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Screen Time and ADHD Behaviors in Chinese Children: Findings From Longitudinal and Cross-Sectional Data

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Abstract

Objective: Research suggests that screen exposure presents a risk for ADHD behaviors in young children. However, the operationalization of screen exposure remains murky and longitudinal data is scarce. In this paper, we examined the relations between better operationalized daily screen time and behaviors of inattention and behaviors of hyperactivity/impulsivity in three cohorts of community samples of young Chinese children. **Method:** Study 1 was longitudinal and included 111 children who were 3.6 years old (Range = 2.4–4.9; *SD* = 0.4) at Baseline and 4.8 years old (Range = 3.9–6.0; *SD* = 0.4) at Follow-Up. Study 2 was cross-sectional and included 172 children aged 4.9 years (Range = 3.0–7.1; *SD* = 1.0). Study 3 was also cross-sectional and included 313 children who were 6.9 years old (Range = 5.7–8.3; *SD* = 0.4). In each study, the parents reported how much time that their children spent daily on iPad/tablet, smart phone, and online games and watching TV in the previous week, and their children's behaviors of inattention (I/A) and hyperactivity/impulsivity (H/I). **Results**: Regression analysis revealed that in Study 1, controlling for child demographics, mother's education, family SES, and corresponding I/A or H/I scores at Baseline, screen time at Baseline predicted I/A scores ($\beta = .27$, $p < .01$) and H/I scores ($\beta = .32$, $p < .001$) at Follow-Up. Similarly, controlling for covariates, screen time predicted I/A scores ($\beta = .25$, $p < .01$) and H/I scores ($\beta = .25$, $p < .01$) in Study 2; I/A scores ($\beta = 0.16$, $p < .01$) and H/I scores ($\beta = .15$, $p < .05$) in Study 3. **Conclusion**: Screen exposure was a risk for inattention and hyperactivity/impulsivity behaviors in urban Chinese children. *(J. of Att. Dis. XXXX; XX(X) XX-XX)*

Keywords

screen time, ADHD, inattention, hyperactivity/impulsivity, longitudinal study, cross-sectional study

Introduction

Increase in Screen Time and ADHD in Young Children

In developed and emerging economies, young children are spending more time on various types of digital, mobile, and screen devices than before (Chen & Adler, 2019; Kabali et al., 2015; Mullan, 2018). Children are being exposed to screen devices at a younger age (Goh et al., 2016; Radesky & Christakis, 2016) and the amount of screen time increases as children get older (Lauricella et al., 2015; Paudel et al., 2017). The increase has to do with the fact that newer electronic products and mobile devices have become available in a relative short span of time (Domingues-Montanari, 2017; Engelhard & Kollins, 2019). For instance, from 1997 to 2014 screen devices available to young children in the United States increased from television or videotape, electronic video game and home computer to additionally include cell phone, smartphone, tablet, electronic reader, and other learning devices (Chen & Adler, 2019). Not surprisingly, the increase in the number of available digital devices leads to an increase in children's screen time (Elias & Sulkin, 2019; Sigman, 2012).

Because young children's interaction with the content of mobile and screen devices often requires them to quickly shift their attention and to respond to multiple types of stimuli (e.g., visual, perception, sensory, and tactile), how this may contribute to their neurological development and functioning within the stage of rapid brain maturation is an important question to address. One commonly investigated topic is how screen exposure is related

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to the diagnosis or symptoms of attention deficit hyperactivity disorder (ADHD) (Beyens et al., 2018). However, a big challenge in studying young children's screen exposure is the lack of established measures as the field is rapidly evolving and there is no established protocol yet (Byrne et al., 2021). Obtaining children's screen time with questions on the amount of time that children spent daily on different device remains the most common in existing studies (Miller et al., 2017).

Along with the increase in mobile and screen device use is a coincidental increase in rates of ADHD in children (Christakis et al., 2018; Sayal et al., 2018). Behaviors of ADHD reflect neurobiological differences (Mahone et al., 2011) and underlying deficit in cognitive and executive functioning such as problem solving, working memory, and self-regulation (Daley & Birchwood, 2010; Johnson & Reid, 2011; Landau & Moore, 1991; Loe & Feldman, 2007). The two main types of ADHD behaviors: inattention and hyperactivity/impulsivity, are usually correlated (Allan & Lonigan, 2019; Willcutt et al., 2012). For most children who later develop ADHD disorder, behaviors of inattention and hyperactivity/impulsivity start to emerge during the preschool years (DuPaul et al., 2001; Halperin et al., 2012). The behavioral characteristics of ADHD are similar in preschool and school age children (Brown & Harvey, 2019). Nonetheless, some studies have shown that during preschool age years, behaviors of ADHD are infrequent and often lack stability (Curchack-Lichtin et al., 2014), while others have shown that these behaviors are quite common in preschool children (Smidts & Oosterlaan, 2007). For instance, Curchack-Lichtin et al., (2014) showed that behaviors of inattention were infrequent for 4 to 5 ages. However, Smidts and Oosterlaan (2007) showed that ADHD behaviors were quite common among 3 to 6-year olds, but behaviors of hyperactivity/impulsivity were more common than behaviors of inattention. Therefore, more research on the prevalence of ADHD behaviors in preschool children is thus valuable.

Furthermore, ADHD can be seen as a social and cultural construct (Timimi & Taylor, 2004). Within a collectivistic context, parents tend to promote interdependence within the family and the school environment and classrooms are typically more structured and task-oriented than those of Western schools and classrooms, which influence the expression of behaviors of ADHD in children (Choi et al., 2019; Luk et al., 2002). For instance, Choi et al. (2019) found that Korean elementary school children scored significantly lower than American counterparts on hyperactivity/impulsivity. Thus, it is valuable to study screen exposure and behaviors of ADHD in different cultural contexts. Thus, studying children from a non-Western social cultural background can expand the understanding of screen exposure and ADHD behaviors. Furthermore, changes that occurred to the society in response to Covid19 may present an interesting opportunity to examine how Covid mitigating measures such as stay-at-home order and mask mandate might be related to ADHD behaviors.

