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Do Schools Promote Executive Functions? Differential Working Memory Growth Across School-Year and Summer Months

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Children's working memory (WM) skills, which support both academic and social success, continue to improve significantly through the school years. This study leverages the first nationally representative data set with direct assessments of elementary school students' WM skills to examine whether WM grows more during the school year or summer months and whether WM growth rates differ by household income. Results demonstrate that WM skills grow more during the school-year months compared to the summer months, suggesting that school environments provide children with unique opportunities to improve and practice their WM skills. Further, lower-income children have significantly faster WM growth rates in the first 2 years of school and the intervening summer, compared to their peers from higher-income families, leading to an overall narrowing in WM disparities by household income during the early school years. However, there was no evidence that schools equalize or exacerbate differences in WM skills between children from lower-income and higher-income households.

Keywords: *working memory, schooling effects, seasonal growth, executive functions*

Every day, young children rely on their working memory (WM) skills to follow directions, keep track of routines, and play complex games with peers. Although it is well established that children's WM skills improve dramatically during the early school years (Lee, Bull, & Ho, 2013; Röthlisberger, Neuenschwander, Cimeli, & Roebers, 2013), it is not clear how much of this growth is due to normal maturation of WM skills and how much is due to schooling effects. Further, there are large socioeconomic disparities in children's WM skills, such that children from lower-socio-economic-status households have lower WM than their more advantaged peers (Hackman, Gallop, Evans, & Farah, 2015; Little, 2017; Sarsour et al., 2011). Through middle childhood, children's WM skills are malleable to their environments, and thus, these socioeconomic disparities in children's WM skills are at least partially explained by differential experiences in children's home and school environments (Finch & Obradović, 2018).

Parental sensitivity, scaffolding, and cognitive stimulation have been linked to higher executive functions, including WM skills (Fay-Stammbach, Hawes, & Meredith, 2014). In preschool classrooms, responsive teaching and classroom organization have been associated with increases in children's WM skills over the school year, after controlling for demographic characteristics and the structural quality of classrooms (Hamre, Hatfield, Pianta, & Jamil, 2014). Children's experiences with teachers may be particularly important for children who have less supportive home environments (Vandenbroucke, Spilt, Verschueren, & Baeyens, 2017). There is evidence that school experiences help close socioeconomic gaps in reading and math skills (Downey, von Hippel, & Broh, 2004; Verachtert, Van Damme, Onghena, & Ghesquière, 2009) and a handful of studies suggesting that children who experience more years of formal schooling have higher executive functions (Burrage et al., 2008; McCrea, Mueller, & Parrila, 1999).

The current study explores how children's WM growth differs between school-year and summer months using a nationally representative sample of American kindergarteners: the Early Childhood Longitudinal Study, Kindergarten Class of 2010–2011 (ECLS-K:2010). These seasonal analyses provide nuanced information on the developmental trajectories of WM and which environmental contexts may shape WM growth. Further, this study tests whether children's growth rates are differentially associated with growth in their WM skills depending on their household income, to disentangle the role of schooling in exacerbating or reducing disparities in children's WM development by household income.

WM Development During Elementary School

WM encompasses children's abilities to hold, update, and manipulate information in the mind over short periods of time (Diamond, 2013). WM is under the broader umbrella of executive function skills, which enable children to cognitively regulate their attention and behaviors (Obradović, Portilla, & Boyce, 2012) and support both academic and social success in the school context (de Wilde, Koot, & van Lier, 2016; McQuade, Murray-Close, Shoulberg, & Hoza, 2013; Swanson, 2011; Vandenbroucke, Verschueren, & Baeyens, 2017). WM is measured using tasks that require children to remember information and mentally work with that information once it is no longer perceptually present (Diamond, 2013). For example, in a WM span task, children would be asked to repeat back a set of words or numbers in reverse order from which they were presented (Alloway, 2007). It is important to note that most tasks that are designed to capture WM partially rely on children's inhibitory control skills to inhibit dominant responses in favor of nondominant responses. WM and inhibitory control support one another, and to successfully complete a WM span task, children must also resist the urge to repeat back the numbers or words in the original order to correctly state the sequence in backward order (Diamond, 2013).

Early indicators of WM appear in children's first year (Diamond, 2013), with improvements through elementary school (Gathercole, Pickering, Ambridge, & Wearing, 2004). Studies in England and Singapore demonstrated that WM skills steadily increased between ages 4 and 15 (Gathercole et al., 2004; Lee et al., 2013). One study focused on the early elementary years showed that WM improved over the first 3 years of formal school in a Swiss sample (Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2012). They found nonlinear patterns, with the largest gains in kindergarten and smaller gains in first and second grade. A study in Belgium found similar increases in WM from kindergarten to first grade (Vandenbroucke, Verschueren et al., 2017). Aside from Lee and colleagues' (2013) study in Singapore, longitudinal studies have been relatively small in scale and followed children over 1 to 2 academic school years. To better target interventions and supports for children's WM skills, more information is needed on the developmental trajectories of children's WM during the elementary school years.

The School Context and WM

The transition to formal schooling is a significant milestone that sets the stage for children's long-term developmental trajectories (Nelson et al., 2017; Pianta, Rimm-Kauffman, & Cox, 1999; Portilla, Ballard, Adler, Boyce, & Obradović, 2014). In kindergarten, teachers begin to have an explicit focus on formal academic instruction with specific goals for children's literacy and numeracy development (Rimm-Kaufman & Pianta, 2000). In recent years, kindergarten has become increasingly academic, such that teachers have reported large increases in literacy and math instruction, time spent on challenging academic topics, and the use of standardized tests from 1998 to 2010 (Bassok, Latham, & Rorem, 2016). Class sizes and student-to-teacher ratios are also much larger in elementary school classrooms compared to students' preschool classrooms, and children are expected to more independently manage their time and behaviors. The new demands of formal schooling—both academic and social—require children to engage their WM skills to keep track of directions and progress on academic work (Alloway, Gathercole, Kirkwood, & Elliott, 2009b), learn more challenging academic material (Peng, Namkung, Barnes, & Sun, 2016), and manage social interactions with peers (McQuade et al., 2013). These experiences in early elementary school should theoretically provide children with opportunities to practice and improve their executive function skills in ways that they could not in the home environment.

Research exploring "schooling effects" has largely focused on the growth rates of children's academic achievement scores in elementary school. These studies compare gains on reading and math test scores during the school-year months to gains during the summer months, under the assumption that school-year learning is influenced by both school and nonschool factors, whereas summer learning is influenced solely by nonschool factors, such as the home environment (Heyns, 1987). Leveraging the exact dates of academic assessments, researchers have been able to more accurately separate school-year from summer learning (Alexander, Entwisle, & Olson, 2001; Downey et al., 2004; Quinn, Cooc, McIntyre, & Gomez, 2016). Using the earlier ECLS-K:1998, Downey and colleagues (2004) demonstrated that both reading and math scores grew faster during the school years compared to the summers. A similar study conducted in Finland also found that children's math skills grew the most during the kindergarten and first-grade school years, compared to the intervening summer vacation (Verachtert et al., 2009). These results are not surprising, as schools are explicitly set up to increase children's academic content knowledge, whereas parents are not directly tasked with teaching their children academic skills during the summer months.

In contrast, the role of schools for children's nonacademic development is not as well defined (Downey, Workman, & von Hippel, 2017). Although both kindergarten teachers and researchers cite executive function skills as a crucial predictor of school adjustment and success (Blair, 2002; Blair & Raver, 2015; Lewit & Baker, 1995), there are not clear supports built into elementary school curricula for the development of these skills. A small number of studies have explored schooling effects on executive function skills by comparing children who are close in age but differ in the number of years of formal schooling experienced. One study showed that kindergarteners had higher WM scores compared to their prekindergarten peers of a similar age (Burrage et al., 2008). They hypothesized that these differences may be due to kindergarteners' prior preschool experiences. Both the prekindergartners and kindergarteners showed equal growth in WM skills during the school year, suggesting that these two grades have equivalent schooling effects. Another study found small schooling effects on executive functions, including WM, for 7- to 9-year-olds, demonstrating that students who had an extra year of elementary school showed higher executive function scores than their age-matched peers in the grade below at a single time point (McCrea et al., 1999). A recent study demonstrated that schooling effects on children's executive function scores are mirrored by schooling effects on their neural development. In a small sample of German children from higher-income families, first graders demonstrated more activation of the right superior prefrontal cortex when engaging in executive function tasks than kindergarteners of the same age (Brod, Bunge, & Shing, 2017). These changes in activation of the brain during the school year were correlated with improvements in executive function task performance during the school year.

