Links Between Behavioral Regulation and Preschoolers’ Literacy, Vocabulary, and Math Skills

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This study investigated predictive relations between preschoolers’ (N = 310) behavioral regulation and emergent literacy, vocabulary, and math skills. Behavioral regulation was assessed using a direct measure called the Head-to-Toes Task, which taps inhibitory control, attention, and working memory, and requires children to perform the opposite of what is instructed verbally. Hierarchical linear modeling (HLM) was utilized because children were nested in 54 classrooms at 2 geographical sites. Results revealed that behavioral regulation significantly and positively predicted fall and spring emergent literacy, vocabulary, and math skills on the Woodcock Johnson Tests of Achievement (all ps < .05). Moreover, growth in behavioral regulation predicted growth in emergent literacy, vocabulary, and math skills over the prekindergarten year (all ps < .05), after controlling for site, child gender, and other background variables. Discussion focuses on the role of behavioral regulation in early academic achievement and preparedness for kindergarten.

Keywords: self-regulation, academic achievement, school readiness, hierarchical linear modeling, executive function

Each year, hundreds of thousands of American children make the transition from preschool to a more structured kindergarten environment. This transition can be particularly problematic for children who have not mastered basic skills involved in regulating behavior, including paying attention, following instructions, and inhibiting inappropriate actions. These skills, which we refer to as behavioral regulation, fall under the broader domain of self-regulation, which is important for functioning in all contexts (Baumeister & Vohs, 2004). Moreover, research documents that children enter school with differing levels of behavioral regulation and that these skills are critical for early school success (Foulks & Morrow, 1989; Lin, Lawrence, & Gorrell, 2003). In one study, a substantial number (17%) of kindergarteners were not able to sit still, follow directions, or work independently without becoming distracted (McClelland, Morrison, & Holmes, 2000). Another investigation found that as many as 46% of teachers reported that more than half of children entering their kindergarten classes did not possess basic regulatory competencies needed to do well in school (Rimm-Kaufman, Pianta, & Cox, 2000). Finally, research has shown that children entering formal schooling without adequate self-regulatory skills are at significantly greater risk for difficulties including peer rejection and low levels of academic achievement (Cooper & Farran, 1988; Ladd, Birch, & Buhs, 1999; McClelland et al., 2000). It is clear that self-regulation is necessary for school success during early elementary school, but there is less research on the contribution of these skills to academic competence prior to kindergarten. The purpose of this study is to examine the association between preschoolers’ behavioral regulation and key academic skills (emergent literacy, vocabulary, and math skills) over the prekindergarten year.

There has been growing interest in and debate about the definition and components of self-regulation in early childhood (Cole, 2007).
Martin, & Dennis, 2004; Kochanska, Murray, & Harlan, 2000; Rueda, Posner, & Rothbart, 2004; Zelazo & Müller, 2002). A review of this research reveals that self-regulation is not a single construct but consists of several aspects of controlling, directing, and planning, including emotion regulation and behavioral regulation. Self-regulation also relates to and involves elements of temperament such as effortful control and cognitive processing such as executive function. However, the relations among these processes are often not clear. Those who focus on emotion regulation distinguish between the activation of an emotional state and the independent regulatory processes that follow (Cole et al., 2004). Others emphasize the temperamental bases of regulation such as effortful control (Kochanska et al., 2000; Murray & Kochanska, 2002; Rothbart & Posner, 2005), which involves several aspects of temperament relating to “the ability to suppress a dominant response to perform a subdominant response” (Kochanska et al., 2000, p. 220). A third line of research highlights specific components of executive function, which is defined as the “processes required for the conscious control of thought and action” (Happaney, Zelazo, & Stuss, 2004, p. 1). Research by Zelazo and colleagues (e.g., Kerr & Zelazo, 2004; Zelazo & Müller, 2002) differentiates between “hot” aspects of executive function that involve regulating affect and motivation, and the more cognitive “cool” aspects of executive function, such as those involved in problem solving. In the present study, our measure of behavioral regulation requires three processes (attention, working memory, and inhibitory control), which have been framed as cognitive cool components of executive function (Blair, 2002).

Literature supports the notion that behavioral regulation involves components of executive function including attention, working memory, and inhibitory control, although the role each plays in regulating overt behavior is debated (Bronson, 2000; Barkley, 1997; Cameron et al., in press; Müller, Zelazo, Hood, Leone, & Rohrer, 2004). In the present study we have not measured these components separately but briefly review their unique contributions, because all three skills are required in our measure of behavioral regulation. Some researchers argue that executive attention or attention-switching are foundational for carrying out behaviors and problem solving (Rothbart & Posner, 2005; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Zelazo & Müller, 2002). Attention allows children to focus on a task or problem, access working memory, and complete behavioral tasks (Barkley, 1997). Other research has highlighted working memory, which allows children to remember and follow directions and helps them plan solutions to a problem (Gathercole & Pickering, 2000; Kail, 2003). Working memory is also argued to play a role in how learning disabilities influence achievement (Geary, 2004). Finally, some research implicates inhibitory control as a primary aspect of controlling behavior (Carlson & Moses, 2001; Rennie, Bul, & Diamond, 2004), which helps children stop incorrect solutions to a problem and carry out more adaptive responses (Dowsett & Livesey, 2000). Inhibitory control develops rapidly during early childhood, and Diamond (2002) has argued it plays a central role as a foundational aspect of executive function during this time.

We used a recently developed direct measure of behavioral regulation (called the Head-to-Toes Task; Cameron et al., in press), which was adapted from work by McCabe and colleagues (McCabe, Rebell-Brito, Hernandez, & Brooks-Gunn, 2004). Children completing the Head-to-Toes Task are asked to respond naturally to a command such as “touch your head” or “touch your toes,” and then are instructed to switch the rules for the task by responding in the opposite way (e.g., the child is told to touch their head when the command is to touch their toes). The task taps children’s behavioral regulation by requiring them to integrate three skills: (a) paying attention to the researcher’s instructions, (b) using working memory to remember the new rule, and (c) inhibiting their natural response to a test command while responding in the correct, unnatural way. Integrating cognitive skills enables a child to regulate their behavior, mentally move forward in time, and plan future actions (Blair, 2002).

