Child Development, March/April 2007, Volume 78, Number 2, Pages 647–663

Relating Effortful Control, Executive Function, and False Belief Understanding to Emerging Math and Literacy Ability in Kindergarten

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This study examined the role of self-regulation in emerging academic ability in one hundred and forty-one 3- to 5-year-old children from low-income homes. Measures of effortful control, false belief understanding, and the inhibitory control and attention-shifting aspects of executive function in preschool were related to measures of math and literacy ability in kindergarten. Results indicated that the various aspects of child self-regulation accounted for unique variance in the academic outcomes independent of general intelligence and that the inhibitory control aspect of executive function was a prominent correlate of both early math and reading ability. Findings suggest that curricula designed to improve self-regulation skills as well as enhance early academic abilities may be most effective in helping children succeed in school.

The emergence of self-regulation provides the basis for a wide array of developing competencies in early childhood ranging from theory of mind (Carlson, Mandell, & Williams, 2004) to child compliance (Kopp, 1989; Stifter, Spinrad, & Braungart-Rieker, 1999). Increasingly, accurate description and measurement of self-regulation is seen as central to understanding the processes through which children adapt to and learn in formal school settings (Blair, 2002; Howse, Calkins, Anastopoulos, Keane, & Shelton, 2003). To date, however, only limited work has examined the relation of various aspects of self-regulation to early school success, the topic of this article. This is particularly true for children at increased risk for early school failure such as those from low-income homes.

Temperament-Based and Neural Systems Approaches to Self-Regulation

One way to characterize the emergence of self-regulation in children is to consider it as the developmental integration of emotion and cognition in early childhood. At a behavioral level, this integration is represented in a temperament-based approach to self-regulation that defines temperament as emotional reactivity and the regulation of this reactivity (e.g., Posner & Rothbart, 2000; Rothbart & Ahadi, 1994). At a neural systems level, this integration is represented in an approach that examines the role of interconnected brain structures of the prefrontal and anterior cingulate cortices in emotional reactivity, emotion regulation, attention, and cognitive control (Bush, Luu, & Posner, 2000; Drevets & Raichle, 1998; Groenewegen & Uylings, 2000).

A prominent aspect of the temperament-based approach to the study of self-regulation in children is the construct known as effortful control (Rothbart & Ahadi, 1994). Effortful control refers to the ability to inhibit a dominant or prepotent response in favor of a subdominant or less salient response. As such, effortful control allows for the regulation of approach and withdrawal behavioral tendencies in the face of immediate cues for reward or punishment. In research on the influence of temperament on child development, researchers have been interested in the relation of effortful control to emotion and emotion-related regulation of behavior (Raver, 2004), to developing social competence and behavior problems (Eisenberg et al., 2003; Valiente et al., 2003) and to the parent–child relationship and compliance with caregivers' requests for behavior regulation (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996).

A prominent aspect of the neural systems approach to the study of self-regulation has been a focus on cognitive processes referred to collectively as executive function. Executive function refers to attention shifting, working memory, and inhibitory

The work reported here was supported, in part, by National Institute of Child Health and Human Development Grants R03 HD39750, P01 HD39667, and R01 HD51502. Thanks are due to Cathy Jantzer, Rebecca Holland, Tanja Rothrauff, and Katherine Wagner for their assistance with data collection. Rachel Peters Razza is now at the National Center for Children and Families, Teachers College, Columbia University, New York, NY.

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 0009-3920/2007/7802-0018

control cognitive processes that are utilized in planning, problem solving, and goal-directed activity (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Executive function is similar to effortful control in that it also refers in part to the ability to inhibit a prepotent or dominant response in favor of a less salient response. Executive function, however, focuses primarily on volitional control of cognitive self-regulatory processes, whereas effortful control includes to some extent, although not exclusively by any means, a focus on automatic or nonconscious aspects of emotional reactivity and regulation. That is, effortful control considers the appetitive or aversive nature of the conditions under which control is required while the primary focus of work on executive function concerns the deployment of cognitive processes under conditions that are essentially affectively neutral.

Recent work suggests that certain of the cognitive processes related to executive function may be influenced by the conscious or nonconscious representation of the motivational or affective significance of stimuli (Bechara, 2004; Gray, Braver, & Raichle, 2002). Data indicating a role for emotional arousal in executive function raise the possibility of a distinction between hot or affectively sensitive and cool or affectively neutral aspects of executive function (Kerr & Zelazo, 2004; Zelazo & Müller, 2002). Furthermore, a role for emotional arousal and reactivity in executive function is indicated by work in both children and adults as well as nonhuman animal models demonstrating that level of stress arousal as indicated by physiological markers of hypothalamic–pituitary–adrenal axis function is associated with executive function ability (Arnsten & Shansky, 2004; Blair, Granger, & Razza, 2005; Liu, Diorio, Francis, & Meaney, 2000; Lupien, Gillin, & Hauger, 1999). Despite this potential overlap, however, work in preschool children from middle-income homes suggests that executive function and effortful control are only moderately correlated (Carlson & Moses, 2001; Davis, Bruce, & Gunnar, 2002; Gerardi-Caulton, 2000; Rothbart, Ellis, Rueda, & Posner, 2003). Therefore, one aim of this study was to examine the relations among measures of effortful control and executive function in young children attending Head Start, the U.S. federal preschool educational program for children in poverty, and to determine the extent to which each is uniquely related to emerging math and literacy ability measured in kindergarten.

False Belief Understanding

An additional aspect of development in early childhood shown in various ways to be highly relevant to both neural systems and temperament-based approaches to self-regulation in young children is false belief understanding. False belief understanding concerns the emergence in the preschool period of the awareness that one may hold and act on beliefs that are false. As such, it is an aspect of a larger, comprehensive construct referred to as theory of mind. False belief understanding is moderately to highly correlated with the inhibitory control aspect of executive function (Carlson & Moses, 2001) but largely unrelated to working memory and attention-shifting aspects of executive function when adjusting for inhibitory control (Carlson, Moses, & Claxton, 2004; Hughes, 1998). False belief understanding is also associated with higher levels of behavior regulation in preschoolers (Hughes, Dunn, & White, 1998) and theory of mind is generally understood to be a central aspect of developing social-emotional self-regulation (Bachevalier & Loveland, 2006). Again, given that limited work has examined false belief understanding and its correlates in preschool children from low-income homes (Hughes & Ensor, 2005; Peters & Blair, 2003; Razza, 2005), a second aim of this study was to examine the relation of false belief understanding to effortful control and executive function. Examination of false belief understanding in relation to other aspects of self-regulation in children facing socioeconomic disadvantage can help to determine the extent to which it may be an independent contributor to developing competence in school settings.

