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The Relation Between Television Exposure and Executive Function Among Preschoolers

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This study investigated the relations between television exposure during the preschool years and the development of executive function (EF). Data were gathered from 107 parents of preschoolers who provided information on children's television viewing, background television exposure, exposure to specific televised content, and the age at which children began watching television. Preschoolers' EF was assessed via one-on-one interviews. We found that several indicators of television exposure were significantly related to EF. These findings suggest that EF may be an important construct for continued research on the effects of media on young children.

Keywords: preschoolers, television, executive function

Many children begin watching television during infancy and, by preschool, have well-established television viewing habits that include multiple hours in front of the set (Rideout, 2011). As a result, the viewing habits of young audiences have become the focus of many studies with a particular eye toward understanding both the short-term and long-term implications of television exposure at young ages (Wartella, Richert, & Robb, 2010). Researchers have found that early exposure to certain types of television is related to poor school readiness and performance (Fitzpatrick, Barnett, & Pagani, 2012), attention difficulties (Swing, Gentile, Anderson, & Walsh, 2010), lower vocabulary scores (Zimmerman, Christakis, & Meltzoff, 2007), and impaired social skills (Conners-Burrow, McKelvey, & Fussell, 2011). Many of these outcomes, as well as other effects that researchers have been keen to link with television exposure, may reflect a more fundamental deficit in executive function (EF). The development of EF is crucial to both cognitive and social functioning (Carlson & Moses, 2001; Kochanska, Murray, & Harlan, 2000), yet this concept is rarely discussed in research exploring the effects of media on children. The purpose of this article was to investigate whether television exposure is related to EF among preschoolers.

EF

EF refers to an interrelated set of higher order cognitive processes that aid in planning, regulating, and controlling behavior (Duncan, 1986; Pennington & Ozonoff, 1996). EF is a multidimensional construct with three distinct subsets of skills: inhibitory control, working memory, and attention flexibility (Miyake et al., 2000). The regulation of these skills is believed to stem from the brain's frontal lobe, and, as such, EF is an important construct to neuropsychologists in their identification of individuals with various disorders or abnormalities involving the brain, including autism, attention-deficit/hyperactivity disorder (ADHD), and severe head injury (Barkley, 1997; Kleinhanz, Akshoomoff, & Delis, 2005; Nadebaum, Anderson, & Catroppa, 2007; Pennington & Ozonoff, 1996). EF is also of interest to developmental psychologists because of its role in problematic everyday behaviors, such as poor impulse control; difficulty following directions; trouble maintaining focus on tasks; and more general behavioral, social, and academic problems (Allan & Lonigan, 2011; Kim, Nordling, Yoon, Boldt, & Kochanska, 2013; Uttendale & Hastings, 2011). Young children frequently encounter challenges to their EF skills, such as when they must override impulses and choose appropriate behaviors (Rhoades, Greenberg, & Domitrovich, 2009).

The development of EF is believed to be a slow, gradual, postnatal phenomenon in which children advance from reflexive, reactive responses to goal-directed, self-regulatory behaviors (Bernier, Carlson, & Whipple, 2010; Diamond, 2001; Kopp, 1982). Growth in this region of the brain is rapid between 2 and 5 years of age (Diamond, 2001) and individual differences in EF emerge between ages 2 and 3 (Carlson, Mandell, & Williams, 2004). Although genetics play a role in the development of EF (Goldberg & Weinberger, 2004), many believe that the combination of rapid growth and the malleability of the neurocognitive system, especially during this time period, renders EF vulnerable to environmental influences (Bernier, Carlson, Deschenes, & Matte-Gagne, 2012; Zelazo & Carlson, 2012).

Some researchers have found that specific parenting behaviors, such as attention-directing behaviors (Conway & Stifter, 2012) and verbal scaffolding (Bibok, Carpendale, & Müller, 2009; Hughes & Ensor, 2009), are related to EF performance, although the results may depend on the child's temperament and the EF skill assessed (Conway & Stifter, 2012). Others have found that general parent-

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ing behaviors, including positive affect, a sensitive and responsive style, making appropriate commentary on children's mental states, and providing autonomy support, are also related to more developed EF (Bernier, Carlson, Bordeleau, & Carrier, 2010; Bernier, Carlson, Deschenes, & Matte-Gagne, 2012; Kraybill & Bell, 2013; Rhoades, Greenberg, Lanza, & Blair, 2011). Positive parenting behaviors can facilitate EF development by promoting the internalization of morals and providing opportunities to practice and develop self-regulation skills. Controlling, demanding, and punitive environments can inhibit EF growth by depriving children of opportunities to regulate their own behavior and requiring them to continually adapt to another's perspective (Talwar, Carlson, & Lee, 2011).

