Early Childhood Research Quarterly xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Early Childhood Research Quarterly

Relations between preschool attention span-persistence and age 25 educational outcomes☆

Megan M. McClelland[a,*], Alan C. Acock[a], Andrea Piccinin[b], Sally Ann Rhea[c], Michael C. Stallings[c]

[a] Oregon State University, United States
[b] University of Victoria, Canada
[c] University of Colorado, United States

A R T I C L E I N F O

Article history:
Received 21 October 2010
Received in revised form 18 July 2012
Accepted 22 July 2012

Keywords:
Attention span-persistence
Self-regulation
Academic achievement
Educational attainment

A B S T R A C T

This study examined relations between children's attention span-persistence in preschool and later school achievement and college completion. Children were drawn from the Colorado Adoption Project using adopted and non-adopted children ($N = 430$). Results of structural equation modeling indicated that children's age 4 attention span-persistence significantly predicted math and reading achievement at age 21 after controlling for achievement levels at age 7, adopted status, child vocabulary skills, gender, and maternal education level. Relations between attention span-persistence and later achievement were not fully mediated by age 7 achievement levels. Logistic regressions also revealed that age 4 attention span-persistence skills significantly predicted the odds of completing college by age 25. The majority of this relationship was direct and was not significantly mediated by math or reading skills at age 7 or age 21. Specifically, children who were rated one standard deviation higher on attention span-persistence at age 4 had 48.7% greater odds of completing college by age 25. Discussion focuses on the importance of children's early attention span-persistence for later school achievement and educational attainment.

© 2012 Elsevier Inc. All rights reserved.

1. Introduction

A large body of research documents the importance of children's early skills for charting later developmental trajectories (Shonkoff & Phillips, 2000). In the search to identify sources of influence, children's early executive function and self-regulation have emerged as a salient predictor of later outcomes (McClelland, Acock, & Morrison, 2006; McClelland, Morrison, & Holmes, 2000). For example, children who enter formal schooling without the ability to pay attention, remember instructions, and demonstrate self-control have more difficulty in elementary school and throughout high school (McClelland, Cameron, Connor, et al., 2007; NICHD Early Child Care Research Network, 2003). In particular, the attention aspect of self-regulation has received increasing consideration as a predictor of later achievement (Duncan et al., 2007). In the present study, we examined the predictive strength of children's early attention span-persistence at age four for later academic achievement and educational attainment between childhood and early adulthood.

1.1. Self-regulation and the role of attention span-persistence

Children's attention span-persistence is related to executive function and the broader self-regulation construct. Self-regulation includes both cognitive and emotional regulation and refers to aspects of attentional or cognitive flexibility, working memory, inhibitory control, and the ability to regulate emotions (Baumeister & Vohs, 2004; Calkins, 2007; Eisenberg & Spinrad, 2004; Graziano, Reavis, Keane, & Calkins, 2007; Li-Grining, 2007; Ursache, Blair, & Raver, 2012). In general, self-regulation helps children manage and direct their own actions in a variety of cognitive, emotional, and social domains (Blair & Diamond, 2008; McClelland, Cameron Ponitz, Messersmith, & Tominey, 2010). For example, self-regulation helps children inhibit an inappropriate behavior (e.g., shouting out an answer in a classroom) and control their emotional reaction to the situation (e.g., stop from having a tantrum). Related to self-regulation are concepts such as effortful control, which is the ability to utilize executive attention to inhibit a dominant response in favor of a subdominant response and is based in the temperament literature (Liew, 2012; Rothbart & Rueda, 2005). Both effortful control and self-regulation are important for children's social (Eisenberg et al., 2005; Eisenberg, Smith, Sadovsky, & Spinrad, 2004), academic (Blair & Diamond, 2008; Blair

☆ Funding for this study was supported by the Colorado Adoption Project grant HD-010333 and grant HD-036773 from the National Institute of Child Health and Human Development (NICHD).

* Corresponding author at: Human Development and Family Sciences, 245 Hallie E. Ford Center for Healthy Children and Families, Oregon State University, Corvallis, OR 97331, United States. Tel.: +1 541 737 9225; fax: +1 541 737 2072.
E-mail address: megan.mcclelland@oregonstate.edu (M.M. McClelland).

0885-2006/$ – see front matter © 2012 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.ecresq.2012.07.008

& Razza, 2007; McClelland, Cameron, Connor, et al., 2007; Valiente, Lemery-Chalfant, Swanson, & Reiser, 2008) and moral development (Kochanska, Murray, & Coy, 1997; Kochanska, Murray, & Harlan, 2000).

Attention span-persistence is an especially relevant aspect of cognitive or behavioral self-regulation and stems from the executive function processes of attentional or cognitive flexibility, working memory, inhibitory control (McClelland et al., 2010). Attention span-persistence refers to selecting and attending to relevant information, such as listening to the teacher, and persisting on a task (Barkley, 1997; Rothbart & Posner, 2005; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Zelazo & Müller, 2002). Moreover, a number of researchers have argued that children's developing self-regulation is connected to activation patterns in the anterior attentional network in the brain (Calkins, 2007; Rothbart & Posner, 2005; Rueda, Posner, & Rothbart, 2004). More specifically, the executive attention network, which helps monitor and resolve conflicting information, may be especially important for regulating emotions and behavior (Rothbart, Sheese, & Posner, 2007). The executive attention network consists of the anterior cingulate and lateral prefrontal areas of the brain, which are activated during tasks requiring cognitive control such as needing to focus and pay attention.

We focus on the attentional aspects of self-regulation because the ability to focus, deal with conflicting information, and persist through difficulty is especially relevant for doing well in school, on academic tasks, and for educational attainment (Andersson & Bergman, 2011; Duncan et al., 2007). In addition, children's self-regulation and underlying executive function abilities experience rapid development during the preschool years and help lay the foundation for later development (Diamond, 2002).

The present study included a parent-report measure that captured a specific aspect of self-regulation, attention span-persistence. Although not a comprehensive measure of self-regulation, data were collected in a large longitudinal study spanning over 30 years and our terminology reflects what was measured at the time (in the late 1970s). In an era of considerable conceptual debate about terms and the definitions of constructs (McClelland & Cameron, 2012), it is important to be specific about what is being measured. Thus, because a comprehensive measure of self-regulation was not available in the overall longitudinal study, we use the term attention span-persistence to best capture what was measured, and define it as the ability to focus, attend to relevant information, and persist on a task. Our decision to use this terminology is also supported by recent studies which have documented the importance of attention and task persistence for later achievement and educational outcomes (Andersson & Bergman, 2011; Deater-Deckard, Petrill, Thompson, & DeThorne, 2005; Duncan et al., 2007).

1.2. The importance of children's attention span-persistence for later achievement

Aspects of children's attention span-persistence have been linked to a number of social and academic outcomes in childhood. For example, a large literature has found that attention span-persistence and related constructs (e.g., self-regulation, executive function, effortful control) predict stronger social outcomes such as social competence and maladjustment (Blair, 2002; Eisenberg, Valiente, & Eggum, 2010), and are an important component of social-emotional interventions (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006). Although studies have used a variety of definitions and constructs, they all include measures which tap aspects of children's ability to focus attention and persist. Thus, we review research that includes constructs of behavioral regulation, executive function, learning-related skills, and effortful control because all these studies include aspects of attention span-persistence in the way they define and operationalize their constructs.

A number of recent studies have documented the importance of attention span-persistence for short-term achievement outcomes after accounting for initial achievement levels and important variables such as child IQ. For example, in one study examining behavioral regulation, the gains children made in early behavioral regulation over the preschool year significantly predicted the gains they made in reading, math, and vocabulary after controlling for initial behavioral regulation and achievement levels (McClelland, Cameron, Connor, et al., 2007). Related research found that children's behavioral regulation in the fall of kindergarten predicted end-of-year reading, math, and vocabulary achievement and gains made in math achievement (Ponitz, McClelland, Matthews, & Morrison, 2009). Another study documented that attention span-persistence was positively associated with cognitive and achievement measures in kindergarten and first grade children (Deater-Deckard et al., 2005). Other research examining similar constructs (e.g., learning-related skills, which include attention span-persistence in the definition of the construct) found that children's learning-related skills at kindergarten significantly predicted reading and math skills between kindergarten and sixth grade and gains in reading and math between kindergarten and second grade beyond the influence of child IQ, initial achievement levels, and a host of background characteristics (McClelland et al., 2006, 2000).