Relation of Effortful Control, Executive Function, and False Belief Understanding to School Readiness

Although effortful control, false belief understanding, and executive function overlap in several respects, there are multiple routes through which each might affect early academic ability in school. The characteristics that comprise effortful control are thought to be important for motivation and engagement in school settings (Rothbart & Jones, 1998) and prior studies indicate that temperamental characteristics such as persistence, activity level, and absence of distractibility as reported by teachers are related to academic success in elementary school (Martin, Drew, Gaddis, & Moseley, 1988; Normandeau & Guay, 1998). Similarly, the emergence of false belief understanding is accompanied by advances in a number of domains, including language development, that are important for interpersonal functioning and thereby to the relationships with teachers and peers that are known to be important contributors to early school achievement (Mashburn & Pianta, 2006). Also, the cognitive processes that comprise executive function are likely to play a role in knowledge acquisition associated with emerging math and reading ability. Prior studies with young children have established relations between executive function and early math ability (Bull & Scerif, 2001; Espy et al., 2004) and deficits in executive function have been noted in learning disability in both reading and math (McLean & Hitch, 1999; Swanson, 1999). However, it is important to consider the extent to which all aspects of self-regulation might overlap with general intelligence (Blair, 2006) and to control for general intellectual ability when examining relations of executive function to academic progress in school.

Furthermore, to the extent that the inhibitory control aspect of executive function is a central component of both effortful control and false belief understanding, it can serve as a focus for the study of self-regulation and school readiness. Through the use of task-switching measures that require the maintenance in working memory of a rule for correct responding while inhibiting a prepotent response tendency that interferes with successful task completion, a growing body of work has come to identify developmental change in inhibitory control ability at approximately 4 years of age as a prominent aspect of developing executive function (Diamond, 2002; Diamond, Carlson, & Beck, 2005; Kirkham, Cruess, & Diamond, 2003) and perhaps self-regulation more generally. It is necessary, however, to juxtapose the inhibitory control explanation for the development of executive function with work by others suggesting that the development of the ability to cognitively represent hierarchical rule structures provides the basis for advances in executive function and self-regulation in early childhood (Happaney & Zelazo, 2003; Zelazo, Müller, Frye, & Marcovitch, 2003). Specifically, the Cognitive Complexity and Control theory – revised (CCC – r) states that the emergence of the cognitive ability to represent embedded if-then rule structures allows for reflection on rule pairs and consequently, increasing competency on executive function and self-regulation tasks.

Study Aims

Given indication of overlap among various aspects of self-regulation, the overarching aim of this study was to examine interrelations among executive function, effortful control, and false belief understanding in children from low-socio economic status backgrounds and to determine the unique contribution of each to measures of emerging math and literacy ability in kindergarten. Given evidence for a predominant role for the inhibitory control aspect of executive function in self-regulation in preschool children (e.g., Carlson & Moses, 2001; Diamond et al., 2005), we were particularly interested in the relation of this aspect of cognitive ability to emerging competence in math and literacy. As age 4 years seems to be a transitional period for the development of inhibitory control, we were interested in determining whether it would continue to be an important contributor to early math and literacy ability over and above other aspects of child self-regulation with which it is associated. However, although we expected based on prior work that executive function, effortful control, and false belief understanding would be moderately interrelated, we expected that each would account for unique variance in mathematics and literacy ability in kindergarten even when controlling for general intelligence. This expectation is in contrast to one in which a single aspect of self-regulation, such as inhibitory control, would be considered as foundational and to underlie relations of other aspects of self-regulation to indicators of school readiness. In light of much prior work demonstrating an independent relation of social development to early school outcomes (Ladd, Herald, & Kochel, 2006), we expected that measures of false belief and effortful control, to the extent that they indicate aspects of social-emotional development associated with interpersonal functioning, would account for unique variance in measures of early school progress over and above that associated with measures of the inhibitory control and attention-shifting aspects of executive function.

Method

Participants

The sample included 170 children who attended Head Start programs predominantly serving White families living in rural and nonurban locations. Children were recruited through a letter sent home to all children enrolled in classrooms of two Head Start programs. The mean age of children at the time of testing in preschool was 5 years, 1 month (range 3 years 9 months to 5 years 8 months). The mean age at the time of testing in kindergarten was 6 years 2 months (range 5 years 7 months to 6 years 11 months). Eighty of the children were female and 90 were male. Among participants reporting ethnicity, 80% reported White, 12% reported more than one ethnicity, 6% reported Asian, and 2% reported

African American. All children were either from households in which family income was below the poverty line as defined by federal poverty thresholds, or were eligible for the Head Start program due to the fact that in the absence of child care, family income would be below the poverty line. Income relative to need in the sample (annual income divided by the poverty threshold as determined by number of persons in the household) had a mean of 1.04 and a median of .86, indicating that over half of the sample were living below the poverty level. This represents an average monthly income adjusted for family size of $381 per month. Eighty-five percent of the sample were below 150% of poverty ($572 per month) and 95% of the sample were below 200% of poverty ($762 per month). Fourteen percent of the sample reported the highest level of education as less than high school, 59% reported a high school diploma or equivalent, and 23% reported some education beyond high school. The majority of children, 71%, lived in a home with two adults and 88% of the sample had one or more siblings in the household.

Procedure

During the preschool year, children were seen individually in two approximately 45-min sessions between 9:00 a.m. and 3:30 p.m. in a quiet testing area. During one of the sessions, the first session for approximately two thirds of the children participating in the study, children were administered a measure of receptive vocabulary and an attention-shifting measure of executive function. Also during this session, heart rate was recorded and saliva samples were collected as part of a larger study. In the second session, a peg-tapping measure of executive function was administered along with two measures of false belief understanding. Parents and teachers reported on child temperament and teachers also reported on child behavior in the classroom. Parents and teachers received packets of questionnaires with a self-addressed stamped envelope and were asked to complete the questionnaires and return them as soon as possible.

All children were seen in the spring of the kindergarten year in a single session, usually in a quiet testing room at the Head Start center at which the child had previously been enrolled. For some children, this session occurred either in a testing room at the Penn State University campus or in a quiet testing room of a local library. Two measures from the preschool testing, peg tapping and item selection, were repeated because the construct they assess, executive function, is central to the study's aims and we were interested in determining the extent of change in performance over one year's time. In addition, early academic measures were administered along with Raven's Colored Progressive Matrices test. Raven's matrices test, a measure of fluid, nonverbal intelligence, was used for the kindergarten assessment, as we had assessed the verbal aspect of intelligence during the preschool year

Measures

Table 1 provides information on the study design and lists the measures and scoring for each construct at each time point.

