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Article type : Original Article

**Children aged 3-4 years were more likely to be given mobile devices for calming purposes if they had weaker overall executive functioning**

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Short title: Mobile devices and executive functioning

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### **Abstract**

**Aim:** Young children with weaker self-regulation use more digital media, but studies have been limited by parent-reported screen time measures. We examine associations between early childhood executive functioning and objective mobile device usage.

**Methods:** The parents of 368 American children (51.6% male) aged 3-4 years of age completed standardised measures of executive functioning, parenting stress and household chaos. They provided

**This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1111/APA.16314](https://doi.org/10.1111/APA.16314)**

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mobile sampling data for 1 week in 2018-2019 and reported how often the children used mobile devices to calm themselves.

**Results:** The children's mean age was about 3.8 years. A third of the children who were given devices to calm them down had weaker executive functioning in the overall and multivariable models, including working memory, planning and organisation. So did 39.7% of the children who used educational apps. Streaming videos, using age-inappropriate apps and using the mobile device for more than 1 hour per day were not associated with executive functioning levels. Parenting stress and household chaos did not moderate the associations.

**Conclusion:** This study confirms previous studies that suggesting that children with weaker overall executive functioning used devices more for calming purposes. It also raises questions about whether children with weaker executive functioning should use educational apps.

### Key Notes

- Existing research on self-regulation and the use of digital media is limited by use of parent-reported screen time measures.
- Use of educational apps and use of devices for calming purposes were associated with weaker emergent metacognition and overall executive functioning in multivariable models.
- The results of this study raise questions about use of educational apps in children with weaker executive functioning.

**Keywords:** preschool children; executive functioning; parenting; mobile device; passive sensing method

### INTRODUCTION

The American Academy of Paediatrics recommends that young children do not use entertainment media for more than 1 hour a day.<sup>1</sup> Despite this, one American study reported that children under 5 years of age spent an average of 2.4 hours per day using screens media.<sup>2</sup> The amount of time that this age group spent with mobile devices, particularly smartphones and tablets, tripled<sup>2</sup> from 2011 to 2017, to about 1 hour per day.<sup>2</sup> However, one study of mobile device tracking suggested that young children's daily use averaged 2 hours per day in 2018-2019,<sup>3</sup> and it has been predicted that media use during the COVID-19 pandemic is likely to be even higher.<sup>4</sup>

Cross-sectional studies have associated the use of screen media in early childhood with weaker social-emotional development. These have included lower scores on the Ages and Stages Questionnaire,<sup>5</sup> more externalising behaviour problems,<sup>6</sup> and poorer performance on delay of gratification tasks.<sup>7</sup> The associations are likely to have been bidirectional, as young children with difficult temperaments<sup>7</sup> or self-regulation problems<sup>8,9</sup> tend to develop heavier media habits.

The central drivers of social-emotional development are the self-regulatory processes that make up executive functioning, such as inhibitory control, emotional control, mental flexibility or self-monitoring. Executive functioning is shaped by early caregiving experiences,<sup>10</sup> including media use. For example, one study showed that children who started watching entertainment media in infancy had weaker executive functioning when they were preschool-aged.<sup>11</sup> Age-inappropriate media content and harsh parenting have also been reported to have negative associations with the executive functioning of preschool children.<sup>12</sup> Findings regarded to mobile media and executive functioning have been inconsistent. Jusienė et al.<sup>13</sup> found no association between screen media use, including mobile devices, and executive functioning in children aged 4-5-years. These related to mental set shifting, working memory and inhibitory control. Other studies have found longitudinal associations between media exposure duration at 2 years of age and a composite measure of attentional, behavioural and emotional control at 4 years.<sup>14</sup> Associations have also been found between spending more time playing mobile apps and weaker executive functioning 1 year later.<sup>15</sup>

One reason why it has been difficult to separate the nature of the associations between mobile device use and executive functioning is that existing parent-report media measures do not tap into the design aspects of mobile devices that may be particularly relevant to executive functioning. For example, children with weaker inhibitory control may find it harder to resist using mobile devices on demand throughout the day. They may impulsively download age-inappropriate games from app stores or may stay on devices longer due to features that encourage engagement, such as autoplay. More active or impulsive children also may be provided with devices to keep them calm. In addition, the design of some mobile games, such as using leader boards and badges to encourage children to play more<sup>16</sup> may be particularly attractive to children with weaker executive functioning.