Aspects of attention span-persistence have also predicted long-term achievement and educational attainment outcomes. For example, attention at ages 5–6 was significantly predictive of reading and math achievement between kindergarten and early adolescence with average effect sizes ranging from .08 for reading and .11 for math (Duncan et al., 2007). Although measured in adolescence, a recent study by Andersson and Bergman (2011) provides additional evidence of the importance of attention span-persistence (called task persistence) for later achievement and success. This study found that task persistence in early adolescence (age 13) predicted grades later in adolescence, and income, occupational level and educational attainment in middle adulthood for men, with effect sizes ranging from .08 for educational attainment to .34 for occupational level (Andersson & Bergman, 2011). Other relevant research has documented that early self-control, which included attention span-persistence in the operationalization of the construct, predicted physical health, substance dependence, income, and criminal offenses in adulthood (Moffitt et al., 2011). Research has also linked attention deficits to poorer school attainment and academic outcomes. For example, a recent study found that teacher ratings of attention problems at age 6 significantly predicted math and reading achievement at age 17 after controlling for a number of background variables, including child IQ (Breslau et al., 2009).

Together, this research supports the notion that paying attention and persisting on tasks are foundational skills that are critical early in life and continue to positively predict a variety of social and academic outcomes throughout childhood and into adulthood. For example, focusing attention and persisting through difficult tasks is especially important for accomplishing major life goals such as gaining a college degree. Other research has noted that academic achievement and educational attainment is significantly predicted by parental socioeconomic status (SES), individual cognitive abilities previous academic performance, and occupational and educational aspirations (Sewell, Halle, & Portes, 1969). Based on this and other research reviewed above, we predicted that early attention span-persistence would be a substantive and significant predictor of later achievement and college completion but that variables such as parental SES, early cognitive abilities and academic achievement, gender, and age may play a role (Sirin, 2005; Strenze, 2007). Thus, the present study examined the importance of attention span-persistence for predicting reading and math achievement at age 21 and college completion by age 25 controlling for background variables previously found to predict educational attainment (Sewell et al., 1969; Sirin, 2005).

1.3. Differential predictability of attention span-persistence for academic outcomes

Although research has found connections between attention span-persistence and both reading and mathematics achievement, relations between aspects of attention and math have been especially strong in early and middle childhood compared to reading (Blair & Razza, 2007; Cameron Ponitz et al., 2009; Duncan et al., 2007). In one study, effect sizes of .56 were found for behavioral regulation (including attention span-persistence) predicting math levels compared to effect sizes of .27 for predicting reading. Moreover, this study found that behavioral regulation predicted math but not reading gains over the kindergarten year (Cameron Ponitz et al., 2009). Other research has found that children's early attention predicted more variance in math achievement (with larger effect sizes) between childhood and adolescence compared to reading achievement (Duncan et al., 2007). Together, this research suggests that early attention may be more strongly related to math skills in childhood and adolescence compared to reading skills, but it is less clear whether this persists into early adulthood.

Although research is still emerging, a few reasons for the link between attention and math have been proposed, including having to focus and pay attention to relevant information when solving math problems, and persisting as problems increase in complexity and difficulty (Blair & Razza, 2007; Cameron Ponitz et al., 2009). Relations between attention and reading have also been found especially in early childhood when early literacy and reading skills are heavily emphasized in classroom settings (McClelland, Cameron, Connor, et al., 2007).

Overall, this research suggests that children with strong attention span-persistence do well in school because they can focus on relevant information while ignoring distractions, monitor their progress, and resolve conflicting information in order to complete tasks. These skills experience rapid development during the preschool years, and are foundational for later social and academic outcomes including completing college in early adulthood.

1.4. Direct and indirect pathways between attention span-persistence and later achievement and educational attainment

Although the importance of early attention span-persistence for academic achievement outcomes has been established after controlling for initial achievement levels, it is possible that these relations may be mediated by early achievement levels, especially in the beginning of a child's academic career. This is based on research finding that academic trajectories tend to be established early in elementary school (Alexander, Entwisle, & Dauber, 1993). For example, children's early attention span-persistence at age 4 may be related to math or reading achievement at age 21 through the influence of attention span-persistence on achievement levels at age 7 and the subsequent influence of achievement levels at age 7 on math or reading achievement at age 21. This hypothesis would suggest that age 4 attention span-persistence helps children do better on reading or math achievement at age 7, which then predicts stronger reading or math achievement at age 21. Thus, the relation between early attention and later achievement would be mostly mediated by early achievement levels at the beginning of school.

A few studies have examined the relative importance of early skills on later academic outcomes, and the complex pathways between early attention and later achievement. For example, one study found that early achievement was a stronger predictor of later achievement than was early attention (Duncan et al., 2007) but did not specify pathways of influence. Another recent study focused on the direction of these relations and found that early learning-related behaviors predicted subsequent literacy achievement but that literacy skills did not significantly predict subsequent learning-related behaviors (Stipek, Newton, & Chudgar, 2010). Finally, one study found that classroom behavior (Interest-Participation and Attention Span-Restlessness) was significantly related to children's math performance in first grade and fourth grade, and that some of these relations were mediated through early math scores (Alexander et al., 1993).

In addition to the notion that achievement levels early in elementary school mediate relations between early attention span-persistence and later achievement levels, it is also plausible that attention span-persistence predicts college completion by age 25 through achievement levels towards the end of formal schooling (e.g., age 21). This is based on research finding that college achievement levels significantly predict college completion (Buchmann & DiPrete, 2006; Ewert, 2010; Velez, 1985). Thus, it is possible that children's early attention span-persistence is related to stronger reading and math levels later in an individual's academic career (age 21), which would then be related to greater odds of completing college by age 25.

To our knowledge, no study has examined whether achievement levels in childhood significantly mediate relations between early attention span-persistence and either achievement in early adulthood or college completion. The present study sought to add specificity to the pathways through which early attention may predict later achievement. We examined direct and indirect pathways between early attention span-persistence on later achievement and educational attainment (college completion) by testing if age 4 attention span-persistence predicts reading and math achievement at age 21 and college completion by age 25 directly or if the influence is fully mediated by age 7 or age 21 achievement levels.

1.5. Goals of the present study

The present study examined whether children's attention span-persistence, as rated by parents at age 4, significantly predict later reading and math skills at age 21, and the odds of completing college by age 25. We had three hypotheses: First, based on previous research (Breslau et al., 2009; Duncan et al., 2007), we expected that higher ratings of attention span-persistence at age 4 would significantly predict stronger reading and especially math skills in early adulthood (age 21). Second, we predicted that attention span-persistence at age 4 would predict the odds of completing college by age 25. In other words, we expected that children with strong attention span-persistence ratings at age 4 would have significantly greater odds of completing college by age 25. This hypothesis was based on research supporting the importance of early attention span-persistence for later achievement and educational outcomes (Andersson & Bergman, 2011).

Third, we examined whether age 7 reading or math achievement significantly mediated relations between attention span-persistence at age 4, and reading and math achievement at age 21. We predicted that higher achievement at age 7 would significantly predict higher achievement at age 21, but that the path between age 4 attention span-persistence and later achievement would be stronger than the indirect pathway through age 7 achievement levels. In other words, we expected that the direct path between age 4 attention span-persistence and age 21 achievement levels would not be fully mediated by achievement levels at age 7. We also examined whether the path between early attention span-persistence and college completion would be fully mediated by age

7 and age 21 reading and math levels. We predicted that attention span-persistence at age 4 would predict greater odds of completing college by age 25 and would not be fully mediated by age 7 or age 21 reading or math achievement. This hypothesis was based on recent research finding that attention span-persistence and self-control early in life (e.g., childhood and adolescence) significantly predicts later educational attainment, even after intellectual ability and early achievement were taken into account (Andersson & Bergman, 2011; Moffitt et al., 2011).

2. Method

2.1. Participants

Data for this study come from the Colorado Adoption Project (CAP), a longitudinal study initiated in 1975 (Plomin, DeFries, & Fulker, 1988). Initial recruitment occurred over a period of seven years, when 245 adopted children, their biological parents, and their adoptive families were recruited through two adoption agencies in Denver, Colorado, at the time of the child's birth. All protocols were reviewed and approved by the University of Colorado-Boulder IRB. Parent consent and child assent/consent were obtained as appropriate. Non-adoptive ($N = 245$) and adoptive families ($N = 245$) were recruited through local hospitals and the non-adoptive children were matched to the adoptive sample on a number of variables, including father's age, education, and occupational status (Plomin et al., 1988). Mother's education level for adoptive mothers ($M = 14.69$, $SD = 1.96$) did not differ significantly from the education levels for non-adoptive mothers ($M = 14.96$, $SD = 2.08$). Over 95% of the families were Caucasian. Fifty-three percent of the overall sample was male. Data were collected yearly in the CAP project, but the achievement data used in the present analysis were collected when the children were ages 4, 7, and 21. Although achievement data was collected at other time points (e.g., ages 12 and 16), we focused on how early achievement levels were related to achievement levels at the end of formal schooling. Between ages 21 and 25, data were collected as part of the study of Nature and Nurture in Social Demography (NNSD), with yearly interviews focusing on transitions to adulthood and substance use. This information was used to determine which of the children had completed college (i.e., obtained a bachelor's degree) by age 25 (for further details on the CAP sample see Rhea, Bricker, Corley, DeFries, & Wadsworth, in press).

