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Screen time and autistic-like behaviors among preschool children in China

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ABSTRACT

Screen time is becoming increasingly common in daily life. Early and excessive screen use has raised growing concerns for children's neuropsychological development. The purpose of this study was to evaluate the association between exposure to screen time in early life and the presence of autistic-like behaviors among preschool children. 29,461 child-caregiver dyads at kindergartens in Longhua New District of Shenzhen, China, were enrolled in this cross-sectional study. Information concerning socio-demographic characteristics, frequency and duration of children's electronic screen exposure for each year since birth, and autistic-like behaviors (measured by the Autism Behavior Checklist) were collected using a self-administered structured questionnaire completed by the primary caregivers. A series of logistic regression models assessed the association between screen time and autistic-like behaviors. Results indicated that younger initial age, longer daily screen time and longer cumulative years of screen exposure since birth were associated with the presence of autistic-like behaviors at preschool age. The risk was enhanced with the increase of both daily screen time and cumulative years of screen exposure during preschool period. Moreover, the cross-over analysis indicated that the first three years following birth might be a sensitive period for children when screen exposure increases the risk of experiencing autistic-like behaviors. In conclusion, our study implied that screen exposure in early life might increase the occurrence of autistic-like behaviors among preschoolers. These findings support the need for early interventions into preschoolers' screen use, however longitudinal studies are necessary to further confirm the causal relationship between early screen time and the incidence of later autistic-like behaviors among preschool children.

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Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by impairments in social interaction, communication, and repetitive behavioral patterns (Marty & Segal, 2015). With a global prevalence of approximately 1% (Elsabbagh et al., 2012), lifelong impairments of ASD create substantial functional and economic burdens for individuals, families and the society (Buescher et al., 2014; Lord et al., 2018). Recently, a genetic overlap was confirmed between clinical ASD and sub-threshold autistic-like behaviors (Bralten et al., 2018), and it has been suggested that the severity of autistic-like behaviors is continuously distributed from mild to severe within the general population (Suzuki et al., 2018; Waterhouse et al., 1996). This reflects the identification of continuums in impairments on other cognitive and social abilities (Constantino & Todd, 2003; Gokcen et al., 2014; Haraguchi et al., 2019; Taylor et al., 2013). A clinical diagnosis of ASD is difficult to confirm until children are aged 4–5 years (Zwaigenbaum & Penner, 2018). However, early autistic-like behaviors such as eye fixations decline and avoidant responses to touch, can be identified in infancy or toddlerhood, with early identification and intervention facilitating improved prognosis (Mammen et al., 2015; Yoon & Vouloumanos, 2014). Therefore, the exploration of risk factors for the onset of autistic-like behaviors among the general population is important.

To date, there has been wide recognition that ASD and autistic-like behaviors are both genetic and environmental in origin (Bolte et al., 2019; Lai et al., 2014). Emerging research suggests that early environmental factors can play an important role in the onset of autistic-like behaviors (Bolte et al., 2019; Slobodin et al., 2019). One important environmental factor appears to be children's screen time, which may cause disparities in early neuropsychological development (Lissak, 2018; Stiglic & Viner, 2019). For instance, longer duration and younger initial age of screen viewing have been found among clinical ASD children compared with typically developing children (Chonchaiya et al., 2011; Must et al., 2014). Interestingly, several cases have been reported where young children with autistic-like behaviors were re-assessed as non-autistic after a few months of screen removal and increases in social interaction (Harle, 2019; Numata-Uematsu et al., 2018). However, to our knowledge, little attention has been given to investigating the influence of early screen exposure during the first few years of early life upon children's neuropsychological development (Slobodin et al., 2019). Given that the newborn brain undergoes dramatic growth and development with considerable plasticity in the initial years of life (Wen et al., 2019), this period has proved to be critical for neurodevelopment and behavior establishment (Jones et al., 2013). As such, due to the increasing access to and younger initial age of screen exposure (Kaur et al., 2019), we sought to explore whether electronic screen exposure in early life, especially in postnatal three years, was related to autistic-like behaviors in preschool children.