Succeeding at the Head-to-Toes Task requires attention, working memory, and inhibitory control, but inhibitory control is a main component. The task shares features of traditional measures of inhibitory control, including the Bear and Dragon Task (Reed, Pien, & Rothbart, 1984), which requires children to respond to behavioral commands given by a Bear puppet, but not a Dragon puppet, and Luria’s handgame, which asks children to respond with one of two hand gestures to a command for the opposite gesture (Hughes, 1998). These tasks help illustrate how inhibitory control develops in early childhood. Diamond’s (2002) work shows that being able to (a) follow multiple task instructions and (b) switch between tasks in which one task conflicts with perception or prior task demands are two milestones children achieve with development, with (a) developing earlier than (b). Another framework to understand the development of cognitive aspects of behavioral regulation is Zelazo’s revised Cognitive Complexity and Control Theory (CCC-r), which posits that executive function is based on cognitive rule systems in which children must develop higher order rules to successfully regulate their behavior (Zelazo, Müller, Frye, & Marcovitch, 2003). Further, working memory and executive attention are important in situations involving attentional control and monitoring, including parts of the Head-to-Toes Task in which children must attend to and remember initial instructions, attend to test commands, and monitor their responses (Roberts & Pennington, 1996; Rothbart & Posner, 2005). Although it was not our aim to evaluate different theories of executive function, working memory and executive attention (including monitoring) are necessary for children to do well on the task and support inhibitory control, which is a primary component.

Using a behavioral measure has advantages over teacher or parent ratings, which may be based on perceptions rather than actual child behavior (McClelland & Morrison, 2003; Rimm-Kaufman et al., 2000). A recent study found that the Head-to-Toes Task showed developmental differences in performance with two sites of children from distinct geographical regions and was a stable and valid measure of early behavioral regulation in diverse populations. Moreover, the greatest variability on Head-to-Toes Task performance was found in 4- and 5-year-olds (prior to kindergarten entry; Cameron et al., in press). Thus, the present study examined links between this direct measure of behavioral regulation and emergent literacy, vocabulary, and math skills in the prekindergarten year, when children were 4 and 5 years old.

Behavioral Regulation and Academic Achievement in Elementary School

Considerable research has demonstrated that behavioral aspects of self-regulation are important for achievement throughout elementary school. Acquiring behavioral regulation (including atten-
tion, working memory, and inhibitory control) provides a foundation for developing positive behavior in classroom contexts and making academic gains. Together, these three cognitive processes allow children to remember and follow teachers’ directions and focus on a task without succumbing to distractions. Those who are unable to inhibit problematic behaviors, such as talking out of turn and failing to complete assignments, are less able to function effectively in the classroom (Alexander, Entwisle, & Dauber, 1993; Ladd, 2003). One investigation using teacher ratings found that learning-related skills (which include attention, working memory, and inhibitory control, as well as social-emotional competence) predicted literacy and math skills from kindergarten to sixth grade and growth in literacy and math from kindergarten to second grade (McClelland, Acock, & Morrison, 2006). Children with poor learning-related skills also demonstrated lower performance than their higher-rated peers on reading and mathematics between kindergarten and sixth grade.

There is also mounting evidence that young children’s attention, working memory, and inhibitory control are each important for school performance and adaptation (Alexander et al., 1993; Blair, 2002; Bull & Scerif, 2001; McClelland et al., 2006; National Institute of Child Health & Human Development [NICHD] Early Child Care Research Network, 2003). For example, socioeconomically disadvantaged (low-socioeconomic status [SES]) kindergarteners showed poorer attention while performing a tedious computer task compared with students from more affluent homes, and lower attention predicted lower achievement skills in the low-SES group (Howse, Lange, Farran, & Boyles, 2003). Working memory has also been tied to early reading and math skills in elementary students (Kail, 2003). One investigation found that 6- and 7-year-old low-achieving students had more difficulty on a task that required them to keep track of visual information, compared to higher achieving students (Gathercole & Pickering, 2000). Finally, failures of inhibitory control have been implied as the main impairment in Attention Deficit/Hyperactivity Disorder (ADHD), in which lower levels of inhibition have been linked to lower achievement in multiple samples (Adams & Snowling, 2001; Lawrence, Houghton, Tannock, Douglas, Durkin, & Whiting, 2002; St. Clair-Thompson & Gathercole, 2006). In the present study, we examined the relation between early academic achievement and performance on a behavioral regulation task requiring attention, working memory, and inhibitory control prior to elementary school.

Behavioral Regulation and Early Achievement in Preschool

Research supports the notion that strong behavioral regulation is associated with higher levels of academic achievement in elementary school. There is less work examining this relation before kindergarten, although researchers have argued that attention, working memory, and inhibitory control included in behavioral regulation are important for learning outcomes prior to formal school entry (Blair, 2002). For example, the NICHD Early Child Care Research Network (2003) found that children’s attention in preschool predicted their reading and math achievement at 54 months of age. Another investigation with prekindergarteners demonstrated that those who had difficulty paying attention and using working memory and inhibitory control to complete goal-directed activities scored relatively lower on a standardized cognitive achievement measure. These children also exhibited more risk factors such as family problems, lower parental education, and behavioral or emotional problems (Bronson, Tivnan, & Seppanen, 1995).

Taken together, findings demonstrate that the processes involved in behavioral regulation relate to children’s early achievement. However, it is not known when during early childhood behavioral regulation emerges as being important for particular aspects of academic achievement. In addition, research has often relied on parent or teacher reports to assess children’s skills or used laboratory-based tasks to measure the processes involved in behavioral regulation, which may not have practical utility in classrooms. We used an easy-to-administer, direct observational measure of behavioral regulation that focuses on inhibitory control and also taps attention and working memory. In contrast to previous studies that have not focused on early childhood or on overall behavioral regulation, we were interested in how behavioral regulation was related to early academic skills prior to formal schooling. We administered the measure to children in the fall and spring of the prekindergarten year along with three assessments of early academic achievement: emergent literacy, vocabulary, and math. This enabled us to examine whether level and growth (i.e., residualized change) in behavioral regulation predicted early academic skill gains.

Classroom Influences

In the current study, it was important to control for the influence of classroom-level variability because children enter formal education widely varying in their skills and knowledge, which may differ by the classroom or school in which they are placed (Christian, Bachman, & Morrison, 2001; Lee, Burkam, Ready, Honigman, & Meisels, 2006). Classroom-level influences also mean that the experiences of children in one classroom over a school year may be similar based on their classroom membership. Researchers have long recognized multiple sources of variance in measured outcomes, such as the child and the classroom, to address research questions (Burstein & Miller, 1981; Haney, 1980; Raudenbush & Bryk, 2002). In the present study, we controlled for classroom-level variability in behavioral regulation and early academic skills, which served as a foundation for exploring the nature and sources of variation in the skills needed for early school success.

Goals of the Present Study

The present study sought to examine whether performance and growth on the Head-to-Toes Task, a measure of behavioral regulation, were significantly related to level and growth in emergent literacy, vocabulary, and math skills over the prekindergarten year. The following two research questions guided this inquiry. First, what is the variability and growth over the prekindergarten year in behavioral regulation, using a measure that relies on direct observation of the child’s behavior rather than teacher or parent report? Based on the extant literature, we anticipated substantial variability and growth in behavioral regulation. Second, we asked whether behavioral regulation would relate to three measures of early academic achievement, expecting that children with higher behavioral regulation would achieve academically at higher levels in fall
and spring of the prekindergarten year, compared to children with lower behavioral regulation. Finally, we hypothesized that growth in behavioral regulation over the school year would be significantly and positively related to gains in emergent literacy, vocabulary, and math skills.