EF and Television Exposure

Two studies to date have explored the link between television viewing and EF among young children. First, Barr, Lauricella, Zack, and Calvert (2010) examined the relation between television exposure during infancy and EF at age 4. They found that children who watched heavier amounts of adult-directed content at age 1 had weaker EF at age 4. Second, Lillard and Peterson (2011) examined the immediate effects of exposure to a fast-paced cartoon on 4-year-olds' EF performance. Compared with children who either viewed an educational cartoon on the American public television network PBS or drew with markers and crayons, children who saw the fast-paced cartoon performed worse on EF tasks immediately after viewing. The authors argued that the rapid pace and fantastical events in the cartoon may have exhausted children's cognitive resources and disadvantaged EF performance. It is also possible that their study revealed that watching educational cartoons or drawing improves EF.

Other researchers have investigated the link between television exposure and outcomes associated with EF without actually measuring EF itself. In fact, controversies surrounding the effect of television on children's attention span and other EF-related outcomes have been active for several decades (Anderson & Collins, 1988). The research examining the relation between early television exposure and attention difficulties has reported mixed results (Anderson, Levin, & Lorch, 1977; Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004; Foster & Watkins, 2010; Salomon, 1979; Stevens & Muslow, 2006; Zimmerman & Christakis, 2007). Other work suggests that greater exposure to television is related to problems with impulse control (Gadberry, 1980) and weaker social skills (Conners-Burrow, McKelvey, & Fussell, 2011). It remains unclear whether these outcomes are due to EF impairment or not because EF tasks were not administered in these studies.

Television exposure during early childhood may weaken EF development for several reasons. First, as Lillard and Peterson (2011) explained, the rapid pace of some television programs may discourage the kind of processing that accompanies thoughtful, deliberate actions. Fast-paced television, which is prevalent in children's programming (Huston et al., 1981), may place children in a context in which they are continually anticipating change, thereby rendering their responses primarily reactive in nature. In an analysis of the formal features of DVDs designed for infants and toddlers, Goodrich, Pempek, and Calvert (2009) found that most programs contained rapid pacing, camera cuts, and other perceptually salient features that attract attention but are difficult for young children to understand. Moreover, commercials disrupt storylines and themselves contain multiple audiovisual elements that may attract and hold children's attention (Valkenburg & Vroone, 2004). Over the long term, exposure to this type of programming may discourage children from practicing more deliberate and thoughtful information processing required to obtain optimal performance on tasks requiring planning, persistence, and patience.

This explanation may be most appropriate for describing very young children's reactions to entertainment programming. According to Huston and Wright (1983), very young children's attention to television is best characterized as reactive and dominated by programs' perceptually salient features. As children mature and gain experience with the medium, they become more deliberate processors whose attention is dictated by a program's informative cues (Anderson, Lorch, Field, & Sanders, 1981; Kirkorian, Anderson, & Keen, 2012). In addition, educational programs are typically less frenetic in their pacing and change than other genres (Huston et al., 1981), and programs aired on public television lack commercial interruptions. As a result, the possibility that heavy television viewing conditions children to respond impulsively and without goal-directed thought may not apply to older children or youngsters who view mostly educational programming.

Second, television that is left on during the day, regardless of whether anyone is watching or not, can result in a noisy, chaotic environment. This "background television" exposure may repeatedly elicit children's attention when youngsters are not purposefully attending to it, thereby interfering with primary tasks, such as playing (Schmidt, Pempek, Kirkorian, Lund, & Anderson, 2008). Background television may be very difficult for young children to ignore because of its captivating audiovisual elements that repeatedly produce orienting responses resulting in physiological changes. In addition, background television may attract parents' attention, thereby producing less and lower quality parent–child interaction (Kirkorian, Pempek, Murphy, Schmidt, & Anderson, 2009). In this way, the presence of a television left on may harm children's EF.

Third, television exposure may be especially detrimental to EF during periods of rapid brain development and plasticity (Ramirez et al., 2013). The environment plays an important role in children's mental growth, especially during infancy (Bernier et al., 2010; Marshall & Fox, 2004; Propper & Moore, 2006; Rhoades, Greenberg, Lanza, & Blair, 2011), when it can "train" the infant's developing brain by repeatedly activating certain synaptic connections and pruning others (Glasser, 2000). As a result, certain environments experienced during infancy can promote children's developing EF skills while others can weaken them (Bernier et al., 2010; Kochanska, Murray, & Harlan, 2000; Propper & Moore, 2006; Rhoades et al., 2011). Television exposure, as a common and increasingly dominant element of the environment, may exert a stronger effect during infancy than during other developmental periods. This possibility may explain the discrepant results obtained by Stevens and Muslow (2006), who found no meaningful relation between television viewing at age 5 and ADHD symptoms, and Christakis, Zimmerman, DiGiuseppe, and McCarty (2004), who observed a significant relation between viewing at age 1 and later attentional problems.