Executive function. We assessed executive function with a peg-tapping measure of inhibitory control (Diamond & Taylor, 1996) and an item-selection measure of attention shifting (Jacques & Zelazo, 2001). For the peg-tapping measure, children were instructed to tap twice with a wooden dowel (15 cm long × 1 cm in diameter) when the experimenter taps once, and once when the experimenter taps twice. The task requires children to inhibit a natural tendency to mimic the action of the experimenter while remembering the rule for the correct response. After practice trials, the child was administered a series of 16 trials in a counterbalanced sequence (8 one-tap and 8 two-tap trials) (Diamond & Taylor, 1996). Diamond, Prevor, Callendar, and Druin (1997) provide information on the neuropsychological basis for the task and provide clinically relevant evidence for impaired performance among children with early and continuously treated phenylketonuria, a condition associated with impaired dopaminergic function in the prefrontal cortex. Coefficient α for the 16 items in these data was .82 in preschool and .75 in kindergarten. A proportion score—the number of correct responses divided by the total number of trials—was used as a measure of performance on the task.

For the item-selection task, children were presented with pictures of three items that vary along some combination of two of three dimensions, including size, shape, and color. Following a pretest, children are presented with 15 trials in which they are instructed to point to two objects that go together in one way. Children are then instructed to point to two objects that go together in another way. The task requires children to identify two of the three objects that are similar along one dimension (i.e., shape) but then to shift cognitive set and identify two of the three objects that are similar along a second dimension (i.e., size). Jacques and Zelazo (2001) have extensively investigated the task in a cross-sectional sample of children between the ages of 2 and 5 years

Table 1
List of Constructs, Measures, and Time Points of Measurement for the Study

Construct	Measure	Time points
Executive function	Peg-tapping measure of inhibitory control Proportion of correct responses on 16 trials, range 0 – 1	Preschool and kindergarten
	Item selection measure of attention shifting Proportion of correct responses on 15 trials, range 0 – 1	Preschool and kindergarten
Effortful control	Children's Behavior Questionnaire composite of inhibitory control, attention, approach, and anger subscales Factor scores of teacher and parent ratings, mean = 0, *SD* = 1	Preschool only
False belief understanding	Unexpected contents and changed locations tasks Sum of test questions, pass = 1 and fail = 0, range 0 – 2	Preschool only
Intelligence	Peabody Picture Vocabulary Test – 3 Normed standardized score, mean = 100, *SD* = 15	Preschool only
	Raven's Progressive Colored Matrices Raw score sum of correct responses, range 0 – 35	Kindergarten only
Academic ability	Math battery adapted from the Early Childhood Longitudinal Study – Kindergarten Raw score sum of correct responses, range 0 – 24	Kindergarten only
	Elision subtest of the Preschool Comprehensive Test of Phonological and Print Processing Raw score sum of correct responses, range 0 – 12	Kindergarten only
	Letter knowledge assessment from the Head Start National Reporting System Direct Child Assessment Raw score sum of correct responses, range 0 – 26	Kindergarten only

and found that the results converge well with those of similar dimensional shift measures of executive function. Coefficient α for the 15 items in these data was .73 in preschool and .77 in kindergarten. Again a proportion score—the number of correct responses divided by the total number of trials—was used as a measure of performance on the task.

False belief understanding. For the measurement of false belief understanding, two assessments that are standard in the literature with preschoolers were used: an unexpected contents task and a changed locations task. For the unexpected contents task, an egg carton was placed in front of the child and the child was asked, "What do you think is inside this carton?" All children correctly answered this control question. The egg carton was then opened and the child was shown that the carton contained crayons instead of eggs. The carton was shut and the child was asked the test question, "What did you think was inside the carton, before we opened it?" followed by the control question, "What is in the carton really?" If the child did not respond, a forced-choice prompt was provided (e.g., "eggs or crayons"). Children were successful if they responded correctly to both the test and control questions (Hughes, 1998; Hughes & Dunn, 1998). This task was scored as *pass* (1), *fail* (0).

For the changed locations task, a scenario was enacted concerning the placement of an object, a bar of chocolate, by one character that was then relocated by another character while the first character was out of sight (Astington & Jenkins, 1995; Holmes, Black, & Miller, 1996; Wimmer & Perner, 1983). Children were asked to predict where the character that did not witness the change would look for the chocolate upon his return. Figurines of two familiar characters, Big Bird and Elmo, were used to act out the scenario. In order to pass this task, children had to correctly answer a control question, "Do you remember where the chocolate is now?" and a test question, "Where will Elmo look for the chocolate?" Children were successful if they responded correctly to both the test and control questions. This task was also scored as pass (1), fail (0). Performance across the two tasks was summed to create a single indicator of false belief understanding.

Effortful control. Information on child effortful control was obtained from teachers and parents (the mother for over 90% of participants) using a short form of the Children's Behavior Questionnaire (Putnam & Rothbart, 2006). Participants responded regarding how true or not a particular behavior is of the child on a 7-point Likert scale ranging from extremely true to extremely untrue of the child.

The Anger, Approach, Attention, and Inhibitory Control subscales were utilized for this analysis. Ratings for items on each subscale were reverse scored if needed and summed. Cronbach's αs for these scales as reported by Putnam and Rothbart range from .65 to .80. Sample items for the Anger subscale include "gets angry when s/he can't find something s/he wants to play with," "gets angry when called in from play before s/he is ready to quit," and "has temper tantrums when s/he doesn't get what s/he wants." Sample items for the Approach subscale include "gets so worked up before an exciting event that s/he has trouble sitting still," "remains pretty calm about upcoming treats" (reverse scored), and "becomes very excited before an outing." Sample items for the Attention subscale include "when practicing an activity, has a hard time keeping her/his mind on it" (reverse scored), "when drawing or coloring in a book, shows strong concentration," and "sometimes becomes absorbed in a picture book and looks at it for a long time." Sample items for the Inhibitory Control subscale include "can wait before entering into new activities if s/he is asked to," "is good at following instructions," and "can easily stop an activity when s/he is told 'no'." Two items on the Anger subscale concerned children's behavior when going to bed; therefore, these items were deleted from the teacher scale. Missing values for items were replaced with the mean of the subscale to which that item belonged. No item had greater than 5% missing. Examination of Cronbach's α for the parent and teacher report subscales in this sample indicated that the teacher ratings were more internally consistent on all subscales than were parent ratings. Internal consistency estimates on the Attention, Approach, Anger, and Inhibitory Control subscales for teachers were .91, .74, .86, and .84. Internal consistency estimates for parents on these same subscales were .71, .57, .51, and .60.