Method

Participants

Children were recruited from two sites: a predominantly middle-to upper-middle-SES urban fringe area with a range of economic and ethnic diversity in Michigan, and a mixed-SES rural site in Oregon. Participants in Michigan were recruited through their preschool programs, housed in a public school district, to participate in a 5-year longitudinal study on early academic and social development. All 3- and 4-year-old children entering preschool were recruited through fall orientations at the district’s six participating schools, as well as through backpack mailing during the first 2 years of the study. One of the preschools was a Title I and Head Start site, and all others were licensed by the state of Michigan. Children from the Title I school were overrecruited. Once the target sample size had been achieved, recruiting was stopped. Recruitment efforts in these locations enrolled approximately 38% of the districts’ children who were entering preschool in the longitudinal study, with a final sample size of \( n = 217 \) for the present investigation, including only 4-year-old children during their prekindergarten year. Participants were enrolled in 42 classrooms.

In Oregon, children and parents were part of a study investigating factors related to self-regulation in preschool. Three preschools accredited by the National Association for the Education of Young Children and three Head Start preschools located in Oregon were invited to participate in the study and all agreed. Recruitment letters were sent home with approximately 165 children entering preschool and were attending full-day and part-day programs and spending an average of 18 hr per week (SD = 10.06 hours). The average education level attained for both mothers and fathers was approximately a college degree (\( M = 15.95 \) years). There were 210 children for whom ethnicity could be identified: 76% were Caucasian, 9% were African American or biracial, 7% were East Indian or Asian, 2% were Latino/a, and 6% were Middle Eastern.

At the Oregon site, the mean age of children at Time 1 (fall) was 4.58 years (SD = 0.27 years) with ages ranging from 4.08 to 5.17 years (see Table 1). The mean age at Time 2 (spring) was 5.11 years (SD = 0.28 years) with ages ranging from 4.58 to 5.67 years. There were approximately equal numbers of girls (52%) and boys in the study. On average, children had spent about 22 months in child care prior to data collection at Time 1 (SD = 18.07 months) and were attending full-day and part-day programs and spending an average of 21 hours per week in prekindergarten (SD = 13.37 hours). Families demonstrated considerable educational and ethnic diversity. The average education level attained for mothers and fathers was approximately an associate’s degree (\( M = 14.63 \) years) and 24% of parents had a high-school education or less (\( n = 22 \)). Twenty-five percent (\( n = 23 \)) of children and families were Latino/a, of which 19 (83%) were primary Spanish speakers. The remaining sample was 48% Caucasian, 19% Asian, and 7% other ethnic group.

Table 1

Descriptive Statistics for Predictor and Outcome Variables for Michigan (\( N = 217 \)) and Oregon (\( N = 93 \)) Sites

<table>
<thead>
<tr>
<th>Variable</th>
<th>Michigan site</th>
<th></th>
<th>Oregon site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( M )</td>
<td>( SD )</td>
<td>Range</td>
</tr>
<tr>
<td>Fall self-regulation</td>
<td>10.42</td>
<td>7.61</td>
<td>0–20.00</td>
</tr>
<tr>
<td>Spring self-regulation</td>
<td>13.24</td>
<td>6.34</td>
<td>0–20.00</td>
</tr>
<tr>
<td>Fall child age (in years)</td>
<td>4.33</td>
<td>0.34</td>
<td>3.12–5.11</td>
</tr>
<tr>
<td>Spring child age (in years)</td>
<td>4.95</td>
<td>0.35</td>
<td>4.14–6.40</td>
</tr>
<tr>
<td>Gender (Girl = 0, Boy = 1)</td>
<td>0.49</td>
<td>0.50</td>
<td>0–1.00</td>
</tr>
<tr>
<td>Fall prior child care experience (in months)</td>
<td>11.89</td>
<td>15.08</td>
<td>0–48.00</td>
</tr>
<tr>
<td>Fall hours per week in prekindergarten</td>
<td>17.93</td>
<td>10.06</td>
<td>6.00–30.00</td>
</tr>
<tr>
<td>Parent education level (in years)</td>
<td>15.95</td>
<td>1.63</td>
<td>11.00–18.00</td>
</tr>
<tr>
<td>Minority (0 = White or Asian, 1 = other minority)</td>
<td>0.24</td>
<td>0.43</td>
<td>0–1.00</td>
</tr>
<tr>
<td>Spanish version of self-regulation task (0 = English version, 1 = Spanish version)</td>
<td>0.00</td>
<td>0.00</td>
<td>0–1.00</td>
</tr>
<tr>
<td>Fall literacy (W-scores)</td>
<td>344.61</td>
<td>24.34</td>
<td>270.00–468.00</td>
</tr>
<tr>
<td>Fall vocabulary (W-scores)</td>
<td>472.08</td>
<td>11.75</td>
<td>418.00–502.00</td>
</tr>
<tr>
<td>Fall math (W-scores)</td>
<td>410.60</td>
<td>17.12</td>
<td>350.00–449.00</td>
</tr>
<tr>
<td>Spring literacy (W-scores)</td>
<td>358.71</td>
<td>26.20</td>
<td>264.00–500.00</td>
</tr>
<tr>
<td>Spring vocabulary (W-scores)</td>
<td>475.96</td>
<td>10.87</td>
<td>429.00–510.00</td>
</tr>
<tr>
<td>Spring math (W-scores)</td>
<td>422.90</td>
<td>15.91</td>
<td>350.00–467.00</td>
</tr>
</tbody>
</table>
The present study combined data for the 310 children (51% girls) from the Michigan and Oregon sites in the fall and spring of the prekindergarten year. For the combined sample, the mean age at Time 1 (fall) was 4.48 years (SD = 0.33 years) with a range between 3.61 and 5.17 years. The mean age at Time 2 (spring) was 4.93 (SD = 0.36 years) years with a range between 4.14 and 6.40 years. On average, children from both sites had spent 14.63 months in child care prior to data collection at Time 1 (SD = 16.54 months) and were enrolled in prekindergarten programs for an average of 18.85 hours a week (SD = 11.22 hours). The mean parent education level was almost a college degree (M = 15.60 years), and across the two sites, 22% of children came from minority ethnic groups (non-Asian or Caucasian). A small sub-group of the parents were Spanish-speaking (n = 19) and had a high school degree or less (n = 23). An ethnic minority dummy variable was created because no significant differences were found between Caucasian and Asian participants’ academic achievement scores, so they were combined into a nonminority group. All other children (African American, Middle Eastern, and Latino/a) were identified as being members of the other minority group. We then used this variable as a control in the analyses.