Our goal was to examine the relation between EF and four indicators of television exposure among preschoolers: cumulative

or lifetime television viewing, cumulative exposure to background television, the age at which children first became television viewers, and children's viewing of specific television content. We expected that indicators of heavy television exposure (i.e., greater lifetime viewing, more lifetime background television exposure, becoming a TV viewer at a younger age) would be related to worse EF performance. We also asked whether children's exposure to specific content would be related to EF.

Method

Participants

A total of 107 preschoolers ($M = 53.37$ months old, $SD = 8.7$; 49.5% girls) and their parents (94% mothers) participated in this study. Most parents were college educated (31.5%) or held a graduate degree (37%), whereas 20% reported having completed "some college," 5.5% reported having completed "some graduate school," and 6% indicated they had completed high school or held a GED. Parents indicated their average annual household income by selecting one of six income categories, ranging from "less than $10,000" to "$200,000 or more." The largest percentage of participants selected "$50,000 to $99,999" (30%), followed by "$25,000 to $49,999" (18%), "$100,000 to $149,999" (18%), "$200,000 or more" (13%), "$150,000 to $199,999" (10%), "$15,000 to $24,999" (5%), "less than $10,000" (4%), and "$10,000 to $14,999" (2%). Approximately 59% of the participants would be considered as low- to middle income, where *middle income* is defined as household incomes between two thirds to double the national median income, or $51,017 for 2012 (Pew Research Center, 2012; U.S. Census Bureau, 2012). Most parents reported their race/ethnicity as Caucasian (80%), with 12% identifying as African American, 3.5% identifying as multiracial, 2.5% identifying as Hispanic, and 2% identifying as Asian. Information about the languages spoken at home was not gathered.

Procedure

Participants were recruited from five preschools in a large, midwestern city in the United States. Parents completed a questionnaire assessing demographics and the sleep and media habits of the participating child. Children were interviewed individually in a quiet location at their preschool by a trained researcher. In a session lasting between 15 and 25 min, the interviewer administered four EF tasks, a vocabulary assessment, and several other tasks measuring theory of mind (for a separate study, Nathanson, Sharp, Aladé, Rasmussen, & Christy, 2013) in a fixed order, following the task administration guidelines of Carlson and Moses (2001). Each child who participated received a small gift and each parent was paid $25. All of the data were gathered during 2012.

Children's Television Exposure

Parents provided estimates of their children's exposure to television. Because all of the participating children were enrolled in preschool and therefore away from home for substantial periods of time, it is likely that parents' viewing estimates were lower compared with estimates obtained from parents whose children do not attend preschool.

Background television. Parents were asked to think about an average day during the week and to report how many hours a TV was left on (regardless of whether anyone was watching it or not) during the *morning hours* (defined for them as "from the time the child awakens until 12 pm"), the *midday hours* (defined as "between lunch time and dinner time"), and the *evening hours* (defined as "between dinner time and the time your child goes to bed"). They were asked to report the same information for an average day on the weekend.

Television viewing by children. Parents reported how many hours their child watches television during the three time periods (morning, midday, and evening) on an average weekday and on an average weekend day. Parents were informed that viewing estimates should include "programs seen on a television, computer, or via DVD or a portable electronic device."

Age-of-TV-viewing onset. In an open-ended format, parents reported the age at which their child first began watching television. When necessary, responses were converted into months.

Children's channel viewing. On a scale from 1 (*never*) to 4 (*all of the time*), parents reported how often their child watched eight different networks or network types when they watched TV, including the Cartoon Network, Disney Channel, Nick Jr., Nickelodeon, Fox, Animal Planet, ABC/NBC/CBS (one question), and PBS.

Children's genre viewing. On a scale from 1 (*never*) to 4 (*all of the time*), parents reported how often their child watched various types of entertainment or educational content when they watched TV, including "action cartoons (e.g., Dragon Ball Z, Kung Fu Panda, Spider-man, Pokemon)," "classic cartoons (e.g., Looney Tunes, Tom & Jerry)," "live action children's programs (e.g., Power Rangers)," "fast-paced cartoons (e.g., The Fairly Oddparents, Phineas and Ferb, Sponge Bob Square Pants)," "situation comedies for children (e.g., iCarly, Victorious, Good Luck Charlie, Shake it Up)," and "educational cartoons (e.g., Caillou, Dora the Explorer, Super Why)."