Screen Time and ADHD Behaviors in Young Children

Probably because behaviors of ADHD reflect underlying difficulties related to executive functioning and self-regulation, while children's interactions with screen devices often directly or indirectly involve these domains, extensive attention has been paid to testing the link between screen exposure and ADHD behaviors. Findings point to a positive link between screen time and behaviors of ADHD (Beyens et al., 2018; Lawrence & Choe, 2021; Nikkelen et al., 2014; Swing et al., 2010).

Research remains limited on children who are on the lower end of preschool ages (Nikkelen et al., 2014; Smidts & Oosterlaan, 2007). As shown in the meta-analysis by Nikkelen et al., only one of the 45 studies (an unpublished Master's thesis) focused on younger preschool children (mean age: 3.9 years). In fact, the vast majority of the 45 studies were cross-sectional and focused on children in the school ages (i.e., six and older). Furthermore, in most of the 45 studies, screen time was defined as the amount time that children spent on two activities: watching TV and playing video games. Admittedly, since the publication of the 2014 meta-analysis by Nikkelen et al., several studies on preschool age children have emerged and the results are similar (Hill et al., 2020; Wu et al., 2017; Xie et al., 2020). However, these studies have typically focused on wider range of preschool school age range (i.e., between 3 and 6 years). The exception was the study by Hill et al. (2020), which included 120 children who were 36 months of age, 20 of whom had elevated ADHD symptoms. The authors concluded that the 20 children spent more time using screen media than the other children. More research on children in the younger end of preschool age can help expand the existing literature.

However, according to Kaye et al. (2020), inconsistency in the operational definition of mobile and screen device is pervasive in the literature. To some extent, this operational challenge is difficult to avoid because newer and additional devices have become available in a relative short span of time (Engelhard & Kollins, 2019). As a result, it is common for existing studies to include varying types of devices and not surprisingly different terms have been used to describe these devices. For instance, the review of the literature by Kaye et al. (2020) showed that terms such as digital media use, media use, screen time, mobile device use, interactive screen exposure and smart device use have all been used in existing studies. To clarify the relationship between screen exposure and ADHD in children, an explicit and clear operationalization of screen exposure is needed.

In addition to discrepancies in the operationalization of screen exposure, the reported associations sometimes varied from positive (Allen & Vella, 2015; Hill et al., 2020; Hosokawa & Katsura, 2018; Tamana et al., 2019; Wu et al., 2017; Xie et al., 2020) to absent (Levelink et al., 2021; Parkes et al., 2013; Stiglic & Viner, 2019). The preponderance of evidence, however, points to increase in screen time as a risk factor for inattention and hyperactive behaviors of ADHD (Allen & Vella, 2015; Hill et al., 2020; Hosokawa & Katsura, 2018; Tamana et al., 2019; Wu et al. 2017; Xie et al., 2020). The magnitude of the associations, however, is typically modest (Beyens et al., 2018).

There is a major shortage of longitudinal data on the relations (Engelhard & Kollins, 2019; Wilmer et al., 2017). Again, the evidence is also mixed. For instance, in a recent study on early screen time and subsequent behavioral adjustment in preschool children in China, Liu et al. (2021) found that those who were exposed to more screen time at 6 months of age, 2.5 years and 4 years of age had more behaviors of hyperactivity at age 4 years of age. This study did not include data on behaviors of inattention. However, Niiranen et al. (2021) found that increased levels of e-media use at 18 months was not related to inattention or hyperactivity in children at age 5 years of age. Similarly, Levelink et al. (2021) and Parkes et al. (2013) found that the amount of time that children spent watching TV and playing computer games was longitudinally unrelated to their ADHD behaviors. Differences in the documented associations may have to do with different types of screen devices included in different studies. For instance, Levelink et al. focused on the time that children spent on watching TV and playing computer games, while Liu et al. focused on the amount of time that the children spent on watching TV and using devices such as mobile phones, tablets, computers, or iPad.

Overall, discrepancies in the existing literature point to the importance of clearly operationalizing screen exposure in terms of types of devices that children are exposed to, in addition to the amount of time that they spend on using these devices. Additionally, there are several obvious gaps within the literature, chief among them is the need for more research on preschool age children and the need for longitudinal data. In the current study, we addressed these issues with longitudinal data collected on preschool children in two time points that were 13 months apart (Study 1), cross-sectional data on preschool children (Study 2), and cross-sectional data on first graders (Study 3). Our main goal was to test the link between screen time and ADHD behaviors in young children within the Chinese urban context.

Methods

Design and Setting

In all three studies, we relied on parent reports to assess the children's screen exposure and behaviors of ADHD. Each parent represented one child. In response to the recent criticism by Kaye et al. (2020) that the conceptualization and operationalization of screen media in the existing studies lack clarity, we explicitly defined screen devices in each study (See Table 1).

We designated the three studies to be Study 1 (youngest cohort), Study 2 (second youngest cohort), and Study 3 (oldest cohort). The same method was used to recruit parents in all three studies. Specifically, upon receiving approval from the first author's Institutional Review Board, information on Study 1 and Study 2 was distributed to the parents through the director of a preschool in Beijing, China. The preschool serves children between 3 and 6 years of age. Baseline of Study 1 took place in August of 2020 and Follow-Up of Study 1 took place in September of 2021. This study was designed to focus on the "freshmen" of the preschool. Study 2 took place in September of 2019. It included children who were already attending the preschool school. Information on Study 3 was distributed to the principal of a newly opened elementary school in the city of Shenzhen, China. The school enrolled 328 children, all of whom were first graders, and the study took place in February of 2019.