Owing to a high intercorrelation among the teacher report inhibitory control, attention, anger, and approach subscales, we used factor analysis to extract the first principal component, the only component with an eigenvalue >1.0, to create a summary indicator of effortful control. This analysis yielded a single factor accounting for 71% of the variance in the subscales, with observed loadings of .93 and .87 for the inhibitory control and attention subscales and −.87 and −.70 for the anger and approach subscales. Higher scores on this factor indicate a higher level of regulation and a lower level of anger and approach reactivity. The same analysis for parent report also yielded a single principal component with an eigenvalue >1.0. However, this factor accounted for only 44% of the total variance with loadings of .81 and .77 for the inhibitory control and attention subscales and −.61 and −.40 for the anger and approach subscales.

In addition to the Anger, Approach, Attention, and Inhibitory Control subscales, we collected only one other temperament subscale: Discomfort. This subscale concerns sensitivity to hot or cold and to pain and minor cuts and bruises. Upon analysis, this subscale was not found to load with the other subscales on the effortful control factor and was unrelated to the academic outcome measures. Therefore, we did not include this subscale in any further analyses.

Academic outcomes. Academic outcomes in kindergarten were assessed in three areas: mathematics knowledge, phonemic awareness, and letter knowledge. Mathematics knowledge was assessed with a math battery adapted from the Early Childhood Longitudinal Study—Kindergarten, created for use in the Head Start National Reporting System Direct Child Assessment. The battery includes 24 items designed to assess basic numeracy, knowledge of shapes, quantity, relative size, addition, subtraction, and simple graphic relations. Children receive 1 point for each item answered correctly. Cronbach's α, calculated for a sample of 14,380 children participating in the Early Childhood Longitudinal Study—Kindergarten, is .92.

To assess reading readiness, phonemic awareness was measured using the Elision subtest of the Preschool Comprehensive Test of Phonological and Print Processing (Pre-CTOPPP) (Lonigan, Wagner, Torgessen, & Rashotte, 2002). This task requires children to segment words into phonemic components and does so by first providing visual aids. Children are shown a plate with four pictures, two of which represent items to be used in a compound word that the child is asked to segment. For example, children are presented with four pictures, one of which is a picture of a bat and another a picture of a man. The examiner shows the child the pictures and names each in turn. The examiner then states the compound word "batman" and asks the child to point to the picture of batman without bat. Two practice items are administered in which the examiner provides the child with instructive feedback if the child answers incorrectly or fails to respond. Nine items are then administered, with the first 3 items presenting pictorially assisted compound word deletions and the last 6 presenting pictorially assisted syllable deletions (point to "tease" without "z"). Three additional compound word deletion items are then presented without pictorial assistance. Children receive a score of 1 for each item answered correctly. Cronbach's α calculated for a Head Start sample of 2,629 children participating in the Head Start impact study is .84.

To further assess reading readiness, letter knowledge was measured with the test of letter knowledge developed for use in the Head Start National Reporting System Direct Child Assessment. Children were presented with the letters of the alphabet in three grids containing eight, nine, and nine letters each. All letters were upper case and in a standard font. The grid of eight letters containing A, O, S, B, E, C, D, and X was presented first, followed by a grid containing the letters P, K, T, G, N, F, L, R, and Z. The final grid contained the letters U, Y, J, H, V, Q, M, W, and I. Before the presentation of each grid, children were instructed to point to all the letters that they know on the page and to tell the experimenter the name of each one. Children received 1 point for each letter named correctly. Cronbach's α, calculated for a Head Start sample of 878 children participating in the Head Start Quality Research Consortium study, is .96.

Intelligence. Fluid and verbal aspects of intelligence were measured using Raven's Colored Progressive Matrices Test (Raven, 1956) and the Peabody Picture Vocabulary Test – 3 (PPVT – 3) (Dunn & Dunn, 1997), respectively. The Colored Progressive Matrices Test is a measure of fluid intelligence in which children are presented with a series of plates containing patterns from which a single uniformly shaped piece is missing. At the bottom of each plate, six versions of the missing piece are presented, only one of which correctly fits the pattern. Children were presented with a demonstration trial and then instructed on successive trials to point to the piece that best completes the pattern. Children were presented with three sets of 12 plates of increasing difficulty. Total number correct summed across the three sets was utilized for analyses.

The PPVT – 3 is a norm-referenced measure of receptive vocabulary for spoken English. Children are presented with a series of plates, each of which contains four line drawings of objects, places, or actions. For each plate, children are asked to indicate the picture that corresponds to a word spoken by the experimenter. Age-based standard scores are calculated relative to a mean of 100 and a standard deviation of 15. The internal consistency, test – retest reliability, and criterion-related validity of the instrument are high (Williams & Wang, 1997). Some children received a short form of the PPVT – 3 in which no basal or ceiling scoring is required. In this version of the measure, children were administered 24 consecutive items of increasing difficulty as determined by item response theory analysis of PPVT – 3 normative data. A scoring algorithm was utilized to derive standard scores from the raw score data. To adjust for a significantly lower mean standard score among children receiving the short form of the measure, we standardized scores for the short and long forms separately before analysis. This provides an individual indicator of receptive vocabulary relative to the mean score for the group receiving that version of the measure and is appropriate for the purposes of controlling for individual differences in receptive verbal ability.

Missing Data

Of the sample of 170 children, data on academic measures in kindergarten were available for 141. Children for whom academic data were missing did not differ in any way from those for whom these data were present. Of the 141 children for whom data were available in kindergarten, 2 were missing data for peg tapping in kindergarten, 2 were missing data for item selection in kindergarten, 9 were missing data for the PPVT, 9 were missing data for teacher-reported regulation, 13 were missing data for false belief understanding, 18 were missing data for peg tapping measured in Head Start, and 23 were missing data for flexible item selection measured in Head Start. The reasons for missing data for all measures primarily related to child refusal to participate in that aspect of the assessment and reflect the difficulty of collecting data with young children. Examination of variables with missing values indicated some systematic relations. Higher scores for letter knowledge were observed among children missing data for either the PPVT, teacher-reported effortful control, or parent-reported effortful control. Individuals missing data for item selection measured in preschool tended to have lower scores for the PPVT.

To address missing data and to avoid the sample size reduction that would result from listwise deletion of cases with missing values, full information maximum likelihood (FIML) estimation was utilized to derive estimates of relations among variables in all analyses. FIML directly estimates model parameters and standard errors using all available data and has been shown to provide more accurate estimates of regression coefficients and variance accounted for than do listwise deletion or mean replacement missing data strategies (Enders, 2001).

Results

We first examined zero-order correlations among all independent variables and then used multiple regression to examine the unique relation of the measures of executive function (the peg-tapping measure of inhibitory control and the item selection measure of attention shifting) to false belief understanding and effortful control. Given prior indications of a role for executive function in both effortful control and false belief understanding, we were interested in the extent to which the inhibitory control and attention-shifting aspects of executive function would make unique or overlapping contributions to these constructs. For the regression equations we entered all variables simultaneously and interpreted coefficients associated with Type III sums of squares to estimate the unique effect of each independent variable on the dependent variable.