Child Measures of EF

The EF measures were taken from Carlson (2005), who studied the performance of over 600 toddlers and preschoolers on a variety of EF tasks. We selected four EF tasks that were shown to work well with preschoolers and that exhibited variation in difficulty across ages 3–5. All of the measures or measure types have been used successfully in prior work with children from a diverse age range (Carlson, 2005; Carlson & Moses, 2001; Gerstadt, Hong, & Diamond, 1994; Kochanska, Murray, & Coy, 1997; Passler, Issac, & Hynd, 1985). Experimenters followed a script to ensure uniformity in task administration.

Grass/snow task. Each child was shown a black poster board with two child-sized felt hand shapes glued at the bottom center of the board, a white card at the top right corner, and a green card at the top left corner. The children were instructed to place their hands on top of the hand shapes and then to point to the white card when the experimenter said "grass" and point to the green card when the experimenter said "snow." The experimenter practiced this with the child until the child demonstrated understanding of the task. The experimenter then conducted 16 trials (presented in a fixed, random order). The child's first response to each trial was

recorded. Correct responses were given a score of 1 and incorrect responses received a 0.

Whisper task. Children were asked to whisper their names and were then presented with 10 laminated cards depicting cartoon characters (six familiar, four unfamiliar) in a fixed, random order. Children were asked to whisper the name of the character. Children received 3 points for each answer they whispered, 2 points for each answer they said in a normal voice, and 1 point for each answer they shouted. Responses were averaged across the 10 trials.

Backward digit span task. Each child was introduced to a puppet of Ernie from the children's television program *Sesame Street*. The experimenter told the child that Ernie was silly and that whatever the experimenter said, Ernie would say backwards. The experimenter demonstrated this to the child with numbers, saying "1, 2" and then having Ernie repeat back "2, 1." As a warm up to the exercise, the experimenter invited the child to say "1, 2" to Ernie and then had Ernie say "2, 1" back to the child. The Ernie puppet was then put away, and the experimenter told the child that they were going to try some more without Ernie. The experimenter said, "Whatever I say, you say it backwards." The experimenter presented three trials of number sets with increasing difficulty, beginning with a set of two numbers and increasing to sets of five numbers. Testing stopped when children erred on three consecutive trials at a given level. The highest level of success was recorded (two, three, four, or five digits) and used as the child's score. Children received a score of 1 if they did not pass two digits.

Tower task. The children were informed that they were going to take turns building a tower with 20 wooden blocks. The experimenter first demonstrated the turn-taking (saying "first I go, then you go"), and then began the tower building with the child. The experimenter waited for either verbal or nonverbal cues from the child that it was the experimenter's turn. The experimenter recorded the number of times that he or she was given a turn. This task was completed twice and scores were averaged across the two trials.

Other Predictors

Children's vocabulary. Children with stronger vocabularies may perform better on EF assessments due to superior understanding of the task instructions, among other reasons, making vocabulary an important control variable (Bernier et al., 2012; Carlson & Moses, 2001; Hughes & Ensor, 2009; Rhoades et al., 2011). We used Missall and McConnell's (2004) Picture Naming Individual Growth and Development Indicator, which consists of a set of 120 flashcards, each showing a color picture of a familiar object (e.g., food, household objects). After a practice session with four sample cards, the experimenter instructed the child to name as many pictures as he or she could and then showed the child one card at a time in a random order until 1 min had elapsed. The number of pictures named correctly served as the child's vocabulary score.

Children's sleep. The number of hours that children sleep at night is related to both EF (Bernier et al., 2010) and television use (Nevarez, Rifas-Shiman, Kleinman, Gillman, & Taveras, 2010). We therefore measured and controlled for the total number of hours that children sleep at night, as reported by parents.

Results

Preliminary Analyses

Children's cumulative background television exposure. Reports of background television were converted into minutes. We then calculated two estimates of background television exposure (during the week and the weekend) by summing across reports of exposure during the three time periods. The sums were then multiplied by either 5 (for the sum during the week) or by 2 (for the sum during the weekend). Average daily background television exposure was calculated by adding the two products together and dividing by 7 ($M = 257.89$, $SD = 217.59$). We calculated children's cumulative exposure to background television by multiplying our background television exposure estimates by the child's current age.

Children's cumulative intentional television viewing. Average television viewing estimates were calculated by converting reports into minutes and then creating two sums (viewing during the week and viewing on the weekends). These sums were then multiplied by either 5 (for weekday viewing) or 2 (for weekend viewing). The two products were then summed and divided by 7 to produce average daily viewing in minutes ($M = 171.98$, $SD = 119.42$). Given that children's television viewing and attention levels usually increase in a linear fashion throughout the preschool years (Anderson, Lorch, Field, Collins, & Nathan, 1986; Anderson & Levin, 1976; Roberts & Foehr, 2008), we calculated children's cumulative television exposure by subtracting the child's age of TV viewing onset (a) from the child's current age (A), multiplying the result by the child's current television viewing estimate (TV), and then dividing the product by 2, or Cum. $TV=[(A-a)\times TV]/2$.

