Published in final edited form as:
J Child Fam Stud. 2016 August ; 25(8): 2423–2434. doi:10.1007/s10826-016-0410-0.

Links between motor control and classroom behaviors: Moderation by low birth weight

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Abstract

It is unclear from past research on effortful control whether one of its components, motor control, independently contributes to adaptive classroom behaviors. The goal of this study was to identify associations between early motor control, measured by the walk-a-line task at age 3, and teacher-reported learning-related behaviors (approaches to learning and attention problems) and behavior problems in kindergarten classrooms. Models tested whether children who were vulnerable to poorer learning behaviors and more behavior problems due to having been born low birth weight benefited more, less, or the same as other children from better motor control. Data were drawn from the national Fragile Families and Child-Wellbeing Study ($n = 751$). Regression models indicated that motor control was significantly associated with better approaches to learning and fewer behavior problems. Children who were low birth weight benefitted more than normal birth weight children from better motor control with respect to their approaches to learning, but equally with respect to behavior problems. Additionally, for low but not normal birth weight children, better motor control predicted fewer attention problems. These findings suggest that motor control follows a compensatory model of development for low birth weight children and classroom behaviors.

Keywords

motor control; learning-related behaviors; behavior problems; effortful control; low birth weight

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Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Introduction

Effortful control (EC) reflects the self-regulatory aspect of early childhood temperament and is defined as the ability to withhold a dominant or prepotent response in order to carry out a subdominant or less salient response (Kochanska, Murray, & Harlan, 2000; Rothbart & Ahadi, 1994; Rothbart & Bates, 2006). A child exhibits EC, for example, when she suppresses her urge to immediately touch an intriguing toy (the dominant response) and waits until an adult grants permission to do so (the subdominant response). Research suggests that EC emerges between 6 and 12 months of age and grows rapidly over the toddler and preschool years (Rothbart, Derryberry, & Posner, 1994). This growth has important implications for children's emotion regulation and behavior (Eisenberg, Smith, & Spinrad, 2011; Raver, 2004), as EC serves to modulate reactivity, the other dimension of temperament that refers to physiological arousability and emotionality (Rothbart & Bates, 2006; Rothbart & Derryberry, 1981). Not surprisingly, research suggests that EC in early childhood predicts several facets of children's behavior at school entry, such as fewer externalizing problems (Gartstein & Fagot, 2003; Olson, Sameroff, Kerr, Lopez, & Wellman, 2005), fewer attention problems (Campbell & von Stauffenberg, 2009; Murray & Kochanska, 2002), and greater social competence (Dennis, Brotman, Huang, & Gouley, 2007). Moreover, due to its interaction with reactivity, there is evidence that these associations may be particularly strong for children with negative emotionality who are at risk for problems in social adjustment (Eisenberg et al., 1997; Pecora, Sette, Baumgartner, Laghi, & Spinrad, 2015; Valiente et al., 2003). Interestingly, while it is clear that EC in early childhood has important implications for children's developmental trajectories, additional research is needed to specify the mechanisms through which EC contributes to school readiness.

When children voluntarily suppress a dominant response and initiate a subdominant response, they may invoke effortful cognitive, motor, and/or vocal control (Eisenberg et al., 2011; Murray & Kochanska, 2002; Zhou, Chen, & Main, 2012). While some studies suggest that EC reflects a unidimensional construct (Allan & Lonigan, 2011; Rothbart, Ahadi, Hershey, & Fisher, 2001; Sulik et al., 2010), a growing number of studies support EC as a multidimensional construct and advocate for its decomposition, particularly in light of research indicating unique links between its subcomponents and key developmental outcomes (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009).

Early research identified four skills underlying EC, which included delaying (e.g., waiting to eat a snack or unwrap a gift), motor inhibition (e.g., slowing motor activity such as walking or drawing), suppressing or initiating responses to signals (e.g., Go- No Go games), and conflict resolution (e.g., Stroop-like tasks; Kochanska, Murray, & Coy, 1997; Kochanska et al., 2000; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996). Subsequent studies have used a comprehensive battery of tasks tapping these different skills to explore the factor structure of EC during early childhood, yielding somewhat mixed results. For example, using exploratory factor analysis in a longitudinal sample of children, Murray and Kochanska (2002) identified three EC factors: the ability to delay, the ability to slow fine or gross motor activity, and the ability to suppress or initiate behavior. Although the factors varied slightly across the developmental periods examined (i.e., toddler, preschool and early school), two components emerged consistently across the ages: motor control and suppress/initiate behavior (Murray & Kochanska, 2002). This two-factor model was further supported using confirmatory factor analysis with similar tasks among children ages 4 to 6 years (Dennis et al., 2007). While both studies found that EC was associated with children's behavior problems, the unique contributions made by its component parts remain unclear. Specifically, the former study reported associations with both internalizing and externalizing behaviors, but it used a composite of EC including all three factors (Murray & Kochanska, 2002). The latter study reported independent associations between motor control and both social competence (ages 4, 5 and 6) and internalizing behavior (age 4 only), but not externalizing behavior; however, it used a sample of children at risk for psychopathology (Dennis et al., 2007). Therefore, further research is needed to understand whether motor control, separate and apart from other factors of EC, contributes to children's behavior.