In all three studies, one parent from each family was invited to complete the survey within one week; they were explicitly informed that the study was about their children's experiences and participation was entirely voluntary. Parents who were interested in participating in the study were directed to an online survey link. During the data collection, the second author was available to respond to questions from parents and to closely monitor the responses. If a clarification was needed from the parents, the request was immediately made. One example for clarification was that a parent reported that the time that the child spent watching TV was "5." To ascertain whether 5 referred to 5 minutes or 5 hours, the second author immediately contacted the parent for clarification. This approach enhanced data quality by reducing missing data and ambiguous responses.

Samples

Study 1 was longitudinal and included 111 preschool-aged children. At Baseline, data on 127 of the 150 new students (response rate: 84.7%) were obtained. At Follow-Up, 16 children had since left the school and data were obtained for the remaining 111 children (55 girls: 49.55%; 56 boys: 50.45%). At Baseline, 87 (78.38%) mothers and 24 (21.62%) fathers provided data; at Follow-Up, 95 (85.59%) mothers and 16 (14.41%) fathers provided data. At both times, the same parents, with the exception of eight, provided data. Study 2 was cross-sectional and included 172 (68 girls: 39.53%; 104 boys: 60.47%) out of 200 children attending the preschool at the time (response rate: 86.0%). The data were provided by mothers 109 (63.37%) and 63 fathers (36.63%). Study 3 was cross-sectional and included

Table 1. Summary of Design Features for Study 1, Study 2, and Study 3.

	Study 1	Study 2	Study 3
Location	Beijing	Beijing	Shenzhen
Design	Longitudinal	Cross-sectional	Cross-Section
N	111	172	313
Age	Baseline: 3.6 (2.5–4.9) Follow-Up: 4.8 (3.9–6.0)	4.9 (3.0–7.1)	6.9 (5.7–8.3)
% of boys	50.45%	60.47%	50.48%
Screen time measure	iPad/tablet, smart phone, TV and online computer games	iPad/tablet, smart phone, TV and online computer games on weekday and weekend	iPad/tablet, smart phone, TV and online computer games on weekday and weekend
ADHD measure	ADHD-RS-IV (Modified)	ADHD-RS-IV	ADHD-RS-IV
Mothers' education	1–5 (*M* = 3.28; SD = 0.67)	1–5 (*M* = 3.09; *SD* = 0.65)	1–5 (*M* = 3.05; *SD* = 0.83)
Fathers' education	1–5 (*M* = 2.37; *SD* = 0.76)	1–5 (*M* = 3.05, *SD* = 0.72)	1–5 (*M* = 3.18; *SD* = 0.84)
Mothers' age	25–45 (*M* = 33.7, *SD* = 3.7)	25–48 (*M* = 34.0, SD = 3.4)	Did not collect
Fathers' age	28–49 (*M* = 34.5, *SD* = 3.9)	29–63 (*M* = 36.2, *SD* = 4.6)	Did not collect
Informant	Baseline: 87 (78.38%) were mothers Follow-Up: 95 (85.59%) were mothers	109 (63.37%) were mothers	231 (73.80%) were mothers

Note. Education: 1 = Junior High School or Less, 2 = High School, 3 = College Degree, 4 = Master's Degree, 5 = Ph.D. Study 1 took place during Covid19 and because the children were not yet attending school at Baseline, parents were not asked about the children's screen exposure on weekday or weekend and eight items from the ADHD scale that focused on classroom behaviors or were deemed to be difficult to observe during the pandemic were excluded.

313 first graders (155 girls; 49.52%; 158 boys; 50.48%), representing 95.4% of the 328 children enrolled at the school. The data were provided by 231 mothers (73.80%) and 82 fathers (26.20%).

Procedure and Measure

Demographic background. In all three studies, the parent provided information on the target child's gender, date of birth and number of children in the household. The parent also provided data on his/her age (the spouse's age if applicable), marital status, and educational level (1 = Junior High School or Less, 2 = High School, 3 = College Degree, 4 = Master's Degree, 5 = Ph.D.; spouse's educational level if applicable) and employment status or occupation (that of the spouse if applicable). Additionally, in Study 1, we collected data on the amount of monthly childrearing expenditure (e.g., food, learning materials, clothes and health care); in Study 2, we collected data on their monthly childrearing expenditure in relation to their monthly earnings (i.e., income-to-expenditure ratio; 1 = Less than 20%; 8 = More than 80%); and in Study 3, we used an occupational survey that was commonly used in China (Lin & Xie, 1988) to gather data on the parent's occupational prestige on 1–14-point scale: the lowest prestige (1 = Not working, housekeeper) to the highest prestige (14 = Specialized Professional such as actuary, lawyer, architect, physician, and journalist).

Screen time. Prior to data collection, we pilot-tested the feasibility of the screen time measure that we adopted from a recent study on preschool Chinese children's screen exposure by Wu et al. (2017) and on Canadian children by Tamana et al. (2019). Based on the pilot-testing results, we asked the parent to write in the amount of time (minutes or hours) in daily total that the child spent on iPad/tablet, smart phone, playing online games on the computer, and watching TV during a typical weekday and on the weekend (Table 1). Note that for children in Study 1, we did not ask parents to report their children's screen time on the weekend because they were not attending any type of learning centers (e.g., daycare). This was because China's Covid19 mitigation measures in the Spring and Summer of 2020 strictly enforced stay-at-home orders and social distancing and young Chinese children are primarily cared for by live-in grandparents before they start preschool (Zhang et al., 2019).