Although these studies provide some initial evidence that school experiences may benefit executive function development more generally, they compare two separate groups of students who may differ on a wide range of factors that are implicated in executive function development (e.g., social-emotional skills, preschool experience). Cutoff designs are also unable to disentangle schooling influences on executive function skills from nonschooling influences on executive function skills. It is possible that differences in children's home learning experiences may be driving these findings. For example, parents may anticipate children's kindergarten entry by engaging in increased learning activities during the summer before they start school (Son & Morrison, 2010; Weiland, McCoy, Grace, & Park, 2017). If these enhanced home learning environments also supported executive function development, then studies using cutoff designs would overestimate the benefits of school for executive functions. Further, these studies used relatively small samples that may not be generalizable to children's schooling experiences more generally. It is important to extend this work to larger, more representative, longitudinal samples that allow for estimation and comparison of school-year and summer growth rates.

Do Schools Equalize or Exacerbate WM Disparities by Household Income?

There are large socioeconomic disparities in children's WM skills (Hackman et al., 2015; Little, 2017; Sarsour et al., 2011). A prior study using the ECLS-K:2010 showed large socioeconomic gaps in children's WM skills at school entry that got smaller from kindergarten to second grade (Little, 2017). Specifically, children whose families were in the top socioeconomic-status quintile had WM scores that were 1.01 standard deviation units higher than their peers from the lowest socioeconomic quintile, on average, at kindergarten entry. This gap was reduced to 0.66 standard deviation units in the spring of second grade. However, Hackman and colleagues (2015) did not find differences in children's executive function growth trajectories from kindergarten to fifth grade by household income, using a large sample of American children drawn from predominantly white and middle-class families around the country (National Institute of Child Health and Development Study of Early Child Care). These contrasting findings may be explained by sample differences, differences in the WM tasks used, or nonlinearities in the effects of socioeconomic status on the development of children's WM skills. It is plausible that there are differences in WM growth rates by socioeconomic status during early elementary school, when children are first adjusting to school, but not in the later grades. Therefore, socioeconomic differences in executive function growth rates might differ over time. Further, neither study examined whether growth differed between school-year and summer months, confounding schooling effects with the natural maturation of WM skills and the effects of nonschool experiences.

Theoretically, public schooling experiences in the United States are supposed to act as "equalizers" where all children have equal access to learning opportunities. Most evidence supports the role of schools as equalizers for academic achievement, with reductions in socioeconomic status gaps in children's reading and math skills during the school-year months (Alexander et al., 2001; Burkam, Ready, Lee, & LoGerfo, 2004; Downey et al., 2004; von Hippel, Workman, & Downey, 2017). When rates of academic skill growth have been compared between school-year and summer months, data from the earlier ECLS-K:1998 data set demonstrated that schools reduced the rate of reading and math inequality between low- and high-socioeconomic-status students compared to the months when school was out of session (Downey et al., 2004). Recent analyses from the ECLS-K:2010 found equalizing effects of schooling on math and reading scores only during the kindergarten year (Quinn et al., 2016; von Hippel et al., 2017). These changes over time may be due to shifts in math and reading curricula over the past two decades (Hiebert, 2015; Porter, McMaken, Hwang, & Yang, 2011) as well as increases in the quality of low-income children's home learning experiences during this time period (Bassok, Finch, Lee, Reardon, & Waldfogel, 2016).

Because WM skills are not directly targeted by classroom curricula, it is unclear whether schools would similarly play an equalizing role in reducing WM disparities between children from low- and high-income families. Related work on teacher-rated socioemotional skills, such as children's approaches to learning, self-control, and interpersonal skills, did not find evidence that schools exacerbated or reduced socioeconomic inequality (Downey et al., 2017). They found large gaps in teachers' ratings of socioemotional skills at school entry that persisted through second grade. However, these analyses are likely biased by teachers' perceptions of students (Garcia, Sulik, & Obradović, 2018) and skewness in teacher ratings of children's behavior (Miner & Clarke-Stewart, 2008; Sulik, Blair, Greenberg, & Family Life Project Investigators, 2017). The present study improves upon this work by using direct assessments of children's skills.

Current Study

Leveraging the only nationally representative data set including direct assessments of children's WM skills, this study examines how growth rates in children's WM skills differ between school-year and summer months. These analyses extend previous work demonstrating seasonal differences in children's academic skill growth rates (Downey et al., 2004; von Hippel et al., 2017) to understand if schooling is similarly associated with benefits in WM development. Although WM is not directly targeted by schooling instruction, children's academic and social experiences at school afford them with many opportunities to further develop and practice their WM skills. Testing whether growth rates differ between school-year and summer months provides insight about which contexts may be most promotive of WM development.

Second, this study explores whether WM growth rates differ by children's household income. Given the importance of executive function skills for long-term outcomes, it is critical to understand whether schools are reducing or exacerbating income disparities in children's WM skills. These analyses provide information about when school- or home-based interventions might be best targeted to reduce WM gaps between children from lower- and higher-income families.

In addition to these conceptual contributions, the current study applies a methodologically rigorous approach to describing seasonal differences in WM development. Prior seasonal research on executive functions has used cutoff designs, which compare students who are close in age but in different grades due to school birthday cutoffs (Brod et al., 2017; Burrage et al., 2008; McCrea et al., 1999). Cutoff designs may confound unobserved differences in children's skills or home environments with schooling effects and are not able to evaluate whether growth during school-year months differs from growth during summer months. The current study utilizes longitudinal data and exact information about when WM test scores were assessed to provide more accurate comparisons of how growth during school-year months differs from that during summer months.

Method

Data and Sample

The data used in this study are drawn from the ECLS-K:2010. The ECLS-K:2010 collects data from a nationally representative sample of about 18,170 children who were in kindergarten in fall 2010 (representing a cohort born in 2004–2005; Tourangeau et al., 2017). The current study uses data from the fall and spring of children's kindergarten, first-grade, and second-grade years. The primary measure of interest, children's WM skills, was measured using direct assessments in the fall and spring of each year. In the fall of children's first- and second-grade years, a random subsample (approximately one third of the total sample) of children took the direct WM assessment. The analytic sample is restricted to first-time kindergarteners; the 840 children who were repeating kindergarten, as reported by parents, were dropped from the sample. Children without a valid sample weight or WM data were also excluded, leaving a final analytic sample of 11,150 children in the kindergarten year.

Measures

WM. Children's WM skills were measured using the Numbers Reversed subtest of the Woodcock-Johnson III (Blackwell, 2001). In this task, the assessor read a sequence of numbers, and the child was asked to orally repeat the sequence in reverse order. For example, if the assessor read the sequence *5, 8, 2*, the child was expected to say *2, 8, 5*. All children began with five sequences of two digits (e.g., 7, 3); then, based on performance, the number of digits in the sequence increased to a maximum of eight digits (e.g., 8, 3, 6, 1, 7, 9, 2, 4). There were 30 possible trials in total (five sets of two- and three-digit trials and four sets of four-, five-, six-, seven-, and eight-digit trials). The task ended when the child got three consecutive trials incorrect within a level. As advised by the National Center for Education Sciences (Tourangeau et al., 2017), a standardized score based on a transformation of the Rasch Ability Scale is used in all regression analyses (*W* score). This score represents a child's ability as well as the difficulty of the item. Two other measures of performance on the Numbers Reversed test are presented descriptively to help anchor the *W* scores: the percentage of items children correctly answered and the longest span of digits children were able to correctly reverse. If children did not answer any trials correctly, their longest span was set to 1.

Household income. Household income, the total income of all persons in the household over the past year, including salaries, other earnings, interest, and retirement, was self-reported by parents during the spring kindergarten interview. Income was measured in 18 categories, ranging from $5,000 or less to $200,001 or more. The midpoint of each income category was used to create a continuous income variable. For children whose parents reported making over $200,001 per year, their household income was set to $350,000. Income was log-transformed and grand-mean centered for all regression analyses.