The main aim of this study was to explore the associations between early childhood executive functioning and these unique aspects of mobile devices, by using objective mobile tracking, which is more accurate than parental reports<sup>3</sup> and generates information about the types of apps children use, as well as duration. We hypothesised that inhibitory self-control would be the executive functioning component that was most strongly linked with mobile device use, as it has been associated with parenting stress<sup>17</sup> and early screen media exposure.<sup>9</sup>

A secondary aim of this study was to examine how by parenting stress and household disorganisation moderated effect any association between mobile devices and executive functioning. Conceptual frameworks of the effects of media have emphasised the importance of understanding the interplay between the family environment, mobile device use and child functioning, so that guidance can be tailored to families' unique needs.<sup>18</sup>

Families may be less structured about media use if the parents are stressed and there are high levels of chaos and disorganisation in the household. They may monitor child mobile media content less or feel they have less self-efficacy when it comes to managing devices. We hypothesised that the

associations between executive functioning and the use of mobile devices would be stronger when there was higher parental stress, chaos and disorganisation.

## **MATERIALS AND METHODS**

### **Study Design**

We analysed data from the Preschool Children Tablet Study, a longitudinal study of child development and mobile media use. The parents of children aged 3-4 years completed online questionnaires during the baseline wave in 2018-2019. They provided a 1-week sample of their child's mobile device usage and received a \$40 gift card for participation. The study was approved by the University of Michigan Institutional Review Board.

### **Participants**

We recruited parents by posting study flyers in paediatric offices and preschools and advertising on social media sites, we also posted the details on our university's research recruitment website. Interested parents contacted our team and were screened for eligibility. To be included in the study, parents needed to be the guardian of 3-4 year-old child, live with the child for more than 5 days per week, read and speak English and own an Android or Apple tablet or smartphone. Regular mobile device use was not an inclusion criterion for this study, as we aimed to examine the full range of device use behaviours, including no use. We excluded children who had developmental delays, used psychotropic medication or used an incompatible mobile device. Of the 423 parents who consented and provided any data, 55 (13%) were excluded due to incomplete mobile device data. The 368 children and parents included in this study did not have significantly different sociodemographic characteristics to those who were excluded.

### **Survey measures**

After providing online consent for themselves and their child, the parents were emailed a link to an online REDCap<sup>19</sup> survey. They were asked to report their child's age, sex, race/ethnicity and whether the child was enrolled in a preschool or receiving childcare. The parents also provided their own age, sex, educational attainment, marital status and employment status. They also provided their household income and size and this enabled us to calculate the income-to-needs ratio.

### **Executive functioning**

The Behaviour Rating Inventory of Executive Function – Preschool<sup>20</sup> was used to assess children's executive functioning difficulties. This includes 3 indices: the Inhibitory Self-control Index, the Flexibility Index and the Emergent Metacognition Index. These can be combined to provide the Global Executive Composite summary score. The raw scores of  $\alpha=0.96$  for the composite score and 0.83-0.96 for the indices were transformed into age-adjusted and sex-adjusted T-scores, with higher scores indicating weaker executive functioning.

### **Parenting variables**

Parents completed the Parenting Stress Index-Short Form<sup>21</sup>, which is a validated measure of parenting stress and parent-child dysfunctional interaction. Household chaos was assessed by asking the parents to complete the Confusion, Hubbub and Order Scale,<sup>22</sup> a 15-item self-report questionnaire that assesses levels of noise, crowding and disorganisation in the home.

### **Media use measures**

The parents were asked if they used mobile devices to calm their child down, which is a measure that has been used in several other studies.<sup>9</sup> They responded on a 5-point scale, with 0 indicating never and 4 being used for very likely. The responses were dichotomised as likely (2/3/4) and not likely (0/1) for the analysis.

Usage was assessed with mobile device sampling, a novel measure of smartphone or tablet use that captures app usage logs and has previously been described in detail.<sup>3</sup> The 129 participants with devices that used Android operating systems, namely 72.1% smartphones and 27.9% tablets, installed a passive sensing app called Chronicle (OpenLattice Inc, Redwood City, CA, USA). The 220 participants using Apple devices, (65.0% iPads and 35.0% iPhones), sent screen grabs of their app usage information to the research team.

More than two-thirds of the children (228, 65.3%) shared mobile devices with their parents and/or siblings. The parents were asked to report which apps their child used at the end of the sampling week, which our research team used to subset the data.