Methods

Study population

The participants of the study were recruited from the 2017 survey of the Longhua Child Cohort Study (LCCS). The LCCS was a population-based child cohort study among preschool children in Longhua District in Shenzhen, China, which aimed to investigate

the relationships between a range of family and school variables and their psycho-behavioral development of young children. After excluding the children with missing data, 29,461 child-caregiver pairs were included for analysis. Ethical approval was obtained from the Ethics Committee of the School of Public Health at Sun Yat-sen University (ethics clearance No.: 2015-016), and all participants gave full informed written consent to participate in the study.

Data collection

Data were collected from a structured questionnaire completed by the children's primary caregiver. The questionnaire acquired information about parents' socio-demographic characteristics (including age at child's birth, education level, family monthly income, and marital status), frequency and duration of children's electronic screen exposure in each year, children's general information (such as gender, birth date), and autistic-like behaviors.

Measurement of exposure to electronic screen

Exposure to electronic screens each year since the child's birth was assessed retrospectively by caregivers based on the same set of questions above (see Table 1). Variables including initial age of screen exposure, daily average screen time and cumulative years of screen exposure were calculated to describe the screen exposure.

Measurement of autistic-like behaviors

Children's autistic-like behaviors were assessed using the Autism Behavior Checklist (ABC) (Bravo Oro et al., 2014; Krug et al., 1980). This is a widely used scale for screening autistic children in research and clinical practice. The Chinese version of ABC was introduced into China by Yang et al. (1993), with an interrater reliability of 0.785, and a test-retest reliability of 0.789 in Chinese children. The scale consists of five subscales including sensory, relating, body and object use, language, and social and self-help skills. The 57 items are distributed randomly on the checklist with a weighted score from 1 to 4,

Table 1. Questions and options for screen exposure (0 to 1 years of age as an example).

No.	Questions	Options
Q1.1	Did your child watch television at age 0–1 years?	0 = 'no' 1 = 'yes'
Q1.2	If 'yes' was chosen for (1.1), how long on average did your child spend watching television per day at age 0–1 years?	1 = '< 30 min' 2 = '30–60 min' 3 = '60–90 min' 4 = '90–120 min' 5 = '> 120 min'
Q2.1	Did your child use handheld electronic devices (e.g. mobile phone, tablet, video games, etc.) at age 0–1 years?	0 = 'no' 1 = 'yes'
Q2.2	If 'yes' was chosen for (2.1), how long on average did your child spend using handheld electronic devices (e.g. mobile phone, tablet, video games, etc.) per day at age 0–1 years?	1 = '< 30 min' 2 = '30–60 min' 3 = '60–90 min' 4 = '90–120 min' 5 = '> 120 min'

and scores of each subscale are added up to obtain the overall score. The Cronbach alpha for the total score in this study was 0.904. A previous study in China recommended the cut-offs of score ≥ 31 and score ≥ 62 for screening and diagnosis of ASD respectively (Yang et al., 1993). Considering that the survey was conducted in mainstream kindergartens, and in order to increase the sensitivity of the scale without missing the borderline cases with autistic-like behaviors, a score of 31 was selected as the cut-off in our study for identifying children with autistic-like behaviors.

Covariates

The following confounding covariates were included in the analysis: child's age and gender, parents' age at child's birth, parents' education level, family monthly income and parental marital status.

Statistical analysis

For continuous variables, we reported their means and standard deviation (SD), and for categorical variables, numbers and proportions were presented. Chi-square tests and Student's t-tests were applied to compare the socio-demographic characteristics between children with and without autistic-like behaviors. To examine the associations between exposure to electronic screens (i.e. exposure to electronic screen or not, daily average screen time and initial age of screen exposure) and autistic-like behaviors, a series of logistic regression models were run after adjusting for the aforementioned covariates. Moreover, we conducted further analyses to probe into the sensitive period and cumulative effect between exposure to electronic screen and autistic-like behaviors. Firstly, children were categorized into eight subgroups depending on different permutations and combinations of exposure (Yes) versus no exposure (No) in each year, over a three-year period following birth. The possibility of sensitive periods was investigated by using logistic regression to examine the likelihood of the presence of autistic-like behaviors for each of these eight subgroups. Secondly, children were divided into three subgroups according to daily average screen time (<60, 60–120, >120 minutes), and logistic regression was used to examine the relationship between cumulative years of screen exposure and autistic-like behaviors within each subgroup. The results were presented as odds ratio (OR) with 95% confidence intervals (CI). Statistical significance was set at a two-tailed test with $p < .05$. Data management and statistical analysis were carried out using SPSS (version 25.0; SPSS Inc., Chicago, IL, USA).

