with change in their negative affect. This finding thus suggests that the development of children's screen time and their negative affect over time are influenced by other contextual factors in their environments.

4.2.2. *RQ$_2$. How are growth parameters of screen time and effortful control related in children aged 12–36 months?*

In this study, growth parameters of children's screen time and effortful control were not related. Particularly, in contrast to previous cross-sectional research (Lawrence et al., 2020; Munzer et al., 2018), we found no concurrent negative interrelation between more initial screen time and an initial higher level of effortful control, which is why we had to reject our hypothesis H_2. There are several possible explanations for this deviation in findings: First, in previous studies, concurrent effects were observed in children who were slightly older than the children in our study (Lawrence et al., 2020; Munzer et al., 2018). Given that children's self-regulation improves greatly in the first 5 years of life (Eisenberg, 2012), effects may only be evident in slightly older children. Second, because low socioeconomic status, as measured by educational level and income, is associated with poorer self-regulation skills (Cliff et al., 2018; Munzer et al., 2018; Piotrowski et al., 2013; Radesky et al., 2014), it may be that no effects were uncovered in this study because the current sample is highly educated. Third, other factors such as maternal support and sensitivity and parenting style, which are positively related to children's self-regulation (Eisenberg, 2012), could have masked possible associations between children's screen time and effortful control. For example, children with highly sensitive caregivers receive optimal support in regulating their emotions, which might compensate for possible associations between children's screen time and their effortful control. Furthermore, another longitudinal study that found partial associations between children's screen time and their self-regulation suggests that content- and context-related factors related to children's screen time may play a more prominent role in shaping self-regulation skills than the simple amount of time using screens (Cliff et al., 2018). Fourth, the present study found less children's screen time than studies that found a negative association between children's screen time and their self-regulation (e.g., Radesky et al., 2014); this could also explain the lack of association in the present study. Finally, methodological differences in the assessment of children's screen time via diary reports and in the assessment of self-regulation via standardized parent report may also have led to this discrepancy in the results. However, the associations between negative affect and screen time make this last explanation less likely.

4.2.3. RQ_3. How are growth parameters of negative affect and effortful control related in children aged 12–36 months?

We found that children with initially higher levels of negative affect tend to have initially lower levels of effortful control, or vice versa. This finding confirms our hypothesis H_3 and is in line with previous research, which states that these two factors are inversely related (e.g., Bridgett et al., 2009; Eisenberg et al., 1993; Kochanska et al., 1998; Rothbart & Sheese, 2007). In addition, we found that a stronger increase in children's negative affect was associated with a stronger decrease in effortful control over time and vice versa. These findings are consistent with the growing body of research suggesting that negative affect and effortful control are inversely related (e.g., Bridgett et al., 2009; Eisenberg et al., 1993; Kochanska et al., 1998; Rothbart & Sheese, 2007).

Research has suggested that negative affect can adversely affect developing regulatory systems (e.g., Bridgett et al., 2009; Calkins & Degnan, 2006; Stifter & Spinrad, 2002). However, because we did not find any correlations between initial levels of effortful control and change in negative affect over time, or between initial levels of negative affect and change in effortful control over time, this suggestion cannot be supported. Moreover, the present results are correlative in nature; they cannot confirm a one-way relationship between negative affect and effortful control. In summary, the findings on the correlations of growth parameters between negative affect and effortful control in children emphasize the validity of the present results.

5. General discussion

The present study explored developmental interrelations of screen time, negative affect, and effortful control in children aged 12–36 months.

In summary, we found a relationship both between growth parameters of children's screen time and negative affect and between growth parameters of children's negative affect and effortful control. However, no relationship was found between growth parameters of children's screen time and effortful control. This is contrary to other studies that suggest that parents' granting their young children screen time as a means of behavior regulation (Coyne et al., 2022; Geurts et al., 2022; Gordon-Hacker & Gueron-Sela, 2020; Gueron-Sela et al., 2023; Radesky et al., 2014, 2016) can potentially interfere with or displace the acquisition of active self-regulatory strategies through parental co-regulation (e.g., displacement hypothesis; Mutz et al., 1993; Roberts et al., 1993). Our results suggest that children's screen time and their negative affect may be related independently of their effortful control, which thus argues against the argument that exposure to screen media displace the development of more active self-regulatory strategies. Because we found a relationship between initial screen time and change in levels of negative affect over time, but not a relationship between initial levels of negative affect and change in screen time over time, we may assume that children's screen time is more likely to influence children's negative affect and not vice versa. This explanation is consistent with Radesky et al.'s (2014). However, because the present results only show correlations and not predictions, this assumption must be interpreted with caution and needs to be examined in future longitudinal studies.

