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Associations between screen time and cognitive development in preschoolers

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Abstract

Objectives: To examine the cross-sectional associations between screen time and cognitive development in preschoolers.

Methods: Participants were 97 preschoolers (36 to 60 months) in Alberta and Ontario, Canada in the supporting Healthy physical AcTive Childcare setting (HATCH) study. The time that children spent watching television, videos or DVDs (television time) or playing video or computer games (video game time) on a television, computer, or portable device was assessed using a parental questionnaire. Television time and video game time were summed to calculate total screen time. Adherence to the screen time recommendation (≤1 hour/day) of the Canadian 24-Hour Movement Guidelines was calculated. Expressive vocabulary and working memory were assessed using the Early Years Toolbox. Due to the distribution of working memory, it was categorized as a binary variable based on the median score. The associations between screen time and cognitive development were examined using mixed models (expressive vocabulary) or generalized mixed models (working memory).

Results: Screen time was not associated with expressive vocabulary. Preschoolers who had higher total screen time were less likely to have better working memory (OR=0.52; 95%CI:0.31, 0.88), despite the null associations for television time (P=0.155) and video game time (P=0.079). Preschoolers who met the screen time recommendation were more likely to have higher working memory capacity (OR=3.48; 95%CI:1.06, 11.47), compared to those who did not meet the recommendation.

Conclusion: Limiting total screen time to no more than one hour per day may facilitate working memory development in preschoolers. Screen time may be unrelated to expressive language development in this age group.

Keywords: *Contemporary technologies; Early childhood; Executive function; Media exposure; Screen use; Young children*

Early childhood is a period of rapid brain growth and maturation. The cognitive skills that emerge in early childhood are essential for physical, mental, and social well-being, as well as education and workplace success later in life (1). Specifically, associations between executive functions (i.e., a collection of cognitive skills, including working memory, inhibitory control,

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and cognitive flexibility [2]) in early childhood and school readiness, academic performance, behavioural conduct, as well as social-emotional competence in later childhood have been reported (3). As such, factors that affect cognitive development in early childhood may have lasting impact on overall wellness. To facilitate children's optimal health and development, it is important to identify and address these antecedents.

Excessive use of screen-based devices may impede cognitive development in early childhood (4). A recent systematic review and meta-analysis based on 42 studies with children under 12 years found that screen time was negatively associated with language development and age was not a moderator (5). However, most of the studies (36/42) included in this review have focused on receptive language and general linguistic skills, while the associations with expressive language were only examined in six studies (negative associations: n=2; null associations: n=4), all with toddlers (1 to 2 years) (5). Of note is that specific language domains are primarily attributed to different brain regions (e.g., Broca's area for expressive language and Wernicke's area for receptive language) and have differential developmental trends (6). These differences may impact the associations between screen time and specific language domains in early childhood. Given the dearth of evidence, a further understanding of the association between screen time and expressive language is needed, particularly in preschoolers.

Studies on screen use and cognitive development in early childhood have primarily focused on language development, and less attention has been paid to other areas of cognitive development, such as executive functions (7). Additionally, most studies of screen time and executive functions in early childhood have examined composite executive functions by combining several measures (8). However, different areas of executive functions may not be equally susceptible to screen exposure at a particular developmental stage, due to their distinctive developmental trajectories (8). Therefore, at this time it is difficult to draw conclusions regarding the association between screen time and executive functions in early childhood, especially for different areas of executive functions.

Another gap in the literature regarding screen time and cognitive development in early childhood is that most studies have examined screen time exclusively as television (TV) time in relation to cognitive development in early childhood, with limited research on computers and contemporary technologies (e.g., tablets, smartphones) (7). However, specific types of screen time may have unique associations with cognitive development in young children. For example, a recent longitudinal study found null association for program viewing but a negative association for app use in regard to inhibition in preschoolers (9). Given the increasing use of computers and contemporary technologies by children under five years, these forms of screens need to be considered when examining screen time and cognitive development in this age group.