Results

Social-demographic characteristics of participants by status of autistic-like behaviors

Table 2 displays an overview of the social-demographic characteristics of the participants. Of the 29,461 children, 875 (2.97%) had autistic-like behaviors. Significant differences were found on child's age, parents' age at birth, education level, marital status, and

Table 2. Social-demographic characteristics of the participants by status of Autistic-like behaviors.

Characteristics	Total (N = 29 461)	Autistic-like Behaviors		χ^2/t	p-Value
		No (N = 28 586)	Yes (N = 875)		
Child's age [mean \pm SD (years)]	29 461	4.60 \pm 0.88	4.33 \pm 0.89	8.98	<0.001
Maternal age at child's birth [mean \pm SD (years)]	29 461	27.17 \pm 4.22	26.01 \pm 4.52	7.46	<0.001
Paternal age at child's birth [mean \pm SD (years)]	29 461	29.73 \pm 4.81	28.80 \pm 5.07	5.36	<0.001
Child's gender [n (%)]				22.46	<0.001
Male	16 000	15 456 (54.1)	544 (62.2)		
Female	13 461	13 130 (45.9)	331 (37.8)		
Maternal education level [n (%)]				95.78	<0.001
Junior high school or lower	7367	7041 (24.6)	326 (37.3)		
High school	8604	8333 (29.2)	271 (31.0)		
College	7236	7073 (24.7)	163 (18.6)		
Undergraduate or above	6254	6139 (21.5)	115 (13.1)		
Paternal education level [n (%)]				114.61	<0.001
Junior high school or lower	6076	5787 (20.2)	289 (33.0)		
High school	7954	7689 (26.9)	265 (30.3)		
College	6777	6624 (23.2)	153 (17.5)		
Undergraduate or above	8654	8486 (29.7)	168 (19.2)		
Monthly household income [n (%)]				91.15	<0.001
\leq ¥5,000	4341	4150 (14.5)	191 (21.8)		
¥5,000–10,000	7779	7487 (26.2)	292 (33.4)		
¥10,001–15,000	5645	5479 (19.2)	166 (19.0)		
¥15,001–20,000	4083	4006 (14.0)	77 (8.8)		
>¥20,000	7613	7476 (26.1)	149 (17.0)		
Parental marital status [n (%)]				16.67	<0.001
Married	28 417	27 595 (96.5)	822 (93.9)		
Unmarried/Divorced/ Widowed/Remarried	1044	991 (3.5)	53 (6.1)		

χ^2 Value for Chi-square test. t: Value for Student's t-test. SD: Standard Deviation. n (%): Number (proportion).

monthly household income between children with and without autistic-like behaviors. See more details in [Table 2](#).

Associations between electronic screen exposure and autistic-like behaviors

Table 3 presents the associations between electronic screen exposure and autistic-like behaviors in the regression models after controlling for the covariates. Compared with children without screen exposure, those who had ever had exposure to electronic screens had a higher risk of autistic-like behaviors (AOR = 1.61, 95% CI = 1.18–2.21). More specifically, children with average screen times of 60–120 minutes (AOR = 1.60, 95%CI = 1.16–2.22) or >120 minutes (AOR = 2.42, 95%CI = 1.73–3.40) per day were significantly more likely to exhibit autistic-like behaviors than those with average screen times of less than 60 minutes per day. A higher risk of autistic-like behaviors was also found among those exposed to electronic screens initially during the 0-1-year-old period (AOR = 2.13, 95% CI = 1.54–2.94), compared with those who had never been exposed to an electronic screen.

Table 3. Associations between electronic screen exposure and autistic-like behaviors.