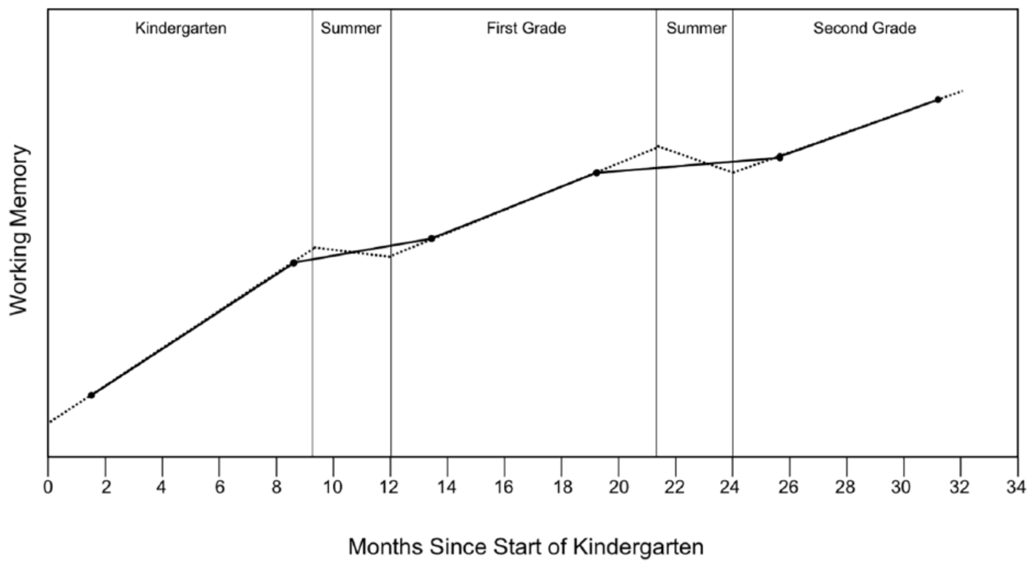

FIGURE 1. *School-year and summer working memory (WM) growth rates using assessments given in the fall and spring of each school year. Hypothetical WM test scores are shown using dots. The solid lines show naive estimates, where growth rates are estimated simply using the differences between each test. Extrapolated WM test scores are shown using the dashed line. The difference between the extrapolated scores at the beginning and end of the school years provides a more accurate estimate of summer learning.*

Analytic Plan

Children's WM skills were assessed at six different time points: the fall and spring of kindergarten, first grade, and second grade. These six assessments allowed for estimation of growth in WM skills during the kindergarten school year, the summer after kindergarten, the first-grade school year, the summer after first grade, and the second-grade school year. WM assessments were generally scheduled a month after the start of school (fall) and a month before the end of school (spring). Therefore, simple subtraction of children's skills between the time points would confound growth during the school-year months and summer months, as shown in Figure 1. By using the exact dates that children's WM scores were assessed, the model estimates growth rates using children's exposure to school in months and extrapolates scores on the assessments to what would have been obtained if children were assessed on the first and last day of the school year. This allows school-year growth in WM to be separately estimated from summer growth in WM. These analyses are similar to those previously used to assess seasonal differences in the growth rates of children's achievement and social-emotional skills using the ECLS-K data sets (Downey et al., 2004, 2017; Quinn et al., 2016).

Multilevel growth curve models (Raudenbush & Bryk, 2002) are used to analyze growth in children's WM skills during each school year and summer. For child i, WM skills WM_{it} are measured at six different time points ($t = 1, \ldots, 6$): the fall and spring of the kindergarten, first-grade, and second-grade school years. The variables ScK_{it}, $Sc1_{it}$, and $Sc2_{it}$ measure the number of months of exposure to kindergarten, first-grade, and second-grade school years, respectively, that child i has experienced by assessment time t. The variables SuK_{it} and $Su1_{it}$ measure months of exposure to summers after kindergarten and first grade, respectively. A measure of total exposure to summer by time t is also included: SuT_{it} (which is the sum of SuK_{it} and $Su1_{it}$).

$$
\begin{aligned}
WM_{it} &= \beta_{0i} + \beta_{1i} ScK_{it} + \beta_{2i} SuK_{it} + \beta_{3i} Sc1_{it} \\
&\quad + \beta_{4i} Su1_{it} + \beta_{5i} Sc2_{it} + \beta_{6i} SuT_{it} + e_{it} \\
\beta_{0i} &= \gamma_{00} + u_{0i} \\
\beta_{1i} &= \gamma_{01} + u_{1i} \\
\beta_{2i} &= \gamma_{02} \\
\beta_{3i} &= \gamma_{03} + u_{3i} \\
\beta_{4i} &= \gamma_{04} \\
\beta_{5i} &= \gamma_{05} + u_{5i} \\
\beta_{6i} &= u_{6i}
\end{aligned}
$$

In this model, β_{0i} can be interpreted as the score the child would have received on the first day of kindergarten; β_{1i}, β_{3i}, and β_{5i} show growth in WM skills per each month of kindergarten, first grade, and second grade, respectively; and β_{2i} and β_{4i} represent growth in WM skills per each month of summer after kindergarten and first grade, respectively. The random-effects error term is constrained to be the same across the two summers, but the average growth rates are still allowed to differ across the two summers. This means that the average growth rate in WM may differ across the two summers, but individual students' growth rates are constrained to

TABLE 1
Descriptive Statistics for Working Memory Measures at Each Wave

		W ability score				Percentage correct				Longest span			
Variable	*N*	*M*	(*SD*)	Min	Max	*M*	(*SD*)	Min	Max	*M*	(*SD*)	Min	Max
Fall kindergarten	14,650	433.279	(30.240)	393	581	11.271	(11.021)	0	90.000	1.961	(0.937)	1	8
Spring kindergarten	14,210	450.338	(30.293)	393	572	17.573	(11.275)	0	83.333	2.456	(0.940)	1	8
Fall first grade	4,280	457.475	(28.430)	393	596	20.174	(10.866)	0	96.667	2.684	(0.917)	1	8
Spring first grade	12,440	469.827	(25.538)	393	596	25.119	(10.309)	0	96.667	3.041	(0.869)	1	8
Fall second grade	3,880	473.443	(23.945)	403	554	26.559	(9.939)	0	70.000	3.163	(0.845)	1	7
Spring second grade	11,410	481.156	(22.881)	403	581	30.011	(10.054)	0	90.000	3.420	(0.859)	1	8

differ from the average summer rates by the same amount in both summers.

In a second set of analyses, the growth parameters for the three school years and two summers were allowed to vary by a continuous measure of children's household income. Therefore, for example, γ_{11} would show how the growth rate of WM skills during the kindergarten school year differed by household income.

$$WM_{it} = \beta_{0i} + \beta_{1i}ScK_{it} + \beta_{2i}SuK_{it} + \beta_{3i}Sc1_{it} + \beta_{4i}Su1_{it} + \beta_{5i}Sc2_{it} + \beta_{6i}SuT_{it} + e_{it}$$

$$\beta_{0i} = \gamma_{00} + \gamma_{10}\text{Income}_i + u_{0i}$$

$$\beta_{1i} = \gamma_{01} + \gamma_{11}\text{Income}_i + u_{1i}$$

$$\beta_{2i} = \gamma_{02} + \gamma_{12}\text{Income}_i$$

$$\beta_{3i} = \gamma_{03} + \gamma_{13}\text{Income}_i + u_{3i}$$

$$\beta_{4i} = \gamma_{04} + \gamma_{14}\text{Income}_i$$

$$\beta_{5i} = \gamma_{05} + \gamma_{15}\text{Income}_i + u_{5i}$$

$$\beta_{6i} = u_{6i}$$

Results

Descriptive Statistics

As shown in Table 1, average levels of children's WM skills increased at each time point. Children showed the largest gains, on average, during the kindergarten school year (17.059 points on the *W* ability score), followed by the first-grade school year (12.353 points). The standard deviation of children's WM skills on the *W* ability score steadily decreased from fall of kindergarten (30.240 points) to the spring of second grade (22.881 points), demonstrating that variability in children's WM skills decreases over the early school years. These patterns in the *W* ability scores were mirrored by patterns in the percentage of correct trials (out of 30) and the longest digit span children achieved. In the fall of kindergarten, 40% of children did not get any trials correct, 60% correctly responded to a two-digit trial, 32% correctly responded to a three-digit trial, and 5% correctly responded to a four-digit trial. By the spring of kindergarten, only 19% of children did not get any trials correct, 81% of children correctly responded to a two-digit trial, 54% correctly responded to a three-digit trial, and 11% correctly responded to four-digit trial. By the end of second grade, very few students (2.03%) were not able to correctly respond to any trials, 98% correctly responded to a two-digit trial, 89% of children correctly responded to a three-digit trial, and 48% of children correctly responded to a four-digit trial.

