Content and Context in Children's Screen Time and Relations to Academic Skills

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Children's screen time has increased dramatically in the past few years and the content and contextual factors related to screen use merits further investigation in determining impacts on academic skills. In this longitudinal study of 128 4 and 5-year-old children, using time diary data to measure children's screen time and direct child assessments of academic skills, this study examined whether contextual factors related to screen time (total screen time, content, parental monitoring, and device type) predicted children's academic skills. Results showed that only use of mobile devices predicted spatial skills at age 5 when considering these contextual factors individually. Via cluster analysis, three unique groups of screen users were uncovered: Cluster 1 was "low total, unmonitored, and non-educational TV," Cluster 2 was called "moderate total, educational mobile devices," and Cluster 3 was "highest total, educational TV and mobile devices." Cluster 2 showed better literacy skills at age 5 than both Cluster 1 and Cluster 3. Findings suggest that certain contextual features of screen time may predict children's literacy skills and the need to move beyond simple global measures of children's total screen time to assess academic outcomes. Future directions of this research and limitations are discussed.

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1.0 Introduction

Children's screen time has nearly tripled in recent years and is a ubiquitous part of most young people's home lives. In fact, 98% of young children live in a home with a mobile device or television (Rideout, 2017), emphasizing the transition to a more technologically based home environment. Technology has altered the structure of the home environment and families have adjusted to accommodate it as an underpinning to nearly every aspect of life, including interactions, entertainment, and learning (Livingstone et al., 2015). To that end, many parents of young children have integrated screen time in their young children's home learning and entertainment (Lieberman et al., 2009; Plowman, 2013).

Young children's exposure to screen time at home is encouraged by major tech companies, app and television program creators, as well as government funded agencies. According to the Sesame Workshop's Analysis of the Education Category of Apple's App Store, over 80% of the top selling paid apps for educational purposes in the iTunes store target children, and toddlers and preschoolers are the most popular age category, with over half of educational apps created for this age group (Shuler, 2012). Moreover, the U.S. Department of Education has allocated millions of dollars in funding to create digital media programs for preschoolers and young elementary school children (LeKander, 2020). However, it remains unclear the extent to which these programs and apps benefit young children's learning, particularly when considering children's exposure to educational screen time in the context of their full screen time. Thus, the purpose the of the present study was to extend prior literature in examining the role of screen time on young children's academic skills when considering both the content and contextual factors associated with children's screen time.

1.1 Guiding Theoretical Frameworks

This work is grounded in Vygotzky's Sociocultural Theory (1978) as some researchers have suggested that media-based tools can operate within a child's zone of proximal development (ZPD) to provide scaffolding, interactivity, modeling, and other supports needed for learning (Wartella et al., 2016). High-quality educational screen time can therefore be an important learning tool for young children. This brings together the social and technological factors that promote children's learning, such as interactivity with screen-based programs, especially with touch screens, screen use with educational content, and parent engagement with children's screen use.

Relatedly, Bronfenbrenner's Bioecological Model (1979) also guides this investigation of children's learning with media and technology in context. Children's screen use and learning is situated in the home environment (Lauricella et al., 2015), such that familial demographic factors, social interactions accompanying the screen time, and a wholistic view of children's total screen time in the home, not just educational programs, play a cumulative role in learning. Thus, examining the context of screen time in conjunction with content is a critical next step in unpacking the role of screens in the home.

1.2 Total Screen Time and Child Outcomes

Young children's screen time is often portrayed negatively, with studies highlighting the detrimental associations with cognitive development (Domingues-Montanari, 2017). However, many of these studies are correlational, in which toddler and preschool aged children's total screen time is negatively associated with academic outcomes, including math (Pagani et al., 2010), and

literacy and language skills (Kostyrka-Allchorne et al., 2017). Such studies have prompted reputable sources like the American Academy of Pediatrics (AAP) to provide recommendations about young children's screen usage, including limiting screen time to only 1-2 hours of high-quality programs for children under 5 years old (AAP Council on Communications and Media, 2016; McNeil et al., 2019). However, most children engage with screens for over 2.5 hours per day (Rideout, 2017) and the specific content is generally understudied.

Concerns have also been raised that screen time may replace opportunities for social interactions that would encourage more learning experiences in the home learning environment (HLE). This is often referred to the displacement hypothesis or the Goldilocks hypothesis (Przybylski & Weinstein, 2017), where children's real life, in person learning experiences are diminished by their increasing use of screens and engaging with the digital world. In this hypothesis, like the recommendations set forth by the AAP, digital experiences in moderation are not considered as harmful as excessive screen use. Indeed, some correlational studies have found that high amounts of screen time are associated with less time for other developmentally appropriate activities, like physical activity, sleep, and home learning through in-person interactions (Janssen et al., 2020; Lehrl et al., 2021).

It is also possible that negative associations between screen time and child outcomes are driven specifically by non-educational screen content, as some experimental studies have shown positive academic outcomes associated with children's engagement with educational screen time (Linebarger et al., 2004; McCarthy et al., 2018; McManis & McManis, 2016; Neumann et al., 2018; Penuel et al., 2012; Rosenfeld et al., 2019; Schacter & Jo, 2017). Given that parents may use educational screen-based programs as part of their home learning practices, it is important to know how, in the context of the home environment and different family backgrounds, educational

screen programs are being incorporated, and whether they are positively impacting children's academic skills above and beyond other home learning.

1.3 Educational Screen Time and Academic Outcomes

Although correlational studies have identified a negative association between screen time and child academic skills outcomes, experimental studies exploring specific television programs have found otherwise. Several classroom-based studies have indicated that educational programs can be beneficial for young children's math (McCarthy et al., 2018) and language learning (Linebarger et al., 2004). Experimental studies carried out in the home have found similar results for math (Alade et al., 2016; Pasnik et al., 2015; Schenke et al., 2019) and language and literacy skills (Chera & Wood, 2003; Chiong & Schuler, 2010; Linebarger, 2015; Rice et al., 1990) where there are mostly positive associations between use of an educational program and child math, language, and literacy skills. While these studies demonstrate positive effects on children's learning, they generally focus on a particular educational program rather than examining educational screen time exposure within the context of children's full screen time.

1.4 Screen Time in Context

Given the proliferation of educational screen content aimed at young children, it is valuable to consider that children will often engage in multiple screen time activities daily. Thus, exploring educational programs as a proportion of total screen time is a more ecologically valid approach as

children's home screen use may consist of more than a single TV program or app. Moreover, their home screen use may also vary in how much time is spent using educational compared to non-educational content.

In addition, parental involvement in children's learning (Fan & Chen, 2001) and screen time (Samudra et al., 2020) often predicts better academic skills, attention, and comprehension. Parent mediated or monitored screen time has been associated with higher teacher reports of grade point average in older children (Gentile et al., 2012). In this way, parents can aid in scaffolding, ask questions related to the child's comprehension of the material, and guide their attention to follow along on-screen activities and scenes (Samudra et al., 2020). However, active co-viewing of screen content may not be necessary to reap the benefits of educational screen-based programs. One study found that simple co-viewing without conversations could lead children to assume parental endorsement of the content (Nathanson, 2001b) and may therefore promote more attention and learning. Better learning outcomes are also associated with screen content that is interactive (Griffith et al., 2020). Thus, exposure to apps and handheld devices where children can also more actively engage with the content is an important consideration for the context in which screen time occurs.

1.5 Key Covariates of Educational Screen Time

In addition, when examining associations between educational screen time and young children's learning, home environment characteristics may need to be addressed due to their relations with screen time and child development, including the home learning environment (HLE) and socioeconomic status (SES). Understanding the role of educational screen time in the home

where other learning activities may also be provided to children is understudied in the literature. Some studies have begun to incorporate digital learning experiences in examining the HLE (Lehrl, 2021) and found that educational screen time was associated with higher academic skills, but effect sizes were smaller compared to that of non-media based HLE activities, such as reading, counting, playing with alphabet toys, attending cultural activities, and singing. A factor analysis revealed that media-based and non-media based HLE did not load onto a single construct, indicating the uniqueness of each of these HLE types. To date, past studies have not considered unique benefits of educational screen time when other non-media-based learning activities are provided at home. Thus, it is possible that educational screen time may be less beneficial for children's learning if parents are able to provide other educational HLE activities and resources. Family SES could also be an important covariate given the negative associations between SES and screen time (Rideout, 2017), as well as robust positive associations between SES and children's developmental outcomes (Bradley & Corwyn, 2002).

1.6 Research Aims

Not only is it critical to understand how the content of children's screen time relates to early learning, it is also important to explore the larger context of children's screen time at home as well. First, exploring educational screen exposure in the context of all screen time can provide a more wholistic account of how children are using educational screen time in comparison to other non-educational screen time. Furthermore, examining educational screen time within the context of other home learning activities and demographic factors can address some limitations in past studies finding positive outcomes for particular educational programs. Screen time, educational or

otherwise, is situated in context such that characteristics of child screen time related to content, parent monitoring, and device type, may work together to influence children's learning. Other studies have utilized this person-centered approach in characterizing screen time related to health outcomes (del Pozo-Cruz et al., 2019; Lee et al. 2015), but none to our knowledge have employed it for the purpose of grouping these contextual factors to provide a more wholistic view of the role of screens for early academic skills.

Thus, the current study provides a detailed comprehensive exploration of children's screen time characteristics and associations with HLE and demographics factors. The first study aim examines (1a) the screen time content with the amount of parental monitoring and device types young children use in their daily lives, (1b) if there identifiable typologies of screen time characteristics among families, and (1c) the home learning and demographic factors that are associated with membership in clustered groups. The second study aim examines (2a) if there are significant associations between exposure to educational screen time, parental monitoring, and device type at age 4 and literacy, number, spatial skills at age 5 when considered within the context of all children's screen time, HLE, and demographic factors, and (2b) if different typologies of screen time at age 4 from person-centered approaches are associated with academic skills at age 5, controlling for other HLE activities, demographic factors, and age 4 outcomes.