There are alternative interpretations of this overall pattern of results: First, it is possible that screen media are not the actual cause of higher levels of negative affect, or vice versa, but rather a symptom of another factor in the child's environment that contributes to children spending more time on screens or exhibiting higher levels of negative affect. Thus, there may be factors in the child's environment that contribute to this relationship between children's screen time and their negative affect. For example, one factor in the child's immediate environment that can increase both screen time and negative affect in children is parental stress (Brauchli et al., 2024; Diener & Swedin, 2020; Duch et al., 2013; Nabi & Krcmar, 2016; Neece et al., 2012; Parks et al., 2016; Shin et al., 2021; Thompson & Christakis, 2007). Second, as previous research has reported, screen-media-related factors such as co-viewing with a parent and whether screen media content is educational or non-educational may play a more prominent role in shaping children's effortful control skills (Cliff et al., 2018) and thus also likely in shaping their negative affect. Third, the results may simply show the developmental trajectory of temperamental features of children's negative affect and effortful control (Rothbart & Bates, 2006). Finally, the relationship between screen time and negative affect could also become evident at low daily screen time exposure, in contrast to the relationship between screen time and effortful control, which may only become evident at high screen time exposure.

5.1. Strengths and limitations

The present study has several strengths, including a large sample from various regions in Switzerland and the use of an accelerated longitudinal design (e.g., Galbraith et al., 2017) with up to four measurement waves for each participant, which allowed us to collect data for a wide age range. Further, we relied on Bayesian estimation (McElreath, 2020), which represents a major strength of this study. Moreover, the focus on a growth model provided us with additional insights that go beyond conventional repeated measures approaches (Chen & Cohen, 2006). In addition, measurement of children's screen time was carefully conducted using multiple sources. This approach is consistent with recent best practices (Barr et al., 2020), which emphasize the use of methods such as online questionnaires and 24-h diaries to collect accurate data on children's screen time. Furthermore, since few studies to date have examined bivariate associations between screen time, emotional and behavioral problems, and self-regulation in children younger than 3 years of age (e.g., Gordon-Hacker & Gueron-Sela, 2020; Radesky et al., 2014), the current study contributes to our knowledge of the developmental interrelation between children's screen time, their negative affect and effortful control from 12 to 36 months of age. In particular, the present study not only examined the relationship between young children's screen time and either their negative affect or effortful control but aimed to examine the developmental interrelationship between all three factors. This adds to our understanding of how young children's screen time and reactive and regulatory dimensions in their behavior are related over the course of early childhood. This trivariate approach aligns with contemporary recommendations and recent suggestions advocating for a multifactorial approach in assessing the effects of young children's screen time (e.g., Guellai et al., 2022).