WM Growth Rates in School-Year and Summer Months

Table 2 shows average growth rates in WM (using the *W* ability scores) during the first three school years and the summers between them. These results demonstrate that children's WM skills improve more during school-year months than in summer months (see Figure 2), as shown by the steeper slopes in the kindergarten, first-grade, and second-grade school-year months compared to the summer months. Children gain an average of 2.775 points per month of kindergarten, 1.567 points per month of first grade, and 0.985 points per month of second grade. In contrast, they gain 0.841 points per month in the summer after kindergarten and 0.395 points per month in the summer after first grade. WM growth rates were significantly larger during the kindergarten and first-grade school-year months compared to the summer between them, $\chi^2(1) = 114.50$, $p < .001$; $\chi^2(1) = 12.12$, $p < .001$, respectively. Similarly, WM growth rates were significantly larger during the first-grade and second-grade school-year months compared to the summer between them, $\chi^2(1) = 36.58$, $p < .001$; $\chi^2(1) = 7.41$, $p = .007$, respectively.

In both school-year and summer months, children's WM growth rate monotonically decreased, such that the largest improvements in WM skills were found during the kindergarten school year. Children had significantly larger gains during the kindergarten months compared to the first-grade months, $\chi^2(1) = 276.28$, $p < .001$, and during the first-grade months compared to the second-grade months, $\chi^2(1) = 52.41$, $p < .001$. Similarly, children showed larger gains during the summer after kindergarten compared to the summer after first grade, $\chi^2(1) = 4.36$, $p = .037$.

TABLE 2

Multilevel Models Demonstrating Associations Between Months in School Years and Summers and Children's Working Memory (WM) Skills

Variable	*B* (*SE*)	*SD*	*p*
Fixed effects			
Initial status (γ_{00})	429.631 (0.329)		<.001
Kindergarten school year (γ_{01})	2.775 (0.043)		<.001
Kindergarten summer (γ_{02})	0.841 (0.163)		<.001
First-grade school year (γ_{03})	1.567 (0.055)		<.001
First-grade summer (γ_{04})	0.395 (0.168)		.019
Second-grade school year (γ_{05})	0.985 (0.057)		<.001
Random effects			
Within-student differences in WM trajectories (e_{it})		17.137	
Between-student differences in WM at kindergarten entry (u_{0i})		25.100	<.001
Between-student differences in kindergarten WM growth rates (u_{1i})		0.061	<.001
Between-student differences in first-grade WM growth rates (u_{3i})		0.042	<.001
Between-student differences in second-grade WM growth rates (u_{5i})		0.167	>.500
Between-student differences in summer WM growth rates (u_{6i})		0.047	.044

Note. All estimates are weighted (W1C0) to adjust for the complex survey design of the Early Childhood Longitudinal Study, Kindergarten Class of 2010–2011. The maximum sample size is 11,150 (rounded to the nearest 10 per National Center for Education Statistics guidelines), but sample size varies at each time point. Income has been log-transformed.

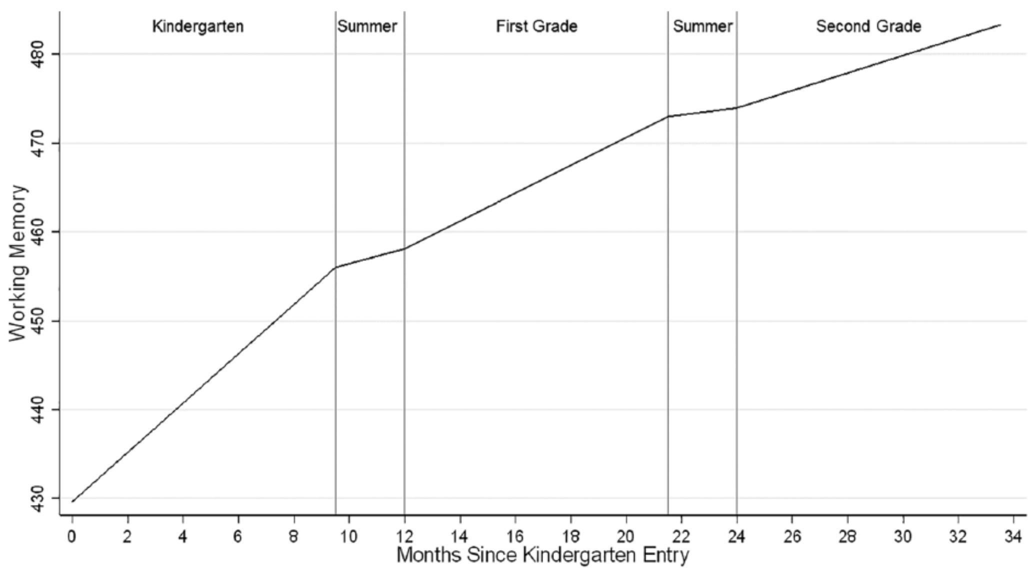

FIGURE 2. *Fitted working memory growth trajectory for all students.*

Moderation of WM Growth Rates by Household Income

Table 3 includes interactions between log-transformed household income and children's growth rates in each school year and summer. There were large disparities in children's WM skills by household income at kindergarten entry ($B = 8.655$, $p < .001$). Further, household income moderated children's growth trajectories in the kindergarten school year, the first-grade school year, and the summer between. Specifically, children from lower-income households had significantly faster growth rates during the kindergarten school year ($B = -0.100$, $p = .016$), the summer after kindergarten ($B = -0.435$, $p = .006$), and the first-grade school year ($B = -0.115$, $p = .032$), compared to children from higher-income households. Results were unchanged with the addition of age at kindergarten entry and gender as covariates. Effect sizes, as measured by pseudo-R^2 statistics, are reported in Table 4. Figure 3 illustrates the

TABLE 3

Multilevel Models Demonstrating Associations Between Months in School Years and Summers and Children's Working Memory (WM) Skills and Moderation by Household Income

Variable	*B (SE)*	*SD*	*p*
Fixed effects			
Initial status (γ_{00})	429.710 (0.332)		<.001
Initial status × Income (γ_{10})	8.655 (0.322)		<.001
Kindergarten school year (γ_{01})	2.783 (0.042)		<.001
Kindergarten school year × Income (γ_{11})	−0.100 (0.041)		.016
Kindergarten summer (γ_{02})	0.805 (0.164)		<.001
Kindergarten summer × Income (γ_{12})	−0.435 (0.158)		.006
First-grade school year (γ_{03})	1.568 (0.056)		<.001
First-grade school year × Income (γ_{13})	−0.115 (0.053)		.032
First-grade summer (γ_{04})	0.377 (0.168)		.025
First-grade summer × Income (γ_{14})	−0.157 (0.161)		.330
Second-grade school year (γ_{05})	0.985 (0.057)		<.001
Second-grade school year × Income (γ_{15})	−0.086 (0.054)		.112
Random effects			
Within-student differences in WM trajectories (e_{it})		17.105	
Between-student differences in WM at kindergarten entry (u_{0i})		23.550	<.001
Between-student differences in kindergarten WM growth rates (u_{1i})		1.873	<.001
Between-student differences in first-grade WM growth rates (u_{3i})		1.288	.002
Between-student differences in second-grade WM growth rates (u_{5i})		0.508	>.500
Between-student differences in summer WM growth rates (u_{6i})		1.418	.332

Note. All estimates are weighted (W1C0) to adjust for the complex survey design of the Early Childhood Longitudinal Study, Kindergarten Class of 2010–2011. The maximum sample size is 11,150 (rounded to the nearest 10 per National Center for Education Statistics guidelines), but sample size varies at each time point. Income has been log-transformed.