Children missing age 4 attention span-persistence data and those missing all of either the math or reading scores were not included in this analysis. Thus, the analyzed sample included 430 children ($N = 221$ non-adoptive families and $N = 209$ adoptive families), which was 55.6% male. For the purposes of this paper, we did not include siblings, which would have complicated our analyses. Retention was very good, with a 92% response rate at age 7 and 85% at age 21, compared to participation at age 4. Data on college completion was available from 286 participants and was determined by self-report of having obtained a bachelor's degree or not by age 25. We compared those with ($N = 286$) and without college data ($N = 144$) on background variables of gender, age 4 vocabulary skills, maternal education level, and adopted status. There were no significant differences on any of these variables between the participants with and without college data. Table 1 provides estimated means, standard deviations, and percentages, and the N for non-missing values for each variable.

Because only 286 out of the overall sample of 430 participants had data on college completion, we examined if people with high attention span-persistence ratings at age 4 were more likely to provide college completion data as adults. To do this, we examined the rate of missing data on college completion at age 25 for those with high versus low attention span-persistence ratings at age 4. Results of a logistic regression indicated that attention span-persistence ratings were not significantly related to whether the person was missing data at age 25 (odds ratio = .98, $p = .568$). We also ran a multinomial logistic regression and found that for each unit increase in attention span-persistence ratings at age 4, the relative risk of a missing value at age 25 increased by a factor of only 1.02, which was not significant ($z = 0.68$, $p = .494$). In contrast, the relative risk of completing college increased by a factor of 1.13 ($z = 2.94$, $p = .003$). Thus, although there was substantial missing data on college completion by age 25, it does not appear that missing this data was significantly related to an individual's attention span-persistence rating at age 4.

Table 1
Estimated means, standard deviations and percentages for the original sample.

	Mean (*SD*)	Non-missing *N*
Attention span-persistence at age 4	17.93 (3.05)	430
Math		
Age 7	10.73 (2.76)	397
Age 21	11.21 (2.69)	364
Reading		
Age 7	31.57 (8.05)	390
Age 21	73.67 (8.52)	360
Vocabulary at age 4	10.18 (2.53)	386
Adopted	48.6%	430
% male	55.6%	430
Maternal education level	14.83 (2.03)	419

2.2. Procedures

When children were 4 years old, parents completed questionnaires rating children's attention span-persistence. Information about child gender, age, and mother's education level was obtained from questionnaires completed at the beginning of the study. Direct assessments administered in a laboratory setting were used to measure children's vocabulary skills at age 4 and math and reading ability at ages 7 and 21. Data on college completion by age 25 were obtained through telephone interviews.

2.3. Measures

2.3.1. Colorado child temperament inventory (CCTI) (Rowe & Plomin, 1977)

The CCTI is a parental rating instrument with six subscales: Emotionality, Activity, Sociability, Attention Span-Persistence, Reaction to Food, and Soothability. The median alpha reliability for all 6 scales is .80 and the median one-week test–retest reliability is .73 for children ages 2–6 years (Rowe & Plomin, 1977). At age 4, only the mothers' ratings were collected. The *Attention Span-Persistence* subscale was used in the current analysis and contained five items: "Plays with a single toy for long periods of time", "Child persists at a task until successful", "Child goes from toy to toy quickly" (reversed), "Child gives up easily when difficulties are encountered" (reversed), and "With a difficult toy, child gives up quite easily" (reversed). Cronbach's alpha for the Attention Span-Persistence subscale was .79 in previous research (Rowe & Plomin, 1977) and .72 in the current sample. Items were rated on a 1 ("not at all like the child") to 5 ("a lot like the child") scale and summed to obtain the subscale and total score (Rowe & Plomin, 1977).

2.3.2. Receptive vocabulary

Receptive vocabulary skills at age 4 were assessed using the Peabody Picture Vocabulary Test (PPVT) (Dunn & Dunn, 1981). The PPVT requires that children identify a word from four pictures and has strong reliability and validity, including split-half reliabilities ranging from .73 to .84 (Dunn & Markwardt, 1970). In the CAP

Please cite this article in press as: McClelland, M. M., et al. Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly* (2012), http://dx.doi.org/10.1016/j.ecresq.2012.07.008

sample, PPVT scores had a test–retest correlation of .70 (Rice, Corley, Fulker, & Plomin, 1986).

2.3.3. Reading achievement

The Peabody Individual Achievement Test (PIAT) *Reading Recognition subtest* was used to measure reading skills at ages 7 and 21 (Dunn & Markwardt, 1970). The Reading Recognition subtest contains 100 items assessing children's recognition of printed letters and words and the ability to read words aloud. It has established reliability and validity: standardization sample one-month retest reliabilities reported for grades 1, 8 and 12 are .89, .87 and .86 and the test–retest reliability across grades K-12 was .89. In the present study, the correlation between PIAT reading scores nine years apart was .53, which can be considered a very conservative lower bound on reliability (see Table 2). Previous studies using the PIAT in the CAP sample have provided evidence for the reliability and validity in scores (Wadsworth, Corley, Hewitt, & DeFries, 2001; Wadsworth, DeFries, Fulker, & Plomin, 1995). The raw score was used in the present study.

2.3.4. Math achievement at age 7

Children's math skills at age 7 were assessed using the Wechsler Intelligence Scale for Children-Revised (WISC-R) Arithmetic subscale (Wechsler, 1974). This measure presents verbal math problems requiring timed oral responses without paper or other visual aids and has shown strong reliability and validity. Reported split-half reliabilities from the standardization sample are .75 at age 7. Previous studies using the Arithmetic subscale in the CAP sample have provided evidence for the reliability and validity in scores (Wadsworth et al., 2001, 1995). The age-scaled score was used.

2.3.5. Math achievement at age 21

Math skills at age 21 were assessed using the Wechsler Adult Intelligence Scale-III (WAIS-III) Arithmetic subscale (Wechsler, 1981). This measure contains 20 arithmetic problems administered orally that must be solved without paper or pencil and has strong psychometric properties. The split-half (odd-even) correlation with the Spearman-Brown correction is .87. The age-scaled score was used.

The Weschler Intelligence Scale Arithmetic subtest score available in this dataset is an age-adjusted standard score, called a scaled score, which is based on the normative sample used in developing the measure. These scores are adjusted so that the mean is 10 and the standard deviation is 3. This allows a comparison of subtest performance within a given individual and between individuals relative to the normative sample. It does not, however, permit an evaluation of growth within individuals, as scores are standardized relative to comparable aged individuals in the normative sample.

2.3.6. College completion by age 25

College completion, a binary outcome variable, was determined by self-report of having obtained a bachelor's degree by age 25. Of those reporting this information ($N=286$), only 23 participants did not attend some level of college. We imputed 100 complete datasets then deleted the cases with missing values on college completion. Although simulation studies have demonstrated the need to include people during the imputation stage who have a missing value on the outcome variable, college, nothing is gained and there is a potential small loss in power unless these cases are deleted prior to the analysis stage (Acock, 2012; von Hippel, 2007).

2.4. Estimation

We used Stata 12.0 structural equation modeling procedure to obtain estimates for predicting math and reading performance at age 21. Math and reading scores at ages 7 and 21 were regressed on attention span-persistence at age 4, controlling for the child' age 4 vocabulary, adoption status, and child's gender (boys as reference). In all our models, we controlled for important variables that have been found to significantly relate to achievement outcomes and educational attainment including gender (Andersson & Bergman, 2011; Li-Grining, Votruba-Drzal, Maldonado-Carreño, & Haas, 2010), maternal education level (Andersson & Bergman, 2011; McClelland, Cameron, Connor, et al., 2007), and receptive vocabulary skills at age 4 (Blair & Razza, 2007; Purpura, Hume, Sims, & Lonigan, in press). Given that the sample included adopted and non-adopted children, we controlled for adopted status based on previous research finding that adopted children had significantly increased behavior problems (Stams, Juffer, Rispens, & Hoksbergen, 2000), and lower academic achievement (Iervolino, 2003; Rhea & Corley, 1994) compared to non-adopted children, although differences were small. Based on this research, we also anticipated that adopted children in our study would score significantly lower on reading and math at both age 7 and age 21, and would have significantly lower odds of completing college by age 25. Although we initially controlled for child age at 4 years, this variable was dropped because the study administered virtually all of the age 4 measures (97.1%) when the child was either 48 or 49 months old and the standard deviation (*SD*) was only 0.03. Thus, there was insufficient variance on age to include it as a control variable.