Procedure

At both sites in the fall and the spring of the prekindergarten year, research assistants administered the emergent literacy, vocabulary, and math tests and a behavioral regulation assessment as part of two batteries. Each battery was administered to individual children in single sessions lasting 30–40 min in Michigan and 10–15 min in Oregon. In Michigan, participants were given stickers as they went through the assessment batteries, which included additional tasks related to literacy development. At the Oregon site, Spanish-speaking children were identified by their teachers as having Spanish as their first language and were given the achievement tests and the behavioral regulation task in Spanish. Assessments were conducted at children’s schools in a quiet room or hallway outside their classrooms.

Measures

Background questionnaire. Parents at both sites completed a background questionnaire in English or Spanish (Oregon site only), which contained questions about children’s age, gender, prior child care experience, ethnicity, and parent education level. For the Oregon site, the background questionnaire was translated into Spanish and back-translated into English for Spanish-speaking parents by two native Spanish speakers. At both sites, families received a total of $20 in gift certificates for participating in any part of the study.

Behavioral regulation. The Head-to-Toes Task was used as a direct assessment of behavioral regulation at both sites (Cameron et al., in press). The task requires three skills: inhibitory control, attention, and working memory, although inhibitory control is a main component (Diamond, 2002). Children were asked to play a game in which they were instructed to do the opposite of what the experimenter said. For example, the experimenter instructed them to touch their head (or their toes), and instead of following the command, children were directed to do the opposite and touch their toes (head). Children were given four practice tests and the instructions were repeated up to three times during the practice tests. After the practice tests were administered, the testing portion of the task was given.

There were a total of 10 items in random order, with possible item scores of 0, 1, or 2 for each item. Higher scores indicated higher levels of behavioral regulation. A 0 was incorrect, 1 was a self-correct (defined as any motion toward the incorrect response but where the child then stopped and responded correctly), and 2 points were given if a child gave the correct response without hesitation or a prior movement to the incorrect response. The sum of scores for the 10 items was computed at each time point and possible scores ranged from 0 to 20 in the fall and in the spring (see Table 1). For the Spanish-speaking children in the study (n = 19), the Head-to-Toes Task was translated into Spanish and back-translated into English by two Spanish speakers, including a professor of Spanish. We then created a dummy variable of whether children received the Head-to-Toes Task in Spanish or English, which was used as a control variable in the analyses (see Table 1 and Results section below).

Preliminary validity for the Head-to-Toes Task, including scores for both the English and Spanish versions of the task, was determined by comparing scores to other measures of behavioral regulation available at one or both sites, such as the teacher-rated Social Skills Rating System (SSRS; Gresham & Elliott, 1990) and the Child Behavior Rating Scale (CBRS; Bronson et al., 1995).1 The teacher-rated SSRS has a self-control scale, which includes 10 questions and has shown adequate reliability in previous research; it was used in Oregon only (Gresham & Elliott, 1990). The teacher-rated CBRS contains eight items assessing behavioral regulation in the classroom and has shown strong reliability in previous research; it was used at both sites (McClelland & Morrison, 2003). For children at the Oregon site, higher scores on the Head-to-Toes Task in fall of the prekindergarten year were significantly related to higher teacher ratings of self-control on the SSRS (r = .33, p < .001) and higher behavioral regulation on the CBRS (r = .46, p < .001). In the spring of the school year, higher scores on the Head-to-Toes Task were correlated with higher teacher ratings of self-control on the SSRS (r = .38, p < .001) and higher CBRS behavioral regulation ratings (r = .48, p < .001). At the Michigan site, children who received higher scores on the Head-to-Toes Task in the fall were rated higher by their teachers on the behavioral regulation scale of CBRS (r = .20, p < .01). Spring Head-to-Toes Task scores and teacher ratings were not significantly correlated (r = .07, p > .05). When the Oregon and Michigan sites were combined, behavioral regulation items on the CBRS were positively related to the Head-to-Toes Task in the fall (r = .27, p < .001) and spring (r = .21, p < .01).

Reliability across examiners for Head-to-Toes Task scores was also assessed for both sites of children demonstrating variability in

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1 We also compared scores on the Head-to-Toes Task with teacher ratings on the SSRS and CBRS for the children who received the Spanish version of the task in the Oregon site. Correlations for this group were similar to those who received the English version of the task but did not reach statistical significance due to the small sample size (n = 19). Moreover, the mean increase from fall to spring on the Head-to-Toes Task was similar for children speaking English (mean increase = 3.29, SD = 7.20) and Spanish (mean increase = 3.35, SD = 7.92).
scores. At the Michigan site, there were no significant differences in Head-to-Toes Task scores by examiners in the fall, \( F(13, 181) = 1.36, p > .05 \), or spring of the prekindergarten year, \( F(13, 191) = 1.22, p > .05 \). At the Oregon site, no significant differences in Head-to-Toes Task scores across examiners were found in the fall, \( F(5, 80) = 1.08, p > .05 \), or spring, \( F(9, 72) = 0.76, p > .05 \).

We also tested for examiner differences in scoring self-corrected responses on the Head-to-Toes Task. At the Michigan site, there were no significant differences in the average number of self-correct responses scored by examiner in the fall, \( F(13, 181) = 1.58, p > .05 \), or the spring, \( F(13, 177) = 0.85, p > .05 \). Similarly, at the Oregon site, there were no significant differences by examiner in the average number of self-correct responses on the Head-to-Toes Task in the fall, \( F(6, 85) = 1.09, p > .05 \), or spring, \( F(9, 72) = 1.19, p > .05 \). Finally, in a recent study, interrater reliability was established on the Head-to-Toes Task by having six examiners score videotapes of 12 children, selected at random, completing the Head-to-Toes Task. Examiners achieved excellent interrater reliability (\( \alpha = .95 \) for self-corrections, .98 overall; Connor et al., 2007). Overall, these results meet generally established reliability levels (Landis & Koch, 1977).

**Emergent literacy skills.** Children’s emergent literacy skills were assessed with the letter–word Identification subtest of the Woodcock Johnson Psycho-Educational Battery—III Tests of Achievement (WJ–III; Woodcock & Mather, 2000) or the Bateria Woodcock-Muñoz—R (Woodcock & Muñoz-Sandoval, 1996). This task required children to identify letters and read real words with fluent pronunciation, which increased in difficulty as children progressed. In previous research, this measure has shown adequate reliability for 4-year-old English- and Spanish-speaking children (.98 and .90, respectively; Woodcock & Muñoz-Sandoval, 1996).