To improve the accuracy of data on the children's screen time, the week prior to data collection, parents were advised to pay attention to the amount of time that their children were spending on various devices. During data collection, the parents were instructed to write down the amount of time that their children spent on each device. For parents who wrote down unspecific amount of time (e.g., 20–30 minutes), a clarification was requested immediately to obtain a specific amount of time. In cases where parents were unable to be specific, we used the average. For instance, if the parent reported that the child spent 20 to 30 minutes watching TV and follow-up clarification did not obtain more specific information (e.g., the parent could not recall specific amount of time), then it was coded as the average of 20 and 30 (i.e., 25 minutes). For parents who wrote in statements such as "doesn't watch TV," "Not allowed to watch TV," "almost never," "very rarely," or "occasionally for a few minutes," we coded these responses as 0. For parents who wrote that they children spent "no more than" a certain amount of time on a device (e.g., no more than 10 minutes watching TV) or "more than" a certain amount of time, we used the reported value (e.g., 10 minutes for "no more than 10 minutes"). Because not all devices were available to all children (e.g., some children did not have access to games), we used the daily total in hours spent on available device in the data analysis.

Behaviors of inattention and hyperactivity/impulsivity. Data on behaviors of inattention (I/A) and hyperactivity/impulsivity (H/I) were collected with the ADHD RS-IV Home Version (DuPaul et al., 1998, 2001; McGoey et al., 2007). The reliability and validity of the Chinese translation of this measure has been established (Su et al., 2015; Yi et al., 2020). The ADHD RS-IV assesses behaviors of Inattention (I/A; nine items) and behaviors of hyperactivity/impulsivity (H/I; nine items). Parents rated the frequency of behaviors on 0-3-point Likert scale (e.g., can't sit still, restless; 0 = Rarely/Never, 1 = Sometimes, 2 = Often, 3 = Always). Note that for Study 1, we excluded five items that were related to classroom and learning behaviors (e.g., Item 1: Fails to give close attention to details or makes careless mistakes in schoolwork) because the children had not started school at Baseline data collection; we additionally excluded three items that were judged by the authors to be difficult to ascertain (e.g., Item 17: Is forgetful in daily activities) because the city's Covid19 mitigating measures rendered it nearly impossible for children to have different daily activities and interactions. This resulted in a reduced number of items for I/A (four items) and H/I (six items). For Study 2 and Study 3, the full scale with all 18 items was used. The internal consistency was good: I/A (Study 1: $\alpha = .81$ at Baseline and .73 at Follow-Up), H/I (Study 1: $\alpha = .78$ at Baseline, .75 at Follow-Up, Study 2: $\alpha = .86$, and Study 3: $\alpha = .89$). In data analysis, the average of items for each subscale was used.

Data Analysis Plan

SAS software version 9.4 (SAS, 2013) was used to conduct data analysis. Prior to data analysis, we examined the distribution of key variables and all of them were normally distributed. Within each study we first ran correlation analysis to obtain Pearson correlation coefficients between the key variables. Then we ran hierarchical linear regressions to determine the relations between screen time and I/A and H/I scores by entering the variables in different steps. In the final step of the regression analysis, we additionally included the children's age, sex and family characteristics (e.g., number of children in the household, maternal education, whether the participating parent was the father or the mother, and family SES indicators) as covariates. Note that for Study 1, there were eight parents who participated at Baseline but their spouses participated at Follow-Up, we tested whether the results would be different when the sex (mother or father) of the participating parents at Baseline or Follow-Up was included as a co-variate. Because which parent provided the data was not significant, we chose to use the parent's information (mother or father) at Baseline in data analysis. We also reported partial R^2 when covariates were included.

Results

Descriptive Statistics

***Study 1*:** All but one of the 111 children were from two-parent households. The mothers were 25 to 45 years of age ($M = 33.7$; $SD = 3.7$) and the fathers were 28 to 49 years of age ($M = 34.5$; $SD = 3.9$). Over 90% of the parents had at least a college level education and had full-time employment. The children were 2.4 to 4.9 years of age at Baseline ($M = 3.6$; SD = 0.4) and were 3.9 to 6.0 years old at Follow-Up ($M = 4.8$; $SD = 0.4$). On average the children spent 1.34 hours a day using various devices ($SD = .91$; Range = 0–3.60). Girls ($n = 55$) and boys ($n = 56$) did not score differently on their screen time (Girls: $M = 1.39$, $SD = .93$, Range = 0–3.60; Boys: $M = 1.29$, $SD = .89$, Range = 0–3.60), $t = .59$, $p = .56$. At Baseline, there was no gender difference in I/A scores (Girls: $M = 0.73$, $SD = 0.58$; Boys: $M = 0.76$, $SD = 0.55$) $t = 0.25$, $p = .80$, but the difference approached statistical significance for H/I scores (Boys: $M = 1.09$, $SD = 0.54$; Girls: $M = 0.91$, $SD = 0.50$), $t = 1.83$, $p = .07$); at Follow-Up, boys scored significantly higher than girls on I/A (Boys: $M = 0.89$, $SD = 0.50$; Girls: $M = 0.68$, $SD = 0.49$), $t = 2.26$, $p < .05$) and nearly significantly higher on H/I (Boys: $M = 1.04$, $SD = 0.53$; Girls: $M = 0.85$, $SD = 0.51$), $t = 1.83$, $p = .07$).

The correlation between Baseline and Follow-Up approached statistical significance for I/A scores ($r = .18$, $p = .06$) and was significant for H/I scores ($r = .19$, $p = .04$), suggesting weak-to-modest continuity for behaviors of inattention and hyperactivity/impulsivity over 13 months. Because there was little variation in the children's age, it was not correlated with their I/A scores ($r = -.001$, $p = .99$ at Baseline and $r = -.07$, $p = .46$ at Follow-Up) or H/I scores ($r = -.10$, $p = .32$ at Baseline and $r = -.04$, $p = .65$ at Follow-Up). As shown in Table 2, at Baseline screen time was not concurrently correlated with I/A and H/I scores, but it was significantly correlated with both I/A and H/I scores at Follow-Up. In both times, I/A and H/I scores were strongly correlated (rs = .66 and .77, $p < .001$).