Variables	Total (N = 29 461)		
	No. of Children	Cases (N%)	AOR (95%CI)
Expose to electronic screen			
No	2024	42 (2.1)	Ref
Yes	27 437	833 (3.0)	1.61 (1.18, 2.21) **
Daily average screen time (minutes)			
Never	2024	42 (2.1)	Ref
<60	9195	215 (2.3)	1.24 (0.88, 1.73)
60–120	13 280	397 (3.0)	1.60 (1.16, 2.22) **
>120	4962	221 (4.5)	2.42 (1.73, 3.40) ***
Initial age of screen exposure (year-old)			
Never	2024	42 (2.1)	Ref
0 to 1	10 939	471 (4.3)	2.13 (1.54, 2.94) ***
1 to 2	6685	174 (2.6)	1.32 (0.94, 1.86)
2 to 3	4740	118 (2.5)	1.37 (0.96, 1.97)
After 3	5073	70 (1.4)	0.87 (0.59, 1.28)

AOR: Adjusted odds ratio. OR with adjustment for child's age, child's gender, maternal and paternal age at child's birth, maternal and paternal education level, monthly household income, parental marital status. CI: Confidence intervals. Ref: Reference. *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

Table 4. Associations between electronic screen exposure postnatal 0 to 3 years and autistic-like behaviors.

Screen Exposure from 0 to 3 years old				Total (N = 29 461)	
Age 0–1	Age 1–2	Age 2–3	No. of Children	Cases (N%)	AOR (95%CI)
No	No	No	7097	112 (1.6)	Ref
Yes	No	No	804	18 (2.2)	1.24 (0.75, 2.06)
No	Yes	No	490	12 (2.4)	1.35 (0.73, 2.47)
No	No	Yes	4740	118 (2.5)	1.51 (1.16, 1.96) **
Yes	Yes	No	581	21 (3.6)	1.96 (1.22, 3.17) **
No	Yes	Yes	6195	162 (2.6)	1.46 (1.14, 1.87) **
Yes	No	Yes	699	29 (4.1)	2.26 (1.48, 3.43) ***
Yes	Yes	Yes	8855	403 (4.6)	2.46 (1.99, 3.05) ***

AOR: Adjusted odds ratio. OR with adjustment for child's age, child's gender, maternal and paternal age at child's birth, maternal and paternal education level, monthly household income, parental marital status. CI: Confidence intervals. Ref: Reference. **: $p < 0.01$; ***: $p < 0.001$.

Associations between electronic screen exposure postnatal 0 to 3 years and autistic-like behaviors

Table 4 illustrates the likelihood of the presence of autistic-like behaviors for seven combinations of screen exposure during aged 0–1, 1–2 and 2–3 years. Children who exposed to electronic screens in the postnatal third year only, or in any combination of two or three years all exhibited a statistically significant higher risk of autistic-like behaviors, compared with those without any screen exposure postnatal 0 to 3 years (with adjusted ORs ranging from 1.46 to 2.46). See more details in Table 4.

Table 5. Associations of daily average screen time and cumulative years of screen exposure with autistic-like behaviors.

Daily Average Screen Time(minutes)	Cumulative Years of Screen Exposure(years)	Total (N = 29 461)		
		No. of Children	Cases (N%)	AOR (95%CI)
<60	Never	2024	42 (2.1)	Ref
	1	1530	37 (2.4)	1.14 (0.72, 1.79)
	2	2126	61 (2.9)	1.51 (1.01, 2.26) *
	3	2455	55 (2.2)	1.24 (0.82, 1.86)
	4	1780	35 (2.0)	1.08 (0.68, 1.70)
	5 or more	1304	27 (2.1)	1.45 (0.87, 2.42)
	P for trend			0.340
60–120	1	513	19 (3.7)	1.70 (0.97, 2.98)
	2	1693	41 (2.4)	1.15 (0.74, 1.78)
	3	3292	91 (2.8)	1.38 (0.94, 2.00)
	4	3701	121 (3.3)	1.63 (1.14, 2.34) **
	5 or more	4081	125 (3.1)	2.10 (1.44, 3.05) ***
	P for trend			<0.001
>120	1	142	5 (3.5)	1.46 (0.56, 3.77)
	2	403	14 (3.5)	1.52 (0.82, 2.84)
	3	1065	42 (3.9)	1.85 (1.19, 2.88) **
	4	1384	76 (5.5)	2.66 (1.80, 3.93) ***
	5 or more	1968	84 (4.3)	2.73 (1.82, 4.10) ***
	P for trend			<0.001