A list of all apps used during the sampling week was reliably coded into categories based on app store listings (Table 1) ( $\alpha=0.72-0.94$ ). We categorised the children by whether they ever used streaming video apps, educational apps and/or age-inappropriate apps during the sampling week. Children who did not use mobile devices during the sampling week – either because they did not regularly use mobile devices, or happened to not use their tracked device that week - were considered to be non-users of each of these app categories.

[TABLE 1 HERE]

Children were categorised as having their own mobile device or not. For children with their own device ( $n=121$ ), We calculated the average daily usage duration for the 121 children with their own devices, which we dichotomised as  $<$  or  $\geq$  1 hour per day based on American Academy of Paediatrics recommendations. We did not calculate duration for children who shared a device with a parent or sibling, since popular apps (YouTube, Netflix, ...) might have multiple users. For children who did not use mobile devices during the sampling week - either because they did not regularly use mobile devices or happened to not use their own device that week – duration of use was set to 0 minutes.

### **Data Analyses**

We inspected all variables to examine distribution and presence of outliers in Behaviour Rating Inventory of Executive Function – Preschool and mobile device use variables. Because Behaviour Rating Inventory of Executive Function – Preschool T-scores were slightly skewed, we used nonparametric bivariate tests (Kruskal-Wallis) to examine associations of Inhibitory Self-control Index, Flexibility Index,

Emergent Metacognition Index, and Global Executive Composite T-scores with mobile device outcome variables.

We built multivariable logistic regression models, with child executive functioning as the independent variable (1-standard deviation change in Inhibitory Self-control Index, Flexibility Index, Emergent Metacognition Index, or Global Executive Composite T-score). Odds of mobile device outcomes were separate dependent variables. Mobile device outcomes were: use for calming, use of educational apps, use of streaming video apps, use of age-inappropriate apps, having own device, and use of device  $\geq 1$  hour per day. We built models by starting with potential confounders known to be associated with mobile device use or executive functioning in the literature (Table 1). We then performed backward elimination, removing variables that were not associated at a  $p < 0.05$  level. We retained child age, child sex, parent education, and parent marital status in final models.

To test moderation, we ran additional models including an interaction term for either Parenting Stress Index-Short Form or Confusion, Hubbub and Order Scale with Global Executive Composite T-score for all mobile device multivariable models.

## RESULTS

Participant sociodemographic characteristics are shown in Table 2. Parents were primarily mothers (93.5%), married or in a committed relationship with a partner (91.0%), and over half had a college degree (63.3%). Children were on average 3.8 years, 74.9% were white non-Hispanic, most had siblings (82.3%), and 65.1% attended center-based childcare. Approximately one-third of parents reported that they were likely to use mobile devices to calm the index child down when upset. The most common activity was educational apps (39.7%), followed by streaming video and age-inappropriate apps (29.6% each). Over half of children with their own mobile device used it for more than 1 hour daily.

[TABLE 2 HERE]

[TABLE 3 HERE]

In multivariable logistic regression models, the odds of using a mobile device to calm was significantly associated with child Emergent Metacognition Index and Global Executive Composite T-score. For every 1 standard deviation increase in T-score, the odds increased by 29% (table 3). Every 1 standard deviation increase in Emergent Metacognition Index or Global Executive Composite T-score was associated with approximately 36% and 26% higher odds, respectively, of using educational apps. Although results neared statistical significance, Inhibitory Self-control Index and Flexibility Index were not significantly associated with odds of any mobile device use variable.

All p-values for an interaction between Global Executive Composite T-score and Parenting Stress Index-Short Form or Confusion, Hubbub and Order Scale were nonsignificant. This indicates no moderating effect of parenting stress or household chaos in multivariable models.

## DISCUSSION

This study examined associations between young children's executive functioning difficulties and objectively measured content and duration of mobile device use. Unexpectedly, the emergent

metacognition was the most significantly executive functioning component associated with mobile device variables. The Emergent Metacognition Index was significantly associated with the use of devices for calming purposes and use of educational apps, and marginally with use of streaming video apps. The Emergent Metacognition Index indicates difficulties in children's ability to pay attention, self-monitor, and adjust their behaviour. Our results thereby raise questions about whether children with weaknesses in these domains use more media, or whether mobile device use is contributing to metacognitive challenges.