2.0 Method

2.1 Participants

A sample of 128 parents and their 4-year-old children were recruited for this longitudinal study from childcare centers, participant registries, and community agencies to include children who did and did not attend formal preschool. Specifically, we recruited child-care centers and preschools during school events and peak pick up and drop off hours in the greater Pittsburgh area. We also utilized the University of Pittsburgh's Clinical and Translational Science Institute (CTSI) Research Participant Registry, Pitt+Me. This registry allows people in the community to participate in research at the university. A socioeconomically diverse sample of families participated in this study with parents reporting average incomes between $0 and $425,000, with a median of $90,000 (SD = $78,547. Parents' educational attainment varied as well, with 8% with a high school diploma, 16% with an associate degree, some college experience, or a nursing certificate, 31% with a bachelor's degree, and 43% pursuing or attained a graduate degree. Children were, on average, 4.4 years-old (SD = 0.29) at the beginning of the study and 50% were male. Parents also reported their employment (40% full time, 27% part-time, 25% not in the labor force, 7% looking for work), marital status (73% married), and child's race/ethnicity (80% White, 13% Black, and 5% Asian or Pacific Islander, 5% other). Around 67% of children attended a childcare center. For age 5 assessments, 113 children participated.

Missing data patterns were carefully analyzed and of the 128 participants, 24% were missing data on at least one variable of interest. Age 4 missing data for literacy, number, and spatial skills ranged from 3 – 16%. Age 5 missing data for these variables ranged from 18 – 22%. Most

participants (95.3%) completed at least one time diary interview at age 4. SES had 7% missing data and child age had <1% missing data. A Little's MCAR test revealed that data were not missing completely at random (χ^2 (184) = 234.5, p = 0.007). In order to decrease bias caused by missing data, we used multiple imputations by chained equations (ICE), using Stata SE software, version 15 (StataCorp LLC). In the present study, imputations were performed on both the independent and dependent variables. Twenty data sets were generated, resulting in a final sample of 128 children. Based on the recommendations by Graham, Olchowski and Gilreath (2007), twenty imputations were sufficient for the percentage of missing data in our study. Following imputation, the twenty data sets were pooled to generate descriptive statistics and perform analyses.

2.2 Measures and Procedures

As part of a larger longitudinal study, the Parents Promoting Early Learning study (PPEL), 4-year-old data were collected during two home visits, two time diary interviews, an electronic questionnaire, and other in-person surveys. During the first home visit, videotaped semi-structured observations with the child and parent, child and parent standardized and experimental assessments, and parent in-person surveys were completed. Following this first home visit, and no later than two weeks after the first home visit, parents received two phone calls to complete the time diary interviews for a workday and a non-workday. In an effort to not fatigue 4-year-olds with assessments and activities, assessments were split across the two home visits. After the first home visit, parents were also sent an electronic link via Qualtrics to complete the online questionnaire. During the second home visit, children were given additional assessments and parents completed additional in-person surveys. Counterbalancing occurred at the assessment

level, where children received one of two assessment sequences at the first home visit, and the assessment sequence was the same for all children during the second home visit.

At age 5, due to restrictions of the COVID-19 pandemic, children's follow-up assessments were conducted via Zoom in three separate video recorded sessions. PowerPoint and the "Share Screen" function of Zoom were used to administer these assessments. All child assessments were split across the three sessions so as not to fatigue the children. Child assessments were administered at all 3 zoom calls, and parents completed surveys during the 2nd and 3rd calls. Parents were also sent an electronic link via Qualtrics to complete a questionnaire after the first session. Counterbalancing occurred at the session level; each session had the same sequence of assessments, but children were assigned one of three different session orders. For the purposes of this study, only data collected from time diaries, child assessments, the parent questionnaire at age 4, and child assessments at age 5 will be assessed.

2.2.1 Time Diaries

Parents completed two time diary interviews over the phone when the children were 4-years-old. They reported all activities carried out by parents and children over a workday and a non-workday. For unemployed parents (29% of the sample), they provided time diaries for a weekday and a weekend day. The rest of the sample of employed parents (68% of the sample) used the workday and non-workday distinction. The time diary data were collected using a modified format of the American Time Use Survey (ATUS; U.S. Bureau of Labor Statistics, 2016). The phone interview always occurred one day after the targeted day in order to capture an accurate recollection of activities. Parents were provided with a time diary activity sheet that they would complete during the target day so as to not solely rely on their memory of activities and duration

of activities. During the phone interview, parents reported all of their activities and their child's activities starting at 4 AM on the target day and ending at 4 AM one day later (the day of the interview). Parents reported the primary activities, and where and with whom those activities took place. If parents reported several activities occurring simultaneously, secondary and tertiary activities were recorded as well. A sum of all activities was generated such that minutes of an activity recorded as primary, secondary, or tertiary would all be summed. Following Kotila and colleagues (Kotila et al., 2013), audio recordings of the interviews were coded into broader categories of activities by trained research assistants. For example, playing on a smartphone or playing on a tablet would be coded as "play and recreation at home: electronic media."

2.2.1.1 Minutes of Time Use from Child Time Diary (TD) Schedule

We modified ATUS codes for the present study to better capture the content of preschool-aged children's academic and recreational activities, rather than using a more global ATUS code like "academic time." Refer to Table 1 for a list of the final codes used. Total time reported that the child was engaged in screen time activities, either as the primary, secondary, or tertiary activity, was summed for both workdays and non-workdays. Again, the primary and secondary activities typically occurred simultaneously and "primary" indicates the first activity mentioned by parents, rather than "primary" indicating a predominant focus during those activity minutes.

2.2.1.2 Screen Time

A measure of screen time using the time diary data was created using the summed workday and non-workday time children engaged with screens. Total screen time consisted of time parents reported that their child was watching TV on a traditional device or an electronic device, using electronic media for play in and out of the home (including apps or other electronic games), or

using an electronic device for math or reading related activities (including apps or other electronic games). Total time that was coded as screen time across the two days was 197.4 minutes for this sample. Screen time that was not a program or a game (e.g. FaceTime, DoorDash) was excluded from this sum, reducing total screen time by 4% (197.4 to 189.6).

Children's screen time was further coded to indicate whether the screen content was *educational* or *non-educational*. To code whether screen content was educational or not, coders referred to Common Sense Media's website (https://www.commonsensemedia.org/; Griffith et al., 2019), and for content not included on Common Sense Media's website, researchers conducted online searches and watched video clips of the TV shows or downloaded and played online games to determine if literacy, number, or spatial skills were promoted in the program. Appendix 1 lists programs coded as educational and non-educational. Educational and non-educational screen time measures were summed across the workday and non-workday. The proportions of educational and non-educational screen time were also calculated as the sum of both days' educational or non-educational screen time divided by the sum of total screen time for both days. This process was also conducted for non-educational screen time. In approximately 26.7 minutes of 189.6 minutes of total screen time (14%), the educational content was unknown. Thus, these minutes of unknown content are excluded from the current analysis and total screen time was reduced to 162.9 minutes. Within the unknown screen time minutes, 9.3 minutes (4.9% of total screen time) was characterized by time where the parent was unsure of the program the child was playing with or watching. Unknown content minutes also included 17.7 minutes (9.3% of total screen time) in which the interviewer failed to ask the parent about the specific screen content during the interview. In total, 57.2 minutes of 162.9 minutes (35%) of this screen time was educational and the remainder, 105.5 minutes (65%) was non-educational.

The educational and non-educational screen time was further divided by *parental monitoring* and *device type*. For each minute of screen time, parents reported who was with the child (if anyone) during the screen time activity and what type of device was used, including traditional TV's, tablets, or smartphones. In the parental monitoring coding, there were 97.4 minutes of 162.9 minutes of total screen time (59.8%) where the parent was physically with the child and 60.4 minutes (37.1%) where the parent was not physically with the child. The remainder of this time included 4.8 minutes (2.9%) in which the interviewer did not ask the parent who the child was with during their screen activity. For device type coding, 75.4 minutes (46.3%) of 162.9 total minutes of screen time were characterized by screen time using a traditional TV, and 41 minutes (25%) using a mobile device (e.g. tablet, smartphone). Only 46.2 minutes (28.4%) were characterized by device use that was unknown because the interviewer did not ask the parent about the device type during the screen activity.

2.2.1.3 Coding Reliability

Time diary coders included graduate students, undergraduate research assistants, and full-time research staff. To ensure inter-coder reliability, 20 percent of time diaries were double coded (Chorney et al., 2015; Hallgren, 2012). Given that the time-diary reports of minutes spent on activities during the previous day were measured continuously, the interclass correlation (ICC) across coders was calculated to check reliability. Reliability across workdays and non-workdays for screen time variables ranged from 0.71 - 0.99. The lowest reliability of 0.71 occurred due to coders often considering watching TV on an electronic device and playing using electronic media interchangeably.

2.2.1.4 Home Learning

Parents also reported children's home learning activities during workdays and non-workdays in the time diary interviews. Parents described when a reading or math activity occurred in the previous 24-hour period. These were coded as either doing reading or math activities through a hard copy, electronic device, or through talking and interactions. The sum of both days' math and reading home learning activities durations was calculated for a composite HLE variable excluding the time doing math and literacy activities on an electronic device, which was included in educational screen time minutes. Also included in this composite was any other academic activity including work on learning foreign languages, writing, and playing rhyming and word games. Given that the time-diary reports of minutes spent on activities during the previous day were measured continuously, the interclass correlation (ICC) across coders was calculated to check reliability. Reliability across workdays and non-workdays for home learning variables ranged from 0.82 - 0.98.