AOR: Adjusted odds ratio. OR with adjustment for child's age, child's gender, maternal and paternal age at child's birth, maternal and paternal education level, monthly household income, parental marital status. CI: Confidence intervals. Ref: Reference. *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$

Associations of daily average screen time and cumulative years of screen exposure with autistic-like behaviors

As shown in Table 5, among subgroups with the same cumulative years of screen exposure (i.e. 3, 4, 5 or more), the risk of developing autistic-like behaviors enhanced with the increase of daily average screen time. Moreover, compared with the reference group of those who had no screen exposure, the likelihood of a child exhibiting autistic-like behaviors was significantly higher when a child had an average daily screen time of less than 60 minutes a day and had been exposed to electronic screens for 2 years (AOR = 1.51, 95%CI = 1.16–1.96); when the child had an average daily screen time between 60 and 120 minutes and had been exposed to electronic screens for 4 years (AOR = 1.63, 95%CI = 1.14–2.34) or over 4 years (AOR = 2.10, 95%CI = 1.44–3.05); and when the child had an average daily screen time of over 120 minutes and had been exposed to electronic screens for 3 years (AOR = 1.85, 95%CI = 1.19–2.88), 4 years (AOR = 2.66, 95%CI = 1.80–3.93) and over 4 years (AOR = 2.73, 95%CI = 1.82–4.10).

Discussion

There is emerging evidence that electronic screen exposure has an impact upon various indicators of preschoolers' neuropsychological development. For example, several previous studies suggested that early screen exposure among infants was correlated with subsequent low communication scores (Duch et al., 2013) and

language delay (Zimmerman et al., 2007), while other studies showed that children with screen exposure during early life had lower cognitive development (Aishworiya et al., 2019; Tomopoulos et al., 2010). In addition, early television exposure has been associated with children's attentional problems (Christakis et al., 2004; Hermawati et al., 2018; Tamana et al., 2019). Similarly, a study by Mistry et al. (2007) reported that sustained television exposure starting from 30 to 33 months of age was related to subsequent behavioral outcomes at age 5.5 years. Likewise, Chonchaiya et al. (2011) reported that children with ASD began to watch television significantly earlier than controls, and there is evidence that intensive early screen exposure may be a causal factor for the development of symptoms of autistic spectrum disorder (Harle, 2019; Hermawati et al., 2018). Our study builds upon this body of literature by revealing that electronic screens exposure in early life, especially from 0 to 3 years old, is significantly correlated with the presence of autistic-like behaviors among preschool children. Additionally, our results showed that the strength of this association is enhanced with the increase of daily screen time in the period of age 0–1, 1–2 and 2–3 years as well as the increase of cumulative years of screen exposure when the daily average screen time is over 60 minutes a day.