We then examined zero-order relations among the aspects of child self-regulation and the indicators of early academic ability. Following this analysis, we again used multiple regression to examine the unique relation of each aspect of child self-regulation to each of the academic outcomes, controlling for verbal and fluid intelligence. In these regression equations, all predictors were again entered simultaneously and coefficients associated with Type III sums of squares were interpreted to estimate the unique effect of each independent variable on the academic ability measures. Relations reported throughout the manuscript are significant at $p < .05$ or below.

Table 2 presents the means and standard deviations for independent variables in the analysis as well as correlations among variables. The table indicates that the inhibitory control and attention shifting aspects of executive function as measured in preschool and kindergarten are moderately stable and are also moderately correlated at both time points. With the exception of attention-shifting measured in kindergarten, the measures of executive function are also related to teacher-reported effortful control in preschool. False belief understanding as measured in preschool demonstrates relations with both the attention-shifting and inhibitory control aspects of executive function and with teacher-reported effortful control. Of some interest is the finding that parent-reported effortful control is related only to the inhibitory control aspect of executive function in preschool and to teacher-reported effortful control. In contrast, child verbal and fluid intelligence are moderately related to all indicators of child self-regulation except parent-reported effortful control. Examination of the relation of child age to each of the variables indicated only minimal relations of age with false belief understanding, $r = .19$, and inhibitory control measured in preschool, $r = .18$. Given the wide age range of the sample, however, we elected to control for age in all subsequent analyses.

Relation of aspects of executive function to effortful control and false belief understanding

Having observed a moderate correlation among various indicators of child self-regulation in preschool, we next examined the unique relation of the attention-shifting and inhibitory control aspects of executive function to the teacher report measure of temperamental effortful control in preschool. This analysis addressed the extent to which the two aspects of executive function account for unique or overlapping variance in effortful control. The results from the regression analysis interpreting Type III

Table 2
Correlation Among Indicators of Child Self-Regulation

	False belief in HS	Inhibitory control in HS	Attention shifting in HS	Inhibitory control in K	Attention shifting in K	Teacher report EC in HS	Parent report EC in HS	PPVT in HS	Mean	*SD*
False belief in HS	—								1.04	0.82
IC in HS	.41**								0.56	0.37
AS in HS	.29**	.34**							0.68	0.25
IC in K	.18*	.39**	.28**						0.89	0.15
AS in K	.29**	.27**	.32**	.41**					0.84	0.14
Teacher EC in HS	.18*	.38**	.27**	.26**	.13				0.01	0.99
Parent EC in HS	.01	.21**	.12	.11	− .01	.31**			0.01	1.00
PPVT in HS	.24**	.27**	.29**	.26**	.25**	.37**	.03		92.9	15.9
Raven in K	.19*	.21*	.26**	.20*	.37**	.21*	.06	.30**	17.26	4.1

Note. AS = attention shifting; EC = effortful control; HS = Head Start; IC = inhibitory control; K = kindergarten; PPVT = Peabody Picture Vocabulary Test.
$^{**}p < 0.01$, $^{*}p < 0.05$.

sums of squares controlling for age and including all variables in the model simultaneously indicated that the inhibitory control aspect of executive function was uniquely related to teacher-reported effortful control, β = .23. Child-receptive vocabulary, β = .26, and parent-reported effortful control, β = .24, were also uniquely related to teacher report of effortful control. Attention shifting in preschool was unrelated to the teacher report variable when in the equation as were false belief understanding and fluid intelligence. However, as noted in Table 2, these variables demonstrated significant zero-order associations with teacher-reported effortful control.

We then examined the relation of the attention-shifting and inhibitory control aspects of executive function to false belief understanding in preschool. Results from a regression analysis interpreting Type III sums of squares and including measures of effortful control, intelligence, and executive function in the model simultaneously indicated that both the inhibitory control, β = .30, and attention shifting, β = .19, aspects of executive function made unique contributions to performance on the composite measure of false belief understanding. Child age, β = .14, was also uniquely related to the outcome while effortful control and fluid and verbal intelligence were not.

Relation of executive function, effortful control, and false belief understanding to academic ability in kindergarten. Having examined the relations of the inhibitory control and attention-shifting aspects of executive function to effortful control and false belief understanding in preschool, we then examined the relation of all aspects of child self-regulation to emerging math and literacy ability in kindergarten. Table 3 presents zero-order correlations of measures of executive function, effortful control, and false belief understanding with mathematics ability, phonemic awareness, and letter knowledge. Measures of verbal and fluid intelligence are also included in the table. Relations among the measures were significant for all but the relation between letter knowledge and attention shifting measured in preschool and the relations of phonemic awareness with teacher-reported effortful control and receptive verbal ability. Parent-reported effortful control was unrelated to all of the academic ability measures.

Table 4 presents the results of separate regression equations predicting the academic outcomes controlling for age and with all predictors entered into each equation simultaneously. The equations present estimates of the unique effect of each variable on the outcome adjusted for all other terms in the model. Results indicated that the inhibitory control aspect of executive function measured both in preschool and kindergarten, teacher-reported effortful control measured in preschool, and fluid intelligence as measured by Raven's progressive matrices test made independent contributions to mathematics ability in kindergarten. False belief understanding measured in preschool and attention shifting measured in kindergarten were also moderately related to the measure of math ability. Although the various aspects of self-regulation examined in the equation were interrelated, many made independent contributions to early mathematics knowledge. Of particular interest is the finding that inhibitory control both in preschool and in kindergarten made independent contributions to the outcome variable.

Examination of relations of executive function, effortful control, and false belief understanding to phonemic awareness, also presented in Table 4, indicated that only the inhibitory control aspect of executive function measured in kindergarten and fluid intelligence as measured by Raven's progressive matrices test were related to this aspect of emergent literacy ability in kindergarten. Thus, unlike the findings for the regression equation predicting math knowledge, no aspect of self-regulation measured in preschool was independently related to phonemic awareness in kindergarten.

Table 3
Correlation Among Measures of Child Self-Regulation in Head Start and Kindergarten and Emerging Math and Literacy Ability Measured in Kindergarten

	IC in HS	AS in HS	False belief in HS	Teacher EC in HS	Parent EC in HS	PPVT in HS	IC in K	AS in K	Raven in K	Mean	*SD*
Math	.47**	.26**	.38**	.39**	.13	.39**	.44**	.42**	.38**	13.1	2.6
Phonemic awareness	.21*	.21*	.27**	.14	.07	.15	.35**	.32**	.32**	9.7	1.8
Letter knowledge	.18*	.10	.22*	.37**	.17	.36**	.25**	.18*	.19*	23.6	5.0

Note. AS = attention shifting; EC = effortful control; HS = Head Start; IC = inhibitory control; K = kindergarten; PPVT = Peabody Picture Vocabulary Test.
$^{**}p < 0.01$, $^{*}p < 0.05$.