2.2.2 Child Outcomes

During the two home visits at age 4 and the online Zoom calls at age 5, children were assessed on several literacy, number, and spatial standardized and experimental assessments. Each assessment was live coded by the assessor but were also recorded for later scoring if necessary. Composite variables of literacy, number, and spatial skills were created to explore these outcomes and provide robust measures to maximize power (Song et al., 2013).

2.2.2.1 Literacy Skills

The standardized assessment, the Letter Word Identification subtest of the Woodcock Johnson Tests of Achievement III (Woodcock et al., 2001) was administered at age 5 as a measure of children's ability to identify isolated letters and words. As this assessment was administered online via Zoom, items were presented as instructed in the WJ manual such that items that were on the same physical page were also presented in the same PowerPoint slide during online administration.

At age 4, children were administered the Elision, Blending Words, Sound Matching, and Memory for Digits subtests of the Comprehensive Test of Phonological Processing (CTOPP) (Wagner et al. 1999). In the Elision subtest, researchers said a word, asked the child to repeat the word, and then asked the child to say only part or only a sound of the word. For example, "say cowgirl," "now say cowgirl without saying cow." There are 34 trials in this task (and administration is suspended after 3 incorrect responses in a row). In the Blending Words subtest, a CD recording played words one part at a time and the child was tasked with putting the word together to make a whole word. For example, "what word do these sounds make: cow-boy." There are 33 trials in this assessment and administration is suspended after 3 incorrect responses in a row. In the Sound Matching subtest, children were presented with a picture book a picture and asked, if a set of several other pictures matches with the first or last sound matches with the first picture. For example, "which of these three picture words starts with the /s/ sound like sock? Sun or bear." There are 26 trials for this task and administration is suspended after 3 incorrect responses in a row. In the last subtest, Memory for Digits, a CD recording plays a sequence of numbers and children are tasked with repeating the digits as they heard them. This task has 28 trials and administration is suspended after 3 incorrect responses in a row. Standard scores of the CTOPP

was computed for a total Phonological Awareness standard score. At age 5, only the Sound Matching subtest was administered, and children will be assessed based on their average score for this assessment. A literacy skills composite consisted of the average of the Sound Matching and Letter Word Identification assessments (r = .71). The CTOPP standard score at age 4 was used as the control variable in predicting age 5 literacy skills.

2.2.2.2 Number Skills

The standardized assessment, the Applied Problems subtest of the Woodcock Johnson Tests of Achievement III (Woodcock et al., 2001), was administered as a measure of children's arithmetic skills and has been normed for children as young as 4 years old. This assessment was administered at age 4 and age 5. Similar to the Letter Word Identification administration, items were presented as instructed in the WJ manual such that items that were on the same physical page were also presented in the same PowerPoint slide during online administration.

At age 5, children were presented with a series of numbers (one number was presented per PowerPoint slide), from single to three digits, and were asked to identify the number. This procedure is similar to that described in Purpura & Lonigan (2015). Total accuracy of the 12 items was used as the score for this measure. A number skills composite was derived from the average of the Numeral Identification and Applied Problems assessments (r = .62). The Applied Problems standard score at age 4 was used as the control variable in predicting age 5 number skills.

2.2.2.3 Spatial Skills

Geometric Sensitivity (Dehaene at al., 2006) is an assessment of children's geometric ability where they were tasked with finding the image (of six total images) that is different from the other images in the set. In this task, there are 12 trials and 4 practice trials. The percentage of

trials a child responded to correctly was used as a measure of geometric sensitivity. This assessment was administered at age 4 and age 5.

A mental transformation task (Levine et al., 1999) was also administered to children, where they were presented with a shape separated in two pieces and four choice options. Children were tasked with determining which of the four complete images the separated shape will be when put together. There were 16 experimental trials 2 practice trials in this task. The percentage of trials a child responded to correctly was used as a measure of their mental transformation skills. This assessment was administered at age 4 and age 5. Spatial skills consisted of an average of the Geometric Sensitivity and CMTT assessments (r = .4). The average of age 4 Geometric Sensitivity and CMTT (r = .4) was used as control for spatial skills at age 5.

2.2.2.4 Covariates

HLE, as measured in minutes, is a key covariate in the study. Demographic factors from the age 4 parent questionnaire, including SES and child age, was also used as covariates in these analyses. Parents reported their total family household income from numerous sources including wages/salary, Social Security, retirement accounts, and government assistance programs. Income from these sources was summed and transformed by taking the natural log of income because income was highly skewed, and extant research shows that income's association with child outcomes is non-linear (e.g. Dearing, McCartney, & Taylor, 2001), with stronger associations for children from low-income families. Parents also reported their educational attainment, and we constructed a continuous measure of the highest level of parental education by assigning years of education to degree achieved (less than high school=11; high school/GED=12; some college, no degree=13; associate's degree=14; bachelor's degree=16; master's or other graduate/professional

degree=18). To create the family SES composite variable, we standardized income and education and averaged them.

3.0 Analysis Plan

All analyses were carried out using StataSE software, version 15 (StataCorp LLC). The first aim of the study was to provide a descriptive account of children's screen use, explore identifiable typologies of screen use characteristics, and to explore the HLE and demographic factors that are associated with membership in group clusters. To address the first aim of the study and using age 4 time diary data, descriptive statistics were used to describe children's screen time, including what devices were used, whether the content was educational, and whether parents were monitoring the screen time in the age 4 time diary data. To further address this aim, k-medians cluster analysis was conducted to identify groupings among screen time content and characteristics; this method allows group membership to emerge from the data rather than being assigned a priori. The k-medians algorithm randomly assigns initial centers for each cluster and assigns each observation to the nearest center. The optimal number of clusters was determined using procedures outlined by Makels (2012) which involves observing a scree plot to determine "kinks" in the curve obtained from the within sum of squares for the cluster solutions. Two to six cluster solutions were examined for this analysis.

Six variables were included in the cluster analysis: total minutes of screen time, minutes of educational screen time, the proportion of educational screen time, minutes of screen time with parental monitoring, and minutes of screen time on a traditional television or on a handheld device. Although there are no strict guidelines regarding considerations for sample size and number of variables for cluster analyses, 6 variables are adequate to conduct cluster analysis using one recommendation of a minimum sample size of 2^k by Dolnicar (2002) where k is equal to the number of variables. Thus, the study sample size of 128 exceeds the ($2^6 = 64$) recommended

minimum sample size. To address the last part of this aim, regressions were performed to determine cluster group differences in predicting home learning minutes, SES, and child age.

The next aim was to examine the longitudinal associations of educational screen time on children's academic skills when considered within the context of all screen time, namely content, parent monitoring, and device type. First, the total minutes of educational screen time was used to predict age 5 literacy, number, and spatial skills including HLE, SES, child age, age 4 controls and total minutes of screen time. Next, literacy, number, and spatial skills outcomes were regressed on the proportion of educational screen time and covariates. Following these analyses, the proportion of screen time variables in the regression models were then replaced with screen time cluster groups to assess whether assignment to a specific cluster differentially predicts child outcomes, also controlling for HLE, SES, child age and performance on age 4 assessments.

4.0 Results

4.1 Descriptive Statistics

Descriptive statistics are displayed in Table 2 and correlations among study variables are displayed in Table 3.

4.2 Research Aim 1a: Characterizing Child Screen Time

As shown in Table 2, children spent a total of 162.9 minutes, on average, using screens. Of that time, 57.2 minutes were spent engaged with educational content and 97.5 minutes were parent monitored. Children spent most of this screen time watching a traditional television (75.4 minutes) compared to mobile devices (41 minutes). There were 46.2 minutes of screen time that device type was unknown. There were 8% of children who did not engage in any screen time across the two days, and 80% of children were at or below the recommended limit of 2 hours of screen time per day (AAP, 2016)

Correlations among study variables are shown in Table 3. Total screen time was significantly negatively correlated with literacy and spatial skills at age 4 and age 5, HLE, and SES. Minutes of parental monitoring showed a similar pattern as total screen time and was significantly negatively related to literacy skills at both time points, spatial and number skills at age 4, HLE, and SES. The proportion of educational screen time was positively associated with literacy skills at age 5. Minutes using a traditional TV was significantly negatively associated with

literacy skills at age 5 and SES while minutes using a mobile device was significantly negatively related to literacy at age 4 and number skills at age 4.

4.3 Research Aim 1b: Typologies of Screen Time

The k-median cluster analysis revealed a solution of 3 groups of screen characteristics for this sample. Table 4 displays unimputed medians, means, and standard deviations of screen characteristic variables for each group. The first cluster (32% of sample) is identified as "low total, unmonitored, and non-educational TV." Relative to the total sample, this group experienced the lowest proportion of educational content and parental monitoring, only used TV as their screen device, but had the fewest minutes of total screen time. The second cluster (25%) is termed "moderate total, educational mobile devices." This group showed a moderate proportion of educational screen time, only used mobile devices, and had a moderate amount of total screen time. The last cluster (43%) is "highest total, educational TV and mobile devices," as this group showed the highest proportion of educational content and minutes parental monitoring and used both TV and mobile devices. This group also had the highest screen time overall in the sample. Groups are characterized based on their distinction from the median of the full sample in the last row of Table 4.

4.4 Research Aim 1c: Associations among Screen Typologies, HLE, and Demographic Characteristics

There were no significant cluster group differences by minutes of HLE, SES, or child age. Results from this analysis are presented in Table 5.