Moreover, it is important to specify links between EC and different types of children's behavior in a classroom context. The literature differentiates learning-related behaviors, often referred to as approaches to learning, which contribute to academic achievement (Duncan et al., 2007), from socioemotional competence, or its inverse, behavior problems. Learning-related behaviors reflect children's enthusiasm for and engagement in educational activities (Hyson, 2008) and include attentiveness, persistence, flexibility, organization, and compliance with instructions (Fantuzzo et al., 2007; McWayne, Fantuzzo, & McDermott, 2004; Stipek, Newton, & Chudgar, 2010). Collectively, these skills facilitate learning by allowing children to attend to the material presented by teachers, as well as follow directions, stay on-task, and work independently (Blair, 2002; Foulks & Morrow, 1989). Socioemotional competence, on the other hand, reflects skills and behaviors that affect the child's expression of internalizing (e.g., sadness, anxiety) and externalizing (e.g., aggression) symptoms, and enable or inhibit positive relationships with teachers and other students.

There are theoretical and empirical grounds to hypothesize that better motor control may predict better learning-related behaviors as well as enhanced socioemotional competence. Researchers have distinguished between hot and cool dimensions of EC depending on whether or not the task involves affective regulation (hot) or not (cool; Allan & Lonigan, 2011; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Kim, Nordling, Yoon, Boldt, & Kochanska, 2013). Specifically, the hot EC dimension is dominant in contexts that include rewards or punishments, such as those that require delay of gratification, while the cool EC dimension is dominant in situations that do not include a salient emotional component, such as slowing motor control (Zelazo & Muller, 2002). There is consensus that hot and cool processes are associated with different regions of the brain (Bush, Luu, & Posner, 2000; Hongwanishkul et al., 2005), and are best represented as distinct dimensions of EC in factor analyses (Brock et al., 2009; Kim et al., 2013; but see Allan & Lonigan, 2011, for an exception). Given their different biological underpinnings, it has been hypothesized that hot EC is particularly predictive of developmental outcomes that involve emotion regulation, such as internalizing and externalizing behavior, while cool EC, which reflects more abstract cognitive processing, is more predictive of academic success (Allan & Lonigan, 2011; Di Norcia, Pecora, Bombi, Baumgartner, & Laugh, 2015). Indeed, these hypotheses are supported by a growing number of studies showing that hot EC tasks predict behavior problems but not academic success, and cool EC tasks predict academic success but not behavior problems (Hongwanishkul et al., 2005; Kim et al., 2013).

Motor control is often measured by asking children to perform a task such as walking on a line or drawing a circle as quickly as they can and then as slowly as they can. Because this task is affectively neutral (e.g., does not promise a reward at its completion), it may be considered a cool EC task (Allan & Lonigan, 2011; Di Norcia et al., 2015; Kim et al., 2013). Accordingly, it may be expected to predict classroom learning-related behaviors, which are largely though not exclusively cognitively based, in early childhood. Children with better gross motor control may be better able to sit still in the classroom, allowing them to pay more attention to academic material presented by teachers. Children with better fine motor control may find writing and drawing assignments easier and may be more apt to take on, persist in, or work independently on challenging work at their seats. In these scenarios, better motor control would predict fewer attention problems and more engagement in learning activities in the classroom. In fact, some studies have linked preschoolers' ability to slow motor activity with higher academic achievement (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Maccoby, Dowley, Hagen, & Dergerman, 1965; but see Liew, Chen, & Hughes, 2010). While it is possible that better motor control indirectly contributes to higher achievement by improving learning-related behaviors, to our knowledge, only one study to date has examined this link. Specifically, Brock et al. (2009) found that children's ability to slow motor activity at the start of the kindergarten year predicted their teachers' reports of adaptive learning behaviors and classroom engagement at year's end, net of their ability to delay gratification.