TABLE 4

Pseudo-R^2 *Effect Size Statistics for Multilevel Models Demonstrating Associations Between Months in School Years and Summers and Children's Working Memory Skills and Moderation by Household Income*

Level 2 variable	Unconditional τ	Conditional τ	Pseudo R^2
Initial status	630.0147	552.3965	0.1232
Kindergarten school year	−0.6497	−0.6222	0.0423
First-grade school year	−0.4088	−0.3708	0.0929
Second-grade school year	−0.0730	−0.0624	0.1447
Summer months (total)	−0.4105	−0.3129	0.2379

decreasing gaps between lower- and higher-income children by showing growth trajectories for children from households at the 10th, 50th, and 90th income percentiles. Households at the 10th income percentile have a total household income of $12,500, households at the 50th income percentile have a total household income of $52,500, and households at the 90th income percentile have a total household income of $150,000.

Wald tests were used to compare the coefficients on the interaction terms between income and WM growth for each time period. The null hypothesis was that the coefficients on the interaction terms were the same across different time periods, such that income similarly moderated WM growth rates over time. The difference in WM growth rates between lower- and higher-income children was marginally larger in the summer after kindergarten compared to the kindergarten school year, $\chi^2(1) = 3.73$, $p = .054$, but not compared to the first-grade school year, $\chi^2(1) = 2.57$, $p = .109$. This shows that there was slightly more equalizing in WM scores during the summer after kindergarten compared to the kindergarten school year. There were not significant differences in WM growth rates between lower- and higher-income children in the kindergarten and first-grade school-year months, $\chi^2(1) = 0.05$, $p = .822$, demonstrating that there are similar equalizing effects of exposure to school during the kindergarten and first-grade school years.

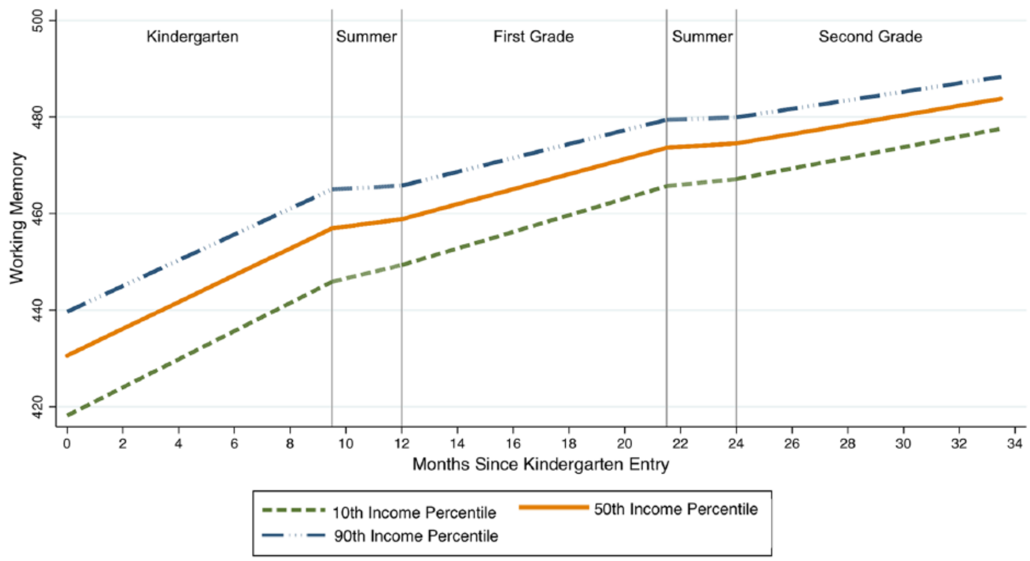

FIGURE 3. *Fitted working memory growth trajectories for students at the 10th, 50th, and 90th income percentiles. Households at the 10th income percentile have a total household income of $12,500, households at the 50th income percentile have a total household income of $52,500, and households at the 90th income percentile have a total household income of $150,000. This figure demonstrates that there were significant differences in working memory growth rates by household income during the kindergarten school year, the summer after kindergarten, and the first-grade school year. There was also significantly more equalizing of scores between lower- and higher-income children during the summer after kindergarten compared to the kindergarten school year.*

Discussion

Although WM skills continue to improve after kindergarten entry (Lee et al., 2013; Vandenbroucke, Verschueren, et al., 2017), there is little information about whether these improvements are due to experiences children have in school. This is the first study to demonstrate that WM skills grow more during the school-year months compared to the summer months, suggesting that school environments provide children with unique opportunities to improve and practice their WM skills. Further, lower-income children showed significantly faster WM growth rates in the first 2 years of school and the intervening summer, compared to their peers from higher-income families. This led to an overall narrowing in WM disparities between children from lower- and higher-income families during the early school years. However, there was no evidence that schools specifically were equalizing or exacerbating inequality in WM skills between lower- and higher-income children, as narrowing occurred both during the school years and during the summer.

WM Growth Rates in School-Year and Summer Months

This study provides nuanced information about the developmental trajectories of WM in early elementary school using a nationally representative sample. First, results demonstrated that children's WM skills show the largest improvements in kindergarten and that growth in WM monotonically decreases over time. In particular, this study focuses on the central executive component of WM, which not only stores information in the mind but actively processes and manipulates that information (Baddeley, 2012). The central executive component of WM is the most complex (Baddeley, 2012) and tends to develop later than the two systems it controls (Davidson, Amso, Anderson, & Diamond, 2006; Garon, Bryson, & Smith, 2008). The findings in this study are similar to several studies highlighting significant improvements in the central executive component of WM during the early elementary years (Gathercole et al., 2004; Lee et al., 2013; Van der Ven, Kroesbergen, Boom, & Leseman, 2012; Vandenbroucke, Verschueren, et al., 2017) and a longitudinal study of young Swiss children who showed the largest gains in WM during the prekindergarten and kindergarten years and smaller gains during the first- and second-grade years (Röthlisberger et al., 2012). None of these previous studies examining WM development differentiated between school-year and summer growth in WM.

Second, these findings highlight that WM skills grow significantly more during the school-year months compared to the summer months. These findings corroborate prior research comparing WM scores for children of similar ages who had different amounts of exposure to formal schooling (Burrage et al., 2008; McCrea et al., 1999). The current study builds on prior schooling-effects research that used birthdate cutoff designs by comparing children to themselves at different points in the academic year, allowing for more precise estimation of what months in the year WM growth occurs. Results are similar to those found in seasonal research on academic skills (Downey et al., 2004), suggesting that the kinds of activities children engage in at school similarly benefit their WM and academic skills, despite the fact that the promotion of WM is not part of typical school curricula.

There are several mechanisms through which school experiences may foster WM development. Broad measures of classroom quality, including emotional support, instructional quality, and classroom organization have been associated with executive function development for preschoolers (Fuhs, Nesbitt, Farran, & Dong, 2014; Hamre et al., 2014; Weiland, Ulvestad, Sachs, & Yoshikawa, 2013). This suggests that classroom dynamics cocreated by both teachers and students, such as positive communication or a productive classroom environment, are important for executive function development in the early childhood period. Building on prior research demonstrating bidirectional links between social development and executive functions (Holmes, Kim-Spoon, & Deater-Deckard, 2015), children's interactions with peers in the classroom and on the playground may also benefit children's WM development.

Improvements in WM skills during the school year may also be directly related to growth in academic skills. Studies highlight bidirectional associations between academic and executive skills in prekindergarten and early elementary school (Fuhs et al., 2014; Nesbitt, Fuhs, & Farran, 2018; Schmitt, Geldhof, Purpura, Duncan, & McClelland, 2017; Van der Ven et al., 2012). Although there is slightly more evidence for bidirectional associations between math and executive function skills (including WM), there is little information about what specific academic activities and curricula are most promotive of WM development. There is evidence that classroom programs that support children's social-emotional development and pretend play have led to improvements in children's executive function skills (Diamond & Lee, 2011).

Some studies suggest that WM training programs, where children repeatedly practice WM tasks, are linked to short-term gains in short-term memory and WM tasks (Diamond & Lee, 2011; Melby-Lervåg & Hulme, 2013; Redick, Shipstead, Wiemers, Melby-Lervåg, & Hulme, 2015). However, these effects do not transfer well to the academic and behavioral skills that matter for school success (Diamond, 2012; Hitchcock & Westwell, 2017; Melby-Lervåg & Hulme, 2013; Redick et al., 2015; Sala & Gobet, 2017). Learning activities that require children to monitor their progress and keep track of complex rules and steps are likely a better way to provide children with opportunities to practice and improve their WM skills (Diamond, 2012). For children in elementary school, games that require strategy, planning, and logical reasoning require children to engage their WM skills. Further, movement and song games where children copy a leader, repeat verses, and have complicated clapping rhythms help children practice their WM skills (Center on the Developing Child, 2014).