4.5 Research Aim 2a: Content and Context in Predicting Academic Skills

The next set of analyses tested the associations between content and contextual factors in predicting literacy, number, and spatial skills at age 5 accounting for HLE, SES, child age, and child performance on these academic skills at age 4 (see Table 6). In model 1, total screen time, educational screen time, parental monitoring, device type, HLE, and SES were not significantly associated with literacy skills or number skills. Using a mobile device was the only significantly predictive contextual screen time variable associated with spatial skills. Child age was positively associated with literacy and number skills. SES was also positively associated with spatial skills in this model. HLE was not associated with any outcomes.

We next considered the proportion of educational screen time as a predictor of child academic skills, also accounting for other contextual screen time variables and covariates. In model 2, the proportion of educational screen time, parental monitoring, device type, HLE, and SES were not significantly associated with literacy skills, with a negative trend association with total minutes using a traditional TV. For number skills, the proportion of educational screen time, parental monitoring, device type, HLE, and SES were not significantly associated with these skills. As in model 1, using a mobile device was the only predictive contextual screen time variable and was

positively associated with spatial skills. Child age was positively associated with literacy and number skills. SES was also positively associated with spatial skills in this model. HLE was not associated with any outcomes and age 4 control variables were associated with all outcomes.

4.6 Research Aim 2b: Typologies of Content and Context in Predicting Academic Skills

We next tested cluster group differences in predicting academic skills, such that cluster groups, instead of individual screen time variables, predicted outcomes (see Table 7). Children with moderate total, educational mobile devices (cluster 2) performed significantly better than peers with low total, unmonitored, and non-educational TV (cluster 1) in literacy skills at age 5 (d = .23), even after accounting for HLE, SES, child age, and age 4 performance on literacy skills. Cluster 2 also scored significantly higher in literacy skills at age 5 than children with the highest total, educational TV and mobile devices (cluster 3) (d = .56). There were no significant differences among cluster 1 and cluster 3 in literacy skills. In addition, no statistically significant associations were detected among cluster groups for number or spatial skills.

5.0 Discussion

The goal of the present longitudinal study was to understand the contextual factors related to children's screen time, and subsequent impacts on their literacy, number, and spatial skills. This is an important step forward in the literature as screen time's impact on academic skills has often been considered via total screen time and has shown to have primarily negative associations on child outcomes related to cognitive and academic outcomes (Domingues-Montanari, 2017). In addition, experimental studies often assess only the impacts of individual educational programs without acknowledging other contextual factors (e.g., Alade et al., 2016; Linebarger, 2015), such as the proportion of educational content within the full amount of screen exposure, parental monitoring, and device type, which all may influence children's screen experiences and academic skills.

In the present study, using time diaries to allow for rich measurement of children's screen time, we uncovered that overall, 4 year-old children in our study watched more TV programs on traditional TVs than used mobile devices which is consistent with past research (Rideout, 2017). Children also engaged with more non-educational than educational content, which is corroborated in recent research (Kaur et al., 2022). Past research has also investigated the content of children's screen time using television diaries and 24-hour recall of screen time content (e.g. Barr et al., 2010); however, we extend this research by also including device type, coding for educational vs. non-educational content and whether the parent was present during the screen time. A majority of studies investigating the effects of screen time on child outcomes still rely on a global measure of total screen time (Barr et al., 2020) and often use parent questionnaires where parents, often incorrectly, retroactively estimate (Barr et al., 2020) their child's average screen time in the

previous month or week. By conducting time diary interviews about the previous day, we can readily ask parents about the content and device type of children's screen time throughout the day. Further, using time diaries as a measure of children's screen time allows approximations of a workday and non-workday (also weekdays and weekends in most cases), which often coincided with school days and non-school days. In this way, we are able to capture the differences in screen time when children spend more of their day outside of the home at school compared to a weekend day, when they might spend more time at home and may have more screen time (Sigmundová et al., 2018; Tang et al., 2018). Lastly, recent calls for a more wholistic approach to measuring children's screen time (Barr et al., 2020) point to the timeliness and appropriateness of employing this methodology.

Our study also found that children with higher total screen time had lower literacy scores, but children who had a higher proportion of educational screen time at age 4 had higher literacy skills by age 5. In addition, children who used mobile devices more often showed better spatial skills at age 5**.** These descriptive findings elucidate the necessity of cluster analysis to assess the role of the combination of content and context in children's screen time and academic skills. In examining the content and contextual factors related to children's screen time, a cluster analysis revealed three different types of screen users in this sample. The first cluster was termed "low total, unmonitored, and non-educational TV," the second cluster was called "moderate total, educational mobile devices," and the final cluster was "highest total, educational TV and mobile devices."

Importantly, there were no significant cluster group differences in HLE, SES, or child age. HLE was negatively related to total minutes of screen time, perhaps corroborating the notion that screen time may be replacing opportunities for social interactions that encourage learning

((Przybylski & Weinstein, 2017). However, HLE was not related to educational screen time or the proportion of educational screen time, which may replicate the finding that educational digital activities are separate from more analog learning experiences in the home (Lehr, 2021).

In all, moderate total, but higher educational screen time using a mobile device was better than high amounts of total screen time, even if a high proportion of the total screen time was educational. Additionally, moderate total, but higher educational screen time on a mobile device was also better than low total screen time with moderate educational television content. The second cluster ("moderate total, educational mobile devices") showed better performance in their literacy skills than both cluster 1 ("low total, unmonitored, and non-educational TV") and cluster 3 ("highest total, educational TV and mobile device"). Effect sizes between cluster 1 and cluster 2 were smaller than that of the difference between groups 2 and 3. This is possibly because of lower total screen time for children in cluster 1 compared to cluster 3. Cluster 2 only used mobile devices and performed better on literacy measures than the other groups, which suggests that the interactivity of apps and mobile devices may support early learning (Griffith et al., 2020). Importantly, the cluster that performed best on literacy outcomes only used mobile devices, indicating the ability of cluster analyses to capture important features of screen time, like mobile device use, in predicting child outcomes.

In contrast, the clustered groups did not differ across math (number and spatial) outcomes. It may be that many of the educational child programs that young children engage with are more heavily focused on developing emergent literacy skills, such as letter recognition and phonological awareness. Future research should address the domain specificity of programs and categorize the TV programs and apps according to specific educational focus (e.g., literacy- or math-focused).

Regression analyses with individual screen time characteristics, in contrast to the cluster groups regression, were not generally related to kids' outcomes, with the exception of mobile devices predicting spatial skills growth. Related research has found that spatial skills training using digital devices in young children to be effective (Bower et al., 2021), and that videogame play in young children is related to spatial skills (Subrahmanyam & Greenfield, 1994). Given this association, further investigation in this area should consider whether the apps children are playing with encourage spatial reasoning or if simple touchscreen interactivity could benefit children's spatial skills. Moreover, given the low average mobile device use in this sample, perhaps when considering the total picture of children's screen time, the association between screen time and spatial skills is diminished, resulting in null findings for spatial skills in the cluster group regression analysis. Future research should also include older children who are more likely to use mobile devices (Rideout, 2017) to capture these nuances.

5.1 Limitations and Conclusions

Despite rigorous measurement tools, comparisons of variable-based and person-oriented approaches, and the use of baseline performance on academic skills to better demonstrate causality, several limitations should be noted. First, correlations among total screen time and minutes of parental monitoring were high, indicating parents' presence during many of children's screen time activities. A further limitation of measuring parental monitoring is not knowing the extent of parents' participation in discussions about the content. Although previous research suggests that parental co-viewing without conversations may be sufficient as it relates to learning from screens (Nathanson, 2001b), it is an important next step to understand how much and the extent to which

parents are engaging with their child during screen time by addressing different types of parental monitoring including active mediation, restrictive mediation, and co-viewing (Gentile et al., 2012).

Another limitation in this study involves missing data. Obtaining information from parents about the device their child was using during their screen time is novel and a crucial consideration based on the promising impacts of interactive screen time. However, among the study variables, minutes of device type showed the most missingness (28%) and would have provided more insight into how much the role of device type is important for understanding the context of children's screen time for their academic skills.

Due to COVID-19, in-person, age 4 data collection was halted for this sample. A larger sample size, as was intended, would have allowed for better generalizability. In addition, most study participants were enrolled in preschool. This highlights the potential selection concerns if parents in this sample used more educational screen time to extend their child's preschool learning. Future studies should include more children who are not enrolled preschool to examine the generalizability of these findings.

Given the increase in children's screen time during, especially during the COVID-19 pandemic (Ribner et al., 2021) further understanding of how screens and the context in which screen time occurs is an important step in exploring the impacts of screen time on children's academic outcomes. In this study, the findings suggest that the context of screen time may promote children's literacy skills, whereas total screen time was not a useful predictor of direct assessments of young children's early learning. Future research should also consider the learning goals of the educational content that children engage with during each instance of screen time, and how much parents are interacting with their child while playing with apps or watching TV programs.

Table 1. Time diary codes.