The usual estimates of standard errors for indirect effects rely on the Sobel method (Muthén & Muthén, 2010). This makes the unrealistic assumption that the sampling distribution for the estimate of the indirect effect is normally distributed. We used a bootstrap estimator with 1000 resamples. Stata 12.0, like other SEM packages, uses a full information maximum likelihood estimate of parameters, which utilizes all available information. Although this approach assumes the missing values are missing at random (MAR), this is a more realistic assumption than listwise deletion would be since that assumes the data are missing completely at random (MCAR) (Acock, 2005, 2012; Enders, 2001). To estimate the likelihood of a person completing college by age 25, we utilized Stata 12.0 logistic regression and the multiple imputation procedure imputing 100 complete datasets for the 286 study participants who had no missing values on the college completion variable.

3. Results

3.1. Descriptive statistics

Means and standard deviations for all variables are presented in Table 1. Average reading scores increased over time between ages 7 and 21 but the mean age-scaled math scores remained stable (as would be expected since scores are rescaled to the age-normed mean of 10) over time. Data for math achievement at ages 7 and 21 were normally distributed and were not significantly skewed. Reading achievement data at age 7 were somewhat positively skewed and data at age 21 were negatively skewed although skewness and kurtosis values were within normal ranges (Kline, 2005).

Table 2 displays the correlations among all the variables. A check of the bivariate scatterplots did not reveal any nonlinearity. Correlations between reading scores at ages 7 and 21 were highest, followed by math scores at ages 7 and 21. Attention span-persistence at age 4 was consistently and significantly, though modestly, related to math and reading at ages 7 and 21 and to college completion by age 25. Reading scores at age 21 had the strongest correlations with college completion. Mother's education level was significantly related to children's vocabulary scores at age 4, reading scores at age 7, and college completion by age 25. Finally, being adopted was significantly related to lower math scores at ages

Table 2
Correlations among outcomes and predictors for the original sample.

Variables	1	2	3	4	5	6	7	8	9	10
Attention span-persistence age 4	–									
Vocabulary at age 4	.07	–								
Gender	.03	−.02	–							
Adopted status	.02	−.07	−.00	–						
Maternal education level	.01	.18*	−.05	−.07	–					
Math age 7	.14*	.22*	−.05	−.10	−.00	–				
Math age 21	.19*	.08	.23*	−.16*	−.06	.39	–			
Reading age 7	.12*	.15*	−.01	−.03	.13*	.27*	.35	–		
Reading age 21	.14*	.17*	−.08	−.18*	.08	.25*	.35*	.53*	–	
College completion age 25	.17*	.11	−.09	−.21*	.12*	.13*	.16*	.16*	.23*	–

Note. Female = 0, male = 1.
* $p < .05$.

7 and 21, reading scores at age 21, and not completing college by age 25.

3.2. Does early attention span-persistence predict later math and reading skills?

Fig. 1 presents our model for early attention span-persistence predicting math and reading skills at age 21. All results controlled for background covariates of vocabulary at age 4, gender, adoption status, and maternal education level. Panel A in Fig. 1 shows that relations between attention span-persistence at age 4 and math skills at age 21 were mostly direct. The direct effect of age 4 attention span-persistence on math skills at 21 was small but statistically significant ($\beta = 0.12$, $p = .007$), after controlling for the covariates and math skills at age 7. The indirect effect of attention span-persistence at age 4 was smaller, although still statistically significant ($\beta = 0.05$, $p = .009$) after controlling for math skills at age 7. For the covariates, results of the total effects indicated that children who were adopted had significantly lower math skills at age 21 ($\beta = -0.15$, $p = .004$), and males had significantly higher math skills at age 21 compared to females ($\beta = 0.21$, $p < .001$). Maternal education level was not significantly related to math skills at age 21 ($\beta = -0.06$, $p = .230$). Overall, the total effect of attention span-persistence at age 4 to math achievement at age 21 ($\beta = 0.17$, $p = .001$), was 70.6% direct and was not fully mediated through age 7 math achievement.

A similar, albeit weaker, pattern of results was found for age 4 attention span-persistence predicting reading achievement at age 21 (see Panel B of Fig. 1). There was a small and marginally significant direct effect of attention span-persistence at age 4 predicting reading achievement at age 21 ($\beta = 0.08$, $p = .083$) beyond the influence of the background covariates. This effect was statistically significant using a one-tailed test, but because we used a two-tailed test for all analyses, we present those results. The indirect effect of attention span-persistence at age 4 on reading at age 21, mediated by reading skills at age 7, was smaller but statistically significant ($\beta = 0.06$, $p = .02$). The total effect of attention span-persistence at age 4 predicting reading achievement at age 21 ($\beta = 0.14$, $p = .009$) was 57.1% direct and 42.9% indirect through reading at age 7. In terms of the covariates, results for the total effects indicated that children who were adopted had significantly lower reading skills at age 21 ($\beta = -0.17$, $p = .001$), boys were marginally more likely to have lower reading skills at age 21 ($\beta = -0.09$, $p = .059$), and children with higher vocabulary skills at age 4 had significantly higher reading skills at age 21 ($\beta = 0.13$, $p = .028$). Finally, maternal education level was not significantly related to reading skills at age 21 ($\beta = 0.05$, $p = .409$). Together, these results indicate that attention span-persistence at age 4 had a significant effect on two key aspects of academic achievement 17 years later and that most of this effect was direct.

Table 3
Final logistic regression results: Attention span-persistence at age 4 predicting college completion at age 25 ($N = 286$).

Predictor	Unstandardized *B*	Odds ratio	*t*-Test
Attention span-persistence at 4	0.13	1.14*	2.96
Vocabulary at 4	0.31	1.03	0.53
Gender	−0.48	0.62	−1.85
Adoption status	−0.87	0.42**	−3.30
Maternal education	0.09	1.10	1.41

Note. Female = 0, male = 1. Adopted = 1, non-adopted = 0.
* $p < .05$.
** $p < .01$.

3.3. Does early attention span-persistence predict college completion by age 25?

To evaluate the association of early attention span-persistence on college completion by age 25, logistic regressions were conducted, with college completion by age 25 as the outcome variable and attention span-persistence at age 4 as the predictor. We controlled for age 7 and age 21 reading as well as age 7 and age 21 math skills as potential mediators. Gender, vocabulary skills at age 4, adoption status, and maternal education level were also included as background covariates (see Table 3).

Results indicated that attention span-persistence at age 4 had a significant effect on college completion by age 25 (odds ratio = 1.11, $p = .024$), but none of the potential mediators had a significant effect. Thus, because reading at age 7 (odds ratio = 1.00, $p = .787$) and 21 (odds ratio = 1.04, $p = .093$), and math at age 7 (odds ratio = 1.03, $p = .574$) and 21 (odds ratio = 1.06, $p = .321$) were not significantly related to college completion by age 25, there could not be any significant indirect effects. Therefore, we re-estimated the model dropping these variables, but keeping the background covariates (see Table 3). Results indicate that for each single point higher a child was rated on attention span-persistence at age 4, s(he) was 14% more likely to graduate from college by age 25 (odds ratio = 1.14, $p = .003$). To help interpret the practical significance of this effect, we can estimate how much a one standard deviation increase in a child's attention span-persistence at age 4 (3.05) has on the likelihood that s(he) will complete college by age 25. The resulting odds ratio was $e^{(.13\times3.05)} = 1.487$. Thus, the direct effect of a child being rated one standard deviation higher on attention span-persistence at age 4 increased the odds of completing college by age 25 by 48.7%. None of the other background covariates except for adoption status were significantly related to college completion by age 25. Children who were adopted had 52.2% lower odds of completing college by age 25 (odds ratio = 0.42, $p = .001$).