**Early vocabulary skills.** Receptive and expressive vocabulary skills, namely the ability to point to and state the name of pictured objects, were assessed with the picture vocabulary subtest of the WJ–III or the Bateria Woodcock-Muñoz—R in English or Spanish (Oregon site only). In other research, reliabilities for 4-year-old English- and Spanish-speaking children were .81, and .73, respectively (Woodcock & Muñoz-Sandoval, 1996).

**Early math skills.** Early mathematical skills, including recognizing and stating pictured quantities, and performing simple calculations needed to analyze and solve practical problems were assessed with the applied problems subtest of the WJ–III or the Bateria Woodcock-Muñoz—R (Oregon site only). This measure has also shown strong reliability for 4-year-old children speaking English or Spanish, .94 and .92, respectively (Woodcock & Muñoz-Sandoval, 1996).

\( W \)-scores were used in analyses for all three achievement tests based on a centered \( W \)-score of 500, which is the average achievement level for a 10-year-old child (Mather & Woodcock, 2001). \( W \)-scores are a conversion of raw scores, which have properties similar to those of the Rasch ability scale (Rasch, 1966) including equal-interval measurement characteristics.

**Results**

The present study examined variability and growth (i.e., residualized change) in a direct measure of behavioral regulation, relations with academic achievement in the fall and spring of prekindergarten, and whether gains in behavioral regulation significantly predicted growth in emergent literacy, vocabulary, and math skills.

**Variability and Growth in Behavioral Regulation**

Descriptive statistics indicated that variability in Head-to-Toes Task scores was present in each site (see Table 2). The distributions of Head-to-Toes Task scores showed some evidence of nonnormality, although they did not meet requirements given for extreme skewness and kurtosis (Kline, 2005). For children at the Michigan site, in the fall and spring, the majority received scores between 1 and 20 on the Head-to-Toes Task, with 27% receiving scores of zero in the fall and 9% receiving scores of zero in the spring. At the Oregon site, a similar pattern was found with the majority of participants receiving scores above zero in the fall and spring. In the fall, 22% of children received scores of zero and 10% received scores of zero in the spring. In Michigan, the average score gain on the task from fall to spring was almost 3 points, and in Oregon, the average gain was almost 4.5 points, although this was not a statistically significant difference (see Table 1). Finally, variability in fall and spring scores (see Table 1) and the change in scores from fall to spring was similar at both sites, \( F(1, 278) = .39, p > .05 \).

Behavioral regulation scores were not significantly correlated with site, nor did scores differ significantly by site in the fall, \( F(1, 300) = 2.70, p > .05 \), or spring, \( F(1, 284) = .01, p > .05 \). However, analyses of variance indicated that children in Michigan were younger, \( F(1, 307) = 15.81, p < .001 \), had fewer months of prior child care experience, \( F(1, 251) = 19.66, p < .01 \), were attending prekindergarten for fewer hours a week, \( F(1, 308) = 4.93, p < .05 \), had parents with significantly more years of education, \( F(1, 246) = 16.38, p < .001 \), were more likely to be White or Asian, \( F(1, 301) = 8.18, p < .01 \), and were not administered the Spanish version of the Head-to-Toes Task, \( F(1, 308) = 55.36, p < .001 \), when compared to the children in Oregon.

\( ^2 \) Six children who scored at ceiling levels at both time points were excluded from this analysis.
For the combined sample, behavioral regulation scores were significantly related to a number of background variables (see Table 3). Children with stronger behavioral regulation in the fall and in the spring were older ($r = .28$, $p < .001$; $r = .12$, $p < .05$), had parents with more years of education ($r = .14$, $p < .05$; $r = .20$, $p < .01$), were White or Asian ($r = -.16$, $p < .01$; $r = -.22$, $p < .001$), and received the Head-to-Toes Task in English rather than in Spanish ($r = -.14$, $p < .05$; $r = -.16$, $p < .01$) compared to children with weaker behavioral regulation scores. In the spring, girls tended to have stronger behavioral regulation than did boys ($r = -.14$, $p < .05$) and children with higher scores tended to have more months of child care experience ($r = .14$, $p < .05$).

**Relations Between Behavioral Regulation and Academic Outcomes**

Our second research question asked about the extent of relations between behavioral regulation and academic outcomes. All scores for the achievement outcomes were normally distributed, but across sites and time points, variability was greater in emergent literacy scores, compared to vocabulary and early math scores (see Table 1). Correlations for the predictor and outcome variables for the combined sample are presented in Table 3. Fall and spring behavioral regulation were significantly correlated with all three academic achievement outcomes at both time points at a $p < .001$ level of significance. The strongest correlation emerged between fall behavioral regulation and fall math, at $r = .22$, $p = .05$; the next was for fall behavioral regulation and fall literacy, at $r = .14$, $p = .18$. In the spring, the correlation emerged between fall behavioral regulation and spring math, at $r = .20$, $p = .05$; the next was fall behavioral regulation and spring literacy, at $r = .14$, $p = .18$. The weakest correlation emerged between fall behavioral regulation and spring emergent literacy, at $r = .18$.

To account for the nesting of children in classrooms, we used Hierarchical Linear Modeling (HLM 6.02; Raudenbush & Bryk, 2002) to further investigate associations between behavioral regulation and achievement and to examine the influence of growth in behavioral regulation on growth in emergent literacy, vocabulary, and math skills. Three models were built: one each for emergent literacy, vocabulary, and math skills in the spring. In the final models, we controlled for fall achievement score, as well as fall and spring behavioral regulation.

**Child- and classroom-level variability.** First, we examined the extent of variation at Level 1 (child) and Level 2 (classroom) for each spring academic outcome. Modeling the influence of classroom-level predictors, such as teacher experience, was beyond the scope of the present study, but it was important to appropriately estimate classroom-level variation in predictors as well as academic outcomes to obtain well-estimated standard errors for the fixed effects (Bidwell & Kasarda, 1980). Results of the vocabulary and math fully unconditional models showed significant variability at the level of the classroom. The intraclass correlation (ICC), which is the portion of the total variance located between classrooms, was 0.002, 0.21, and 0.11 for spring emergent literacy, vocabulary, and math, respectively. Although the unconditional model for emergent literacy revealed no significant variability at Level 2, we used HLM rather than regression and note that the results of the two analytic strategies would have been highly similar.

**Building the final model.** We then added Level-1 predictors to each outcome, trimming predictors that did not reach significance (Raudenbush & Bryk, 2002). Initial models included minority group (0 = White or Asian, 1 = Other Minority), parent education

### Table 3

Table 3.