Differences in WM Growth Rates by Household Income

Similar to results by Little (2017), there were significant disparities in children's WM skills by household income at kindergarten entry. This corroborates a large body of research demonstrating that household income during the early childhood period is associated with children's executive function skills (Finch & Obradović, 2018; Lawson, Hook, & Farah, 2018; Raver, Blair, & Willoughby, 2013) and emphasizes the importance of children's experiences prior to kindergarten entry for their cognitive development. Socioeconomic differences in children's WM skills are likely mirrored by disparities in related cognitive skills, such as children's attention, inhibitory control, and cognitive flexibility, which are all supported by the prefrontal cortex (Hackman et al., 2015; Noble, Houston, Kan, & Sowell, 2012; Noble, McCandliss, & Farah, 2007).

Findings by Burrage and colleagues (2008) showed that prekindergarten and kindergarten experiences have similar effects on WM development. Ensuring that children from lower-income families have access to high-quality preschool settings could help reduce income-based WM disparities by providing children with the benefits of schooling experiences earlier in life. Evidence from Boston demonstrated that access to a prekindergarten program with empirically validated curricula and a coaching system increased children's executive function skills, with larger impacts for low-income children receiving free or reduced-price lunch (Weiland & Yoshikawa, 2013). Increasing access to high-quality preschool programs at a national scale could significantly reduce income gaps in WM skills at kindergarten entry (Duncan, Ludwig, & Magnuson, 2007; Yoshikawa et al., 2013).

There was no evidence that schools play a clear role in exacerbating or reducing WM disparities by household income. Gaps between lower- and higher-income children closed during both the kindergarten and first-grade school years as well as the intervening summer. Downey and colleagues (2017) similarly found a neutral role of schools for socioeconomic gaps in teachers' ratings of children's social-emotional skills in the ECLS-K:2010. Together, these results highlight differences in the role of schools for non-academic and academic skills. Recent findings from the ECLS-K:2010 demonstrated that children from lower-socioeconomic-status families fell more behind on reading and math skills during the summer after kindergarten (Quinn et al., 2016; von Hippel et al., 2017), and a larger body of literature highlights summer learning disparities for children's academic skills (Alexander et al., 2001; Burkam et al., 2004; Downey et al., 2004; Heyns, 1987). For math and reading skills, schools seem to play an equalizing role (particularly in the kindergarten year) by reducing socioeconomic gaps in achievement scores during the school year (Downey et al., 2004; Quinn et al., 2016; von Hippel et al., 2017), whereas schools do not play a clear role in reducing socioeconomic gaps in nonacademic skills.

However, findings showed that lower-income children's WM skills grow at a faster rate during the first 2 years of school and the intervening summer, compared to their higher-income peers. It is possible that children's school experiences spark a cascade of experiences that allow low-income children to practice and improve their WM skills, including at home during the summer months. Beginning in kindergarten, children gain increased exposure to literacy and math concepts that affect the kinds of activities they are able to engage in. For example, numeracy skills learned in the kindergarten classroom may support children in playing more complex board games, which would then allow them to practice their WM skills with siblings and parents. Further, children make many more social connections at school entry. These new friendships likely foster the development of WM during the early school years (Holmes et al., 2015). Kindergarten experiences may be particularly novel, and thus impactful, for lower-income children, who tend to have lower-quality learning experiences before school entry (Bradley, Corwyn, McAdoo, & Coll, 2001; Espinosa, Laffey, Whittaker, & Sheng, 2006; Kaushal, Magnuson, & Waldfogel, 2011). The present study builds on literature from the early childhood period, demonstrating compensatory effects of preschool attendance for low-income children (McCartney, Dearing, Taylor, & Bub, 2007; Votruba-Drzal, Coley, Koury, & Miller, 2013), such that attending preschool had significantly larger effects on school readiness skills for lower-income children compared to their more advantaged peers.

Strengths, Limitations, and Future Directions

This study leveraged nationally representative, longitudinal data to provide a more detailed picture of children's WM development in the early elementary years; however, several limitations should be noted. Although this study improved on cross-sectional research previously used to estimate WM schooling effects, this study is limited to young children in the first 3 years of elementary school. Children's early school years represent an important transition period (Pianta et al., 1999; Rimm-Kaufman & Pianta, 2000), coupled with significant increases in WM skills (Gathercole et al., 2004; Röthlisberger et al., 2012; Van der Ven et al., 2012). Therefore, schooling effects may differ for older children, who are more acclimated to the school context and whose WM skills are not improving as quickly.

Second, this study used only one direct assessment to measure children's WM development. The ECLS-K:2010 data set was specifically chosen because it is the first nationally representative data containing direct assessments of children's executive function skills. Previously, researchers have used teacher ratings of students' executive function skills, which are subject to biases (Garcia et al., 2018). However, the use of a single task does not provide information on other executive function components (inhibitory control and cognitive flexibility) or the other aspects of WM (e.g., verbal and visuospatial WM), which have been shown to have slightly different developmental trajectories (Davidson et al., 2006; Garon et al., 2008; Lee et al., 2013). The ECLS-K:2010 does include a direct assessment of children's cognitive flexibility using the Dimensional Change Card Sort task, but the task was changed from a tabletop version to a computerized version in second grade (Tourangeau et al., 2017), not allowing for comparison across those years. These findings warrant replication with a larger battery of executive function tasks and specifically WM tasks that tap verbal and visuospatial WM. Improvements in WM skills could be partially due to practice effects because children were given the same WM task at each assessment. This is unlikely, given that there were approximately 6 months between assessments, but utilization of a larger battery of WM tasks that changed across assessments would help elucidate if improvements in WM scores were due to practice effects.

This study is descriptive and does not provide causal information about why children's growth rates may differ across school-year and summer months or why there are differences in children's WM development by family income. In future research, researchers should explore which aspects of the school environment are predictive of executive function development. Further, it will be important to disentangle whether household income is predictive of children's executive function trajectories or whether these patterns are driven by other aspects of children's home environments. I encourage researchers to include race-ethnicity information as well as other covariates that may confound the link between household income and executive function outcomes.

Finally, the findings in this study can be generalized to the overall U.S. school population and utilized a large sample size that provides the power to detect small differences in growth rates and moderation by income. Future research should leverage these data to understand how developmental trajectories of WM skills differ by other child-level factors, such as gender, receipt of special needs services, and English language learner status.

Conclusion

In summary, this study highlights children's schools as a key developmental context for the development of WM skills. The first 2 years of school may provide a unique window of opportunity to boost the WM skills of children from low-income families. Whereas prior work has focused largely on the role of parents in the development of executive function skills, this study emphasizes the need to identify specific aspects of children's school experiences that are the most promotive of executive function development. Future research needs to move beyond general measures of classroom quality to better disentangle which teacher behaviors, curricula, learning activities, and interactions with peers can support children's WM development.

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References

Alexander, K., Entwisle, D. R., & Olson, L. S. (2001). Schools, achievement, and inequality: A seasonal perspective. *Education Evaluation and Policy Analysis*, *23*(2), 171–191.

Alloway, T. P. (2007). *Automated Working Memory Assessment*. London, UK: Harcourt Assessment.