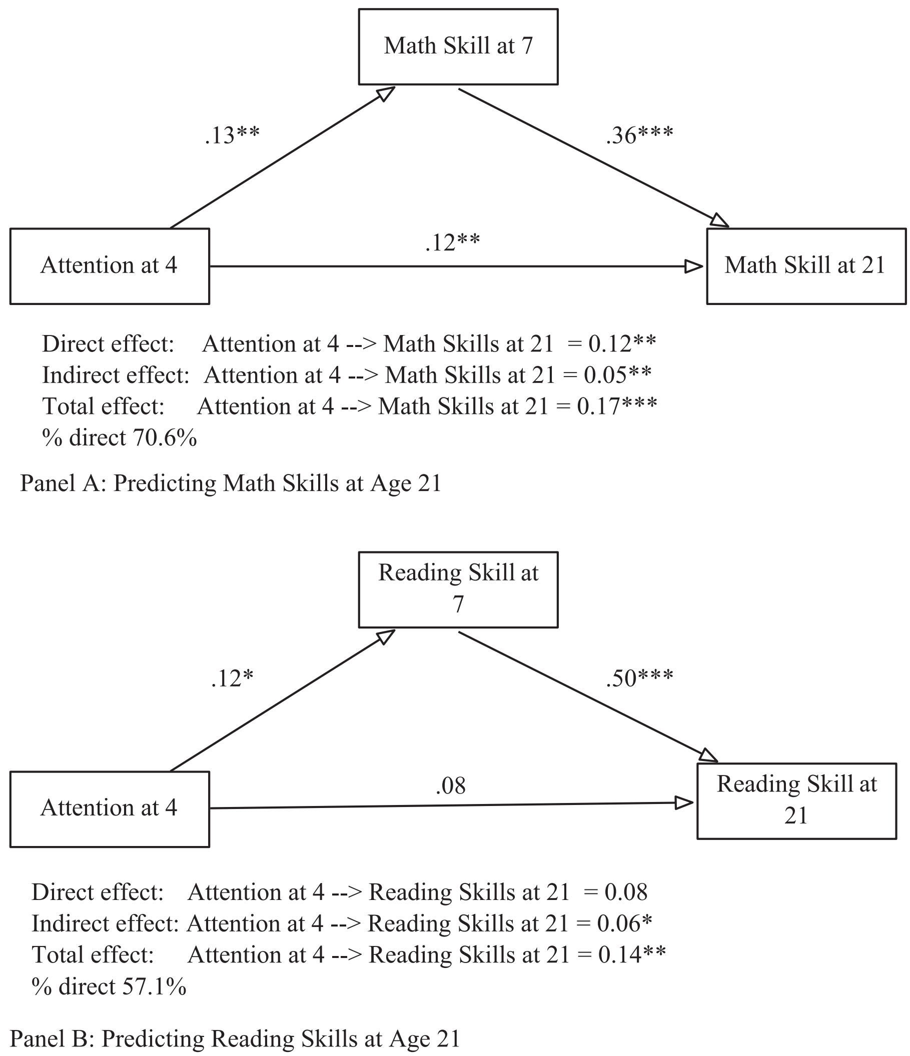

Fig. 1. Direct and indirect effects of age 4 attention span-persistence on math and reading skills at age 21. Vocabulary skills at 4, adoption status, gender, maternal education controlled. $^{*}p < .05$, $^{**}p < .01$, and $^{***}p < .001$.

4. Discussion

The present study examined the contribution of children's early attention span-persistence to later reading and math achievement, and to college completion by age 25. Children's parent-rated attention span-persistence at age 4 was an important predictor of later math and reading skills at age 21 and the odds of completing college by age 25. In addition, relations between early attention span-persistence and age 21 achievement were mostly direct and were not fully mediated by early achievement at age 7. Finally, relations between age 4 attention span-persistence and college completion were not significantly mediated by age 7 or age 21 reading or math achievement.

4.1. Direct and indirect pathways between attention span-persistence and later achievement and educational attainment

The results for early attention span-persistence predicting later achievement add to a growing body of literature documenting the importance of aspects of children's attention span-persistence, self-regulation, and related skills for long-term academic success (Andersson & Bergman, 2011; Breslau et al., 2009; Duncan et al., 2007; McClelland et al., 2006). Significant relations were found between early parent-rated attention span-persistence and age 21 reading and math skills, and college completion by age 25, after controlling for early vocabulary skills, gender, adoption status, and maternal education level. The odds ratio for early attention span-persistence predicting college completion provides another benchmark for interpreting these results and indicates that being rated one standard deviation higher on early attention span-persistence at age 4 increased the odds by 48.7% of completing college by age 25. In addition, the standardized coefficients for attention span-persistence predicting achievement outcomes at age 21 in the present study were comparable or stronger than coefficients reported in previous studies although effects overall were modest (Andersson & Bergman, 2011; Breslau et al., 2009; Duncan et al., 2007).

Results from the present study are unique in that they document the contribution of children's early attention span-persistence on achievement throughout schooling and into early adulthood, including college completion by age 25. Although some research has examined direct relations between early aspects of attention span-persistence or self-regulation and later social and academic outcomes (Andersson & Bergman, 2011; Duncan et al., 2007; Moffitt et al., 2011), few studies have specified the pathways through which early aspects of self-regulation may influence later outcomes. The present study found that direct relations between early attention and math and reading achievement at age 21 were stronger than the indirect relations through reading or math achievement at age 7. This suggests that attention span-persistence was directly related to age 21 reading and math achievement and was not fully mediated by age 7 achievement levels. Although the direct effects were larger, it is important to note that the indirect relations did predict a moderate percentage of the overall effects. In particular, the indirect effects for attention span-persistence predicting age 21 reading through age 7 reading were stronger than the indirect effects for attention span-persistence predicting later math. These results suggest that early attention span-persistence was related to later achievement at age 21 through achievement at age 7, but the direct effect between attention span-persistence and later achievement accounted for more variance in later achievement outcomes.

Results also indicated that relations between age 4 attention span-persistence and college completion by age 25 were not significantly mediated by either age 7 or age 21 reading or math achievement levels. In other words, an individual's attention span-persistence rating by his/her parents was a stronger predictor of college completion by age 25 than his/her reading or math score at age 7 or age 21. These results suggest that children's attention span-persistence early in life (at age 4) significantly contributes to their reading and math achievement up to 17 years later and is a significant predictor of educational attainment. The ability to pay attention and persist through difficult tasks may be especially important for completing college in a timely manner (by age 25). The finding that age 7 and age 21 reading or math skills were not significant predictors of college completion in this sample suggests that acquiring a college degree requires more than performing well on reading and math assessments. This was somewhat surprising because previous research has found that college grades and achievement significantly predict college completion (Buchmann & DiPrete, 2006; Ewert, 2010; Velez, 1985). The difference in results could be due to measurement because other studies finding significant effects of college grades completion have examined grades and GPA rather than standardized achievement tests (Buchmann & DiPrete, 2006; Velez, 1985). It may also be that as children get older, standardized achievement tests are less predictive of educational attainment than other characteristics like grades or GPA, which may be more related to self-control or attention span-persistence (Duckworth, Quinn, & Tsukayama, in press).

These results also parallel research on delay of gratification by Mischel and colleagues (Mischel, Shoda, & Rodriguez, 1989), which demonstrate that the ability to delay gratification early in life predicts higher SAT scores and social and cognitive outcomes in adolescence. Similarly, other research suggests that self-discipline is a stronger predictor of academic performance in adolescence than IQ (Duckworth & Seligman, 2005; Duckworth, Tsukayama, & May, 2010). Although delay of gratification taps emotional aspects of self-regulation, also known as "hot" executive function (Hongwanishkul, Happaney, Lee, & Zelazo, 2005), and attention span-persistence taps cognitive aspects self-regulation or "cool" executive function, they are clearly related (McClelland et al., 2010). Thus, evidence supports the notion that attention and persistence early in life tap cognitive and emotional aspects of self-regulation (or executive function), which are important predictors of later educational outcomes.

These findings also support the view that children's academic trajectories begin early in life (Masten et al., 2005; McClelland et al., 2006, 2010). For example, recent research suggests that a negative trajectory can begin early in life for children with self-regulation difficulties (including attention problems) (Blair & Diamond, 2008). According to this view, children with poor self-regulation have difficulty navigating classroom settings, which can lead to teachers becoming frustrated and expecting poor behavior and school performance from these children, which can then lead to children having poor perceptions of themselves as students. Over time, this pattern can lead children to be increasingly disengaged from school and to experience academic failure as they get older. Although we did not directly measure teacher–child relationships or children's disengagement from school, the results from the present study support this possibility and suggest that children's ability to focus their attention span-persistence, attend to relevant information, and persist through difficulty, can be very helpful as they progress through school and into early adulthood, compared to children with poor attention span-persistence skills (Duckworth et al., in press, 2010; McClelland et al., 2010).

It is important to note that our focus was on how children's early achievement at the beginning of formal schooling (age 7) was related to achievement levels toward the end of formal schooling (age 21). However, there are other intervening variables that may play a role in predicting children's reading and math skills at age 21 and college completion by age 25, which were not captured in this study. For example, including factors such as school engagement, later attention span-persistence or self-regulation, educational aspirations, intelligence, and grades between ages 5 and 21 would add complexity but also specificity to our models (Andersson & Bergman, 2011; Duckworth et al., 2010; Moffitt et al., 2011). In spite of not having these intervening variables, we included variables (e.g., early achievement levels) that are some of the strongest predictors of later achievement levels (Duncan et al., 2007). However, future research should examine a more comprehensive group of variables to better address this issue.

Finally, we found that children who were adopted performed significantly worse on reading and math achievement at age 21 and had significantly lower odds of completing college by age 25. Although adoption or adopted status was not a focus of our study, it is important to control for adopted status based on previous research findings that adopted children fare worse on achievement and social outcomes compared to non-adopted children in childhood and adolescence, and early adulthood, although effect sizes have been small (Bricker et al., 2006; Iervolino, 2003; Rhea et al., in press; Rhea & Corley, 1994).