Table 2. Means (SDs), Ranges of Key Measures and Correlation Coefficients.

	Screen		I/A		H/I		Correlation coefficient		
Study	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	Screen-I/A	Screen-H/I	I/A-H/I
1-Baseline	1.34 (.91)	0–3.60	.75 (.56)	0–2.25	1.00 (.53)	0–2.50	−.04	.01	.66***
1-Follow-Up	NA	NA	.79 (.51)	0–2.00	.94 (.52)	0–2.17	.28**	.29**	.77***
2	1.70 (.99)	0–4.00	.89 (.52)	0–2.67	1.01 (.51)	0–2.89	.22**	.23**	.81***
3	1.58 (1.14)	0–3.50	.83 (.50)	0–2.10	.67 (.47)	0–2.00	.17**	.14*	.84***

Note. Screen = Screen time; I/A = Inattention; H/I = Hyperactivity/Impulsivity.
Study 1: The correlation between Baseline and Follow-Up was .18 for I/A scores ($p = .06$) and was .19 for H/I scores ($p < .05$).
*$p < .05$. **$p < .01$. ***$p < .001$.

***Study 2*:** All but 11 of the 172 children were from two-parent households. The children were 3.9 to 7.1 years old ($M = 4.9$, $SD = 1.0$). The mothers were 25 to 48 years old ($M = 34.0$; $SD = 3.4$) and the fathers were between 29 and 63 years old ($M = 36.2$, $SD = 4.6$). Most of the parents (88% of the mothers, 95% of the fathers) had at least a college level education. The children's age was positively correlated with screen time ($r = .21$, $p < .01$) and I/A score ($r = .17$, $p < .05$), but not with H/I score ($r = .10$, $p = .17$). There was no gender difference on I/A scores (Boys: $M = 0.92$, $SD = 0.53$; Girls: $M = 0.85$, $SD = 0.51$), $t = 0.88$, $p = 0.38$) but boys scored higher than girls on H/I (Boys: $M = 1.09$, SD = 0.50; Girls: $M = 0.89$, $SD = 0.51$), $t = 2.49$, $p < .05$). Girls and boys did not score differently on their screen time (Girls: $M = 1.64$, $SD = 1.04$; Boys: $M = 1.73$, $SD = 0.95$), $t = 0.49$, $p = .62$). As shown Table 2, screen time was positively correlated with I/A and H/I scores. Finally, I/A and H/I scores were highly correlated ($r = .81$, $p < .001$).

***Study 3*:** All but 15 children were from two-parent households. All fathers and 84.3% of the mothers worked outside of home. Their occupational prestige ranged from the lowest (e.g., housekeeper) to the highest (e.g., doctors). The children were 5.7 to 8.3 years of age ($M = 6.9$, $SD = 0.4$). Because there was little variation in the children's age, it was not correlated with screen time ($r = .06$, $p = .31$), I/A scores ($r = -.01$, $p = .79$) or H/I scores ($r = -.01$, $p = .88$). There was no difference between boys and girls in screen time (Boys: $M = 1.58$, $SD = 1.16$; Girls: $M = 1.56$, $SD = 1.13$), $t = .10$, $p = .92$, but boys scored significantly higher than girls on I/A (Boys: $M = 0.88$, $SD = 0.50$; Girls: $M = 0.77$, $SD = 0.50$), $t = 2.00$, $p < .05$ and on H/I (Boys: $M = 0.74$, $SD = 0.47$; Girls: $M = 0.60$, $SD = 0.45$), $t = 2.80$, $p < .01$. As shown in Table 2, screen time was positively correlated with I/A scores and H/I scores, while I/A and H/I scores were strongly correlated ($r = .84$, $p < .001$).

Across the three studies, the general pattern was that their average I/A scores were lower than their H/I scores, but for the children in Study 3, the pattern was reversed.

Hierarchical Linear Regression

Study 1: As shown in Table 3, screen time at Baseline alone was significant in predicting both I/A and H/I scores (Step 1). When the child's corresponding I/A or H/I scores 13 months prior were controlled for (Step 2), screen time remained significant in predicting I/A and H/I scores. Finally, when other variables were controlled for (Step 3), screen time remained significant in predicting both I/A and H/I scores. The variance accounted for was 8.0% for I/A scores and H/I scores at Follow-Up in Step 1, 12% for I/A scores and H/I scores at Follow-Up in Step 2 and 22% for I/A scores and H/I scores in Step 3. Remarkably, its magnitude remained similar across the three models and between I/A scores and H/I scores. Partial R^2 also showed that including covariates did not change the variance that screen time at Baseline accounted for in the children's I/A scores and H/I scores at Follow-Up.

Study 2: As shown in Table 4, screen time alone significantly predicted I/A and H/I scores (Step 1) and remained significant after controlling for the children's age, sex, mother's age, education level, number of children at home, monthly childrearing expenditure, and the participant's role (mother or father) (Step 2). Screen time predicted I/A scores and H/I scores in a similar manner. The variance accounted for by screen time alone was 5% for I/A scores and H/I scores; the variance accounted for by screen exposure and other covariates was 10% for I/A scores and 13% for H/I scores. Partial R^2 also showed that including covariates did not change the variance that screen time accounted for in the children's I/A scores and H/I scores.