General codes
1. Sleeping
2. Grooming/hygiene
   2A. Parent
   2B. Child
   2C. Give/rec. med/first-aid
3. Watching TV
   3A. Traditional TV
   3B. Electronic device
4. Eating and drinking
5. Religious activities
   5A. In-Person
   5B. Online Service
   5C. Other
6. Errands
7. Interacting family and friends
   7A. From household
   7B. Not-household
   7C. Scolding/negative emotion
8. Shopping
   8A. Grocery
   8B. Food/Meals
   8C. Other
9. Transportation
   9A. Car
   9B. Bus
   9C. Walking
   9D. Bike
10. Resting/leisure
11. Child bed time
12. Other (put a note in sub-code)

Parent codes
13. Working at job
14. Attend class or studying
15. Preparing meals or snacks
16. Cleaning
17. Laundry
18. Other domestic work
19. Reading
   19A. Electronic device
   19B. Hard copy
20. Use phone/electronic media
21. Exercising
22. Playing with child
23. Academic work with child
   23A. Online Schooling
   23B. Homework
   23C. Other
24. Nursing/Caring child
25. Supervising child
26. Interacting with partner

Child codes
27. Preschool/School
   27A.Center
   27B. Home
   27C. Religious
   27D. Online
28. Household chores
29. Play and recreation at home
   29A. Arts
   29B. Music
   29C. Blocks/building/puzzles
   29D. Dramatic
   29E. Gross motor
   29F. Fine motor
   29G. Playing video games
   29H. Electronic media
   29I. Nature/science activities
   29J. Other

30. Play and recreation out home
   30A. Arts
   30B. Music
   30C. Blocks/building/puzzles
   30D. Dramatic
   30E. Gross motor
   30F. Fine motor
   30G. Playing video games
   30H. Electronic media
   30I. Nature/science activities
   30J. Other
31. Math
   31A. Hard copy
   31B. Electronic device
   31C. Talking/interaction
32. Reading
   32A. Hard copy
   32B. Electronic device
   32C. Talking/interaction
33. Other out of home activities
   33A. Museum
   33B. Zoo
   33C. Library
   33D. Park
   33E. Other
34. Other academic work
   34A. Foreign languages
   34B. Writing
   34C. Rhyming or word games
   34D. Other

35. Transitions (general code)
   35A. Drop off/pick up
   35B. Getting ready

-1. Parent was not with child
-2. Can't remember
-3. Refusal/ didn't respond
-4. Interviewer didn't ask

WHERE CODES

Child
1. In home
2. Patio/backyard/driveway
3. Child care
4. Friends/relative home
5. Out of home

Parent
1. In home
2. Patio/backyard/driveway
3. Work place
4. Friends/relative home
5. Out of home

WHO CODES

Child
1. Reporting parent
2. Non-reporting parent
3. Siblings
4. Relatives
5. Non-relatives caregiver
6. Peers
7. Pets
8. Other
-1. No one/child was alone
-4. Not specified/interviewer didn't ask
-5. Not specified but not with parent

Parent
1. Child
2. Other children
3. Partner
4. Friends/relatives
5. Co-workers
6. Pets
7. Other
-1. No one/ they were alone
-4. Not specified/interviewer did not ask
-5. Not specified but not with the child of interest

Table 2. Descriptive statistics of study variables.

	Mean	SD	Min	Max
Literacy Skills	-0.01	0.92	-1.8	2.6
Number Skills	-0.01	0.93	-2.8	2.3
Spatial Skills	-0.01	0.84	-1.9	2.07
HLE	63.9	84.7	0	420
SES	0.05	0.07	-2.4	1.3
Age	4.4	0.3	4.0	4.9
Age 4 PA	0	1	-3.9	2.4
Age 4 AP	0	1	-3.6	2.5
Age 4 Spatial	-0.02	0.84	-1.8	2.6
Total minutes of ST	162.9	127.4	0	670
Minutes of educational ST	57.2	62.7	0	282
Proportion of educational ST	0.39	0.36	0	1
Minutes of parental monitoring	97.5	99.3	0	560
Minutes using traditional TV	75.4	89.9	0	380
Minutes using mobile device	41	70.9	0	560

Note: Literacy, Number, Spatial, Age 4 PA, Age 4 AP, and Age 4 Spatial means are derived from z-scores. Means of screen time variables are derived from raw data. Literacy achievement is measured by Letter Word Identification and Sound Matching. Number skills is measured by Applied Problems and Numeral Identification. Spatial skills is assessed using Child Mental Transformation Task (CMTT) and Geometric Sensitivity. HLE = Home Learning Environment in minutes. SES = composite variable of socioeconomic status including parent education and household income. Age 4 PA is Phonological Awareness standard score; age 4 AP is Applied Problems; age 4 control for spatial skills at age 5 is CMTT and geometric sensitivity composite. ST = screen time.

Table 3. Bivariate correlations among study variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Literacy Skills	1.0														
2. Number Skills	.71**	1.0													
3. Spatial Skills	.64**	.65**	1.0												
4. HLE	.22*	.28**	.16^{+}	1.0											
5. SES	.30**	.36**	.33**	.14	1.0										
6. Age	.08	.18^{+}	.23*	-.00	-.23*	1.0									
7. Age 4 PA	.61**	.53**	.37**	.24*	.35**	-.11	1.0								
8. Age 4 AP	.56**	.71**	.55**	.27**	.47**	-.00	.56**	1.0							
9. Age 4 Spatial	.51**	.61**	.56**	.20*	.23*	.24**	.46**	.58**	1.0						
10. Total minutes of ST	-.30**	-.15	-.22*	-.19*	-.26**	-.02	-.28**	-.22	-.22*	1.0					
11. Minutes of educational ST	-.09	-.03	-.12	-.09	.01	-.03	.06	.03	-.08	.43**	1.0				
12. Proportion of educational ST	.25*	.19^{+}	.08	.13	.14	.01	.22*	.21*	.18^{+}	-.19*	.65**	1.0			
13. Minutes of parental monitoring	-.19*	-.11	-.17^{+}	-.22*	-.25**	-.05	-.27**	-.19*	-.18*	.78**	.25**	-.19*	1.0		
14. Minutes using traditional TV	-.26**	-.15	-.21	-.13	-.19*	-.05	-.05	-.14	-.06	.55**	.29**	.09	.47**	1.0	
15. Minutes using mobile device	-.00	-.02	.13	-.04	-.18^{+}	-.00	-.34**	-.19*	-.07	.52**	.13	-.06	.45**	-.11	1.0

Note: $^{+}$p < .1, * p < .05, ** p < .01. Correlations are derived from raw data. Literacy achievement is measured by Letter Word Identification and Sound Matching. Number skills is measured by Applied Problems and Numeral Identification. Spatial skills is assessed using Child Mental Transformation Task (CMTT) and Geometric Sensitivity. HLE = Home Learning Environment in minutes. SES = composite variable of socioeconomic status including parent education and household income. Age 4 PA is Phonological Awareness standard score; age 4 AP is Applied Problems; age 4 control for spatial skills at age 5 is CMTT and geometric sensitivity composite. ST = screen time.

Table 4. K-medians cluster analysis results.

	Total minutes of screen time	Proportion of educational screen time	Minutes of educational screen time	Minutes of parent monitored screen time	Minutes using traditional TV	Minutes using mobile device
Cluster 1 Low total, unmonitored, and non-educational TV n = 36	85 [96.9(53.9)]	.28 [.37(.41)]	25 [34.9(44.1)]	30 [40.1(45.2)]	60 [66.9(41.9)]	0 [6.7(35.9)]
Cluster 2 Moderate total, educational mobile devices n = 28	122.5 [159.1(135)]	.41 [.42(.37)]	30 [50.9(64.3)]	77.5 [104.8(111.7)]	0 [.54(2.8)]	33.5 [72.8(109.9)]
Cluster 3 Highest total, educational TV, and mobile devices n = 48	210 [248.4(112.6)]	.37 [.40(.30)]	90 [89.5(64.2)]	150 [156.6(92.5)]	115 [141.1(102.3)]	50 [56.8(54.2)]
Total N = 112	155 [177.4(122.8)]	.37 [.40(.36)]	50 [62.3(62.9)]	85 [1.6.2(99.1)]	60 [81.1(90.8)]	5 [44.7(72.9)]
Range	10 - 670	0-1	0 - 282	0-1	0-380	0-560

Note: Medians are reported for each group and means(sd) are reported in brackets

Table 5. Regression model predicting HLE, SES, and child age by cluster group.

	HLE		SES		Child Age	
	R^2	**β**	**R^2**	**β**	**R^2**	**β**
Model	**-.00**		**.00**		**-.00**	
						0.11
Cluster 2 Moderate total, educational mobile devices		0.03		-0.04		
Cluster 3 Highest total, educational TV and mobile devices		-0.07		-.16		.02

Note: * p < .05, ** p < .01. Standardized coefficients are shown. Cluster 1 (low total, unmonitored, and non-educational TV) is the reference group. HLE = Home Learning Environment in minutes. SES = composite variable of socioeconomic status including parent education and household income.

Table 6. Regression model predicting literacy achievement, number skills, and spatial skills outcomes with total screen time. Model 1 includes total minutes using screens and total minutes using educational screens and Model 2 shows these predictions using only.

	Literacy Skills		Number Skills		Spatial Skills	
	R^2	**β**	**R^2**	**β**	**R^2**	**β**
Model 1	**.42****		**.56****		**.36****	
Total minutes of ST		-0.22		0.02		-0.10
Total minutes of educational ST		0.02		0.03		-0.04
Minutes of parental monitoring		0.10		-0.03		0.00
Minutes using traditional TV		-0.08		0.00		0.00
Minutes using mobile device		0.09		0.09		0.23*
HLE		0.06		0.05		0.05
SES		0.13+		0.12		0.25**
Age		0.19*		0.21**		0.14
Age 4 Control		0.56**		0.68**		0.43**
Model 2	**.44****		**.57****		**.37****	
Proportion of educational screen time		0.12		0.10		-0.02
Minutes of parental monitoring		0.03		0.00		-0.05
Minutes using traditional TV		-0.17+		0.02		-0.05
Minutes using mobile device		0.02		0.10		0.19*
HLE		0.05		0.05		0.05
SES		0.13		0.12		0.25**
Age		0.19*		0.21**		0.13
Age 4 Control		0.56**		0.67**		0.45**

Note: +p < .1, * p < .05, ** p < .01. Standardized coefficients are shown. Literacy achievement is measured by Letter Word Identification. Number Skills is measured by Applied Problems. Spatial skills is assessed using Child Mental Transformation Task (CMTT) and Geometric Sensitivity. Age 4 control for literacy achievement at age 5 is the Comprehensive Test of Phonological Processing (CTOPP) standard score; age 4 control for number skills at age 5 is Applied Problems; age 4 control for spatial skills at age 5 is CMTT and geometric sensitivity composite. HLE = Home Learning Environment in minutes. SES = composite variable of socioeconomic status including parent education and household income. ST = screen time.