4.2. Differential predictability for attention span-persistence on later reading and math

Although age 4 attention span-persistence predicted reading achievement at age 21, relations were stronger for attention span-persistence predicting math achievement at age 21 (direct effects of .12 for math at age 21 compared to .08 for reading). Moreover, the indirect relations between early attention span-persistence and age 21 reading were significantly (although not fully) mediated by age 7 reading achievement. Thus, although direct relations were found between early attention span-persistence and reading achievement at age 21, reading achievement at age 7 had a stronger predictive relation on later reading achievement than did math achievement at age 7 predicting math at age 21.

These results suggest that attention span-persistence may be especially important for math achievement throughout schooling. Similar results have been found in other recent studies (Cameron Ponitz et al., 2009; Duncan et al., 2007), although this is the first study to find that early attention span-persistence at age 4 predicts math skills in early adulthood (e.g., age 21) and also predicts college completion by age 25. In young children, attention span-persistence may be particularly important for math because less instructional emphasis is devoted to math in the classroom compared to reading (Connor, Morrison, & Slominski, 2006; NICHD Early Child Care Research Network, 2002), which could mean that children need to focus their attention and persist in order to do well in math rather than learning content that is explicitly emphasized.

As students get older, aspects of attention span-persistence such as focusing on relevant information and persisting through difficulty may help children to solve increasingly complicated math problems. In addition, doing well on math achievement tests may require children to pay attention and hold increasingly complex information in mind, compared to reading achievement tests (Blair & Razza, 2007; Cameron Ponitz et al., 2009).

It is possible however, that the differential predictability in attention span-persistence predicting math and reading achievement could also be due to measurement. For example, the PIAT Reading Recognition subtest was used at age 7 and age 21 rather than a more advanced reading assessment such as passage comprehension. Math was assessed using the Arithmetic subscale from the WISC-R at age 7 and the WAIS-III at age 21. Thus, it is possible that the math assessment captured more variability in math skills compared to the reading assessment. However, although reading scores were somewhat positively skewed at age 7 and negatively skewed at age 21, skewness and kurtosis values were within normal ranges (Kline, 2005), suggesting that there was sufficient variability in reading achievement scores at both time points.

4.3. Program and policy implications

The results from the present study highlight the importance of children's early attention span-persistence skills for achievement throughout formal schooling and into adulthood. This suggests that efforts to improve early attention span-persistence may have long-lasting educational benefits that persist into adulthood. Contexts that support and facilitate attention span-persistence and opportunities to practice these skills in early childhood settings may be especially beneficial (McClelland, Cameron, Wanless, & Murray, 2007). For example, early childhood curricula that include engaging and fun activities that help children pay attention and persist on tasks would help promote these skills as well as long-term academic achievement (Diamond, 2010; Diamond & Lee, 2011).

Related to this, a number of recent studies have demonstrated that interventions in early childhood are effective in promoting attention span-persistence and broader self-regulatory skills. For example, the *Tools of the Mind* curriculum helps children practice self-regulatory skills (including paying attention) in the preschool classroom and has been found to significantly improve short-term self-regulation (Barnett et al., 2008; Diamond, Barnett, Thomas, & Munro, 2007). Other research has found that a computerized training program helped improve children's executive attention skills (Rueda et al., 2005) and an intervention focusing on social-emotional skills, executive function, and academic achievement significantly improved functioning in these domains in a sample of foster children (Pears, Fisher, Heywood, & Bronz, 2007). Another intervention that included classroom games focusing on attention span-persistence, inhibitory control, and working memory significantly improved children's self-regulation for children low in these skills, and gains in early literacy skills for all children in the intervention group (Tominey & McClelland, 2011). Finally, a large efficacy trial found that a multicomponent school readiness intervention significantly improved self-regulation and early achievement in low-income children over the preschool year. Moreover, partial support was found for gains in self-regulation (including attention) mediating children's gains in achievement (Raver et al., 2011). Together, this research and the results of the present study support the notion that early attention span-persistence is malleable, that interventions can improve these skills, and that improved attention span-persistence and self-regulation are related to stronger achievement in children.

The results of this study also have important policy implications and add to accumulating research showing that supporting early education programs that focus on self-regulation (including attention span-persistence) in addition to early academic achievement can have long-term benefits (Heckman, 2009; Heckman, Stixrud, & Urzua, 2006; Moffitt et al., 2011). Moreover, this study suggests that early attention span-persistence may be more predictive of educational attainment (e.g., college completion) than academic achievement in childhood or early adulthood. Based on this, policies that support early education programs with a focus on self-regulation and attention span-persistence may be especially important for promoting long-term educational attainment.

4.4. Limitations

The present study revealed long-term predictability between early attention span-persistence and later school success, but a number of limitations must be noted. First, the CAP sample, drawn from an adoption study, was not representative of the US population and consisted of mostly Caucasian, middle-income children and families. Both adopted and non-adopted controls were analyzed and it is notable that data were available from birth to beyond age 25, with relatively little attrition. Second, although the college completion data were based on self-report and were only available on 286 out of the 430 participants, post hoc analyses did not indicate selection bias. We also used multiple imputation using full information maximum likelihood to take advantage of all available data.

Third, in the present study, parents rated children's attention span-persistence, which could have introduced bias. Other research has relied on teacher ratings to assess these constructs, which although useful, can also be biased (McClelland et al., 2006). It is noteworthy, however, that in the present study and other related research (Ladd & Dinella, 2009; McClelland et al., 2006), ratings by parents and by teachers have had such strong longitudinal predictive value. In addition, other research documenting the long-term predictability of attention span-persistence and self-regulatory skills have used a variety of measures including parent and teacher ratings, direct assessments, and observations, and have found similar results (Andersson & Bergman, 2011; Moffitt et al., 2011).

Fourth, as noted above, it is possible that other mediating or interventing variables may have played a role in the relations between attention span-persistence at age 4 and later achievement (age 21) and college completion (by age 25). Future research should include a broader set of variables to better examine this possibility.

Finally, parents rated children's attention span-persistence at age 4 before they entered formal schooling. Measuring these skills after children have entered kindergarten and gained experience navigating classroom environments would have been helpful. Future research can also benefit from clear definitions of constructs and improved measurement of children's skills including direct measures of attention span-persistence and self-regulation (Cameron Ponitz et al., 2008, 2009; McClelland et al., 2010; Rueda et al., 2005).

4.5. Conclusions

Results of this study demonstrated that children's ratings of attention span-persistence at age four, as rated by parents, significantly predicted math and reading skills at ages 7 and 21. The majority of these effects was direct and was not substantially mediated by age 7 reading or math skills. In addition, children who were rated one standard deviation higher on attention span-persistence at age 4 had 48.7% greater odds of completing college by age 25. This relation was not significantly mediated by either math or reading skills at ages 7 or 21. Overall, the results of this study add to a growing body of evidence documenting the importance of aspects of

Please cite this article in press as: McClelland, M. M., et al. Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly* (2012), http://dx.doi.org/10.1016/j.ecresq.2012.07.008

self-regulation for long-term achievement and educational attainment.

Acknowledgement

We are very grateful to Robin Corley for assistance with data management.

References

Acock, A. C. (2005). Working with missing values. *Journal of Marriage and the Family*, *67*, 1012–1028. http://dx.doi.org/10.1111/j.1741-3737.2005.00191.x

Acock, A. C. (2012). What to do about missing values. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), *APA handbook of research methods in psychology, Vol 3: Data analysis and research publication* (pp. 27–50). Washington, DC, US: American Psychological Association.

Alexander, K. L., Entwisle, D. R., & Dauber, S. L. (1993). First-grade classroom behavior: Its short- and long-term consequences for school performance. *Child Development*, *64*, 801–814.

Andersson, H., & Bergman, L. R. (2011). The role of task persistence in young adolescence for successful educational and occupational attainment in middle adulthood. *Developmental Psychology*, *47*(4), 950–960. http://dx.doi.org/10.1037/a0023786

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94.

Barnett, W. S., Jung, K., Yarosz, D. J., Thomas, J., Hornbeck, A., Stechuk, R., et al. (2008). Educational effects of the tools of the mind curriculum: A randomized trial. *Early Childhood Research Quarterly*, *23*(3), 299–313. http://dx.doi.org/10.1016/j.ecresq.2008.03.001

Baumeister, R. F., & Vohs, K. D. (2004). *Handbook of self-regulation: Research, theory, and applications*. New York, NY: Guilford.