However, this study also has several limitations: First, a sample recruited online does not necessarily reflect the overall population, which limits the generalizability of the results. The findings of this study apply largely to well-resourced homes. Second, the extensive data collection, which combined several approaches, required substantial time and effort from the participants. This coupled with the fact that the sample is predominantly composed of individuals with high levels of education suggests that individuals with limited resources, such as those from lower socioeconomic backgrounds, may be underrepresented in the current study. This appears to be an important limitation, as low socioeconomic status is associated with more screen time (Duch et al., 2013; Levine et al., 2019), higher levels of negative affect (Gordon--Hacker & Gueron-Sela, 2020), and poorer self-regulation skills (Cliff et al., 2018; Piotrowski et al., 2013; Radesky et al., 2014) among young children. Therefore, the current findings should be interpreted as relevant to a more highly educated population. Third, the study was conducted exclusively in German, one of the four national languages in Switzerland (German, French, Italian, Rhaeto-Romanic); it can therefore only be assumed that the sample reflects the German-speaking population of Switzerland. Fourth, our data were collected during the COVID-19 pandemic, when restrictions imposed by governments to contain the virus created a unique home environment and particular stressors for families (Fisher et al., 2020). This may have affected both children's screen time (e.g., Dore et al., 2021; Eales et al., 2021; Fitzpatrick et al., 2022) and their negative affect (e.g., Giannotti et al., 2022; Sun et al., 2022). Additionally, data collection during the COVID-19 pandemic may partially account for the recruitment of a population that had the time and resources to commit to research. However, this population is interesting because of children's low screen exposure and apparently high levels of adherence to media use guidelines (e.g., World Health Organization, 2019). Future studies should combine data across study populations to enhance the generalizability of findings during and after the pandemic. Fifth, the exclusive use of parental reports may introduce biases such as social desirability (Paulhus, 2017) and recall biases. The present sample may be influenced by self-selection bias, suggesting that our participants may consist primarily of parents who were comfortable with reporting their children's screen time. Parents who felt uneasy reporting their children's screen time may have chosen not to participate in the study. In addition, the study itself may have served as an intervention into children's screen time if parents paid particular attention during the measurement waves to ensure that their child did not spend too much screen time. Last, we did not consider context- or content-related screen media factors, despite their essential role in the development of young children (e.g., Barr & Linebarger, 2017; Cliff et al., 2018; Guellai et al., 2022).

5.2. Conclusion and directions of further research

Our study was the first to examine developmental interrelations between screen time, negative affect, and effortful control in children aged 12–36 months. The current findings highlight several important implications that contribute to our understanding of the relationship of young children's screen time and their emotional development. Overall, the current findings suggest a longitudinal relationship between children's screen time and negative affect and another between children's negative affect and effortful control but none between children's screen time and effortful control during the second and third years of life. Thus, because there was no link between screen time and effortful control, we did not find evidence for displacement in the development of self-regulatory strategies among children of highly educated parents. The results further demonstrate that when examining the effects of screen time in young children, negative affect, and effortful control, despite their bivariate relationship, should not be equated and must be considered independently. These findings open directions for future research in this area. Further longitudinal research is needed to address the effects of young children's screen media use on their negative affect and effortful control. This research should prioritize the following areas: (1) Exploring the development of screen time, negative affect, and effortful control in children's first 12 months of life to address potential knowledge gaps. (2) Examining children from low socioeconomic status households, as they may face additional family risk factors, including parental stress (e.g., Steele et al., 2016), that can influence children's screen time (e.g., Duch et al., 2013; Levine et al., 2019) and socio-emotional development (e.g., Diener & Swedin, 2020). (3) Studying children with excessive screen media use, as they appear to be at a higher risk for emotional and behavioral problems (e.g., Gueron-Sela et al., 2023) and lower self-regulation skills (e.g., Lawrence et al., 2020). (4) Analyzing context- and content-related screen media factors, which may also play a prominent role in understanding the effects of screen media use on early childhood development (e.g., Cliff et al., 2018). (5) Exploring further factors within both the child's immediate and broader environment to gain a more nuanced understanding of the complex role of screen media use in the development of young children.

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CRediT authorship contribution statement

Valérie Brauchli: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft. **Peter Edelsbrunner:** Conceptualization, Formal analysis, Methodology, Writing – review & editing. **Raquel Paz Castro:** Conceptualization, Writing – review & editing. **Rachel Barr:** Conceptualization, Supervision, Writing – review & editing. **Agnes von Wyl:** Conceptualization, Supervision, Writing – review & editing. **Patricia Lannen:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data availability

Data will be made available on request.

Appendix A

Table A.1
Screen Time Measures

Variable	Item	Assessment Questionnaire	Introduction/Introductory question	Question	Answer format
Screen time	st1	Initial questionnaire	Now think about the past week. On average, how much of the day do the following descriptions apply to {Child's_first_name}?	{Child's_first_name} was engaged with a screen (e.g., smartphone, tablet, computer, television)?	In hours; quarter steps (0–12h; 0.25h steps)
	st2	Daily review (day 1) Daily review (day 3) Daily review (day 5) Daily review (day 7)	To how much time do the following descriptions of today apply to {Child's_first_name}?	{Child's_first_name} was engaged with a screen (e.g., smartphone, tablet, computer, television)?	In hours; quarter steps (0–12h; 0.25h steps)
	st3	Closing questionnaire	Now think about the past week. On average, how long a day did your child engage in …	View digital photos/pictures/picture books Watching videos (e.g., YouTube, cartoons), television Playing with interactive apps (e.g., puzzles, Talking Tom)	In hours; quarter steps (0–12h; 0.25h steps)