Our findings revealed more use of educational apps in children with weaker Emergent Metacognition Index and overall executive functioning. It is possible that parents of children with more dysregulated behaviour may seek out educational experiences by downloading apps labelled as such.<sup>23</sup> Unfortunately, an analysis of app quality, based on the Four Pillars of Learning Framework,<sup>16</sup> showed that most educational apps have simple cause-effect or rote learning goals. In addition, most such apps had extraneous enhancements or advertisements that likely distract from underlying educational goals. Therefore, it is plausible that children who play more educational apps have weaker metacognition and overall executive functioning due to direct effects of distracting or oversimplified digital play experiences. Weaker metacognition and overall executive functioning in children who play more educational apps could be due to displacement of other offline play experiences as well.

We also found that weaker metacognition and overall executive functioning were associated with increased odds of parent-reported frequency of using devices for calming purposes. This result is consistent with prior research showing cross-sectional and longitudinal associations between regulatory problems, difficult temperament, and social-emotional delays with higher media use or use for calming purposes.<sup>6-8</sup> Similarly, young children with early executive functioning deficits may have more intense emotional reactions, more impulsivity, and less organised behaviour, making them more challenging to parent without using media. It is also possible that the converse is true, but directionality was not testable in this cross-sectional analysis. However, one longitudinal study<sup>24</sup> showed that parental report of regular exposure (>0 hours of screen use) to screen-based media at 4 months of age predicted poorer performance on a test of inhibition at 14 months.

We did not find a moderating effect of parenting stress or household chaos on associations between executive functioning and mobile media use, contrary to hypotheses. This suggests that the use of mobile devices by children with weaker executive functioning occurs regardless of these contextual factors. As our sample was relatively educated with mostly 2-parent families, future research should explore parenting stress and household disorganisation in single-parent households or parents with their own executive functioning weaknesses. In addition, future research should discriminate when use of mobile devices for calming purposes is the primary behaviour management strategy – versus a strategy of last resort when parents need the child to be occupied, as has been common during the COVID-19 pandemic.

### **Strengths and limitations**

A strength of this study was the measure of objective duration and content of mobile device use, a novel measurement approach that improves upon global parent-reported 'screen time' estimates. This study also had several limitations. Some findings had marginal significance, indicating that the study may have been underpowered to detect associations. We included non-device-using participants in our analyses to increase generalizability of our sample and to maximize statistical power, but it is possible that true associations might have been detected in a larger sample. A high proportion of respondents were mothers, so we were unable to assess fathers' unique perspectives; however, this is a common pitfall in paediatric and developmental studies. Although this sample had high income diversity, more research is needed to understand relationships between executive functioning and media use in families from different cultural backgrounds. We did not track the mobile devices of parents, whose media use practices correlate strongly with those of children.<sup>25</sup> Parent self-reported technofence has been linked with child behaviour problems,<sup>26</sup> so future work should examine both parent distraction and quality of child app usage. Due to the cross-sectional design of the study, we were unable to test directionality of effects, and future longitudinal research is needed.

## **CONCLUSION**

Mobile media, streaming video, and app usage become increasingly prevalent in the daily lives of young children. It is thus important to understand how such media use is influenced by, and influences, child characteristics. This study affirms prior research suggesting that children with weaker overall executive functioning use mobile devices more for calming purposes. It raises the question regarding whether use of educational apps is more common in children with weaker executive functioning. Clinicians can continue to counsel parents to seek out high-quality educational media for young children, while building strategies for parenting that do not involve external distractors.

## **FUNDING**

This research was funded by the Eunice Kennedy Shriver National Institute of Child Health and Development (NICHD 1R21HD094051).

## **CONFLICTS OF INTEREST**

The authors have no conflicts of interest to declare.

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**Table 1: Mobile app coding scheme**

<b>App Category</b>	<b>Description</b>
Streaming video	Video streaming services that have content suitable for children under 5 years old (e.g., Netflix, Hulu, Apple TV, Amazon Prime, Disney NOW)
Child educational app	App appears targeted at younger children and: <ul style="list-style-type: none"> <li>- Google Play formally categorizes as “educational”</li> <li>- iTunes has the app in an “education” list or the app developer makes educational claims for their app.</li> </ul>
Age-inappropriate app	Apps appear targeted to older children or general audiences (e.g., Cookie Jam, Candy Crush, Subway Surfers).