Children's channel viewing. A principal-components factor analysis with oblimin rotation of the eight channel viewing items resulted in three factors explaining approximately 66% of variance. The first factor, explaining about 31% of the variance, consisted of viewing of Fox, Animal Planet, and ABC/CBS/NBC. The second factor included viewing of Cartoon Network, Disney Channel, Nick Jr., and Nickelodeon and explained 21% of the variance. The third factor consisted only of PBS viewing and explained close to 13% of the variance. Two scales were constructed to reflect *adult entertainment viewing* (average of Fox, Animal Planet, and ABC/CBS/NBC viewing) and *children's entertainment viewing* (average of Cartoon Network, Disney Channel, Nick Jr., and Nickelodeon). PBS viewing was retained as a single-item measure of *educational content viewing*.

Children's genre viewing. A principal-components factor analysis with oblimin rotation of the six genre viewing items revealed two factors, one representing viewing of action cartoons, classic cartoons, and live action programs (explaining about 39% of the variance), and another reflecting viewing of fast-paced cartoons and situation comedies (explaining about 18% of the variance). Responses to viewing of action cartoons, classic cartoons, and live action programs were averaged to create a scale of *children's action/violent entertainment viewing*. Responses to viewing of fast-paced cartoons and situation comedies were averaged to create a scale of *children's comedy entertainment*. Viewing of *educational cartoons* did not load on either of these factors and was retained as a single-item measure.

Composite EF. Correlations among the EF tasks ranged from .18 to .36. Scores on the grass/snow, whisper, backward digit span, and tower tasks were standardized and then summed to create an overall assessment of children's EF. This enabled us to examine the relation between television exposure and EF as a whole rather than assign disproportionate weight to specific tasks that may have unique task demands (Willoughby & Blair, 2011).

The descriptive statistics for all of the study's measures are displayed in Table 1.

Main Analyses

We constructed four regression models to address our prediction that television exposure would be related to worse EF performance (see Table 2). Model 1 included a group of "nonmedia predictors": parent's education, income, the child's age, preschool (dummy coded), vocabulary, and sleep. Model 2 contained the nonmedia predictors and added the age-of-TV-viewing-onset variable. With this model, we observed whether and how the age of TV-viewing onset contributed to the variance in EF while accounting for the nonmedia predictors. Model 3 contained the nonmedia predictors, the age-of-TV-viewing-onset variable and the measure of cumulative background television exposure. This model allowed us to observe whether children's lifetime exposure to background television contributed uniquely to EF performance when accounting for the nonmedia predictors and the age at which children first began viewing television. Model 4 was identical to Model 3 except that cumulative intentional television viewing was included instead of cumulative background television. Because cumulative background exposure and cumulative viewing were highly correlated, $r(97) = .65$, $p < .001$, we examined these predictors in separate models. Missing data were omitted from the analyses.

In Model 1, the nonmedia predictors accounted for a significant 37% of the variance in EF, with child's age and vocabulary emerging as significant predictors. Model 2 explained a significant 7% of additional variance compared with Model 1. This model revealed that children who began watching television at older ages performed better on EF assessments than children who began viewing at younger ages. In Model 3, cumulative background television exposure explained a marginally significant amount of variance, suggesting that heavier cumulative exposure to background television was related to weaker EF. In Model 4, children's cumulative television viewing explained a significant amount of variance, with heavier lifetime exposure related to weaker EF. With cumulative television viewing in the model, the age-of-TV-viewing-onset variable became a nonsignificant predictor of EF. Across all four models, we found that the strongest predictors of EF were age, vocabulary, the age of first viewing, the cumulative amount of time children had spent watching television, and the number of sleep hours.

We constructed three regression models to address our question of whether children's exposure to specific content is related to EF (see Table 3). To understand the unique contribution of content viewing, we controlled for children's cumulative television viewing and cumulative background television exposure. Model 1 contained the nonmedia predictors; Model 2 contained the nonmedia predictors plus television exposure controls; and Model 3 contained the nonmedia predictors, the television exposure controls, and the measures of channel viewing and genre viewing.

We found that Model 3 explained a significant 8% of additional variance in EF compared with Model 2. Viewing of PBS was associated with better EF performance, whereas viewing of educational cartoons was related to worse EF performance. With all of the variables entered in Model 3, the significant predictors of EF were children's age, vocabulary, cumulative television viewing time, sleep, educational cartoon viewing, and PBS viewing.