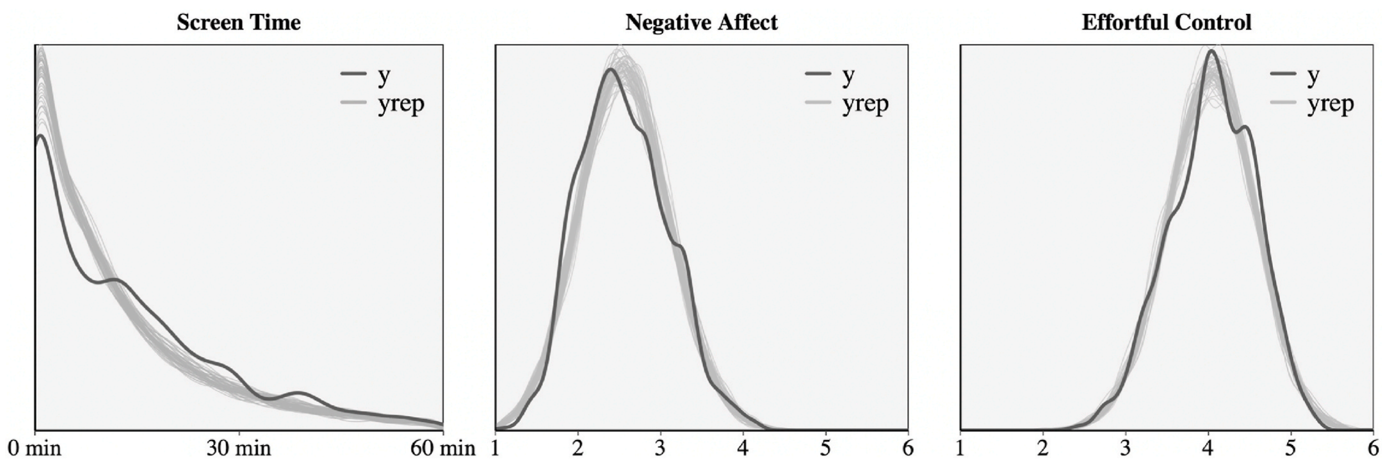

Fig. A.1. Example Posterior Predictive Plots of Children's Screen Time, Negative Affect, and Effortful Control from age 12 to 36 Months
Note. Screen time = hurdle-lognormal distributed; negative affect and effortful control = Gaussian distributed; *y* represents empirical distribution within first imputed data set, *yrep* 20 draws from model posterior (i.e., model predictions including variation due to uncertainty).