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**Table 2: Participant Demographic Characteristics**

Characteristic	Mean (SD), Median [IQR], or n (%)
<b>Parent:</b>	
Age	34.0 (4.60)
Sex	
Female	344 (93.5)
Male	24 (6.5)
Education	
<=High school/GED	25 (6.8)
Some college/2-year degree	114 (31.0)
4-year college degree	94 (25.5)
Advanced degree	135 (36.7)
Marital status	
Married/partner	334 (91.0)
Single/separated/divorced	33 (9.0)
Employment	
Unemployed	102 (27.7)
Part-time	73 (19.8)
Full-time	169 (45.9)
Multiple jobs	24 (6.5)
PSI-SF full score (percentile)	45.4 (33.0)
<b>Child:</b>	
Age	3.82 (0.53)
Sex	
Female	178 (48.4)
Male	190 (51.6)
Race/ethnicity	
White non-Hispanic	274 (74.9)
Under-represented minority	92 (25.1)
Only child	
Yes	65 (17.7)
No	303 (82.3)
Child preschool/child care	
Center-based child care	231 (65.1)
Home-based child care	30 (8.5)
Stays home with parent/caregiver	94 (26.5)
BRIEF-P Inhibitory Self-Control Index T-score	47.0 [41.0; 57.0]
BRIEF-P Flexibility Index T-score	47.0 [40.5; 55.5]
BRIEF-P Emergent Metacognition Index T-score	46.0 [40.0; 57.0]

BRIEF-P General Executive Composite T-score	47.0 [40.0; 56.0]
<b>Household:</b>	
Income-to-needs ratio	3.00 (1.71)
CHAOS total score	3.39 (3.00)
<b>Child Mobile Device Use:</b>	
Use mobile device to calm	
Likely (2/3/4)	123 (33.4)
Not likely (0/1)	216 (58.7)
Use educational apps	
Yes	146 (39.7)
No	222 (60.3)
Use streaming video apps	
Yes	109 (29.6)
No	259 (70.3)
Use age-inappropriate apps	
Yes	109 (29.6)
No	259 (70.3)
Have own mobile device	
Yes	121 (32.9)
Share device with family member	228 (62.0)
Do not regularly use mobile devices	19 (5.2)
Use of mobile device $\geq$ 1 hour/day <sup>b</sup>	
Yes	72 (51.4)
No	68 (48.6)

<sup>b</sup>Denominator is 140 (121 with own devices; 19 with no device)

Abbreviations: PSI-SF= Parenting Stress Index-Short Form; BRIEF-P = Behaviour Rating Inventory of Executive Function – Preschool; CHAOS=Confusion, Hubbub and Order Scale

**Table 3: Multivariable associations between BRIEF-P Indices and GEC T-scores and mobile device use variables**

	Likely to use mobile device to calm aOR <sup>a</sup> (95% CI)	Use educational apps aOR <sup>a</sup> (95% CI)	Use streaming video apps aOR <sup>a</sup> (95% CI)	Use age-inappropriate apps aOR <sup>a</sup> (95% CI)	Have own mobile device aOR <sup>a</sup> (95% CI)	Use of mobile device ≥1 hour/day aOR <sup>a</sup> (95% CI)
BRIEF-P ISCI T-score (1-SD increase)	<b>1.24 (0.97, 1.57)<sup>†</sup></b>	1.19 (0.96, 1.48)	1.12 (0.89, 1.42)	1.20 (0.95, 1.52)	1.15 (0.92, 1.44)	1.35 (0.94, 1.95)
BRIEF-P FI T-score (1-SD increase)	1.21 (0.95, 1.53)	1.06 (0.85, 1.32)	1.14 (0.91, 1.43)	1.14 (0.91, 1.44)	1.19 (0.95, 1.48)	1.30 (0.91, 1.87)
BRIEF-P EMI T-score (1-SD increase)	<b>1.29 (1.01, 1.65)<sup>*</sup></b>	<b>1.36 (1.09, 1.70)<sup>*</sup></b>	<b>1.22 (0.97, 1.54)<sup>†</sup></b>	1.08 (0.85, 1.37)	1.15 (0.91, 1.44)	1.18 (0.81, 1.73)
BRIEF-P GEC T-score (1-SD increase)	<b>1.29 (1.01, 1.65)<sup>*</sup></b>	<b>1.26 (1.00, 1.57)<sup>*</sup></b>	1.17 (0.93, 1.47)	1.14 (0.89, 1.44)	1.17 (0.94, 1.47)	1.24 (0.86, 1.80)

<sup>a</sup>Adjusted for child age, parent education, child sex, marital status

<sup>†</sup>p < .10; <sup>\*</sup>p < .05

Abbreviations: ISCI = Inhibitory Self-control Index; FI = Flexibility Index; EMI = Emergent Metacognition Index; GEC = General Executive Composite; SD = standard deviation, aOR = adjusted odds ratio