***Study 3*:** As shown in Table 5, screen time alone was a significant predictor for both IA and H/I Scores (Step 1) and remained significant after controlling for the children's age, sex, the mother's education level and occupational prestige, number of children in the household, and the participant's role (mother or father) (Step 2). The variance explained by Step 1 was 3% for I/A scores and 2% for H/I scores; it was 5% for I/A scores and H/I scores in Step 2. Partial R^2 also showed that including covariates did not change the variance that screen time accounted for in the children's I/A scores and H/I scores.

Overall, the three studies yielded a similar result: more screen time, alone and when other variables were controlled for, positively predicted higher inattention scores and hyperactivity/impulsivity scores. A particularly noteworthy finding was from Study 1 where screen time positively predicted inattention scores and hyperactivity/impulsivity

Table 3. Summary of Regression Analysis Predicting Preschool Children's ADHD Scores at Follow-Up in Study 1 ($N = 111$).

	I/A scores at follow-up						H/I scores at follow-up					
	b	S.E.	β	*t*	Partial R^2	R^2	*b*	S.E.	β	*t*	Partial R^2	R^2
Step 1						.08						.08
Screen time at Baseline	0.16	0.05	.28**	2.91	.08		0.17	0.06	.29**	2.85	.08	
Step 2						.12						.12
Screen time at Baseline	0.16	0.05	.29**	3.03	.08		0.16	0.05	.28**	2.78	.08	
IA or H/I at Baseline	0.17	0.09	.19*	2.03	.04		0.19	0.10	.19~	1.85	.04	
Step 3						.22						.22
Screen time at Baseline	0.15	0.07	.27**	2.94	.08		0.18	0.05	.32***	3.30	.08	
IA or H/I at Baseline	0.17	0.07	.19*	2.32	.04		0.16	0.09	.16~	1.73	.04	
Child age at Baseline	−0.10	0.10	−.10	−0.92	0		−0.07	0.10	−.06	−0.72	0	
Sex												
Female	−0.23	0.09	−.23*	−2.53	.05		−0.15	0.09	−.14	−1.58	.02	
Male	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			
Mother's age	0	0.01	0	0.02	0		0	0.01	0	-0.01	0	
Mother's education	−0.10	.07	−.14	−1.21	.02		0.01	0.08	.01	0.17	0	
Childrearing expenditure	0	0	.13	1.30	.01		0	0	.24*	2.31*	.05	
Number of children												
1	0.18	0.09	.17*	1.99	.02		−0.18	0.10	−.16~	1.88	.02	
2	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			
Relation to child												
Mother	0.02	0.12	.02	0.18	0		0.14	0.14	.11	0.99	.01	
Father	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			

~$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

scores 13 months later at Follow-Up, even after corresponding inattention scores and hyperactivity/impulsivity scores at Baseline were controlled for.

Discussion

Our main goal in this paper was to examine the associations between children's screen time and behaviors of inattention and hyperactivity/impulsivity. To fill in the gaps in the literature, we obtained data on one group of preschool-aged children longitudinally, one group of preschool-aged children and one group of first graders cross-sectionally from two cities in China.

Pattern of Screen Exposure and ADHD Behaviors

We found that in terms of the amount of time that the children spent on screen devices, the reported averages and ranges from our samples were similar to recent studies on Chinese children (e.g., Liu et al., 2021; Wu et al., 2017; Xie et al., 2020). In terms of the general pattern of I/A and H/I scores, on average the preschool age children (i.e., Study 1 and Study 2) scored higher on H/I than on I/A. This is consistent with the existing literature on preschool children from Western countries such as the US, Italy and the Netherlands (e.g., McGoey et al., 2007; Re & Cornoldi, 2009; Smidts & Oosterlaan, 2007). For school age children, the pattern is consistent with existing studies on Chinese children (Su et al., 2015) but is the opposite of studies on children from Western countries (e.g., Magnússon et al., 1999). These results expand the body of literature on the notion that ADHD should be seen as a cultural construct (Dwivedi & Banhatti, 2005; Timimi & Taylor, 2004). However, because there is also argument that ADHD is not a cultural construct (Rohde et al., 2005), more research in this area is needed.

Instability of Behaviors of Inattention and Hyperactivity/Impulsivity in Early Childhood

Data from all three studies showed strong correlation between inattention and hyperactivity/impulsivity in all three cohorts in our study. The strong correlation reflects similar underlying genetic contribution to inattention and hyperactivity/impulsivity (Nikolas & Burt, 2010). According to Toplak et al. (2009) and Yi et al. (2020), there is a unitary component to ADHD behaviors that include a dimension of Inattention and a dimension of Hyperactivity/Impulsivity.

Although stability of inattention behaviors and hyperactivity/impulsivity behaviors have been commonly documented in school age children and adolescents (e.g., Döpfner et al., 2015), not much research is available on

Table 4. Summary of Regression Analysis Predicting Preschool Children's ADHD Scores in Study 2 ($N = 172$).

	I/A scores						H/I scores					
	b	S.E.	β	*t*	Partial R^2	R^2	*b*	S.E.	β	*t*	Partial R^2	R^2
Step 1						.05						.05
Screen time	0.12	0.04	.22**	2.77	.05		0.12	0.04	.23**	3.02	.05	
Step 2						.10						.13
Screen time	0.13	0.05	.25**	3.22	.05		0.13	0.04	.25**	3.03	.05	
Child age	0	0.04	0	−0.01	0		0	0.04	0	−0.01	0	
Sex of child											.03	
Female	−0.19	0.08	−.18*	−2.41	.03		−0.19	0.08	−.18*	−2.45	0	
Male	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			
Mother's age	0	0.01	−.01	−0.37	0		0	0.01	−.03	−0.40	0	
Mother's education	0.10	0.06	.13	0.12	0		0.10	0.05	.13~	1.89	.01	
Childrearing expenditure	0.05	0.03	.13~	1.71	0		0.05	0.03	.13	1.59	.02	
Number of children												
1	−0.09	0.09	−.09	0.30	.01		−0.10	0.09	−.08	−1.07	.01	
2	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			
Relation to child												
Mother	0.10	0.08	.10	0.21	.01		−0.10	0.08	−.10	−1.34	.01	
Father	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			

Note. Childrearing expenditure = percentage of monthly income the family spent on the child.
~$p < .10$. *$p < .05$. **$p < .01$.