Table 1
Descriptive Statistics of All Measures

Measure	*M*	*SD*	Observed range	α or *r*, if applicable	*N*
Parent education	4.5	1.34	2–6		107
Parent income	5.31	1.68	1–8		105
Child age (months)	53.37	8.7	38–74		107
No. hours sleep	10.04	1.1	6.5–12.0		105
Child vocabulary	19.98	6.3	7–35		106
Cumulative background TV (minutes)	13,573.45	11,160.51	0–67,680		105
Cumulative TV viewing (minutes)	3,162.08	2,483.71	0–10,597.71		99
Onset of TV view (months)	18.37	9.09	0–36		101
Adult entertainment viewing channels	1.25	.35	1.00–2.67	.67	102
Child entertainment viewing channels	1.96	.57	1.00–3.50	.70	102
Educational viewing channel (PBS)	2.2	.72	1–4		105
Action/violent viewing	1.50	.52	1.0–3.3	.70	106
Comedy viewing	1.61	.62	1.0–3.5	.45	107
Educational cartoon viewing	2.8	.76	1–4		106
Grass/snow	11.30	4.52	0–16		106
Whisper	2.74	.33	1.9–3.0		100
Tower	6.73	3.58	0–10		105
Back. digit span	1.76	1.20	1–5		104

Note. Categories for parent education were "less than high school"; "high school or GED"; "some college"; "college degree"; "some graduate school"; and "graduate degree" (coded as 1–6, respectively). Categories of parent income were "less than $10,000"; "$10,000 to $14,999"; "$15,000 to $24,999"; "$25,000 to $49,999"; "$50,000 to $99,999"; "$100,000 to $149,999"; "$150,000 to $199,999"; and "$200,000 or more" (coded as 1–8, respectively). No. = number; Back. digit span = Backward digit span.

Table 2
Summary of Regression Analyses for Nonmedia and Media Variables Predicting Children's Executive Function

Variable	Model 1: Nonmedia predictors			Model 2: Age-of-TV-viewing onset			Model 3: Cumulative background TV			Model 4: Cumulative TV viewing		
	B	*SE B*	β	*B*	*SE B*	β	*B*	*SE B*	β	*B*	*SE B*	β
Parent education	−.14	.22	−.07	−.18	.21	−.09	−.28	.21	−.14	−.27	.21	−.14
Parent income	.32	.19	.20	.30	.18	.20	.27	.18	.17	.25	.18	.16
Child's age	.11	.03	.36***	.09	.03	.31***	.11	.03	.36***	.13	.03	.42***
Preschool 1	−.53	.80	−.08	−.28	.77	−.04	−.32	.76	−.05	−.56	.77	−.08
Preschool 2	−.01	1.10	.00	−1.2	1.1	−.10	−.94	1.1	−.08	−1.3	1.1	−.11
Preschool 3	−.02	.76	.00	.10	.72	.02	−.21	.74	−.04	−.32	.75	−.06
Preschool 4	−.13	.76	−.02	−.46	.73	−.07	−.70	.73	−.11	−.69	.73	−.11
Child's vocabulary	.15	.04	.36***	.14	.04	.33***	.13	.04	.31***	.13	.04	.30***
Child's sleep	−.22	.24	−.10	−.34	.23	−.14	−.38	.23	−.16†	−.49	.24	−.21*
Onset of TV view				.09	.03	.30***	.08	.03	.29**	.05	.03	.18
Cumulative back. TV							−4.2	.00	−.18†			
Cumulative TV view										.00	.00	−.26*

Note. Cell entries for all models are standardized regression coefficients with all variables in the model entered into the equation. $R^2 = .37$, $p < .001$ for Model 1; $R^2 = .44$, $p < .001$ for Model 2; $R^2 = .46$, $p < .001$ for Model 3; $R^2 = .47$, $p < .001$ for Model 4. back. = background.
† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Discussion

The purpose of this study was to understand the relation between preschoolers' television exposure and their EF. Despite EF's relevance to many of the social and cognitive outcomes that are commonly studied as outcomes of television exposure, this construct has been largely ignored in the literature. We found that several indicators of television exposure were significantly related to EF. These findings suggest that EF may be an important construct for continued research on the effects of media on young children.