When exposure during a certain period results in a stronger impact on subsequent disease risk than it would at other times, this period is regarded as a sensitive period for exposure (Ben-Shlomo et al., 2014; Braveman & Barclay, 2009). Intriguingly, as shown in Table 2, compared to those never exposed to electronic screen, preschoolers initially exposed to electronic screen from aged 0 to 1 (AOR = 2.13, 95% CI = 1.54 ~ 2.94) had a significantly increased risk of autistic-like behaviors, while those initially exposed to electronic screens from aged 1 to 2 (AOR = 1.32, 95% CI = 0.94 ~ 1.94) as well as aged 2 to 3 (AOR = 1.37, 95% CI = 0.96 ~ 1.97) increased the risk of autistic-like behaviors with marginal significance, but those initially exposed to electronic screen after aged 3 years displayed no significant risk of autistic-like behaviours. Moreover, the cross-over analysis (Table 4) showed that screen exposure in the postnatal third year only, or in any combination with two or three years out of the postnatal three years translated into a higher risk of preschool autistic-like behaviors. However, screen exposure only in the postnatal first or second year was not significantly associated with the higher risk of preschool autistic-like behaviors, which might be due to small sample size in the two subgroups. In line with our findings, previous observational studies in humans showed that exposure to fast-paced television in the first 3 years of life was linked to subsequent attentional deficits in later childhood (D. A. Christakis et al., 2018). These findings might be explained by the fact that the first few years of life are the most crucial to brain function developments (D. A. Christakis et al., 2018), which support the American Academy of Pediatrics recommendation that children under 18 months should avoid screen exposure (Guram & Heinz, 2018). Similarly, the World Health Organization (Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children under 5 Years of Age, 2019), the Italian (Bozzola et al., 2018) as well as the Canadian Paediatric Society (2017) have suggested the guideline that screen time for children younger than 2 years is not advocated. Taken together, it is hypothesized that the postnatal three years might be the sensitive period in early life for screen exposure increasing the

risk of preschool autistic-like behaviors. Our findings, if adequately confirmed in further studies, can help to strengthen and improve these recommendations.

Several potential mechanisms on adverse associations between electronic screen exposure in early life and autistic-like behaviors have been proposed. First, experiments have showed that the role of live social interaction in early speech and language learning cannot be replaced by exposing to social interactions using screen-based media (Kuhl, 2007; Kuhl et al., 2003, 1991). Similarly, children who spend more time on electronic screens have reduced audible language (D. Christakis et al., 2009), conversation (Mendelsohn et al., 2008), and social interactions with caregivers and peers (Gerhold et al., 2002). This is problematic given that all of these experiences are critical to the development of young children's social skills (Zhao et al., 2018). Second, the engagement in social media has been shown to result in irregular bedtime and shorter night-time sleep durations (Thompson & Christakis, 2005; Wu et al., 2017). In addition, blue light from screens suppresses the rise of melatonin secretion, lengthening sleep latency and impairing morning alertness (Chang et al., 2015). Poor sleep has been shown to be a risk factor for behavioral problems and psychological symptoms, and specifically for ASD behaviors (Vandendriessche et al., 2019; Wu et al., 2017). Third, specific characteristics of media exposure such as rapid screen changes resulting in excessive non-normative stimulation have been hypothesized to have direct, adverse effects on the developing brain (D. A. Christakis, 2009). Moreover, audio-visual output from screen media competes with social audio-visual processing of infants and therefore has a negative impact on the development of the social brain and higher cognitive pathways (Heffler & Oestreicher, 2016). Finally, increased screen time has been linked to lower integrity of the brain white matter tracts which supported language and literacy skills among preschool children (Hutton et al., 2019).

This study examined the association between electronic screen exposure in early life and the presence of autistic-like behaviors in large sample size of Chinese preschool children, which also explored the cumulative effect and the sensitive period of screen exposure in novelty, but despite this strength, several limitations deserve comment. First, as a cross-sectional study, the design precluded us drawing any strong conclusions on causal inferences, and longitudinal research is warranted to further verify assumption of causality. Second, the data collected about electronic screen exposure were retrospective and relied on parent-reported measures, which might be prone to recall bias and the interpretation requires caution and caveats. Measurement for screen time would be more accurate recording by electronic devices used by children. Third, the current study merely assessed the effect of screen time, omitting information on the content and context during screen time, which may mediate the effect incurred by screen exposure (Christakis, 2009; Zhao et al., 2018). Fourth, the family history of mental health problems, acting as a risk factor of ASD, was not available in our dataset and was not controlled for in the analyses, which may be a potential confounder of the findings.

In conclusion, our study found that a younger age of initial electronic screen viewing, longer daily screen time and longer cumulative screen time in preschool period are associated with increased risk of autistic-like behaviors. The present study offered preliminary guidance for the supervision of preschoolers' electronic screen use, but longitudinal studies are necessary to assess causality. The findings do

support more attention being paid to the boundaries on acceptable levels of daily screen time in order to offset the adverse consequences due to excessive or improper screen use among preschool children.

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Disclosure statement

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