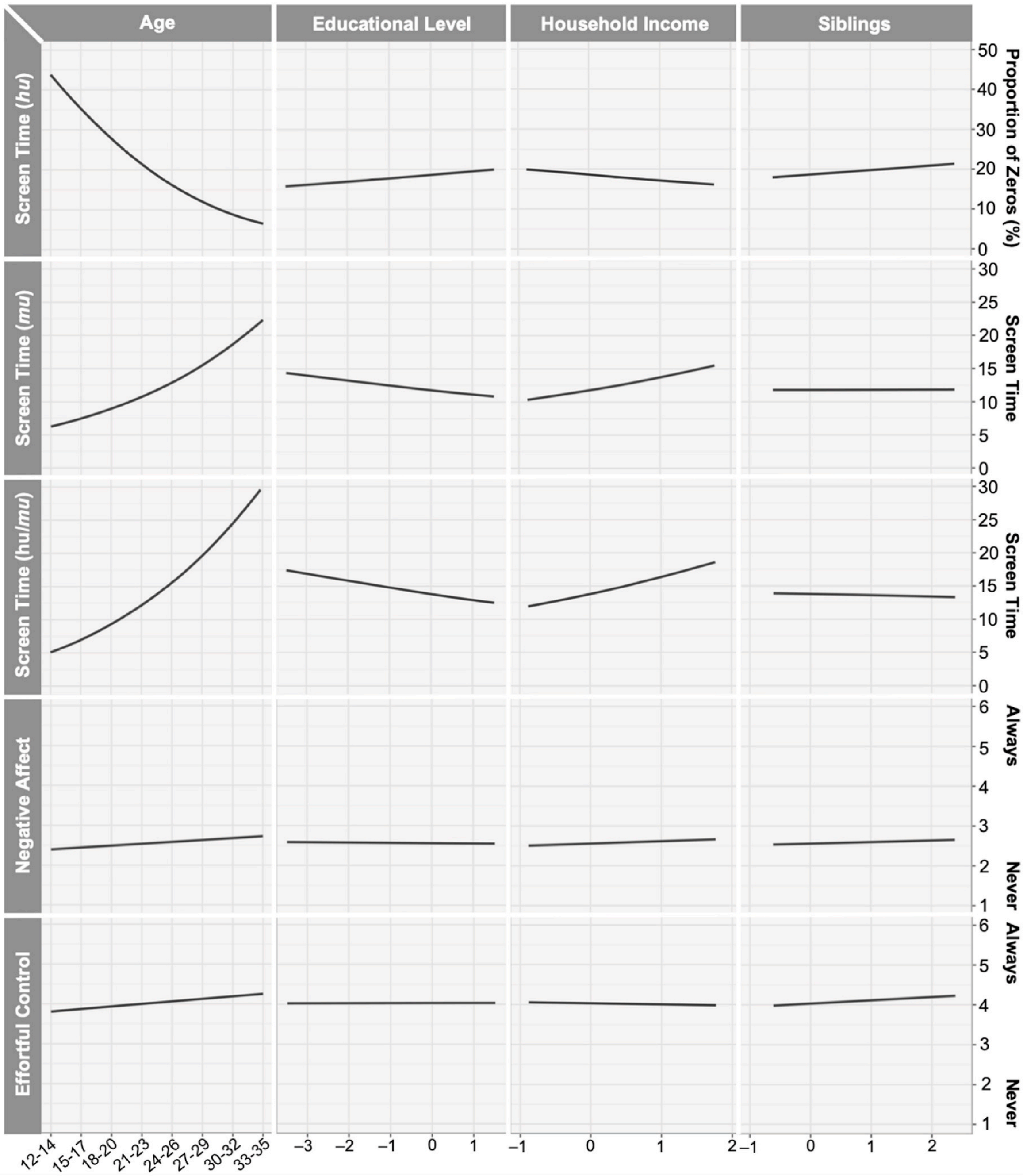

Fig. A.2. Conditional Effect Plots of Children's Screen Time, Negative Affect, and Effortful Control and Covariates Participant's Educational Level, Gross Household Income, and Siblings

Note. Screen time in three parts: hurdle-part (*hu*), nonhurdle part (*mu*), and compilation of both parts (*hu* + *mu*); Screen time (*mu*) is in minutes; Children's age is in months; covariates were centered at their means.