A number of global and national guidelines on 24-hour movement behaviours recommend no screen time for children under 2 years and limited screen time (≤1 hour/day) for those aged 2 to 5 years (10–12). However, low adherence rates in young children, ranging from 11% to 51%, have been reported in several surveillance studies from multiple countries (13–17), and the associations between meeting the recommendation and cognitive development in this population is unclear (15). This study aimed to address gaps in the literature by examining the associations between different types of screen time (TV time, video game (VG) time, total screen time, meeting the screen time recommendation) and indicators of cognitive development (working memory, expressive vocabulary) in a sample of Canadian preschoolers.

METHODS

Study design and participants

The current study analysed baseline data from the supporting Healthy physical AcTive Childcare setting (HATCH) study. HATCH is a 6-month quasi-experimental pre–post-design study, which aimed to determine the immediate physical activity, sedentary time, and health benefits of the Alberta Childcare Accreditation Program Quality Standards. A more detailed description of this study can be found elsewhere (18). Briefly, 20 childcare centres in and around Edmonton, Alberta, or Ottawa, Ontario, Canada were recruited. One centre dropped out without explanation, and their data were therefore excluded. All children aged 19 to 60 months at baseline were eligible to participate if they attended the centre full time and intended to stay enrolled during the HATCH study. Parents of 269 children (47%) provided consent for their child's participation, though 18 children were deemed ineligible (age: n=7, part-time attendance: n=7, leaving the centre: n=2). Of the remaining 253 children, only preschoolers (36-60 months; n=122) were included in the current study, given the measures of cognitive development used in our study were only validated in this age group. Two children were further excluded due to a cognitive disability that may affect cognitive performance, leaving a sample of 120 eligible participants.

Measures

Screen time variables

In this study, participating childcare centres had no screen-based devices for children or had minimal screen time (<15 minutes/day). As such, TV time and VG time were assessed using the HATCH parental questionnaire: "*on average, how much time per day outside of childcare does your child watch television, videos or DVDs on a television, computer, or portable device?*" and "*on average, how much time per day outside of childcare does your child play video/computer games on devices such as learning laptop, leapfrog leapster, computer, laptop, tablet, cell*

phone, the internet, PlayStation, XBOX?" The questions were adopted from the Canadian Health Measures Survey and have demonstrated good 1-week test–retest reliability (intra-class correlation=0.82) (19). Responses in hours and minutes for weekdays and weekend days for each question were used to calculate weighted mean hours per day. Total screen time was then calculated as the sum of TV time and VG time. Total screen time >5 hours/day, as well as TV time and VG time of the same participant, were considered extreme value and truncated (n=6). According to the screen time recommendation within the Canadian 24-Hour Movement Guidelines for preschoolers (≤1 hour/day) (10), total screen time was further classified into two categories (meeting the recommendation; not meeting the recommendation).

Cognitive development variables

Cognitive development variables were measured using the Early Years Toolbox (EYT), which has been psychometrically tested in children aged 3 to 5 years (20). Expressive vocabulary was assessed with the task 'Expressive Vocabulary' and working memory was assessed with the task 'Mr Ant', with higher overall accuracy scores indicating better performance. Each task had standardized instructions, practice, feedback and scoring, with guidance and initial instructions supplemented by a data collector as needed.

Potential covariates

Age was calculated in months based on the reported birth date and the date of assessment. *Sex* had two response options (male and female). Based on the frequency distribution, race/ethnicity was dichotomized into Caucasian or other races/ethnicities, and parental education was categorized as below bachelor level, bachelor's degree, and above bachelor level. Childcare centre group (Alberta, Ontario) was considered as a potential covariate in the current study.

Statistical analysis

Statistical analyses were performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). Data for expressive language and working memory were checked for normality and outliers. Data for working memory was not normally distributed and transformations did not improve the distribution. Therefore, working memory was categorized as a binary variable based on the median score (code '0' represents score<1 [range: 0.00 to 0.67]; code '1' represents score≥1 [range: 1 to 3]).

Descriptive statistics were calculated. Null models were used to determine the intra-class correlation coefficient (ICC) of centre cluster with expressive language (ICC=0.15) and working memory (ICC=0.31), respectively. Therefore, the clustering effect of childcare centres were adjusted for in all models. The binary associations of potential covariates were examined in mixed models with expressive vocabulary and in generalized mixed models with working memory. All potential covariates that met a cut-off of P<0.10 in the binary models for expressive vocabulary and/or working memory were considered as covariates for multiple regression models (Supplementary Table S1) (21,22). The associations of screen time variables were examined in mixed models with expressive vocabulary and in generalized mixed models with working memory, adjusted for covariates. Distribution of model residuals was visually checked to confirm that the assumption of normality was met. A P-value<0.05 was set as the significance level.