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2009). The Working Memory Rating Scale: A classroom-based behavioral assessment of working memory. *Learning and Individual Differences*, *19*(2), 242–245. https://doi.org/10.1016/j.lindif.2008.10.003

Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology*, *63*(1), 1–29. https://doi.org/10.1146/annurev-psych-120710-100422

Bassok, D., Finch, J. E., Lee, R., Reardon, S., & Waldfogel, J. (2016). Socioeconomic gaps in early childhood experiences: 1998 to 2010. *AERA Open*, *2*(3). doi:10.1177/2332858416653924

Bassok, D., Latham, S., & Rorem, A. (2016). Is kindergarten the new first grade? *AERA Open*, *2*(1), 233285841561635. doi:10.1177/2332858415616358

Blackwell, T. L. (2001). Woodcock-Johnson III Test. *Rehabilitation Counseling Bulletin*, *44*(4), 232–235. doi:10.1177/003435520104400407

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist*, *57*(2), 111–127. doi:10.1037/0003-066X.57.2.111

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology*, *66*(1), 711–731. doi:10.1146/annurev-psych-010814-015221

Bradley, R. H., Corwyn, R. F., McAdoo, H. P., & Coll, C. G. (2001). The home environments of children in the United States Part I: Variations by age, ethnicity, and poverty status. *Child Development*, *72*(6), 1844–1867. doi:10.1111/1467-8624.t01-1-00382

Brod, G., Bunge, S. A., & Shing, Y. L. (2017). Does one year of schooling improve children's cognitive control and alter associated brain activation? *Psychological Science*, *28*(7), 967–978. doi:10.1177/0956797617699838

Burkam, D. T., Ready, D. D., Lee, V. E., & LoGerfo, L. F. (2004). Social-class differences in summer learning between kindergarten and first grade: Model specification and estimation. *Sociology of Education*, *77*(1), 1–31. doi:10.1177/003804070407700101

Burrage, M., Ponitz, C., McCready, E., Shah, P., Sims, B. C., Jewkes, A., & Morrison, F. (2008). Age- and schooling-related effects on executive functions in young children: A natural experiment. *Child Neuropsychology*, *14*(6), 510–524. doi:10.1080/09297040701756917

Center on the Developing Child. (2014). *Enhancing and practicing executive function skills with children from infancy to adolescence*. Cambridge, MA: Harvard University. Retrieved from http://www.developingchild.harvard.edu

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037–2078. doi:10.1016/j.neuropsychologia.2006.02.006

de Wilde, A., Koot, H., & van Lier, P. (2016). Developmental links between children's working memory and their social relations with teachers and peers in the early school years. *Journal of Abnormal Child Psychology*, *44*(1), 19–30. doi:10.1007/s10802-015-0053-4

Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science*, *21*(5), 335–341. doi:10.1177/0963721412453722

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. doi:10.1146/annurev-psych-113011-143750

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, *333*(6045), 959–964. doi:10.1126/science.1204529

Downey, D. B., von Hippel, P. T., & Broh, B. A. (2004). Are schools the great equalizer? Cognitive inequality during the summer months and the school year. *American Sociological Review*, *69*(5), 613–635. doi:10.1177/000312240406900501

Downey, D. B., Workman, J., & von Hippel, P. T. (2017). Socioeconomic, racial, and gender gaps in children's social/behavioral skills: Do they grow faster in school or out? *SSRN Electronic Journal*. doi:10.2139/ssrn.3044923

Duncan, G. J., Ludwig, J., & Magnuson, K. A. (2007). Reducing poverty through preschool interventions. *Future of Children*, *17*(2), 143–160. doi:10.1353/foc.2007.0015

Espinosa, L. M., Laffey, J. M., Whittaker, T., & Sheng, Y. (2006). Technology in the home and the achievement of young children: Findings from the Early Childhood Longitudinal Study. *Early Education & Development*, *17*(3), 421–441. doi:10.1207/s15566935eed1703_5

Fay-Stammbach, T., Hawes, D. J., & Meredith, P. (2014). Parenting influences on executive function in early childhood: A review. *Child Development Perspectives*, *8*(4), 258–264. doi:10.1111/cdep.12095

Finch, J. E., & Obradović, J. (2018). Adversity and stress: Implications for the development of executive functions. In S. A. Wiebe & J. Karbach (Eds.), *Lifespan development and plasticity of executive functions* (pp. 147–159). New York, NY: Routledge.

Fuhs, M. W., Nesbitt, K. T., Farran, D. C., & Dong, N. (2014). Longitudinal associations between executive functioning and academic skills across content areas. *Developmental Psychology*, *50*(6), 1698–1709. doi:10.1037/a0036633

Garcia, E. B., Sulik, M. J., & Obradović, J. (2018). Teachers' perceptions of students' executive functions: Disparities by gender, ethnicity and ELL status. *Journal of Educational Psychology*. Advance online publication. doi:10.1037/edu0000308

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, *134*(1), 31–60. doi:10.1037/0033-2909.134.1.31

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, *40*(2), 177–190. doi:10.1037/0012-1649.40.2.177

Hackman, D. A., Gallop, R., Evans, G. W., & Farah, M. J. (2015). Socioeconomic status and executive function: Developmental trajectories and mediation. *Developmental Science*, *18*(5), 686–702. doi:10.1111/desc.12246

Hamre, B., Hatfield, B., Pianta, R., & Jamil, F. (2014). Evidence for general and domain-specific elements of teacher-child interactions: Associations with preschool children's development. *Child Development*, *85*(3), 1257–1274. doi:10.1111/cdev.12184

Heyns, B. (1987). Schooling and cognitive development: Is there a season for learning? *Child Development*, *58*(5), 1151. doi:10.2307/1130611

Hiebert, E. H. (2015). Changing readers, changing texts: Beginning reading texts from 1960 to 2010. *Journal of Education*, *195*(3), 1–13. doi:10.1177/002205741519500302

Hitchcock, C., & Westwell, M. S. (2017). A cluster-randomised, controlled trial of the impact of Cogmed Working Memory Training on both academic performance and regulation of social, emotional and behavioural challenges. *Journal of Child Psychology and Psychiatry*, *58*(2), 140–150. doi:10.1111/jcpp.12638

Holmes, C. J., Kim-Spoon, J., & Deater-Deckard, K. (2015). Linking executive function and peer problems from early childhood through middle adolescence. *Journal of Abnormal Child Psychology*, *44*(1), 31–42. doi:10.1007/s10802-015-0044-5

Kaushal, N., Magnuson, K., & Waldfogel, J. (2011). How is family income related to investments in children's learning? In G. J. Duncan & R. J. Murnane (Eds.), *Whither opportunity?* (pp. 187–206). New York, NY: Russell Sage Foundation. Retrieved from http://www.jstor.org/stable/10.7758/9781610447515.14

Lawson, G. M., Hook, C. J., & Farah, M. J. (2018). A meta-analysis of the relationship between socioeconomic status and executive function performance among children. *Developmental Science*, *21*(2), e12529. doi:10.1111/desc.12529

Lee, K., Bull, R., & Ho, R. M. H. (2013). Developmental changes in executive functioning. *Child Development*, *84*(6), 1933–1953. doi:10.1111/cdev.12096

Lewit, E. M., & Baker, L. S. (1995). School readiness. *Future of Children*, *5*(2), 128. doi:10.2307/1602361

Little, M. (2017). Racial and socioeconomic gaps in executive function skills in early elementary school: Nationally representative evidence from the ECLS-K:2011. *Educational Researcher*, *46*(2), 103–109. doi:10.3102/0013189X17698700

McCartney, K., Dearing, E., Taylor, B. A., & Bub, K. L. (2007). Quality child care supports the achievement of low-income children: Direct and indirect pathways through caregiving and the home environment. *Journal of Applied Developmental Psychology*, *28*(5/6), 411–426. doi:10.1016/j.appdev.2007.06.010

McCrea, S. M., Mueller, J. H., & Parrila, R. K. (1999). Quantitative analyses of schooling effects on executive function in young children. *Child Neuropsychology*, *5*(4), 242.

McQuade, J. D., Murray-Close, D., Shoulberg, E. K., & Hoza, B. (2013). Working memory and social functioning in children. *Journal of Experimental Child Psychology*, *115*(3), 422–435. doi:10.1016/j.jecp.2013.03.002

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, *49*(2), 270–291. doi:10.1037/a0028228

Miner, J. L., & Clarke-Stewart, K. A. (2008). Trajectories of externalizing behavior from age 2 to age 9: Relations with gender, temperament, ethnicity, parenting, and rater. *Developmental Psychology*, *44*(3), 771–786. doi:10.1037/0012-1649.44.3.771

Nelson, T. D., Nelson, J. M., James, T. D., Clark, C. A. C., Kidwell, K. M., & Espy, K. A. (2017). Executive control goes to school: Implications of preschool executive performance for observed elementary classroom learning engagement. *Developmental Psychology*, *53*(5), 836–844. doi:10.1037/dev0000296

Nesbitt, K. T., Fuhs, M. W., & Farran, D. C. (2018). Stability and instability in the co-development of mathematics, executive function skills, and visual-motor integration from prekindergarten to first grade. *Early Childhood Research Quarterly*. Advance online publication. doi:10.1016/j.ecresq.2018.02.003

Noble, K. G., Houston, S. M., Kan, E., & Sowell, E. R. (2012). Neural correlates of socioeconomic status in the developing human brain: *Developmental Science*, *15*(4), 516–527. doi:10.1111/j.1467-7687.2012.01147.x

Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science*, *10*(4), 464–480. doi:10.1111/j.1467-7687.2007.00600.x

Obradović, J., Portilla, X., & Boyce, W. T. (2012). Executive functioning and developmental neuroscience: Current progress and implications for early childhood education. In R. C. Pianta (Ed.), *The handbook of early education* (pp. 324–351). New York, NY: Guilford Press.