Table 5. Summary of Regression Analysis Predicting ADHD Scores in Study 3 ($N = 313$).

	I/A scores						H/I scores					
	b	S.E.	β	*t*	Partial R^2	R^2	*b*	S.E.	β	*t*	Partial R^2	R^2
Step 1						.03						.02
Screen time	0.07	0.02	.17**	3.05			0.06	0.02	.14*	2.47	.02	
Step 2						.05						.05
Screen time	0.07	0.02	.16**	2.97	.03		0.06	0.02	.15*	2.48	.02	
Child age	−0.04	0.07	−.03	−0.50	0		−0.01	0.06	−.01	−0.20	0	
Sex					.01						.02	
Female	−0.11	0.06	−.11*	−2.03			−0.15	0.05	−.15**	−2.73		
Male	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			
Mother's education	−0.08	0.04	−.14~	−1.08	.01		−0.07	0.04	−.13~	−1.78	0	
Parent occupational prestige	0	0.05	0	−0.08			0	0.04	.01	0.11	0	
Number of children					0						.01	
1	0.01	0.15	.01	0.06			0.07	0.15	.06	0.45		
2	0	0.14	0	0.01			0	0.14	0	0		
3	−0.10	0.14	−.10	−0.74			−0.10	0.14	−.10	−0.77		
4	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			
Relation to child					0							
Mother	−0.02	0.06	−.02	−0.37			0	0.06	0	0.05	0	
Father	0 (Ref.)	0 (Ref.)	0 (Ref.)				0 (Ref.)	0 (Ref.)	0 (Ref.)			

~$p < .10$. *$p < .05$. **$p < .01$.

whether there is stability in ADHD behaviors for children aged 3 years to age 4 years. As part of our study, we aimed to fill in the gaps in the literature by including a longitudinal dataset on children who are in preschool ages (i.e., from 3.6 to 4.8 years of age in Study 1). We found that there was a weak stability in Inattention behaviors and hyperactivity/impulsivity behaviors over the course of 13 months. This was interesting because the children's average inattention scores and average hyperactivity/impulsivity scores at Baseline were similar to their respective average scores at Follow-Up. So, the lack of strong behavioral stability was likely that the children displayed different types of ADHD behaviors at the two time points. To explain why the children showed different ADHD behaviors at the two time points, we offer a developmental speculation and a contextual speculation.

Developmentally, behaviors of inattention and hyperactivity/impulsivity are rather instable during this age (Halperin et al., 2012). Specifically, Halperin and associates suggested that preschool age was a developmental stage when symptoms of ADHD first became evident. Additionally, they suggested that because at this age, children's brain is more susceptible to environmental influences and physical exercise, both of which could facilitate structural and functional development. As such, instability in the behaviors of ADHD is likely not an exception.

Contextually, according to Hinshaw (2018), the expressions of ADHD behaviors are influenced by transactional patterns with family, school, peer interactions and neighborhood characteristics and policy. As such, a drastically altered social context likely influences the expression of ADHD behaviors. The Chinese government's response to Covid19 had certainly led to major changes in all levels of a young child's social ecology. As such, we speculate that the drastic different circumstances caused by Covid19 measures surrounding the two time points of the study may also be responsible. Specifically, at Baseline data collection, the children had already experienced roughly 9 months of Covid mitigating measures such as stay-at-home order, mask wearing and social distancing. These measures drastically restructured the children's experiences in every possible way. As such, at Baseline, the children's behaviors likely were affected by the Covid mitigation measures. Even after the children entered preschool in September of 2020, the school continued to strictly enforce mask wearing and social distancing measures for several months. At Follow-Up data collection 13 months later, the children's routines and school activities had largely returned to normal. As a result, there were major differences between the two time points in children's social interactions, classroom activities and the parents' vigilance level. These differences likely have contributed to the extent to which ADHD behaviors were expressed and observed/observable.

In short, the children's developmental stage and their experiences during and after Covid19 measures could have lowered the correlations between in the children's ADHD behaviors at the two points. If our second speculation is supported by other studies, it would offer a fresh perspective that Covid19 mitigation measures affected young children's behaviors.

Screen exposure as a Risk for ADHD Behaviors

Data from the two older cohorts, as well as longitudinal follow-up from the youngest cohort, yielded evidence that screen time positively correlated with behaviors of inattention and behaviors of hyperactivity/impulsivity. This finding is consistent with the existing literature (Wu et al., 2017; Xie et al., 2020). Thus, our study adds to the body of existing literature on screen exposure and young children's ADHD behaviors.

However, data from the youngest cohort did not show a correlation between screen time and ADHD behaviors at Baseline. Specifically, for the youngest cohort (i.e., Study 1), there was no concurrent association between screen time and Inattention behaviors or hyperactivity/impulsivity scores at age three, but there were statistically significant longitudinal correlations between screen time at age three and Inattention behaviors and hyperactivity/impulsivity behaviors at age four. These findings have not been reported elsewhere. Because the existing literature on has focused on children who were typically older than our sample, we know of no studies that we could draw upon to reliably gauge our finding. For instance, the study by Tamana et al. (2019) included children who were 5 years old, while the study by Xie et al. (2020) included children who were 3 to 6 years old. Both studies reported that children who spent more time on screen devices had more ADHD behaviors. However, neither study treated screen time as a continuous variable. Instead, both studies divided screen time into two categories (e.g., $>$60 minutes a day and $<$60 minutes a day).