RESULTS

Of the 120 eligible preschoolers, 97 had complete data on the variables of interest and were included in statistical analyses. There were no significant differences in age and sex between children included and excluded in the analytic models. The descriptive characteristics of the analytic sample are presented in Table 1.

The associations between screen time and cognitive development in preschoolers are shown in Table 2, and associations between covariates and outcome variables in these multiple regression models are presented in the supplementary file (Supplementary Tables S2–S5). None of the screen time variables were associated with expressive vocabulary. Regarding working memory, there were no significant associations for TV time or VG time. However, higher total screen time was associated with lower odds of having better working memory (OR=0.52; 95%CI:0.31, 0.88). Compared with nonadherence, adherence to the screen time recommendation was associated with higher odds of having better working memory (OR=3.48; 95%CI:1.06, 11.47).

DISCUSSION

This study examined the associations between screen time and cognitive development in preschoolers. Total screen time was unfavourably associated with working memory, despite the null associations observed for TV time and VG time. Additionally, compared with preschoolers who did not meet the screen time recommendation, those who met the recommendation were more likely to have better working memory. However, the amount of screen time, irrespective of the type of device, was unrelated to expressive vocabulary in our sample.

The inclusion of computer and contemporary screen time in our study is an important addition to the current evidence base, as most existing studies have not taken this type of screen exposure into account when examining the associations between screen time and cognitive development in early childhood (7). In contrast to our findings, some recent studies that have considered contemporary screen use in preschoolers have found no

Table 1. Participant characteristics

Variables	n=97
Age (months)	43.20 ± 5.83
Sex (%)	
Male	52 (53.6)
Female	45 (46.4)
Race/ethnicity	
Caucasian	50 (51.5)
Other	47 (48.5)
Parental education	
Above a bachelor's degree	33 (34.0)
A bachelor's degree	29 (29.9)
Below a bachelor's degree	35 (36.1)
TV time (h/d)	1.36 ± 0.94
VG time (h/d)	0.35±0.80
Total screen time (h/d)	1.71 ± 1.21
Meeting the screen time recommendation (≤ 1 h/d)	32 (33.0)
Expressive vocabulary (score)	18.97 ± 8.24
Working memory (%)*	
Scores <1	40 (41.2)
Scores ≥1	57 (58.8)

Data presented as mean ± standard deviations for continuous variables (age, TV time, VG time, total screen time, and vocabulary) and frequencies (percentages) for categorical variables (sex, race/ethnicity, parental education, meeting the screen time recommendation, and working memory).

TV Television; VG Videogame.

*Working memory was categorized as a binary variable based on the median score (code '0' represents score<1 [range:0.00–0.67]; code '1' represents score ≥1 [range:1–3]).

associations for both total screen time (9,23), and adherence to the screen time recommendation (15), with working memory in preschoolers. Nevertheless, our findings for working memory are supported by previous neuroscience that has revealed unfavourable associations between screen exposure and anatomical changes in children's prefrontal cortex, which is involved in executive functions (24). One plausible mechanism underlying the associations observed in our study is that extended screen time likely displaces and distracts developmentally appropriated activities (e.g., family interaction, book reading). Since screen-based devices tend to provide impoverished stimulations compared to the real-time environment, such displacement and distraction may affect early brain development that is important for cognitive skills in young children (25). Another potential mechanism is that the rapid-image changes in most screen activities tend to impede children's sensory processing and attentional capabilities (26). This reduced ability to process sensory and attentional stimuli may in turn lead to children's difficulties in filtering irrelevant stimuli, consequently impairing their working memory performance (27).