Peng, P., Namkung, J., Barnes, M., & Sun, C. (2016). A meta-analysis of mathematics and working memory: Moderating effects of working memory domain, type of mathematics skill, and sample characteristics. *Journal of Educational Psychology*, *108*(4), 455–473. doi:10.1037/edu0000079

Pianta, R. C., Rimm-Kauffman, S., & Cox, M. J. (1999). An ecological approach to kindergarten transition. In R. C. Pianta & M. J. Cox (Eds.), *The transition to kindergarten* (pp. 3–12). Baltimore, MD: Brookes.

Porter, A., McMaken, J., Hwang, J., & Yang, R. (2011). Common Core standards: The new U.S. intended curriculum. *Educational Researcher*, *40*(3), 103–116. doi:10.3102/0013189X11405038

Portilla, X. A., Ballard, P. J., Adler, N. E., Boyce, W. T., & Obradović, J. (2014). An integrative view of school functioning: Transactions between self-regulation, school engagement, and teacher-child relationship quality. *Child Development*, *85*(5), 1915–1931. doi:10.1111/cdev.12259

Quinn, D. M., Cooc, N., McIntyre, J., & Gomez, C. J. (2016). Seasonal dynamics of academic achievement inequality by socioeconomic status and race/ethnicity: Updating and extending past research with new national data. *Educational Researcher*, *45*(8), 443–453. doi:10.3102/0013189X16677965

Raudenbush, S. W., & Bryk, A. S. (Eds.). (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Thousand Oaks, CA: Sage.

Raver, C. C., Blair, C., & Willoughby, M. T. (2013). Poverty as a predictor of 4-year-olds' executive function: New perspectives on models of differential susceptibility. *Developmental Psychology*, *49*(2), 292–304. doi:10.1037/a0028343

Redick, T. S., Shipstead, Z., Wiemers, E. A., Melby-Lervåg, M., & Hulme, C. (2015). What's working in working memory training? An educational perspective. *Educational Psychology Review*, *27*(4), 617–633. doi:10.1007/s10648-015-9314-6

Rimm-Kaufman, S. E., & Pianta, R. C. (2000). An ecological perspective on the transition to kindergarten. *Journal of Applied Developmental Psychology*, *21*(5), 491–511. doi:10.1016/S0193-3973(00)00051-4

Röthlisberger, M., Neuenschwander, R., Cimeli, P., Michel, E., & Roebers, C. M. (2012). Improving executive functions in 5- and 6-year-olds: Evaluation of a small group intervention in prekindergarten and kindergarten children. *Infant and Child Development*, *21*(4), 411–429. doi:10.1002/icd.752

Röthlisberger, M., Neuenschwander, R., Cimeli, P., & Roebers, C. M. (2013). Executive functions in 5- to 8-year olds: Developmental changes and relationship to academic achievement. *Journal of Educational and Developmental Psychology*, *3*(2). doi:10.5539/jedp.v3n2p153

Sala, G., & Gobet, F. (2017). Working memory training in typically developing children: A meta-analysis of the available evidence. *Developmental Psychology*, *53*(4), 671–685. doi:10.1037/dev0000265

Sarsour, K., Sheridan, M., Jutte, D., Nuru-Jeter, A., Hinshaw, S., & Boyce, W. T. (2011). Family socioeconomic status and child executive functions: The roles of language, home environment, and single parenthood. *Journal of the International Neuropsychological Society*, *17*(01), 120–132. doi:10.1017/S1355617710001335

Schmitt, S. A., Geldhof, G. J., Purpura, D. J., Duncan, R., & McClelland, M. M. (2017). Examining the relations between executive function, math, and literacy during the transition to kindergarten: A multi-analytic approach. *Journal of Educational Psychology*, *109*(8), 1120–1140. doi:10.1037/edu0000193

Son, S.-H., & Morrison, F. J. (2010). The nature and impact of changes in home learning environment on development of language and academic skills in preschool children. *Developmental Psychology*, *46*(5), 1103–1118. doi:10.1037/a0020065

Sulik, M. J., Blair, C., & Greenberg, M., & The Family Life Project Investigators. (2017). Child conduct problems across home and school contexts: A person-centered approach. *Journal of Psychopathology and Behavioral Assessment*, *39*(1), 46–57. doi:10.1007/s10862–016–9564–8

Swanson, H. L. (2011). Working memory, attention, and mathematical problem solving: A longitudinal study of elementary school children. *Journal of Educational Psychology*, *103*(4), 821–837. doi:10.1037/a0025114

Tourangeau, K., Nord, C., Le, T., Wallner-Allen, K., Vaden-Kiernan, N., Blaker, L., & Najarian, M. (2017). *Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K:2011): User's manual for the ECLS-K:2011 kindergarten–second grade data file and electronic codebook, public version* (NCES No. 2017-285). Washington, DC: U.S. Department of Education.

Van der Ven, S. H. G., Kroesbergen, E. H., Boom, J., & Leseman, P. P. M. (2012). The development of executive functions and early mathematics: A dynamic relationship. *British Journal of Educational Psychology*, *82*(1), 100–119. doi:10.1111/j.2044-8279.2011.02035.x

Vandenbroucke, L., Spilt, J., Verschueren, K., & Baeyens, D. (2017). Keeping the spirits up: The effect of teachers' and parents' emotional support on children's working memory performance. *Frontiers in Psychology*, *8*. doi:10.3389/fpsyg.2017.00512

Vandenbroucke, L., Verschueren, K., & Baeyens, D. (2017). The development of executive functioning across the transition to first grade and its predictive value for academic achievement. *Learning and Instruction*, *49*, 103–112. doi:10.1016/j.learninstruc.2016.12.008

Verachtert, P., Van Damme, J., Onghena, P., & Ghesquière, P. (2009). A seasonal perspective on school effectiveness: Evidence from a Flemish longitudinal study in kindergarten and first grade. *School Effectiveness and School Improvement*, *20*(2), 215–233. doi:10.1080/09243450902883896

von Hippel, P. T., Workman, J., & Downey, D. B. (2017). Are schools (still) a great equalizer? Replicating a summer learning study using better test scores and a new cohort of children. *SSRN Electronic Journal*. doi:10.2139/ssrn.3036094

Votruba-Drzal, E., Coley, R. L., Koury, A. S., & Miller, P. (2013). Center-based child care and cognitive skills development: Importance of timing and household resources. *Journal of Educational Psychology*, *105*(3), 821–838. doi:10.1037/a0032951

Weiland, C., McCoy, D. C., Grace, E., & Park, S. O. (2017). Natural window of opportunity? Low-income parents' responses to their children's impending kindergarten entry. *AERA Open*, *3*(1), 233285841668150. doi:10.1177/2332858416681509

Weiland, C., Ulvestad, K., Sachs, J., & Yoshikawa, H. (2013). Associations between classroom quality and children's vocabulary and executive function skills in an urban public prekindergarten program. *Early Childhood Research Quarterly*, *28*(2), 199–209. doi:10.1016/j.ecresq.2012.12.002

Weiland, C., & Yoshikawa, H. (2013). Impacts of a prekindergarten program on children's mathematics, language, literacy, executive function, and emotional skills. *Child Development*, *84*(6), 2112–2130. doi:10.1111/cdev.12099

Yoshikawa, H., Weiland, C., Brooks-Gunn, J., Burchinal, M. R., Espinosa, L. M., Gormley, W. T., . . . Zaslow, M. J. (2013). *Investing in our future: The evidence base on preschool education*. Ann Arbor, MI: Society for Research in Child Development.

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