Several forms of television exposure were negatively related to EF. First, children who had spent a greater number of cumulative hours viewing television had poorer EF than children who had viewed fewer cumulative hours. Television provides a steady stream of mostly fast-paced entertainment that provides quick rewards and is perceived as "easy" to process (Salomon, 1984). Watching television does not permit viewers, especially young ones, much choice in extracting meaning from content or pondering characters or situations in ways that are incompatible with what is depicted on the screen. Moreover, television, like an attention-directing adult, requires children to continually engage, disengage, and re-engage their attention to stimuli that may be important to the program but are not of inherent interest to them. It seems reasonable to suspect that television viewing is not

Table 3
Summary of Hierarchical Regression Analysis for Nonmedia, Viewing Time, and Content Viewing Variables Predicting Children's Executive Function

Variable	Model 1: Nonmedia predictors			Model 2: TV viewing time			Model 3: TV viewing content		
	B	*SE B*	β	*B*	*SE B*	β	*B*	*SE B*	β
Parent education	−.14	.23	−.07	−.30	.22	−.15	−.30	.22	−.16
Parent income	.32	.20	.20	.24	.19	.15	.18	.18	.11
Child's age	.11	.03	.36***	.15	.03	.49***	.13	.03	.44***
Preschool 1	−.53	.82	−.08	−.78	.78	−.11	−.79	.82	−.11
Preschool 2	−.01	1.1	.00	−.81	1.1	−.07	−.41	1.1	−.04
Preschool 3	−.02	.78	.00	−.56	.76	−.11	−.42	.82	−.08
Preschool 4	−.13	.04	−.02	−.67	.75	−.11	−.74	.76	−.12
Child's vocabulary	.15	.04	.36***	.13	.04	.30***	.13	.04	.31***
Child's sleep	−.22	.24	−.10	−.50	.24	−.21*	−.66	.24	−.28**
Cumulative TV view				.00	.00	−.36**	.00	.00	−.37**
Cumulative back. TV				−5.7	.00	−.02	7.2	.00	.03
PBS							.85	.32	.23**
Adult ent. channels							−.46	.71	−.06
Child ent. channels							−.35	.59	−.08
Children's violent/action							.23	.55	.05
Children's comedy							.40	.44	.09
Educ. cartoons							−.84	.34	−.24**

Note. Cell entries for all models are standardized regression coefficients with all variables in the model entered into the equation. $R^2 = .37$, $p < .001$ for Model 1; $R^2 = .45$, $p < .001$ for Model 2; $R^2 = .54$, $p < .001$ for Model 3. back. = background; ent. = entertainment; Educ. = Educational.
* $p < .05$. ** $p < .01$. *** $p < .001$.

conducive to developing skills in attention allocation, cognitive flexibility, and working memory. It is important to note that we do not know whether the relation between television viewing and EF is causal or not. Even in the case of a causal relation, we do not know the direction of causality or whether the relations might be bidirectional.

Second, the age at which children first began watching TV was related to preschoolers' EF. Children who began watching television at younger ages had weaker EF than children who became viewers at older ages. There are several reasons why viewing during infancy may be a risk factor for impaired EF development. Brain development is rapid during the first years of life, and early experiences can have profound effects on development (Kolb, Forgie, Gibb, Gorny, & Rownree, 1998). As Glasser (2000) noted, experiences in infancy contribute to the strengthening and pruning of certain synaptic connections, which can result in longer term effects on development. In fact, research has revealed that environmental factors and parenting behaviors during infancy predict EF performance among preschoolers (Kraybill & Bell, 2013; Rhoades et al., 2011). Likewise, Christakis has argued that heavier exposure to television at young ages shapes brain development, resulting in outcomes including ADHD (Christakis, Ramirez, & Ramirez, 2012; Zimmerman & Christakis, 2007). As a result, exposure to television during this sensitive period of brain development may have long-term effects on how children allocate their attention and process information.

In addition, the type of material that infants view may be especially problematic for EF. Programs directed at infants provide "nonnormative stimulation" characterized by rapid pace and atypical sequencing, which may have adverse effects on infants' cognition and behavior (Christakis et al., 2012; Goodrich, Pempek, & Calvert, 2009). Moreover, compared with other age groups, infants should be most influenced by this nonnormative stimulation because they almost exclusively rely on a television program's perceptually salient stimuli for processing the material (Huston & Wright, 1983). However, our data cannot reveal whether children who began watching television during infancy consumed mostly infant-directed videos or not. Continued research is needed to understand why viewing during infancy may be detrimental to EF.

Two types of content exposure were predictive of EF. First, PBS viewing was positively related to EF. PBS viewing may reflect exposure to high-quality programming or storytelling without commercials. Commercials not only disrupt storylines and require children to perpetually disengage and re-engage with unfolding stories but also contain high concentrations of perceptually salient stimuli (Valkenburg & Vroone, 2004). The combination of high-quality programming with the absence of commercials may enable children to develop effective EF skills. Lillard and Peterson (2011) also found that exposure to a PBS program was related to better EF performance compared with exposure to a fast-paced program aired on commercial television. Second, educational cartoon viewing was related to worse EF performance. Perhaps the addition of educational lessons to an animated, stimulating format harms children's ability to engage in effective information processing. Hudon, Fennell, and Hoftyzer's (2013) factor analysis of toddlers' television habits revealed that viewing of "educational programs," such as *Dora the Explorer* and *Blues Clues*, was not an indicator of "quality" television viewing and not predictive of vocabulary scores among bilingual toddlers. Because other work has revealed that educational cartoon viewing was beneficial (Linebarger & Walker, 2005), more research on this genre is needed.