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. http://dx.doi.org/10.1037/0003-066X.57.2.111

Blair, C., & Diamond, A. (2008). Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. *Development and Psychopathology*, *20*(3), 899–911. http://dx.doi.org/10.1017/S0954579408000436

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*, *78*(2), 647–663. http://dx.doi.org/10.1111/j.1467-8624.2007.01019.x

Breslau, J., Miller, E., Breslau, N., Bohnert, K., Lucia, V., & Schweitzer, J. (2009). The impact of early behavior disturbances on academic achievement in high school. *Pediatrics*, *123*(6), 1472–1476. http://dx.doi.org/10.1542/peds.2008-1406

Bricker, J. B., Stallings, M. C., Corley, R. P., Wadsworth, S. J., Bryan, A., Timberlake, T. S., et al. (2006). Genetic and environmental influences on age at sexual initiation in the Colorado Adoption Project. *Behavior Genetics*, *36*(6), 820–832. http://dx.doi.org/10.1007/s10519-006-9079-2

Buchmann, C., & DiPrete, T. A. (2006). The growing female advantage in college completion: The role of family background and academic achievement. *American Sociological Review*, *71*(4), 515–541. http://dx.doi.org/10.1177/000312240607100401

Calkins, S. D. (2007). The emergence of self-regulation: Biological and behavioral control mechanisms supporting toddler competencies. In C. A. Brownell, & C. B. Kopp (Eds.), *Socioemotional development in the toddler years: Transitions and transformations* (pp. 261–284). New York, NY: Guilford.

Cameron Ponitz, C., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly*, *23*, 141–158. http://dx.doi.org/10.1016/j.ecresq.2007.01.004

Cameron Ponitz, C., McClelland, M. M., Matthews, J. M., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology*, *45*(3), 605–619. http://dx.doi.org/10.1037/a0015365

Connor, C. M., Morrison, F. J., & Slominski, L. (2006). Preschool instruction and children's emergent literacy growth. *Journal of Educational Psychology*, *98*(4), 665–689. http://dx.doi.org/10.1037/0022-0663.98.4.665

Deater-Deckard, K., Petrill, S. A., Thompson, L. A., & DeThorne, L. S. (2005). A cross-sectional behavioral genetic analysis of task persistence in the transition to middle childhood. *Developmental Science*, *8*(3), F21–F26. http://dx.doi.org/10.1111/j.1467-7687.2005.00407.x

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. T. Stuss, & R. T. Knight (Eds.), *Principles of frontal lobe function* (pp. 466–503). London, England: Oxford University Press.

Diamond, A. (2010). The evidence base for improving school outcomes by addressing the whole child and by addressing skills and attitudes, not just content. *Early Education & Development*, *21*(5), 780–793. http://dx.doi.org/10.1080/10409289.2010.514522

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science*, *318*, 1387–1388. http://dx.doi.org/10.1126/science.1151148

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

Duckworth, A. L., Quinn, P. D., & Tsukayama, E. What No Child Left Behind leaves behind: The roles of IQ and self-control in predicting standardized achievement test scores and report card grades. *Journal of Educational Psychology*, in press.

Duckworth, A. L., & Seligman, M. E. P. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological Science*, *16*(12), 939–944. http://dx.doi.org/10.1111/j.1467-9280.2005.01641.x

Duckworth, A. L., Tsukayama, E., & May, H. (2010). Establishing causality using longitudinal hierarchical linear modeling: An illustration predicting achievement from self-control. *Social Psychology and Personality Science*, *1*, 311–317. http://dx.doi.org/10.1177/1948550609359707

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology*, *43*(6), 1428–1446. http://dx.doi.org/10.1037/0012-1649.43.6.1428

Dunn, L. M., & Dunn, L. M. (1981). *Peabody Picture Vocabulary Test-Revised*. Circle Pines, MN: American Guidance Service.

Dunn, L. M., & Markwardt, F. C. (1970). *Examiner's manual: Peabody individual achievement test*. Circle Pines, MN: American Guidance Service.

Eisenberg, N., Sadovsky, A., Fabes, R. A., Losoya, S. H., Valiente, C., Reiser, M., et al. (2005). The relations of problem behavior status to children's negative emotionality, effortful control, and impulsivity: Concurrent relations and predictions of change. *Developmental Psychology*, *41*, 193–211. http://dx.doi.org/10.1037/0012-1649.41.1.193

Eisenberg, N., Smith, C. L., Sadovsky, A., & Spinrad, T. L. (2004). Effortful control: Relations with emotion regulation, adjustment, and socialization in childhood. In R. F. Baumeister, & K. D. Vohs (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 259–282). New York, NY: Guilford.

Eisenberg, N., & Spinrad, T. L. (2004). Emotion-related regulation: Sharpening the definition. *Child Development*, *75*(2), 334–339. http://dx.doi.org/10.1111/j.1467-8624.2004.00674.x

Eisenberg, N., Valiente, C., & Eggum, N. D. (2010). Self-regulation and school readiness. *Early Education & Development*, *21*(5), 681–698. http://dx.doi.org/10.1080/10409289.2010.497451

Enders, C. K. (2001). The performance of the full information maximum likelihood estimator in multiple regression models with missing data. *Educational and Psychological Measurement*, *61*, 713–740. http://dx.doi.org/10.1177/0013164401615001

Ewert, S. (2010). Male and female pathways through four-year colleges. *American Educational Research Journal*, *47*(4), 744–773. http://dx.doi.org/10.3102/0002831210374351

Graziano, P. A., Reavis, R. D., Keane, S. P., & Calkins, S. D. (2007). The role of emotion regulation in children's early academic success. *Journal of School Psychology*, *45*(1), 3–19. http://dx.doi.org/10.1016/j.jsp.2006.09.002

Heckman, J. J. (2009). *Stimulating the young*. Retrieved from http://www.american.com/archive/2009/august/stimulating-the-young

Heckman, J. J., Stixrud, J., & Urzua, S. (2006). The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. *Journal of Labor Economics*, *24*, 411–482. http://dx.doi.org/10.1086/504455

Hongwanishkul, D., Happaney, K. R., Lee, W. S. C., & Zelazo, P. D. (2005). Assessment of hot and cool executive function in young children: Age-related changes and individual differences. *Developmental Neuropsychology*, *28*(2), 617–644. http://dx.doi.org/10.1207/s15326942dn2802_4

Iervolino, A. C. (2003). Adopted and nonadopted adolescents' adjustment. In S. Petrill, R. Plomin, J. C. DeFries, & J. K. Hewitt (Eds.), *Nature, nurture, and the transition to adolescence* (pp. 109–132). New York, NY: Oxford University Press.

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). New York, NY: Guilford Press.

Kochanska, G., Murray, K. T., & Coy, K. C. (1997). Inhibitory control as a contributor to conscience in childhood: From toddler to early school age. *Child Development*, *68*(2), 263–277.

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology*, *36*(2), 220–232. http://dx.doi.org/10.1037/0012-1649.36.2.220

Ladd, G. W., & Dinella, L. M. (2009). Continuity and change in early school engagement: Predictive of children's achievement trajectories from first to eighth grade? *Journal of Educational Psychology*, *101*(1), 190–206. http://dx.doi.org/10.1037/a0013153

Li-Grining, C. P. (2007). Effortful control among low-income preschoolers in three cities: Stability, change, and individual differences. *Developmental Psychology*, *43*(1), 208–221. http://dx.doi.org/10.1037/0012-1649.43.1.208

Li-Grining, C. P., Votruba-Drzal, E., Maldonado-Carreño, C., & Haas, K. (2010). Children's early approaches to learning and academic trajectories through fifth grade. *Developmental Psychology*, *46*(5), 1062–1077. http://dx.doi.org/10.1037/a0020066

Liew, J. (2012). Effortful control, executive functions, and education: Bringing self-regulatory and social-emotional competencies to the table. *Child Development Perspectives*, *6*(2), 105–111. http://dx.doi.org/10.1111/j.1750-8606.2011.00196.x

Masten, A. S., Roisman, G. I., Long, J. D., Burt, K. B., Obradovic, J., Riley, J. R., et al. (2005). Developmental cascades: Linking academic achievement and externalizing and internalizing symptoms over 20 years. *Developmental Psychology*, *41*(5), 733–746. http://dx.doi.org/10.1037/0012-1649.41.5.733

McClelland, M. M., Acock, A. C., & Morrison, F. J. (2006). The impact of kindergarten learning-related skills on academic trajectories at the end of elementary school. *Early Childhood Research Quarterly*, *21*, 471–490. http://dx.doi.org/10.1016/j.ecresq.2006.09.003

McClelland, M. M., & Cameron, C. E. (2012). Self-regulation in early childhood: Improving conceptual clarity and developing ecologically-valid measures. *Child Development Perspectives*, *6*(2), 136–142. http://dx.doi.org/10.1111/j.1750-8606.2011.00191.x

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary and math skills. *Developmental Psychology*, *43*(4), 947–959. http://dx.doi.org/10.1037/0012-1649.43.4.947

McClelland, M. M., Cameron, C. E., Wanless, S. B., & Murray, A. (2007). Executive function, behavioral self-regulation, and social-emotional competence: Links to school readiness. In O. N. Saracho, & B. Spodek (Eds.), *Contemporary perspectives on social learning in early childhood education* (pp. 83–107). Charlotte, NC: Information Age.