Table 4
Regression Equation Predicting Emerging Math and Literacy Ability in Kindergarten from Child Self-Regulation Measured in Head Start and Kindergarten

	Kindergarten outcome measures								
	Math			Phonemic awareness			Letter knowledge		
	b	*SE*	β	*b*	*SE*	β	*b*	*SE*	β
PPVT in HS	0.33	0.22	.12	– 0.13	0.18	– .08	1.27	0.47	.25**
Teacher EC in HS	0.45	0.20	.18*	– 0.04	0.17	– .01	1.45	0.46	.28**
False belief in HS	0.51	0.24	.16†	0.36	0.19	.16†	1.10	0.56	.18*
Inhibitory control in HS	1.15	0.60	.17*	– 0.12	0.50	– .01	– 1.33	1.37	– .12
Attention shifting in HS	– 0.55	0.80	.01	0.37	0.68	.06	– 2.23	1.87	– .10
Inhibitory control in K	3.55	1.36	.20**	3.21	1.13	.27**	5.86	2.95	.17*
Attention shifting in K	2.77	1.46	.15†	1.25	1.22	.09	– 0.43	3.35	– .01
Raven in K	0.10	0.05	.16*	0.10	0.04	.23**	0.04	0.10	.03
R^2			.45			.23			.30

Note. EC = effortful control; HS = Head Start; K = kindergarten.
**$p<0.01$, *$p<0.05$, †$p<0.10$.

Examination of relations of executive function, effortful control, and false belief understanding to letter knowledge, also in Table 4, indicated that teacher-reported effortful control, false belief understanding, and receptive vocabulary in preschool and the inhibitory control aspect of executive function measured in kindergarten were related to letter knowledge. Here, the results are somewhat similar to those obtained for mathematics ability, indicating relations of various aspects of child self-regulation to letter knowledge and again indicating the inhibitory control aspect of executive function to be a consistent correlate of early academic ability.

Relations among aspects of self-regulation as predictors of academic outcomes. To assess the extent of overlapping variance in the academic outcomes associated with executive function, false belief understanding, and effortful control, we reran the regression equations including specific subsets of the predictors. This analysis allowed us to examine the extent to which standardized regression coefficients changed across models with different sets of predictors. Standardized regression coefficients from the various models predicting mathematics ability in kindergarten are presented in Table 5. The second column of the table presents standardized coefficients from the full model and the third column presents standardized coefficients in a model from which the measures of executive function in kindergarten have been removed. As expected, due to the correlation between the inhibitory control aspect of executive function measured in preschool and in kindergarten, $r = .39$, the effect for inhibitory control in preschool increased by 47%. As shown in the table, this reflects an increase in the standardized coefficient for this variable from β = .17 to .25. Variance accounted for by this model, $R^2 = .41$, represents a small reduction from the full model. The effects for

Table 5
Changes in Standardized Regression Coefficients Associated with the Prediction of Math Ability Measured in Kindergarten

	Full model	Model with EF measures in K removed	Model with inhibitory control measures removed	Model with false belief and effortful control removed
Inhibitory control in HS	.17	.25	—	.28
Attention shifting in HS	.01	.01	.01	.01
Inhibitory control in K	.20	—	—	.20
Attention shifting in K	.15	—	.23	.15
False belief understanding in HS	.16	.18	.22	—
Teacher report effortful control in HS	.18	.18	.24	—

Note. HS = Head Start; K = kindergarten.

general fluid intelligence and receptive vocabulary remained unchanged in this and subsequent models and are not shown in the table. For the equations predicting phonemic awareness and letter knowledge, also not shown, no changes were observed with the removal of the kindergarten time point for the measures of executive function.

The fourth column of Table 5 presents standardized coefficients in a model from which the preschool and kindergarten measures of the inhibitory control aspect of executive function have been removed. Here, the effect for false belief understanding increased by approximately 37% from $\beta = .16$ to .22, the effect for attention shifting measured in kindergarten increased by 53% from $\beta = .15$ to .23, and the effect for teacher-reported effortful control increased by 33% from $\beta = .18$ to .24. Again, variance accounted for by this model was very similar to the full model at $R^2 = .41$. For the equation predicting phonemic awareness (not shown), removal of the measures of inhibitory control resulted in a significant effect for attention shifting measured in kindergarten, $\beta = .19$. For letter knowledge, no changes in predictors were associated with the removal of the measures of inhibitory control.

Finally, the last column of Table 5 presents standardized coefficients in a model from which false belief understanding and teacher-reported effortful control have been removed. Change was observed only in the coefficient relating inhibitory control measured in preschool to math ability, which increased by approximately 60% from $\beta = .17$ to .28. No effects were observed for the prediction of phonemic awareness or letter knowledge. Again, variance accounted for by this model was highly similar to all models at $R^2 = .43$.

Discussion

The primary aim of this study was to determine the extent to which distinct but overlapping aspects of developing self-regulation in young children were associated with emerging academic ability in kindergarten. The findings indicated that although the various aspects of child self-regulation, including executive function, effortful control, and false belief understanding, were moderately correlated in this sample of children from low-income homes, each tended to account for unique variance in early mathematics or literacy ability. For mathematics knowledge and letter knowledge, self-regulation measured both in preschool and in kindergarten accounted for significant variation. Teacher-reported effortful control and the inhibitory control aspect of executive function were positively associated with mathematics ability and with the letter knowledge aspect of emerging literacy. False belief understanding was significantly related to letter knowledge and exhibited a marginally significant relation with mathematics knowledge and phonemic awareness. Unlike mathematics and letter knowledge, no preschool measures of self-regulation were related to phonemic awareness. As with mathematics knowledge, however, fluid intelligence was uniquely positively associated with phonemic awareness. In contrast, the measure of receptive verbal ability was uniquely associated only with letter knowledge. Overall, the results indicated some overlap in the prediction of early academic ability from measures of self-regulation but also indicated some unique relations of predictors to outcomes. We first consider overlap in prediction and then consider the reasons for unique relations among predictors and outcomes.