We speculate that rapid brain maturation and rapid development of executive functioning during the preschool years may play a role (Anderson & Reidy, 2012). Because children's brain size reaches about 90% of its adult size by age 5 years (Dekaban & Sadowsky, 1978), it is possible that rapid shift in attending to various sound, visual perceptual stimuli may be neurobiologically accommodated by the rapidly developing brain and over time, this may lead to changes in children's neurological functioning, resulting in lagged behavioral expressions of ADHD. Indeed, there is evidence that over time, preschool children's attention abilities are altered by screen time (Zivan et al., 2019). Because our data were collected during the timeframe of rapid brain maturation, more research is needed to determine if this finding applies to different age groups or over a time span shorter or longer than 13 months.

To account for the discrepancy in findings between Baseline in Study 1 and Studies 2 and 3, we speculated that difference in age, timing and how we measured ADHD might be at play. Specifically, in Study 1, we only included children who were on average 3.6 years old at Baseline; in Study 2, we included children who were 4.9 years old on average, and in Study 3 the children were nearly 7 years old. Differences in the children's ages are related to differences in their school experiences (e.g., what teachers expect them to do, classroom sizes and their understanding of rules) and parental expectations of behaviors (Smith et al., 2020). In Study 1, the children had not started school at Baseline data collection. Relatedly, because the children in Study 1 had no schooling experiences at Baseline, we modified the ADHD measures by excluding items that described children's ADHD behaviors in classroom settings or in learning tasks. We also excluded items that we deemed to be difficult to assess because the children had not really had the opportunity to interact with peers and people outside of their home due to Covid19 measures. These differences could be responsible for the discrepancy. Future studies that utilize ADHD measures that are less sensitive to school setting could help address this issue.

Limitations

While all three studies had the strength of an exceptionally high response rate, several limitations need to be kept in mind. First, although the method that we used to gather data on screen exposure is consistent with exiting literature, the method was crude and needs to be further refined to gather information on the content of the children's screen exposure or the role of the parents in the children's screen exposure. Second, our studies were conducted in two schools in two major Chinese cities that are among the most affluent cities in China. We do not know if our findings reflect experiences of children who live in different conditions (e.g., rural regions). Third, in Study 1, we excluded from the ADHD measure eight items, which resulted a decrease in the number of items for inattention and hyperactivity/impulsivity. How this might have impacted the results is unknown. As such, caution is warranted in interpreting the findings. Fourth, and finally, like any studies that relied on parents to provide data on their children, social desirability might lead to underreporting of issues that parents perceive to reflect poorly of their parenting competency or their children but over-reporting to questions that may present them in a more positive light. These limitations may prevent findings from our study from being generalized.

Implication and Future Direction

Because of the noticeable difference in the magnitude of screen time-ADHD scores correlations between Study 1 and Studies 2 and 3, and the finding that concurrent screen time-ADHD score correlations were weaker than longitudinal correlations in Study 1, we recommend more longitudinal research be conducted for children in different age groups. Additionally, notwithstanding its intuitive appeal, simply measuring the amount of time is a crude method as children's screen experience can vary greatly from passive (e.g., watching TV), interactive (e.g., playing interactive games) to social (e.g., chatting with friends and family). Future research should start to investigate the function and nature of children's interactions with various devices in order to develop more sophisticated tools to measure children's screen experiences. The protocol that was commonly used in the existing studies focused on duration of time that a child spent on a device. This approach does not capture important aspects of children's screen experiences. For instance, what types of cognitive, emotional and social demands do young children's interactions with various devices entail? What are the purposes, from a parenting perspective, of digital devices in childrearing? Obtaining data in these areas will be a valuable step towards detecting specific mechanisms that link screen time and ADHD behaviors. Additionally, because some studies have shown that screen exposure has a dose effect on ADHD behaviors (Tamana et al., 2019; Xie et al., 2020), more research that is focused on possible dose effect of screen exposure would help with more concrete parenting and policy recommendations.

Since digital, mobile and screen device use may take away children's time from other activities (e.g., physical activities, sleeping, social interactions with others), screen time may have a trade-off effect on children's physical, social, cognitive and behavioral development (e.g., Fang et al., 2019; Raman et al., 2017). Thus, it is possible that screen time leads to decrease in other activities that children need for healthy cognitive development. Future studies should focus on possible moderating effect of changes in other activities in the link between screen exposure and ADHD behaviors.

Within the literature, the relation between screen time and ADHD behaviors has sometimes been conceptualized as bidirectional such that children with ADHD behaviors are also more likely to be drawn to screen devices (Beyens et al., 2018; Weiss et al., 2011). One way to be more certain about the directionality is to compare the association between screen time and ADHD behaviors concurrently and longitudinally. A screen time to ADHD behavior direction is supported if the concurrent link between association is absent but a delayed link is present. This is exactly what we uncovered in Study 1. As such, our finding offers tentative evidence that screen exposure may contribute to the emergence of future ADHD behaviors. This conclusion can be further strengthened if there is a lack of association between Baseline ADHD behaviors and Follow-Up screen time. Unfortunately, our study was not designed to test this. We recommend more research that focuses on this age group's screen experiences and ADHD behaviors to illuminate their relationship.

Finally, behaviors of ADHD not only affect children themselves but also their families (Harpin, 2005). Because our findings suggest that screen exposure time was a significant risk factor, it is important that parents be mindful of managing their children's device use. Interventions that target parents' role in the increase in children's screen exposure will be valuable. For instance, because parents are increasingly relying on screen devices to engage with their children and to manage their children's emotions (Elias & Sulkin, 2019; Kabali et al., 2015; Radesky et al., 2016), psychoeducation might be valuable in informing parents the potential harm of screen exposure to their children.

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