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<th>Variable</th>
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<td>8. Parent education level (in years)</td>
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<td>9. Minority (0 = White or Asian, 1 = Other Minority)</td>
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<td>11. Fall vocabulary (W-scores)</td>
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<td>13. Spring literacy (W-scores)</td>
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<td>14. Spring vocabulary (W-scores)</td>
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<td>15. Spring math (W-scores)</td>
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</table>

† $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$.
level, hours in prekindergarten each week, and prior child care
experience, but none of these variables were significant predictors
of the academic outcomes and so were excluded from the final
models to maintain parsimony. Site (Michigan = 1, Oregon = 0)
was also added at Level 2 but was not a significant predictor for
emergent literacy, vocabulary, or math skills, and was therefore
trimmed from each final model (emergent literacy, \( t = -0.68, p >
0.05 \); vocabulary, \( t = 0.64, p > 0.05 \); math skills, \( t = -0.99, p >
0.05 \)). Models were also tested without the variable denoting chil-
dren given the Spanish version of the behavioral regulation task,
and results did not differ from our final models with this variable
included. Because the administration of the behavioral regulation
assessment in Spanish was associated with lower parent education
level \( (r = -0.60) \), we tested for an interaction between receiving
the assessment in Spanish and parent education level on children's
behavioral regulation scores. However, this interaction was not
statistically significant. To maintain consistency in our final mod-
els, we kept the Level-1 predictors of gender, age at fall assess-
ment, and whether children were given the behavioral regulation
task in Spanish in each model because they were significant
predicators or theoretically important to include.

Behavioral regulation and academic achievement. To further
examine significant associations found in the correlations between
behavioral regulation and achievement (see Table 3), we tested
whether behavioral regulation predicted achievement, in the fall
and spring, after controlling for age, gender, and language of
assessment (Spanish or English). First, higher behavioral regula-
tion scores in the fall and spring were associated with higher
achievement at corresponding time points (all \( ps < 0.05 \)). Second,
we assessed the predictive value of fall and spring behavioral
regulation on spring academic skills without controlling for fall
achievement. Both fall and spring behavioral regulation uniquely
predicted academic skills levels, demonstrating that higher behav-
ioral regulation in the fall and spring was associated with increased
academic outcomes in the spring of the prekindergarten year (all
\( ps < 0.05 \)). Third, spring behavioral regulation predicted all spring
academic outcomes, controlling for fall achievement but without
fall behavioral regulation in the model (all \( ps < 0.05 \)). These
findings formed the basis for our three final models, in which we
examined whether growth in behavioral regulation predicted
growth in emergent literacy, math, and vocabulary skills. The final
model for spring vocabulary is shown in the Appendix as an
exemplar. The final sample size for all analyses was \( N = 310 \).

Growth in behavioral regulation and growth in emergent liter-
acy. Overall, children with stronger growth in behavioral regu-
lation, controlling for all other variables, demonstrated stronger
emergent literacy score gains than did children with weaker
growth in behavioral regulation (see Table 4). The corresponding
effect size for a one standard deviation change in Head-to-Toes
Task score was small but significant, \( d = 0.09 \).\(^3\) For every 7-point
increase in behavioral regulation from fall to spring, children’s
emergent literacy increased by 2.7 points, or the average gain in
emergent literacy associated with just over 1 month of prekind-
geraden, \( t = 2.14, p < 0.05 \). Because we included fall behavioral
regulation in the model, this indicated that the more children’s
Head-to-Toes Task scores increased during the prekindergarten
year, the greater was their literacy skill growth (spring controlling
for fall literacy score). Not surprisingly, children with higher fall
emergent literacy scores demonstrated stronger spring literacy
scores than did children with lower fall literacy scores, \( t = 20.18,
p < 0.001 \). No other predictors were significant. Results from the
random effects in Table 4 demonstrate the extent and variation in
spring literacy scores. The final model with predictors explained
43.3% of the variance in emergent literacy scores. The majority
(99%) of the remaining unexplained variance was attributed to
children and 1% of the unexplained variance to classrooms, which
was not significant, \( \chi^2 = 64.17, p = 0.12 \). Instead, the variance
components for Level-1 effects indicated large individual differ-
ences between children.

Growth in behavioral regulation and growth in vocabulary. Children who made greater gains in behavioral regulation also
showed more growth in vocabulary skills than did those with less
growth in behavioral regulation after controlling for all other
variables, \( t = 2.10, p < 0.05 \) (see Table 5). Specifically, for every
7-point increase in behavioral regulation, spring vocabulary score
increased by 1.9 points, \( d = 0.15 \). This was equivalent to the
learning gain in vocabulary made in about 2.8 months of prekind-
geraden. In addition, participants with higher fall vocabulary
scores had higher spring vocabulary scores than did those with
lower fall vocabulary scores, \( t = 10.96, p < 0.001 \). Finally, com-
pared to English-speaking participants, children who received the
Spanish version of the Head-to-Toes Task received significantly
lower vocabulary scores in the spring, \( t = -5.04, p < 0.001 \).
Random effects for spring vocabulary scores indicated that the
final model with all variables explained 53.8% of the variance in
early vocabulary scores. For the remaining unexplained variance,
90.5% was attributed to children; the other 9.5% was attributed to
classrooms, which was significant, \( \chi^2 = 80.07, p < 0.01 \).

Growth in behavioral regulation and growth in early math.
Finally, greater improvement over the prekindergarten year in
behavioral regulation predicted growth in math skills after con-
 trolling for all other variables, including fall behavioral regulation
and math scores, \( t = 2.05, p < 0.05 \) (see Table 6). For every 7-point
increase in behavioral regulation, children’s spring early math
score was predicted to increase, on average, 1.4 points, \( d = 0.09 \),
or the learning in math associated with about 3 weeks of prekind-
geraden. Children who initially had higher math scores had higher
spring math scores compared with those who had lower math
scores in the fall, \( t = 10.25, p < 0.001 \). Results from the final model
explained 51.8% of the variance in early math scores, attributing
89.6% of the unexplained variance to children and 10.4% of the
unexplained variance to classrooms, which was a significant
Level-2 effect, \( \chi^2 = 89.81, p < 0.01 \).

Discussion

Variability and Growth in Behavioral Regulation

In the current study, children’s scores on a direct measure of
behavioral regulation demonstrated variability over the prekind-
geraden year. We also found that performance on the behavioral
regulation assessment improved significantly from fall to spring.
These results indicate that the measure reliably captured individual
differences and gains in attention, working memory, and inhibitory

\(^3\) We calculated effect sizes using the standard deviation of the outcome
variables (emergent literacy, vocabulary, or math). We used Cohen (1988)
to interpret the effect sizes \((2 = \text{small}; 5 = \text{medium}; 8 = \text{large})\).
control, although inhibitory control was a main component. The task directly measured children’s ability to attend, remember two rules, and inhibit one response while responding correctly and did not rely on either teacher or parent report.