Table 7. Regression model predicting literacy achievement, number skills, and spatial skills outcomes with cluster groups.

	Literacy Skills		Number Skills		Spatial Skills	
	R^2	**β**	**R^2**	**β**	**R^2**	**β**
Model	**.49****		**.58****		**.36****	
Cluster 2 Moderate total, educational mobile devices		0.21^{*aa}		0.07		0.05
Cluster 3 Highest total, educational TV and mobile devices		-0.04^{aa}		0.06		0.04
HLE		0.04		0.05		0.04
SES		0.16*		0.11		0.26**
Age		0.17*		0.19**		0.17*
Age 4 Control		0.57**		0.67**		0.44**

Note: $^{+}$p < .1, * p < .05, ** p < .01, ^{aa} <. 01. Cluster 1 (low total, unmonitored, and non-educational TV) is the reference group. Standardized coefficients are shown. Literacy achievement is measured by Letter Word Identification. Number skills is measured by Applied Problems. Spatial skills is assessed using Child Mental Transformation Task (CMTT) and Geometric Sensitivity. Age 4 control for literacy achievement at age 5 is the Comprehensive Test of Phonological Processing (CTOPP) standard score; age 4 control for number skills skills at age 5 is Applied Problems; age 4 control for spatial skills at age 5 is CMTT and geometric sensitivity composite. HLE = Home Learning Environment in minutes. SES = composite variable of socioeconomic status including parent education and household income. ST = screen time.

Appendix A Program Names

Educational TV

Sesame Street
Remy and Boo
Ask the Storybots
Blues Clues & You!
Blue's Clues
Bubble Guppies
Daniel Tiger's Neighborhood
Dinosaur Train
Mister Rogers' Neighborhood
One Big Ocean
Peep and the Big Wide World
Peg + Cat
Reading Rainbow
Ready Jet Go!
Sid the Science Kid
Super Monsters
Snoopy in Space
Tumble Leaf
Wallykazam!
Dino Dana
Gullah Gullah Island
Go! Go! Cory Carson
Little Einsteins
Let's Go Luna!
Llama Llama
Thomas the Tank Engine
Green Eggs and Ham
Videos: shapes, songs
Youtube Kids: letters game
YouTube: sea animal educational videos
Numberjacks
Youtube Kids: Steve and Maggie
Leapfrog: Phonics Farm
Annedroids
Catie's Amazing Machines
Super WHY!
Team Umizoomi
The Cat in the Hat Knows a Lot About That
Word Party
Puffin Rock
Justin Time
Clifford the Big Red Dog
Mother Goose Club
WordWorld
The Big Comfy Couch
Mickey Mouse Clubhouse
Peppa Pig
Paw Patrol
Super Wings
Cyberchase
The Electric Company
If I Were an Animal
The Magic School Bus
Molly of Denali
My World Kitchen
Nature Cat
Odd Squad
Word Girl
WALL-E
Elinor Wonders Why
Animal Atlas
Design Squad Nation
The Henry Ford's Innovation Nation
Nutri Ventures
Our Planet
Planet Earth
Wild Kratts
Wonder Quest
Xploration Outer Space
Thomas Edison's Secret Lab
Animal Planet
The Land Before Time
Elmo's World
Alphablocks
Chinese language learning video
CoComelons
Dora the Explorer
Paw Patrol: Mighty Pups
Creative Galaxy
Doc McStuffins
Earth to Luna
Helpsters
Julie's Greenroom
Martha Speaks
Octonauts

An American Girl Story-Melody, 1963: Love Has to Win
Beakman's World
Bill Nye the Science Guy
Brainchild
Carmen Sandiego
Jacques Cousteau's Ocean Tales
Nature
Planet Earth: Blue Planet II
RAD Lands
SciGirls
Secret Millionaires Club
The Who Was? Show
Where on Earth is Carmen Sandiego?
Wild Kratts: Creatures of the Deep Sea
Xploration Awesome Planet
YouTube: multiplication video
Brain Games
Chill with Bob Ross

Genius by Stephen Hawking
Get the Math
Hack Along with GoldieBox
Kid Stew
HowStuffWorks
Liberty's Kids
One Strange Rock
Jane
National Geographic Documentary
Horrible Histories
MythBusters
Antiques Roadshow
Bang Goes the Theory
Cosmos: A Spacetime Odyssey
Great Migrations
How We Got to Now
NOVA
Victorian Slum House
History Channel
Age of A.I.
The Great American Read
American Experience
America Revealed
America: The Story of Us
Cooked
Finding Your Roots with Henry Louis Gates, Jr.
First Life with David Attenborough
Hamilton's America
The Numbers Game
Through the Wormhole with Morgan Freeman
United Stats of America
White Rabbit Project
Scrappy Roots with Simone Giertz
America Inside Out with Katie Couric
Anthony Bourdain: Parts Unknown
Origins: The Journey of Humankind
The Weight of the Nation
The Story of God with Morgan Freeman
Breakthrough
Roots
Underground

Educational Apps and games

Underground
ABC Mouse
Bug Mazing
Daniel Tiger's Grr-ific Feelings
LeapFrog
PBS Kids
ABCya Counting Fish
ABCya Make a Cake
ABCya Make a Cupcake
Kiddopedia
Disney Game: tracing letters
PBS Kids: games about money
Fish School
Preschool prep - letters
Smart Shapes
Vooks
ABC Practice App
Khan Academy Kids
Daniel Tiger's Neighborhood: Play at Home with Daniel
Daniel Tiger's Day and Night
Toca Robot Lab
Team Umizoomi
Leapster
Daniel Tiger Activity App
Monster Math
Baby Panda's Supermarket
Elmo Loves ABCs
Osmo
Endless Reader
The Lion Guard
Teach Your Monster to Read: Phonics & Reading Game
ScratchJr
Wii Sports
Duolingo

Non-educational Television Programs

Car Patrol
Buddi
Youtube: Wheels on the Bus

Ben & Holly's Little Kingdom
Calico Critters
Hey Duggee

Puppy Dog Pals
Sunny Days
Esme & Roy
Sofia the First
Caillou
Mickey's Once Upon a Christmas
Luo Bao Bei
Sunny Bunnies
Chicka Chicka Boom Boom
Zoboomafoo
Sheriff Callie's Wild West
Drive in Movie Ads
Frosty the Snowman
Pocoyo

Motown Magic
Winnie the Pooh
Mini Adventures of Winnie the Pooh
Little Baby Bum
Rudolph the Red-Nosed Reindeer
Alice in Wonderland
Blippi
Hello Ninja
Pinkalicious
Pinkalicious & Peterrific
PJ Masks
Rainbow Rangers
Wishenpoof!
Ryan Toys Review
Marvel Super Hero Adventures
True and the Rainbow Kingdom
Youtube: Loch Lomond
Youtube: Greensleeves
Morphle
Bluey
Dump Trucks and Diggers: Color Learning Fun
Videos: nursery rhymes
Barbie Movie
Cartoons: unspecified
Youtube: Chad Wild Clay
Youtube: DIY jewelry videos
Youtube: Chad and Vy
Youtube: DIY Slime Videos
T.O.T.S.
Cleo & Cuquin
Out of the Box
Youtube: kids playing
Mickey's Christmas Carol
Youtube: Kids Diana Show
YouTube: My Cat Chooses Which Mystery Box I Open
The Little Engine That Could
Youtube: Come Play with Me
Youtube: music videos
YouTube: Sergei Polunin dance
YouTube Kids: songs about counting and drawing numbers
Netflix Christmas Movie
Masha and the Bear
Youtube: Parker Plays
Youtube: baby shark
Youtube: unboxing
Youtube: Paw Patrol Toys
Youtube: Baby Bus
Youtube: singing program
Unspecified: animal show
YouTube Kids: kids playing with trucks
Music videos
Pete the Cat
Truck videos
Noddy, Toyland Detective
L.O.L. Surprise!
Unspecified: cartoons
Abby Hatcher
Curious George
Mickey Mouse Mixed-Up Adventures (formerly known as Mickey and the Roadster Racers, but don't add these parentheses)
Piglet's Big Movie
Pooh's Heffalump Movie
Youtube: Afro Ken
Christmas Classics
Angry Birds Toons
Elena of Avalor
Frozen
Happily Ever After: Fairy Tales for Every Child
Inspector Gadget
House of Mouse
Shopkins
Super Friends
The Little Mermaid
The Lion Guard
Monsters, Inc.
Too Cute
Dragon Rescue Riders
Elena and the Secret of Avalor
Vampirina
Bolt
Tom and Jerry
Bambi
Phineas and Ferb
Toy Story 4
A Bug's Life
Finding Nemo
Cars
Pixar Short Films Collection: Volume 1
Mulan
Sleeping Beauty
The Muppets
Beauty and the Beast
Danger & Eggs
The Fairly OddParents
Ferdinand
The Fox and the Hound
Frozen 2
Inside Out
Mary Poppins
Shrek
Shrek 2
Shrek 3
SpongeBob SquarePants
The Princess and the Frog
Pokemon
Rugrats
Dr. Seuss' The Grinch
The Rescuers
Moana
Cloudy with a Chance of Meatballs 2
Paddington 2
Jack and the Beanstalk
Mr. Peabody & Sherman
Bugs Bunny