The null associations observed between TV time, VG time, and working memory align with recent studies with preschoolers, which reported no associations for various types of device use (e.g., TV, smartphone, tablets, computers, and consoles) (8,9,23). A possible explanation for these null findings is that a dose-response relationship may exist between screen time and working memory in children in this age group. Specifically, screen exposure via each of these devices may not result in an observable negative impact but cumulatively can impair working memory in early childhood. It should be noted that our study, consistent with the literature, only considered the quantity of TV use and VG use, in relation to working memory in

Table 2. The associations between screen time and cognitive development (n=97)

Screen time	Expressive vocabulary*		Better working memory†	
	B (95%CI)	P value	OR (95%CI)	P value
TV time (h/d)	−0.47 (−2.03, 1.09)	0.549	0.67 (0.38, 1.17)	0.155
VG time (h/d)	1.27 (−0.64, 3.19)	0.189	0.53 (0.26, 1.08)	0.079
Total screen time (h/d)	0.25 (−1.05, 1.55)	0.702	**0.52 (0.31, 0.88)**	**0.016**
Meeting the screen time recommendation‡	−2.14 (−5.27, 0.99)	0.179	**3.48 (1.06, 11.47)**	**0.040**

All models were adjusted for age (months), race/ethnicity, parental education, childcare centre location, and the clustering effect of childcare centres.

Bold font indicates P<0.05.

B Unstandardized coefficient beta; CI Confidence interval; OR Odds ratio.

*Linear mixed models were performed for expressive vocabulary models.

†Generalized linear mixed models were performed for working memory models. Working memory was categorized as a binary variable based on the median score (code '0' represents score <1 [range:0.00–0.67]; code '1' represents score ≥1 [range:1–3]). The reference group was children with a working memory score < 1.

‡The reference group was children who did not met the screen time recommendation.

preschoolers. However, the potential effects of these activities may also depend on the quality of children's screen experience. For example, TV time with high-quality context (foreground versus background) and content (e.g., child- versus adult-directed; educational versus entertainment; slow- versus fast-paced; realistic versus fantastical) appear less detrimental to general executive function in preschoolers (28). Therefore, future research considering these quality factors may need to examine our findings regarding associations between TV time, VG time, and working memory. Moreover, the associations between screen time and other areas of executive function (e.g., inhibition, shifting) may be different from that of working memory in early childhood, which should be further examined.

Our findings suggest that screen time, irrespective of the type of screen, may be unrelated to expressive vocabulary in preschoolers. The null finding observed for TV time aligns with previous studies focusing on toddlers and expressive vocabulary (29,30). This is in contrast to previous work examining receptive vocabulary and general language development (5). As such, the inconsistencies with our study may be due to the different developmental trends of different language domains. For example, given the later development and the smaller vocabulary size of expressive language in comparison to receptive language (6), expressive language may not be as susceptible to TV exposure as receptive language in the early years. Alternatively, some possible protective factors (e.g., educational content, co-viewing, and older onset age of screen use) that were unmeasured in our study may have attenuated the potential detrimental effects of TV viewing on language development (5). Of note is that our findings for VG time may be inconclusive, as a recent study found an association between excessive use of a mobile media device and expressive language delay in 18-month-old children (31). Since there is a paucity of data on screen time and expressive language development in early childhood, future research is necessary to examine these associations, especially for VG time, in the preschool population.

One strength of the present study is the examination of different types of screen time. The examination of one specific area of executive function (i.e., working memory) and language development (i.e., expressive language) may also deepen our understanding of the associations between screen time and specific cognitive domains. A limitation of this study is the cross-sectional design, which precludes causal inference. The relatively small sample size may also have resulted in lower statistical power and contributed to the wide confidence intervals (e.g., the odds ratio estimated for the association between meeting the screen time guideline and working memory). Furthermore, there may be unmeasured covariates (e.g., home learning environment) leading to residual confounding. Finally, the sample in the present study was comprised only of children attending childcare centres, which may limit the generalizability of our findings.

CONCLUSION

Higher total screen time was unfavourably associated with working memory in preschoolers, while adherence to global and national screen time recommendations appeared to be a protective factor. Therefore, these findings provide further evidence for the importance of paediatricians and other health professionals discussing screen time recommendations with families, given these individuals are seen as a credible source for parents (32). Screen time was unrelated to expressive vocabulary in our sample. However, our findings need to be confirmed in future research with larger samples.

SUPPLEMENTARY DATA

Supplementary data are available at *Paediatrics & Child Health* Online by searching for pxab067.

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