As stated above, the walk-a-line task is affectively neutral and therefore may be characterized as tapping cool EC. In general, it is believed that cool EC predicts cognitive control abilities rather than socioemotional control abilities. While this may be true when cool EC is measured by a battery of tasks (Di Norcia et al., 2015), it is nonetheless possible that performance on the walk-a-line task, in particular, has implications for children's socioemotional competence. Unlike other cool EC tasks that make exclusively cognitive or attentional demands (e.g., a visual Stroop task) on children, the walk-a-line task taps motor control, a skill that is easily observable by others in the classroom. Motor control, even on affectively neutral tasks, may therefore have unique consequences for social interactions with teachers and peers. Better motor control should facilitate joint play with peers by allowing children to follow directions and remain engaged during games. Furthermore, children with better motor control are likely to be viewed as more compliant by teachers, and children perceived as more compliant typically have higher quality relationships with teachers and are better liked by peers (Hughes, Cavell, & Willson, 2001; Ladd, Birch, & Buhs, 1999). In contrast, children viewed as non-compliant may be perceived as difficult by teachers, which in turn is likely to elicit rejection by other students (Hamre & Pianta, 2001; Hughes & Chen, 2011; Mercer & DeRosier, 2008). These results are in line with the concept of the teacher as an "invisible hand" that influences children's peer relationships and interpersonal growth in the classroom (Farmer, McAuliffe Lines, & Hamm, 2011). Thus, children with poor motor control may be isolated from other children, which could engender feelings of aggression as well as deny them the opportunity to practice prosocial skills.

These mechanisms may explain the association found by Dennis et al. (2007) between better motor control and greater social competence. Moreover, Bierman et al. (2008) found that preschoolers' ability to slow motor activity at the start of the year predicted greater teacher-reported social competence and lower aggression at the end of the year. The link between motor control and socioemotional competence is also consistent with research showing that children with poor motor skills more generally are at risk of social isolation from peers and demonstrate lower levels of social competence (Dunn, Dunn, & Bayduza, 2007; Gulay, Seven, & Damar, 2010). Given the sparse findings to date, there is a need for more research on whether slowed motor activity independently predicts children's socioemotional behavior in the classroom.

Children who are born low birth weight (< 2500 g.) are at risk of poorer cognitive and behavioral outcomes in early childhood, including those related to both learning behaviors and socioemotional competence. Children born low birth weight, and in particular, very low birth weight (< 1500 g.), are more vulnerable than normal birth weight children to attention deficits and hyperactivity at school age (Breslau et al., 1996; Hack et al., 2009; Klebanov, Brooks-Gunn, & McCormick, 1994; Mick, Biederman, Prince, Fischer, & Faraone, 2002; Szatmari, Saigal, Rosenbaum, Campbell, & King, 1990). There is also some evidence suggesting that low birth weight children are more likely to display aggressive behavior (Breslau et al., 1996; Gray, Indurkhya, & McCormick, 2004; Rickards, Kelly, Doyle, & Callanan, 2001). Therefore, children born low birth weight may be in greater need than normal birth weight children of skills that can be marshaled in the service of enhancing adaptive learning and socioemotional behaviors. Motor control may be one such skill set.

Two studies have found that low birth weight predicts lower inhibitory control during the preschool years (Li-Grining, 2007; Schlotz, Jones, Godfrey, & Philips, 2008), but both studies used a composite of cognitive and motor inhibitory control. No studies have tested whether low birth weight is associated with poorer motor control per se, although a great deal of evidence links low birth weight to poorer fine and gross motor skills in general (Breslau et al., 1996; Hack et al., 2009; Martel, Lucia, Nigg, & Breslau, 2007; Taylor, Minich, Bangert, Filipek, & Hack, 2004; Whitaker et al., 2006). For the present study, however, the question of interest is not whether low birth weight children have poorer motor control, on average, than normal birth weight children, but whether the link between motor control and classroom behaviors operates differentially by birth weight. That is, if motor control is associated with improved learning behaviors and socioemotional competence, is this association stronger, weaker, or the same for low birth weight children compared to normal birth weight children?

The literature on the predictors of school readiness shows that child vulnerabilities such as low birth weight may follow two very different patterns. The first pattern reflects a compensatory model of development, in which children at greater developmental risk reap greater rewards from growth-enhancing capacities such as EC compared to peers at lower risk (Luthar, Cicchetti, & Becker, 2000). For example, past studies find that kindergarten children's approaches to learning conferred more returns to academic achievement over the elementary school years for children who were at the highest risk because they had the lowest initial academic scores (Bodovski & Farkas, 2007; Li-Grining, Votruba-Drzal, Maldonado-Carreño, & Haas, 2010). However, another pattern commonly found in development is the cumulative growth model, in which children at higher risk benefit less from factors that promote development than children at lower risk, causing group differences by vulnerabilities to multiply (DiPrete & Eirich, 2006). Curiously, both patterns may apply to capacities such as EC in predicting different development outcomes. For example, a recent study found that although approaches to learning in kindergarten promoted academic achievement over time most for those children with the lowest initial levels of competence, they were most protective against externalizing problems over time for those with the highest initial levels of behavioral competence (Razza, Martin, & Brooks-Gunn, 2015).