Rio
Transformers Rescue Bots
Football
Aladdin
Hockey
Home: Adventures with Tip & Oh
Yoga video
Skiing
Trolls
Tarzan
Soccer
Despicable Me
Polly Pocket
Finding Dory
The Boss Baby: Back in Business
Pocahontas
Bunk'd
Kung Fu Panda
Tennis Masters
Baseball
Henry Danger
Alvin and the Chipmunks: Chip-Wrecked
Alvin and the Chipmunks
The Boss Baby
The Wizard of Oz
My Little Pony 'n Friends
Up
Babe
American Ninja Warrior Junior
Cupcake and Dino
Halloweentown
Scooby-Doo
Power Rangers
Pup Academy
How to Train Your Dragon 2
The Good Dinosaur
Lego Jurassic World
Zumbo's Just Desserts
How to Train Your Dragon: The Hidden World
Sing
Teen Titans Go!
Bigfoot
Pac-Man and the Ghostly Adventures
Coco
The Nightmare Before Christmas
Batman
Halloween movie
Big Hero 6
Silly Symphony
Onward
Mighty Mike
Ninja Turtles
Miraculous: Tales of Ladybug & Cat Noir
Jessie
Looney Toons

Wreck-It Ralph
The Real Ghostbusters
Monster Trucks
The Adventures of Sonic the Hedgehog
Elf
Liv and Maddie
The Croods
Dragons: Race to the Edge
Ralph Breaks the Internet
The Little Rascals
Teen Titans
The Amazing World of Gumball
Shark Tale
Incredibles 2
Elliot: The Littlest Reindeer
Dude Perfect
Avatar: The Last Airbender
The Willoughbys
Floor Is Lava
Family Feud
On the Town
Zootopia
We Bare Bears
The Great British Baking Show
Willy Wonka and the Chocolate Factory
Bye Bye Birdie
Holey Moley
Matilda
My Pet Dinosaur
The Santa Clause
Dinosaur King
Newsies
Coraline
The Kid Who Would Be King
Trollhunters
Home Alone
The Little Prince
The Masked Singer
Cats the Musical
The Pacifier
Star Wars
Youtube: America's Funniest Home Videos
America's Funniest Home Videos
Hocus Pocus
House Hunters
The Christmas Chronicles
Spider-Man 3
Harry Potter
Wonder Women
Transformers
Black Panther
Jurrasic Park
Thor: Ragnarok
The Way We Love
Avengers: Endgame
News
SNL: politics
Chasing Monsters
Saturday Night Live
New Girl
The Goldberg's
Gilmore Girls
Law & Order

Cobra Kai
Meet the Press
Pokemon GO
Welcome to Sudden Death
NCIS: Los Angeles

Non-educational apps and games

Giggles Car Wash
Unspecified: games on phone
Park Master
Sandbox - Pixel Art Coloring
My City
Tag with Ryan
Mario Kart
Talking Tom Cat
Super Mario World
Angry Birds
Unspecified: shooting game
Animal Crossing
The Lengend of Zelda
Wii Dancing
Katamari Damacy Reroll
Minecraft
Super Mario Odyssey
Sonic
Zelda
Sonic the Hedgehog
Roblox
Slender-Man
Granny
Bendy and the Ink Machine

Bibliography

AAP Council on Communications and Media. (2016). Media and young minds. Pediatrics, 138(5), e201625. https://doi.org/ 10.1542/peds.2016-2591 Anderson, D. R., Bryant, J., Wilder, A., Santomero, A., Williams, M., & Crawley, A. M. (2000). Researching Blue's Clues: Viewing Behavior and Impact. *Media Psychology*, *2*(2), 179–194. https://doi.org/10.1207/S1532785XMEP0202_4

Aladé, F., Lauricella, A. R., Beaudoin-Ryan, L., & Wartella, E. (2016). Measuring with Murray: Touchscreen technology and preschoolers' STEM learning. *Computers in Human Behavior*, *62*, 433–441. https://doi.org/10.1016/j.chb.2016.03.080

Barr, R., Kirkorian, H., Radesky, J., Coyne, S., Nichols, D., Blanchfield, O., Rusnak, S., Stockdale, L., Ribner, A., Durnez, J., Epstein, M., Heimann, M., Koch, F. S., Sundqvist, A., Birberg-Thornberg, U., Konrad, C., Slussareff, M., Bus, A., Bellagamba, F., & Fitzpatrick, caroline. (2020). Beyond Screen Time: A Synergistic Approach to a More Comprehensive Assessment of Family Media Exposure During Early Childhood. Frontiers in Psychology, 11. https://doi.org/10.3389/fpsyg.2020.01283

Barr, R., Lauricella, A. R., Zack, E., & Calvert, S. L. (2010). The relation between infant exposure to television and executive functioning, cognitive skills, and school readiness at age four. https://www.researchgate.net/publication/256373809

Bower, C. A., Zimmermann, L., Verdine, B. N., Pritulsky, C., Golinkoff, R. M., & Hirsh-Pasek, K. (2022). Enhancing spatial skills of preschoolers from under-resourced backgrounds: A comparison of digital app vs. concrete materials. *Developmental Science*, *25*(1). https://doi.org/10.1111/desc.13148

Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. Annual Review of Psychology, 53, 371–399.

Bronfenbrenner, U. (1979).The ecology of human development: Experiments by nature anddesign.Cambridge, MA: Harvard University Press.

Chera, P., & Wood, C. (2003). Animated multimedia "talking books" can promote phonological awareness in children beginning to read. In *Learning and Instruction* (Vol. 13). www.elsevier.com/locate/learninstruc

Chiong, C., & Shuler, C. (2010). *The Joan Ganz Cooney Center at Sesame Workshop Learning: Is there an app for that?* www.joanganzcooneycenter.org.

Chorney, J. M., McMurty, C. M., Chambers, C. T., & Bakeman, R. (2015). Developing and

modifying behavioral coding schemes in Pediatric Psychology: A practical guide. Journal of Pediatric Psychology, 40(1), 154.164.

Dehaene, S., et al., *Core knowledge of geometry in an Amazonian indigene group.* Science, 2006. **311**(5759): p. 381-4.

Del Pozo-Cruz, B., Perales, F., Parker, P., Lonsdale, C., Noetel, M., Hesketh, K. D., & Sanders, T. (2019). Joint physical-activity/screen-time trajectories during early childhood: Socio-demographic predictors and consequences on health-related quality-of-life and socio-emotional outcomes. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1). https://doi.org/10.1186/s12966-019-0816-3

Dolnicar, S. (2002). *A Review of Unquestioned Standards in Using Cluster Analysis for Data-A Review of Unquestioned Standards in Using Cluster Analysis for Data-Driven Market Segmentation Driven Market Segmentation*. https://ro.uow.edu.au/commpapers

Domingues-Montanari, S. (2017). Clinical and psychological effects of excessive screen time on children. In Journal of Paediatrics and Child Health (Vol. 53, Issue 4, pp. 333–338). Blackwell Publishing. https://doi.org/10.1111/jpc.13462

Fan, X., & Chen, M. (2001). Parental Involvement and Students' Academic Achievement: A Meta-Analysis. In *Educational Psychology Review* (Vol. 13, Issue 1).

Federal Communications Commission (FCC). (2019). *Children's Educational Television.* Consumer Guide prepared for the Beareau of Consumer and Govermental Affairs. Washington D.C.

Gentile, D. A., Nathanson, A. I., Rasmussen, E. E., Reimer, R. A., & Walsh, D. A. (2012). Do You See What I See? Parent and Child Reports of Parental Monitoring of Media. *Family Relations*, *61*(3), 470–487. https://doi.org/10.1111/j.1741-3729.2012.00709.x

Griffith, S. F., Hanson, K. G., Rolon-Arroyo, B., & Arnold, D. H. (2019). Promoting early achievement in low-income preschoolers in the United States with educational apps. *Journal of Children and Media*, *13*(3), 328–344. https://doi.org/10.1080/17482798.2019.1613246

Griffith, S. F., Hagan, M. B., Heymann, P., Heflin, B. H., & Bagner, D. M. (2020). Apps As Learning Tools: A Systematic Review. In Pediatrics (Vol. 145, Issue 1). NLM (Medline). https://doi.org/10.1542/peds.2019-1579

Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: An overview and tutorial. Tutor Quantitative Methods in Psychology, 8(1), 23-34.

Janssen, X., Martin, A., Hughes, A. R., Hill, C. M., Kotronoulas, G., & Hesketh, K. R. (2020). Associations of screen time, sedentary time and physical activity with sleep in under 5s: A systematic review and meta-analysis. In *Sleep Medicine Reviews* (Vol. 49). W.B. Saunders Ltd. https://doi.org/10.1016/j.smrv.2019.101226

Kaur, N., Gupta, M., Malhi, P., & Grover, S. (2022). Prevalence of Screen Time Among Children Aged 2 to 5 Years in Chandigarh, a North Indian Union Territory (Vol. 43, Issue 1). www.jdbp.org%7Ce29

Kostyrka-Allchorne, K., Cooper, N. R., & Simpson, A. (2017). *The relationship between television exposure and children's cognition and behaviour: 1 A systematic review*.

Kotila, L.E., Schoppe-Sullivan, S.J., & Kamp Dush, C.M. (2013). Time in parenting activities in dual-earner families at the transition to parenthood. Family Relations, 62(5), 795-807.