Behavioral Regulation and Relations to Emergent Literacy, Vocabulary, and Math Skills

Children with higher behavioral regulation achieved at significantly higher levels in emergent literacy, vocabulary, and math in the fall and spring of the prekindergarten year, after controlling for age, gender, and whether the behavioral regulation task was given in Spanish. It is important to note that the relation between fall behavioral regulation and spring achievement dropped to nonsignificance when fall achievement was entered into the final models. In spite of this, these results point to a robust relation between behavioral regulation and academic skills and support the notion that behavioral regulation is an important aspect of school readiness (Blair, 2002; Bronson, 2000). We also found that children exhibiting more growth in behavioral regulation from the fall to spring of prekindergarten demonstrated significantly greater gains in emergent literacy, vocabulary, and math skills, compared with those showing less behavioral regulation growth. Effect sizes were small, but these results are meaningful because analyses controlled for a number of key variables. Moreover, children who made a one standard deviation change in behavioral regulation made learning gains associated with 1 month of prekindergarten for emergent literacy skills, almost 3 months of prekindergarten for vocabulary skills, and about 3 weeks of prekindergarten for early math skills. These results are especially meaningful given rapid development in multiple skill areas in the early childhood period (Shonkoff & Phillips, 2000).

Previous findings show that aspects of behavioral regulation, including attention, working memory, and inhibitory control, predict emergent literacy and math skills in preschool (Blair, 2002; Bronson et al., 1995; NICHD Early Child Care Research Network, 2003) and elementary school (Howse, Calkins, Anastopoulos, Bronson, 2000).

Table 4
Hierarchical Linear Modeling Results for Spring Prekindergarten Emergent Literacy Skills (Both Sites; N = 310)

<table>
<thead>
<tr>
<th>Fixed effect</th>
<th>Coefficient</th>
<th>SE</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>348.24</td>
<td>14.50</td>
<td>24.01***</td>
</tr>
<tr>
<td>Gender (Boy = 1), γ1₀</td>
<td>2.77</td>
<td>1.98</td>
<td>1.34</td>
</tr>
<tr>
<td>Child age, γ2₀</td>
<td>2.20</td>
<td>3.24</td>
<td>0.68</td>
</tr>
<tr>
<td>Fall literacy score, γ3₀</td>
<td>0.84</td>
<td>0.04</td>
<td>20.18***</td>
</tr>
<tr>
<td>Fall behavioral regulation score, γ₄₀</td>
<td>0.04</td>
<td>0.15</td>
<td>0.30</td>
</tr>
<tr>
<td>Spring behavioral regulation score, γ₅₀</td>
<td>0.38</td>
<td>0.18</td>
<td>2.14*</td>
</tr>
<tr>
<td>Spanish-version behavioral regulation, γ₆₀</td>
<td>1.98</td>
<td>4.32</td>
<td>0.46</td>
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</table>

Random effect

<table>
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<th>Variance component</th>
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<th>χ²</th>
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<tr>
<td>Intercept, u₀</td>
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</tr>
<tr>
<td>Level-1 effects, r₁</td>
<td>263.34</td>
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Note. Deviance = 2358.41.
* p < .05. *** p < .001.

Table 5
Hierarchical Linear Modeling Results for Spring Prekindergarten Vocabulary Skills (Both Sites; N = 310)

<table>
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<td>Child age, γ2₀</td>
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<td>Fall vocabulary score, γ3₀</td>
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<td>Fall behavioral regulation score, γ₄₀</td>
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<td>0.08</td>
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<td>Spring behavioral regulation score, γ₅₀</td>
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<td>Spanish-version behavioral regulation, γ₆₀</td>
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<td>2.80</td>
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Random effect

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<tr>
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Note. Deviance = 2014.80.
* p < .05. *** p < .001. ** p < .01.
**Table 6**

Hierarchical Linear Modeling Results for Spring Prekindergarten Math Skills (Both Sites; N = 310)

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<td>1.45</td>
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<td>Child age, ( \gamma_{20} )</td>
<td>4.33</td>
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<td>Fall math score, ( \gamma_{30} )</td>
<td>0.51</td>
<td>0.05</td>
<td>10.25***</td>
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<td>Fall behavioral regulation score, ( \gamma_{40} )</td>
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<td>Spring behavioral regulation score, ( \gamma_{50} )</td>
<td>0.27</td>
<td>0.13</td>
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<th>( \chi^2 )</th>
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<td>89.81***</td>
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<td>Level-1 effects, ( r_0 )</td>
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*Note.* Deviance = 2185.41.

† \( p < .10 \). †† \( p < .05 \). ††† \( p < .01 \). †††† \( p < .001 \).

Keane, & Shelton, 2003; Kail, 2003; McClelland et al., 2000, 2006). Development in the cognitive mechanisms related to behavioral regulation may be linked to early academic skills as well (Diamond, 2002; Carlson & Moses, 2001). In other words, as children learn to focus their attention and moderate automatic behavioral tendencies (i.e., develop inhibitory control) they become better able to successfully regulate their classroom behavior, including paying attention, remembering instructions, and completing tasks. This would contribute to improved performance on the Head-to-Toes Task, and would also enable greater content learning, measured by the achievement outcomes. However, overall executive function development and general increases in an underlying mechanism, such as speed of information processing (Kail, 2003), could account for gains in which children demonstrate parallel growth in self-regulation and emergent literacy, math, and vocabulary (Shonkoff & Phillips, 2000). Although it was beyond the scope of this study to identify specific mechanisms underlying growth in behavioral regulation, disentangling these processes has theoretical, definitional, and methodological implications and is an aim for future work (McClelland, Cameron, Wanless, & Murray, in press; Pintrich, 2000).

In the present study, random effects results showed greater variability in children’s vocabulary and math skills attributed to classrooms, compared to emergent literacy skills. This finding was unexpected, because emergent literacy may be an explicit focus of instruction in some classrooms. We note that this pattern was found at the beginning and the end of the school year, suggesting that some “classroom” differences were actually present before the prekindergarten year (Olson, 2006). It is also important to remember that child and classroom variability were calculated as proportions of the total variance. Thus, classroom differences likely existed for emergent literacy and were proportionally larger in the spring than in the fall, but they were statistically overshadowed by individual differences between children. This likely reflects the wide variability in parenting practices around literacy in early childhood (Sénéchal, 2006). The present interpretation suggests that classroom differences in literacy instruction may have existed, but these effects were outweighed by the individual differences in emergent literacy skills with which children came to prekindergarten and which continued to operate over the year. Results indicate that learning gains in math and vocabulary differed significantly between classrooms as well as children in this sample.