Our study's results have implications for how scholars understand the effects of television on children. Many scholars are interested in how television affects children's social skills. To behave in a nonaggressive and prosocial manner, children must learn to inhibit impulsive behavior and perform less personally desirable and often competing actions (e.g., expressing anger through words rather than harmful physical displays) as well as maintain social rules in working memory while applying them to achieve desirable goals (e.g., sharing toys or asking for a turn rather than grabbing or hoarding toys). Programs with aggressive characters can provide negative role models that children may imitate, and many studies have been conducted to investigate this possibility (Christakis et al., 2013; Paik & Comstock, 1994). Our work revealed that television may negatively affect children's social behavior by directly affecting cognitive functioning, which may, in turn, manifest in poor social behavior. Unlike Barr et al. (2010), we found that even exposure to presumably child-oriented content (reflected in measures of children's intentional television viewing) was negatively related to EF.

In addition, our results suggest that researchers investigating the predictors of EF may wish to consider the predictive value of children's television viewing time. The models that included television exposure explained between 44% and 54% of the variance in preschoolers' EF, with cumulative viewing time, age-of-TV-viewing onset, PBS viewing, and educational cartoon viewing remaining significant predictors along with children's age and vocabulary scores. As with parenting behaviors, television exposure may be an important environmental influence on EF.

Although not part of the major theoretical rationale for the study, we found one surprising result involving the relation between sleep and EF. Contrary to prior work (Bernier et al., 2010), we found that sleep was negatively related to EF. Post hoc analyses revealed that although sleep shared a positive relation with EF at the zero-order level, $r(105) = .13$, $p = .19$, the relation became negative once controls were included. As part of our post hoc analyses, we examined the interactions between sleep duration and the other predictors and found that sleep interacted with the age-of-TV-viewing onset variable in predicting EF ($\beta = -.89$, $p < .05$; no other interactions were significant). The relation between sleep duration and EF was positive among children who began watching TV at younger ages, but the relation was negative among children who commenced TV viewing at an older age. When we included this interaction in our models, our results became slightly stronger or remained about the same. It is unclear why these relations held. We encourage future research to replicate these findings.

The quality of our measures is one of the study's strengths. Unlike other parent reports of background television, which rely on single-item measures (e.g., Rideout, Vandewater, & Wartella, 2003; Vandewater et al., 2005), our measure required parents to report the length of exposure in specific periods and on specific days of the week. Moreover, we were able to construct cumulative exposure measures. As with many risk factors, such as sun exposure or cigarette smoke, individuals' cumulative time spent viewing television may be uniquely related to outcomes. Finally, our EF tasks reflected a combination of skills and were measured

directly instead of relying on parent report. Of course, other measures of both television exposure and EF may be superior to ours, such as diary reports or direct observations of children's viewing (Bryant, Lucove, Evenson, & Marshall, 2007; Vandewater & Lee, 2009), which may be less susceptible to biased reporting, or EF assessments that use more than four tasks. Our research should be replicated using other valid measures of television exposure and EF to determine whether and how our results vary using different assessment tools.

There are several limitations of this study. First, the study was correlational, and as a result, we cannot rule out the possibility that parents respond to children with weaker EF performance by increasing their television exposure. Children with poor impulse control and difficulties maintaining attentional focus may be more challenging to satisfy with play. In addition, because of the genetic component of EF development (Goldberg & Weinberger, 2004; Polderman et al., 2007), it is possible that parents with weaker EF rely more on television to entertain their children (who may also have weaker EF) than other parents. Finally, children with weaker EF may prefer to watch more television, including more stimulating and fast-paced content. Consequently, television exposure may be a response to children's behavior rather than the cause of poor performance.

Second, we cannot conclude whether EF is influenced by television exposure per se or some other aspect of family life that is correlated with high exposure. Parents who permit heavy viewing may approach parenting differently than other caregivers (Sebire & Jago, 2013). It could be that some aspect of this parenting style is responsible for the relation between television exposure and EF, such as decreased or lower quality parent–child communication. Future work should measure both television exposure and other aspects of parenting to determine whether observed relations are due to television exposure, parenting, relationship quality, or some combination of these factors.

In sum, this study suggests that television exposure is related to higher order cognitive processes and that exposure during infancy may be especially problematic for cognitive and social function years later. Continued work is needed to understand the link between children's television viewing and EF. Given that EF is implicated in a wide variety of social difficulties, researchers should seriously consider the relevance of EF in explaining the link between television exposure and social behavior.

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