Lauricella, A. R., Wartella, E., & Rideout, V. J. (2015). Young children's screen time: The complex role of parent and child factors. Journal of Applied Developmental Psychology, 36, 11–17. https://doi.org/10.1016/j.appdev.2014.12.001

Lehrl, S., Linberg, A., Niklas, F., & Kuger, S. (2021). The Home Learning Environment in the Digital Age—Associations Between Self-Reported "Analog" and "Digital" Home Learning Environment and Children's Socio-Emotional and Academic Outcomes. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.592513

LeKander, B. (2020). Office of Elementary & Secondary Education. *Ready to Learn: Ready to Learn Announces $29 Million for Television and Digital Media Focusing on Career Awareness Among Early Learners.* Retrieved from: https://oese.ed.gov/offices/office-of-discretionary-grants-support-services/innovation-early-learning/ready-to-learn-television-rtl/

Levine, S. C., Huttenlocher, J., Taylor, A., & Langrock, A. (1999). Early sex differences in spatial skill. Developmental Psychology, 35, 940–949.

Lieberman, D. A., Bates, C. H., & So, J. (2009). Young children's learning with digital media. In Computers in the Schools (Vol. 26, Issue 4, pp. 271–283). https://doi.org/10.1080/07380560903360194

Linebarger, D. L., Kosanic, A. Z., Greenwood, C. R., & Doku, N. S. (2004). Effects of viewing the television program between the Lions on the emergent literacy skills of young children. *Journal of Educational Psychology*, *96*(2), 297–308. https://doi.org/10.1037/0022-0663.96.2.297

Linebarger, D. (2015). Super Why! to the Rescue: Can Preschoolers Learn Early Literacy Skills from Educational Television? *International Journal for Cross-Disciplinary Subjects in Education*, *6*(1), 2060–2068. https://doi.org/10.20533/ijcdse.2042.6364.2015.0286

Livingstone, S., Mascheroni, G., Dreier, M., Chaudron, S.and Lagae, K.(2015) How parents of young children manage digital devices at home: The role of income, education and parental style.London: EU Kids Online, LSE.

Macqueen, J. (1967). *SOME METHODS FOR CLASSIFICATION AND ANALYSIS OF MULTIVARIATE OBSERVATIONS*.

Makles, A. (2012). Stata tip 110: How to get the optimal K-means Cluster Solution. The Stata Journal: Promoting Communications on Statistics and Stata, 12(2), 347–351. https://doi.org/10.1177/1536867x1201200213

McCarthy, E., Tiu, M., & Li, L. (2018). Learning Math with Curious George and the Odd Squad: Transmedia in the Classroom. *Technology, Knowledge and Learning*, *23*(2), 223–246. https://doi.org/10.1007/s10758-018-9361-4

Mcmanis, M. H., & Mcmanis, L. D. (2016). Using a Touch-Based, Computer-Assisted Learning System to Promote Literacy and Math Skills for Low-Income Preschoolers. In *Journal of Information Technology Education: Research* (Vol. 15). http://www.informingscience.org/Publications/3550.

Nathanson, A. I. (2001b). Parent and child perspectives on the presence and meaning of parental television mediation. Journal of Broadcasting & Electronic Media, 45, 210 – 220.

Neumann, M. M. (2018). Using tablets and apps to enhance emergent literacy skills in young children. *Early Childhood Research Quarterly*, *42*, 239–246. https://doi.org/10.1016/j.ecresq.2017.10.006

Pagani, L. S., Fitzpatrick, C., & Barnett, T. A. (2013). Early childhood television viewing and kindergarten entry readiness. *Pediatric Research*, *74*(3), 350–355. https://doi.org/10.1038/pr.2013.105

Pasnik, S., Moorthy, S., Llorente, C., Hupert, N., Dominguez, X., & Silander, M. (2015). *Supporting Parent-Child Experiences with PEG+CAT Early Math Concepts: Loulou Bangura, Education Development Center Danae Kamdar, SRI International Report Design*

Penuel, W. R., Bates, L., Gallagher, L. P., Pasnik, S., Llorente, C., Townsend, E., Hupert, N., Domínguez, X., & VanderBorght, M. (2012). Supplementing literacy instruction with a media-rich intervention: Results of a randomized controlled trial. *Early Childhood Research Quarterly*, *27*(1), 115–127. https://doi.org/10.1016/j.ecresq.2011.07.002

Plowman, L. (2013) Digital media and the everyday lives of young children. In The Children's Media Yearbook 2013, ed. L. Whitaker, pp.135---140, Children's Media Foundation, London.Pew Research Center. (2020). *Parenting Children in the Age of Screens*. https://www.pewresearch.org/internet/2020/07/28/parenting-children-in-the-age-of-screens/

Przybylski, A. K., & Weinstein, N. (2017). A Large-Scale Test of the Goldilocks Hypothesis: Quantifying the Relations Between Digital-Screen Use and the Mental Well-Being of Adolescents. Psychological Science, 28(2), 204–215. https://doi.org/10.1177/0956797616678438

Purpura, D. J., & Lonigan, C. J. (2015). Early Numeracy Assessment: The Development of the Preschool Early Numeracy Scales. Early Education and Development, 26(2), 286–313. https://doi.org/10.1080/10409289.2015.991084.

Ribner, A. D., Coulanges, L., Friedman, S., Libertus, M. E., Hughes, C., Foley, S., Devine, R., Fink, E., Selby, A., Brocki, K., Frick, M., Badinlou, F., Feng, X., Chan, M., Slaughter, V., Clark, S., Su, Y., Wan, S., Lecce, S., … Silver, A. (2021). Screen Time in the Coronavirus 2019 Era: International Trends of Increasing Use Among 3- to 7-Year-Old Children. Journal of Pediatrics, 239, 59-66.e1. https://doi.org/10.1016/j.jpeds.2021.08.068

Rice, M. L., Huston, A. C., Truglio, R., & Wright, J. (1990). Words from "Sesame Street": Learning Vocabulary While Viewing. In *Developmental Psychology* (Vol. 26, Issue 3).

Rideout, V. (2017). The Common Sense census: Media use by kids age zero to eight. San Francisco, CA: Common Sense Media

Rosenfeld, D., Dominguez, X., Llorente, C., Pasnik, S., Moorthy, S., Hupert, N., . . . Vidiksis, R. (2019). A curriculum supplement that integrates transmedia to promote early math learning: A randomized controlled trial of a PBS KIDS intervention. *Early Childhood Research Quarterly, 49*, 241-253. doi:http://dx.doi.org.pitt.idm.oclc.org/10.1016/j.ecresq.2019.07.003

Samudra, P. G., Wong, K. M., & Neuman, S. B. (2020). Is attention the missing link? Coviewing and preschoolers' comprehension of educational media. Journal of Applied Developmental Psychology, 67. https://doi.org/10.1016/j.appdev.2019.101108

Schacter, J., & Jo, B. (2017). Improving preschoolers' mathematics achievement with tablets: a randomized controlled trial. *Mathematics Education Research Journal*, *29*(3), 313–327. https://doi.org/10.1007/s13394-017-0203-9

Schenke, K., Redman, E. J. K. H., Chung, G. K. W. K., Chang, S. M., Feng, T., Parks, C. B., & Roberts, J. D. (2020). Does "Measure Up!" measure up? Evaluation of an iPad app to teach preschoolers measurement concepts. *Computers and Education*, *146*. https://doi.org/10.1016/j.compedu.2019.103749

Shuler, C. (2012). iLearn II; An Analysis of the Education Category of the iTunes App Store. New York: The Joan Ganz Cooney Center at Sesame Workshop.2

Sigmundová, D., Badura, P., Sigmund, E., & Bucksch, J. (2018). Weekday–weekend variations in mother-/father–child physical activity and screen time relationship: A cross-sectional study in a random sample of Czech families with 5- to 12-year-old children. European Journal of Sport Science, 18(8), 1158–1167 https://doi.org/10.1080/17461391.2018.1474951

Subrahmanyam, K., Greenfield, P. M. (1994). Effect of Video Game Practice on Spatial Skills in Girls and Boys KAVERI SUBRAHMANYAM. In JOURNAL OF APPLIED DEVELOPMENTAL PSYCHOLOGY (Vol. 15).

Tang, L., Darlington, G., Ma, D. W. L., & Haines, J. (2018). Mothers' and fathers' media parenting practices associated with young children's screen-time: a cross-sectional study. *BMC Obesity*, *5*(1). https://doi.org/10.1186/s40608-018-0214-4

Taylor, B., Puchner, L., Reeves, A., & Knowlton, D. (2020). *Screen Time and Children's Health: Administrator and Teacher Perceptions*.

U.S. Bureau of Labor Statistics (2016). American Time Use Survey user guide: Understanding ATUS 2003 to 2015.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press

Wagner, R.K., J.K. Torgesen, and C.A. Rashotte, *Comprehensive Test of Phonological Processing*. 1999, Pro-Ed: Austin, TX.

Wartella, E., Beaudoin-Ryan, L., Blackwell, C. K., Cingel, D. P., Hurwitz, L. B., & Lauricella, A. R. (2016). What kind of adults will our children become? The impact of growing up in a media-saturated world. Journal of Children and Media, 10(1), 13–20. https://doi.org/10.1080/17482798.2015.1124796

Woodcock, R.W., K.S. McGrew, and N. Mather, *Woodcock-Johnson III Tests of Achievement*. 2001, Riverside Publishing: Rolling Meadows, Illinois.

Zippert, Erica & Loehr, Abbey & Rittle-Johnson, Bethany. (2018). A New Teacher-Based Assessment of Preschoolers' Patterning Skills. 10.13140/RG.2.2.36822.09286. McClelland, M. M., Cameron, C. E.