Children who received the Head-to-Toes Task in Spanish had weaker vocabulary skills, which were also assessed in Spanish. There was also a strong relation between lower parent education level (which is a proxy for lower SES) and speaking Spanish as a primary language. Children in lower SES families tend to have smaller vocabularies than higher SES children (Hart & Risley, 1995). The relatively lower vocabulary scores for participants receiving the Spanish version of the Head-to-Toes Task may indicate risk factors and unmeasured sociocultural variables, which were not fully captured by parent education level.

Overall, results from two groups of children demonstrated remarkable consistency, and no significant effect of site (Michigan or Oregon) was found. These results are noteworthy because the Oregon site had a greater number of parents with less education and a Spanish-speaking group of children, while the Michigan site had a greater number of middle- and high-SES families and participants from four different ethnic groups. Indeed, across the two sites, 22% of children in this sample came from minority ethnic groups (non-Asian or Caucasian). Thus, this study supports the utility of using the Head-to-Toes Task to predict achievement in diverse groups.

**Practical Implications**

Strengthening attention, working memory, and inhibitory control skills prior to kindergarten may be an effective way to ensure that children also have a foundation of early academic skills, although we cannot make causal claims based solely on the results of this study. The predictive nature of growth in behavioral regulation to emergent literacy, vocabulary, and math skills is especially important in light of recent efforts focusing on cognitive and literacy skills for school readiness, as in programs like Head Start (Schumacher, Greenberg, & Mezey, 2003), Early Reading First, and in the No Child Left Behind Act. Our study reveals that
prekindergarten behavioral regulation is another critical component of assessing school readiness and should be included in measures that gauge preparedness for kindergarten and early school success (Blair, 2002; McClelland et al., 2000; Raver, 2002; Raver & Zigler, 2004).

Several studies reveal that experimental interventions can improve aspects of behavioral regulation in early childhood (Dowsett & Livesey, 2000; Webster-Stratton, Reid, & Hammond, 2001). For example, impulsive children can be taught to talk to themselves, via self-monitoring, as a means of controlling their behavior (Reid, Trout, & Schartz, 2005). Studies also show that after several training sessions, children’s inhibitory control (Dowsett & Livesey, 2000) and attention (Rueda et al., 2005) skills improve significantly. For example, Dowsett and Livesey reported that preschoolers identified as having poor inhibition, who participated in laboratory training sessions that included gaining experience with multiple rule-use tasks (e.g., a modification of the Wisconsin Card Change Sort task), improved over those in a control group on an experimental inhibitory control measure. Given this evidence, it seems possible that laboratory interventions targeting behavioral regulation can be successful and may produce improved academic achievement as well. Experimental research is needed to establish this causal claim.

The question of how to enhance behavioral regulation skills within the preschool context is also critical. Although information on classroom instruction was not available in the present study, significant unexplained variance (approximately 10%) was attributed to classroom effects on math and vocabulary outcomes. Classroom-based interventions to bring all children up to the same skill levels should focus on promoting inhibitory control, attention, and working memory, along with helping teachers best enhance early academic competencies. On a practical level, teachers and parents can promote behavioral regulation in ways that take into account children’s individual characteristics, their family environment, and broader sociocultural factors that influence readiness for school (McClelland, Kessenich, & Morrison, 2003). Additional research should identify the mechanisms through which such interventions are most effective. Including broadly representative samples is critical to examine how behavioral regulation can be fostered in children from a variety of cultural and socioeconomic backgrounds (Denckla, 1994).

**Limitations of the Study**

This study revealed important links between behavioral regulation and emergent literacy, vocabulary, and math skills, but there were some limitations. First, the number of participants in Oregon was relatively small (n = 93), compared to the Michigan site (n = 217). Nonetheless, no significant effect of site membership was found in the HLM analyses. Future research should include equally large and diverse samples to provide further validation of the findings. Second, because skills were measured in prekindergarten only, we could not assess the impact of inhibitory control, attention, and working memory as children entered kindergarten. Future studies will incorporate multiple time points to better examine the influence of these skills on gains in emergent literacy, vocabulary, and math skills over time, especially after children enter kindergarten. Third, we can make no causal claims that improving behavioral regulation will lead to stronger emergent literacy, vocabulary, or math skills. Intervention studies aimed at improving attention, working memory, or inhibitory control, with participants randomly assigned to treatment and control conditions, are needed.

**Conclusion**

Results from this study add to a growing body of research demonstrating the importance of behavioral aspects of self-regulation for early academic skills and school success. Moreover, this study connects gains in behavioral regulation over the prekindergarten year, measured directly with an observational task, with growth in emergent literacy, vocabulary, and math skills. These results, incorporating participants from two regions of the United States, can be used by researchers, parents, and teachers to promote behavioral regulation in preschool, which can help ensure that children make a successful transition to kindergarten.

**References**


Cole, P. M., Martin, S. E., & Dennis, T. A. (2004). Emotion regulation as...


### Appendix

**Final Hierarchical Linear Modeling Model for Spring Vocabulary**

#### Level 1

\[
Y_{ij} = \beta_{0j} + \beta_{1j}(\text{Boy})_{ij} + \beta_{2j}(\text{Child Age})_{ij} \\
+ \beta_{3j}(\text{Vocabulary Fall})_{ij} \\
+ \beta_{4j}(\text{Head-to-Toes Task Fall})_{ij} \\
+ \beta_{5j}(\text{Head-to-Toes Task Spring})_{ij} \\
+ \beta_{6j}(\text{Spanish Version})_{ij} + r_{ij} 
\]  

#### Level 2

\[
\beta_{0j} = \gamma_{50} + u_{0j} 
\]

\[
\beta_{1j} = \gamma_{10} 
\]

\[
\beta_{2j} = \gamma_{20} 
\]

\[
\beta_{3j} = \gamma_{30} 
\]

\[
\beta_{4j} = \gamma_{40} 
\]

The outcome, spring vocabulary \((Y_{ij})\) for child i in classroom j, is a function of the coefficients \((\beta_{0j})\) at Level 1 as they relate to a child’s gender \((\text{boy} = 1)\), age, fall vocabulary score, fall and spring self-regulation scores, whether the self-regulation task was administered in Spanish, and the residual, or unique error for the individual child \((r_{ij})\). At Level 2, \(\beta_{0j}\) is a function of the fitted mean spring vocabulary score across children \((\gamma_{50})\), plus error \((u_{0j})\) at the classroom level. \(\gamma_{10}\) is the effect of gender and \(\gamma_{20}\) represents the effect of age on spring vocabulary. \(\gamma_{30}\) is the effect of fall vocabulary on spring vocabulary; \(\gamma_{40}\) and \(\gamma_{50}\) represent the effects of fall and spring self-regulation, respectively, on spring vocabulary; and \(\gamma_{60}\) represents the effect of receiving the self-regulation task in Spanish on spring vocabulary score. The effect of these predictors did not vary at the classroom level and thus were fixed.

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