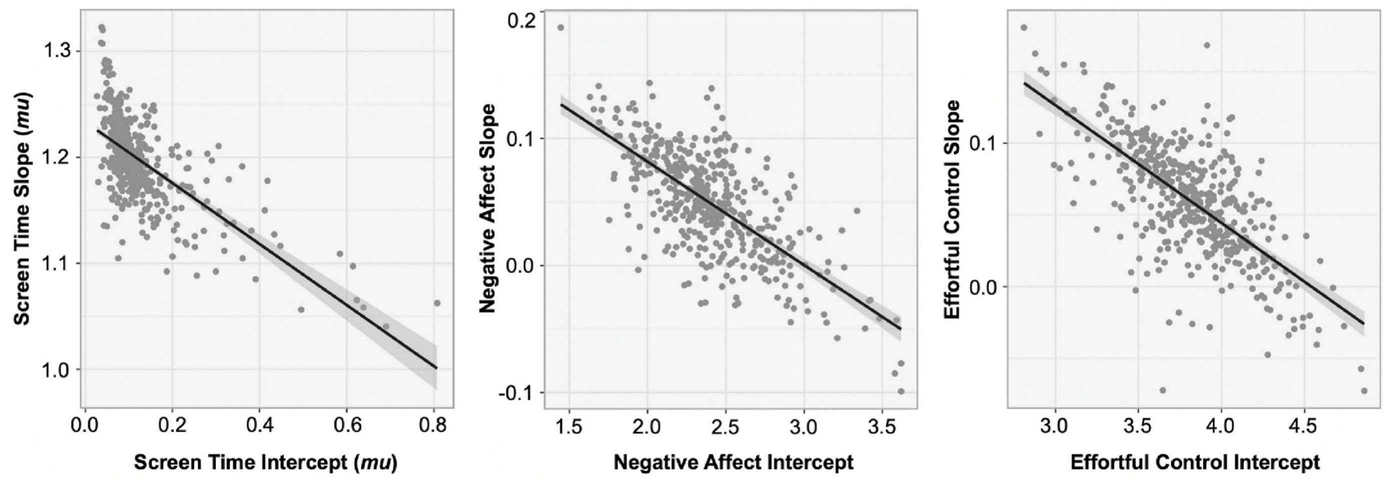

Fig. A.3. Correlations of the Univariate Growth Parameters.

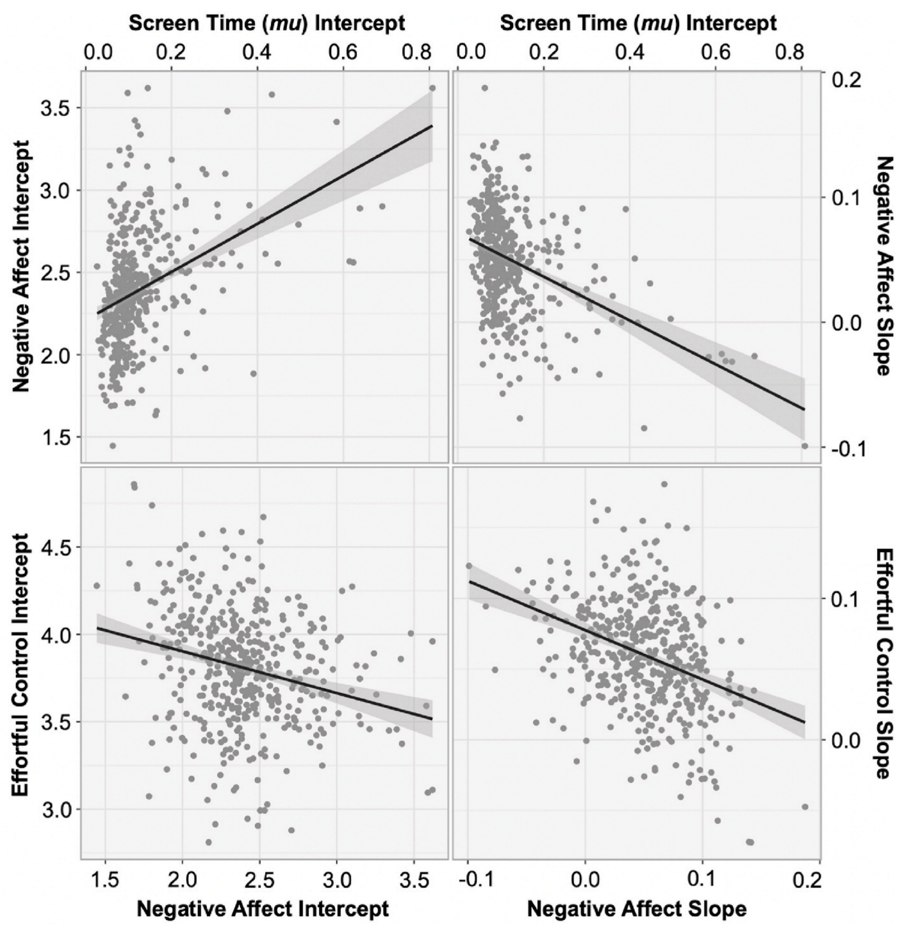

Fig. A.4. Correlations of the Bivariate Growth *Parameters*
Note. Correlation plots of bivariate growth parameters where 90% HDI did not include zero, except for the correlation between the slope of negative affect and the slope of effortful control, where the 90% HDI barely included 0.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2024.108138.

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