McClelland, M. M., Cameron Ponitz, C., Messersmith, E., & Tominey, S. (2010). Self-regulation: The integration of cognition and emotion. In W. Overton (Vol. Ed.) & R. Lerner (Eds.), *Handbook of life-span human development* (Vol. 1: Cognition, biology and methods, pp. 509–553). Hoboken, NJ: Wiley and Sons.

McClelland, M. M., Morrison, F. J., & Holmes, D. L. (2000). Children at-risk for early academic problems: The role of learning-related social skills. *Early Childhood Research Quarterly*, *15*, 307–329. http://dx.doi.org/10.1016/S0885-2006(00)00069-7

Mischel, W., Shoda, Y., & Rodriguez, M. L. (1989). Delay of gratification in children. *Science*, *244*, 933–938. http://dx.doi.org/10.1126/science.2658056

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., et al. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences*, *108*(7), 2693–2698. http://dx.doi.org/10.1073/pnas.1010076108

Muthén, L. K., & Muthén, B. O. (2010). *Mplus user's guide* (6th ed.). Los Angeles, CA: Muthén & Muthén.

NICHD Early Child Care Research Network. (2002). The relation of global first-grade classroom environment to structural classroom features and teacher and student behaviors. *Elementary School Journal*, *102*, 367–387. http://dx.doi.org/10.1086/499709

NICHD Early Child Care Research Network. (2003). Do children's attention processes mediate the link between family predictors and school readiness? *Developmental Psychology*, *39*, 581–593. http://dx.doi.org/10.1037/0012-1649.39.3.581

Pears, K. C., Fisher, P. A., Heywood, C. V., & Bronz, K. D. (2007). Promoting school readiness in foster children. In O. N. Saracho, & B. Spodek (Eds.), *Contemporary perspectives on social learning in early childhood education* (pp. 173–198). Charlotte, NC: Information Age.

Plomin, R., DeFries, J. C., & Fulker, D. W. (1988). *Nature and nurture during infancy and early childhood*. New York, NY: Cambridge University Press.

Purpura, D. J., Hume, L. E., Sims, D. M., & Lonigan, C. J. Early literacy and early numeracy: The value of including early literacy skills in the prediction of numeracy development. *Journal of Experimental Child Psychology*, in press.

Raver, C. C., Jones, S. M., Li-Grining, C., Zhai, F., Bub, K., & Pressler, E. (2011). CSRP's impact on low-Income preschoolers' preacademic skills: Self-Regulation as a mediating mechanism. *Child Development*, *82*(1), 362–378. http://dx.doi.org/10.1111/j.1467-8624.2010.01561.x

Rhea, S. A., Bricker, J. B., Corley, R. P., DeFries, J. C., & Wadsworth, S. J. (in press). Design, utility, and history of the Colorado Adoption Project: Examples involving Adjustment Interactions. *Adoption Quarterly*.

Rhea, S. A., & Corley, R. (1994). Applied issues. In J. C. De Fries, R. Plomin, & D. W. Fulker (Eds.), *Nature and nuture during middle childhood* (pp. 295–309). Oxford, England: Blackwell.

Rice, T., Corley, R., Fulker, D. W., & Plomin, R. (1986). The development and validation of a test battery measuring specific cognitive abilities in four-year-old children. *Educational and Psychological Measurement*, *46*, 699–708. http://dx.doi.org/10.1177/0013164486463026

Riggs, N. R., Jahromi, L. B., Razza, R. P., Dillworth-Bart, J. E., & Mueller, U. (2006). Executive function and the promotion of social-emotional competence. *Journal of Applied Developmental Psychology*, *27*(4), 300–309. http://dx.doi.org/10.1016/j.appdev.2006.04.002

Rothbart, M. K., & Posner, M. I. (2005). Genes and experience in the development of executive attention and effortful control. *New Directions for Child and Adolescent Development*, *109*, 101–108. http://dx.doi.org/10.1002/cd.142

Rothbart, M. K., & Rueda, M. R. (2005). The development of effortful control. In U. Mayr, E. Awh, & S. Keele (Eds.), *Developing individuality in the human brain: A tribute to Michael I. Posner* (pp. 167–188). Washington, DC: American Psychological Association.

Rothbart, M. K., Sheese, B. E., & Posner, M. I. (2007). Executive attention and effortful control: Linking temperament, brain networks, and genes. *Child Development Perspectives*, *1*(1), 2–7. http://dx.doi.org/10.1111/j.1750-8606.2007.00002.x

Rowe, D. C., & Plomin, R. (1977). Temperament in early childhood. *Journal of Personality Assessment*, *41*, 150–156. http://dx.doi.org/10.1207/s15327752jpa4102_5

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2004). Attentional control and self-regulation. In R. F. Baumeister, & K. D. Vohs (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 283–300). New York, NY: Guilford Press.

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences*, *102*, 14931–14936. http://dx.doi.org/10.1073/pnas.0506897102

Sewell, W. H., Halle, A., & Portes, A. (1969). The educational and early occupational attainment process. *American Sociological Review*, *34*, 82–92. http://dx.doi.org/10.2307/2092789

Shonkoff, J. P., & Phillips, D. A. (2000). *From neurons to neighborhoods: The science of early childhood development*. Washington, DC: National Academy Press.

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research*, *75*, 417–453. http://dx.doi.org/10.3102/00346543075003417

Stams, G. J., Juffer, F., Rispens, J., & Hoksbergen, R. A. (2000). The development and adjustment of 7-year-old children adopted in infancy. *Journal of Child Psychology and Psychiatry*, *41*(8), 1025–1037. http://dx.doi.org/10.1111/1469-7610.00690

Stipek, D., Newton, S., & Chudgar, A. (2010). Learning-related behaviors and literacy achievement in elementary school-aged children. *Early Childhood Research Quarterly*, *25*(3), 385–395. http://dx.doi.org/10.1016/j.ecresq.2009.12.001

Strenze, T. (2007). Intelligence and socioeconomic success: A meta-analytic review of longitudinal research. *Intelligence*, *35*, 401–426. http://dx.doi.org/10.1016/j.intell.2006.09.004

Tominey, S. L., & McClelland, M. M. (2011). Red light, purple light: Findings from a randomized trial using circle time games to improve behavioral self-regulation in preschool. *Early Education & Development*, *22*(3), 489–519. http://dx.doi.org/10.1080/10409289.2011.574258

Ursache, A., Blair, C., & Raver, C. C. (2012). The promotion of self-regulation as a means of enhancing school readiness and early achievement in children at risk for school failure. *Child Development Perspectives*, *6*(2), 122–128. http://dx.doi.org/10.1111/j.1750-8606.2011.00209.x

Valiente, C., Lemery-Chalfant, K., Swanson, J., & Reiser, M. (2008). Prediction of children's academic competence from their effortful control, relationships, and classroom participation. *Journal of Educational Psychology*, *100*(1), 67–77. http://dx.doi.org/10.1037/0022-0663.100.1.67

Velez, W. (1985). Finishing college: The effects of college type. *Sociology of Education*, *58*(3), 191–200.

von Hippel, P. T. (2007). Regression with missing Ys: An improved strategy for analyzing multiply imputed data. *Sociological Methodology*, *37*, 83–117. http://dx.doi.org/10.1111/j.1467-9531.2007.00180.x

Wadsworth, S. J., Corley, R. P., Hewitt, J. K., & DeFries, J. C. (2001). Stability of genetic and environmental influences on reading performance at 7, 12, and 16 years of age in the Colorado Adoption Project. *Behavior Genetics*, *31*, 350–353. http://dx.doi.org/10.1023/A:1012218301437

Wadsworth, S. J., DeFries, J., Fulker, D., & Plomin, R. (1995). Cognitive ability and academic achievement in the Colorado Adoption Project: A multivariate genetic analysis of parent-offspring and sibling data. *Behavior Genetics*, *25*(1), 1–15. http://dx.doi.org/10.1007/bf02197237

Wechsler, D. (1974). *Manual for the Wechsler Intelligence Scale for Children-Revised*. New York, NY: The Psychological Corporation.

Wechsler, D. (1981). *Manual for the Wechsler Adult Intelligence Scale-Revised*. Cleveland, OH: The Psychological Corporation.

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 445–469). Malden, MA: Blackwell Publishing.

Please cite this article in press as: McClelland, M. M., et al. Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly* (2012), http://dx.doi.org/10.1016/j.ecresq.2012.07.008