Executive Function and Developing Academic Ability

Among the various aspects of self-regulation examined, the inhibitory control aspect of executive function was the only one to be independently related to all three measures of academic ability. This role for inhibitory control in the study of self-regulation and early academic ability is of some interest, given work suggesting inhibitory control to be a central feature of the development of executive function in early childhood (Diamond, 2002; Diamond et al., 2005; Kirkham et al., 2003). Evidence in favor of the inhibitory control account for the development of executive function is provided by data indicating that children's performance on a classic measure of executive function in young children, the dimensional change card sort task, is improved when the conditions of task administration reduce the inhibitory control requirement of the task but not the relational complexity among the items to be sorted (Brooks et al., 2003; Diamond et al., 2005; Kloo & Perner, 2005). Although by no means the only working hypothesis concerning the development of executive function, the inhibitory account provides a comprehensive explanation for the emergence of a central aspect of self-regulation in early childhood.

In contrast to Diamond's inhibitory account, Zelazo and colleagues (Zelazo et al., 2003; Zelazo, Frye, & Rapus, 1996; Zelazo & Müller, 2002) suggest that developmental increases in executive function generally, including inhibitory control, reflect advances in an underlying cognitive ability to represent complex rule structures. Although data from this study cannot directly address the inhibitory versus complexity distinction in the development of executive function, the findings are consistent with the idea that executive function is a central aspect of cognitive development during the preschool period. Furthermore, the inhibitory and cognitive complexity accounts for the development of executive function suggest somewhat different interpretations of the relation of executive function to academic ability. An inhibitory account suggests that the ability to inhibit prepotent response tendencies in the face of irrelevant or distracting information, such as in the context of a math problem or when discriminating letters or phonemes, is a unique contributor to developing academic ability over and above that of specific knowledge of problem elements or solutions. In contrast, the cognitive complexity account places emphasis on the role of knowledge of problem elements and relations among these elements as central to executive function and its relation to academic ability. In the cognitive complexity account, the ability to maintain knowledge of embedded rule structures enables reflection, which in turn allows for the inhibition of prepotent response tendencies, the retention of information in working memory, and the appropriate shifting of attention among aspects of a given problem or task. At the risk of oversimplifying distinctions between the two approaches, an inhibitory account emphasizes doing somewhat more than knowing, while the cognitive complexity account emphasizes knowing somewhat more than doing. That is, the inhibitory account suggests that an individual can have knowledge of correct relations among problem elements but still experience difficulty inhibiting a prepotent response tendency that interferes with the correct solution of the problem based on knowledge alone. In contrast, the complexity account suggests that knowledge of the higher order rule structures that define relations among problem elements allows for the executive functioning required for problem solution.

Executive function and ability in mathematics. Although both the inhibitory and cognitive complexity accounts for the development of executive function have merit, the finding that inhibitory control both in preschool and kindergarten accounted for unique variance in mathematics ability provides further indication of the salience of this aspect of executive function for the development of early academic ability. The relation between inhibitory control and mathematics ability reported here with preschoolers from low-income homes is consistent with prior work in preschoolers from typical income homes in which the inhibitory control but not the attention-shifting aspect of executive function was related to mathematics ability (Espy et al., 2004). However, in a study examining mathematics ability in children in the first grade, at age 7 years, independent effects were reported for inhibitory control, attention shifting, and working memory aspects of executive function, with the most robust relation being that for working memory (Bull & Scerif, 2001).

Findings of moderate to strong relations between executive function and mathematics ability in the developmental literature are consistent with neuroscientific work demonstrating an overlap in the neural substrates supporting executive function and numerical ability and quantitative reasoning. Using functional brain imaging, parietal–frontal cortical circuitry known to be important for executive function abilities (Klingberg, 2006) has been shown to support the representation of numerosity and the solution of simple calculation problems (Dehaene, Molko, Cohen, & Wilson, 2004; Prabhakaran, Rypma, & Gabrieli, 2001; Simon et al., 2004). Similarly, using single-unit physiology with nonhuman primates, neurons tuned to specific numerosities have been identified in prefrontal and parietal cortical areas important for both numerical ability and executive function (Neider, 2005; Neider & Miller, 2004).

Also, at the sociological level, relations between executive function and mathematics ability are consistent with historical evidence indicating a shift in the math curriculum for children in the early elementary grades toward instructional strategies and problem types designed to exercise executive function abilities directly. Historical review of mathematics textbooks in use in U.S. public schools over the last 100 years indicates an increasing pedagogical emphasis on the promotion of ''thinking skills'' and executive function abilities as central to the development of early competence in math (Blair, Gamson, Thorne, & Baker, 2005). Primarily this emphasis is seen in the use of pattern completion and visual–spatial working memory problems in the early elementary grades that require children to use executive function to reason about problem elements. An important feature of pattern completion and working memory types of problems is that no automatized knowledge or formal problem-solving algorithm can be provided to facilitate their solution (Blair, Knipe, Cummings, Baker, Gamson, Eslinger, & Thorne, in press).

The relation of executive function to mathematics ability is particularly apparent when considered from the standpoint of what it is that children are expected to do, cognitively speaking, when solving mathematics problems. Proficiency in mathematics at all levels requires the individual to reason actively about problem elements when arriving at possible solutions. The problem-solving process requires the individual to represent information in working memory, to shift attention appropriately between problem elements, and to inhibit a tendency to respond to only the most salient or most recent aspect of a given problem. Certain aspects of mathematical ability are dependent upon factual knowledge that can be readily retrieved from long-term memory. Solutions to simple addition problems or the times tables are notable examples. Even for very young children, however, mathematics is inherently effortful and makes explicit demands on executive function abilities.

Executive function and emerging literacy. In contrast to mathematics, phonemic awareness and letter knowledge are aspects of emergent literacy that are becoming less effortful and more automatic as children develop. In the parlance of intelligence researchers, reading is a crystallized cognitive ability, one that is composed of highly automatic letter and phoneme identification processes. The results reported here suggest a role for executive function in the process of acquiring automaticity in letter identification and phonemic awareness but one that is less substantial than for math. Variance in phonemic awareness and letter knowledge associated with the combined self-regulation measures was smaller than that observed for mathematics. In contrast to findings for math ability, our results perhaps indicate that letter identification and phonemic awareness abilities make demands of executive function as this knowledge is being acquired. Multiple measures of self-regulation in this low-income sample distinguished children who had acquired letter knowledge from those who had not. For phonemic awareness, the inhibitory control aspect of executive function measured in kindergarten was the only aspect of self-regulation related to this outcome. It is likely that this aspect of emerging literacy is developing more slowly than letter knowledge in this sample and reduced variability may have limited our ability to detect relations between multiple aspects of self-regulation and this outcome. Given the relations of self-regulation measures to letter knowledge, it may be that relations between self-regulation and phonemic awareness will become more prominent as children make further progress toward literacy acquisition.

Social-Emotional Contributions to Developing Academic Ability in Kindergarten

Of further interest to the study of self-regulation and academic achievement is the possibility that relations of false belief understanding and effortful control to academic outcomes reflect the influence of social and interpersonal functioning on early progress in school. Prior work has established that social-emotional competence is an independent contributor to early academic progress (Ladd, Birch, & Buhs, 1999). As a construct denoting the understanding of one's own as well as others' beliefs and intentions as predictors of actions, false belief understanding represents an aspect of interpersonal functioning that is likely to facilitate not only knowledge acquisition but also the demonstration of acquired knowledge in assessment situations. Similarly, as with prior work on relations between temperament and early academic achievement, the unique effect for effortful control in this sample likely represents the influence of attentiveness and motivation and persistence in learning situations on early academic ability (Martin et al., 1988; Rothbart & Jones, 1998). As instructional environments make demands on children's ability to self-regulate in social interactions, it is likely that social-emotional aspects of self-regulation as manifest in false belief understanding and temperamental effortful control, particularly when executive function and general cognitive ability are controlled, are central aspects of interpersonal competence through which learning takes place.

For letter knowledge in particular, the relatively large relations of teacher-reported effortful control and false belief understanding to this outcome, along with verbal intelligence and the inhibitory control aspect of executive function measured in kindergarten, would seem to indicate that children who have not yet attained a developmentally expected knowledge of the letters of the alphabet are characterized by general problems with self-regulation. Given that the majority of the children in the sample knew all or almost all of their letters in kindergarten, the relative few in the sample who lacked this knowledge were distinguishable on multiple aspects of self-regulation from their more knowledgeable peers. To the extent to which letter knowledge is a valuable indicator of early reading ability, the findings from this study indicate that problems with reading are likely to be associated with general problems with self-regulation for some children.

It is also important, however, to further consider overlap among aspects of self-regulation in this sample and not to overemphasize unique relations between specific aspects of self-regulation and specific academic outcomes. The relation of the inhibitory control aspect of executive function to false belief understanding and effortful control observed in this study is consistent with results obtained in other samples of preschool children (Carlson & Moses, 2001; Davis et al., 2002; Rothbart et al., 2003). Unlike prior work (Carlson & Mandell et al., 2004), however, we also identified an independent relation between attention shifting and false belief understanding even when covarying inhibitory control. This may be due to the preschool sample in this study being somewhat larger and older ($n = 170$, mean age 5 years 1 month) than preschool samples in other studies ($n = 81$, mean age 4 years 0 month in Carlson & Mandell et al., 2004).

Conclusions and Limitations

Although the results provide relatively straightforward evidence for relations among aspects of self-regulation and early academic ability, it is necessary to consider the extent to which the method of measurement may have influenced the findings. It is also necessary to consider the extent to which temperamental effortful control as an aspect of self-regulation reported on by teachers may reflect general perceptions of child ability, particularly academic ability. Method of measurement for executive function and false belief understanding was through direct assessment while method of measurement for effortful control was through questionnaires completed by parents and teachers. It may be that if data on executive function and false belief understanding had been gathered through questionnaires or if information on effortful control had been obtained using behavioral assessments, results would have been different. Certainly the way in which psychological constructs are measured can influence relations among variables.

In the interpretation of the effect for teacher report of effortful control on academic outcomes, it may be that teachers' ratings of child temperament are unique to the classroom and school context and influenced by perceptions of child academic ability. Effects for teacher-reported effortful control on academic outcomes, however, were observed when controlling for aspects of verbal and fluid intelligence as well as for measures of executive function and false belief understanding. This indicates that although teachers' reports may have been influenced by academic ability, the relation of teacher-reported effortful control to child academic ability persists even when taking into account objective predictors of child academic competence. Whether effortful control as reported by teachers should be considered as temperament per se, or perhaps an aspect of temperament-like behavior unique to the classroom setting and reflecting engagement in and liking of schooling, is an important direction for future research. Similarly, although the null findings for parent-reported effortful control are puzzling and not interpretable, our results suggest that further differentiation of the relation of temperament to children's early progress in school is needed. Parents observe children in a much wider range of contexts than do teachers and no doubt have an accurate although distinct view of the effortful control aspect of temperament. The relatively poor internal consistency estimates of the parent report subscales in this low-income sample, however, may reflect misunderstanding or misreading of items by parents and may perhaps limit the validity of this measure in this analysis.

A further issue related to measurement is the absence in the full-regression models of a unique relation of attention shifting as measured by the item selection task to any of the measures of academic ability. The series of regression equations in Table 5 indicated that the relation of attention shifting to mathematics ability and phonemic awareness was accounted for by inhibitory control. This suggests that both the peg tapping and item selection measures provide useful assessments of executive function but, as with most if not all measures of the construct, they overlap in certain respects. The relation of abstraction as an aspect of attention shifting to emerging academic ability, however, may be somewhat later in developing in this sample and even in kindergarten may be subsumed by inhibitory control. It is important to acknowledge, however, the possibility that error in measurement at the preschool assessment may have influenced the results, as the item selection measure of attention shifting is somewhat more complex to administer than the peg-tapping measure of inhibitory control.

Also, in studies with young children, participant fatigue can sometimes affect the validity of assessments. At 45 min, our assessment sessions were well within the range of what most children were able to bear. For some children, however, fatigue may have influenced performance on the various measures. By skillfully engaging children in our assessment procedures, however, we believe that we effectively minimized any effects of child fatigue on our data.

In conclusion, although issues associated with measurement may have influenced the findings to some degree, studies demonstrating relations of various aspects of self-regulation including effortful control, false belief understanding, and executive function to indicators of school readiness may be of particular value to efforts to ensure the early school success of children from low-income homes. In the attempt to improve educational achievement and decrease inequities in educational progress associated with socioeconomic status, it is important to understand the nature of multiple influences on early progress in school. Of course, the results from this study, as with the vast majority of studies examining self-regulation in young children, are correlational and cannot establish a definitive causal relation between self-regulation and academic ability. Given the central role of self-regulation in child development, examination of the construct from both temperament-based and neuropsychological approaches can improve understanding of behaviors that underlie early success in school and serve as targets for systematic efforts to enhance the quality of children's early educational experiences. The development and experimental evaluation of well-specified preschool and early school-age curricula designed to promote academic achievement by fostering self-regulation is an important direction for research on school readiness. As a first step in this direction, two promising studies, one with a preschool sample (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005) and the other with a school-age sample with attention deficit hyperactivity disorder (Klingberg et al., 2005), have demonstrated the effects of intensive computer-based training on certain of the aspects of executive function. An important direction for future work will be the replication with diverse populations of effects seen in these studies and assessment of the generalizability of training effects to academic ability.

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