Low birth weight is commonly attended by neonatal complications, such as intraventricular hemorrhage or periventricular leukomalacia (Taylor et al., 2004). These brain insults appear to interfere with normal development in a wide range of domains. A previous study found a link between low birth weight and inattention/hyperactivity at age 6 that was partially mediated by motor coordination problems, but this link was weaker among girls than boys (Martel et al., 2007). The authors speculated that because girls are less vulnerable to inattention/hyperactivity than boys, female sex attenuated the risk posed by low birth weight. Thus, to the degree that motor control protects against classroom behavior problems, it could attenuate the risk posed by low birth weight for classroom behavior problems. Otherwise framed, if motor control deters classroom behavior problems, this deterrence should be stronger in low than in normal birth weight children because they are more vulnerable. Such a finding would reflect a compensatory model of development, in which more vulnerable children reap greater rewards from growth-enhancing capacities.

The Current Study

The present study poses two questions. First, we investigate whether there are associations between motor control in toddlerhood and two dimensions of children's kindergarten classroom behavior – learning behaviors and behavior problems. Specifically, a distinction is made between classroom behaviors such as attentiveness that support learning, which contribute to academic achievement (Duncan et al., 2007), and those reflecting behavior problems, such as aggression and poor social skills. Thus, we seek to replicate previously-found links between motor control and behavior problems (Bierman et al., 2008) and learning-related behaviors (Brock et al., 2009) in a single sample, and with motor control measured during toddlerhood and classroom behaviors measured during kindergarten rather than both in a single school year. Second, we ask whether motor control follows a compensatory model of development, in which low birth weight children benefit more than normal birth weight children, a cumulative model, in which low birth weight children benefit less than normal birth weight children, or a model in which all children benefit equally from motor control. The results will indicate whether motor control, typically measured as only one indicator in a composite of EC, merits attention as a factor promoting school readiness, particularly among low birth weight children.

Method

Participants

This study drew data from the Fragile Families and Child Wellbeing Study (FFCWS), which follows a birth cohort of approximately 4,900 children in 20 cities across the U.S. By design, children born to unmarried parents were oversampled. The cities were selected to be representative of all mid-sized U.S. cities (see Reichman, Teitler, Garfinkel, & McLanahan, 2001). Hospitals were sampled within cities, and births were sampled within hospitals. Mothers were interviewed in the hospital after giving birth, and fathers were interviewed soon after. The core study consisted of phone interviews when the child was 1, 3, 5, and 9 years.

The present study is restricted to a subsample of the core called the In-Home Longitudinal Study of Preschool Aged Children. All mothers who completed the age 5 core interview (n =3,700 across 18 cities) were invited to participate in this substudy but only 64% completed the in-home visit (n =2,366). As part of the substudy, mothers were asked for permission to contact the child's kindergarten teacher. Kindergarten teachers were contacted via mail, and surveys were completed for 1,039 children (69% response rate). An additional condition for inclusion in our analytic sample was that children participated in the In-Home study at age 3 when motor control was assessed. This criterion resulted in the exclusion of 288 families, which brought the final analytic sample to 751 children.

Families in the analytic sample were no longer representative of mid-sized U.S. cities and were slightly more advantaged compared to those excluded due to nonparticipation or attrition. For example, children in the analytic sample were significantly ($p < .05$) more likely to be white (26% vs. 21%), less likely to be black (45% vs. 50%), more likely to have married parents (35% vs. 31%), and more likely to have a mother with some college or more education (46% vs. 39%). Nonetheless, these families were still largely disadvantaged. For example, 62% of families had incomes below 200% of the federal poverty threshold, a benchmark for economic hardship, and another 16% had incomes below 300%.

Procedure

Children's motor control was directly assessed during the in-home visit at age 3 by trained data collectors who also conducted the maternal interviews. Kindergarten teachers reported on children's classroom behavior at age 5 via a questionnaire that was sent via mail.

Measures

Motor control—Motor control was measured using the walk-a-line task (Kochanska et al., 2000). Children were first asked to walk the length of a six-inch-wide, six-foot-long line at normal speed. Children were then asked to walk the line twice more at a very slow speed. For each of these three trials, data collectors used stopwatches to record the time (in seconds) that children took to walk the line. Data collectors began timing each child as soon as he or she began moving and stopped as soon as both of the child's feet were off the line. The difference between the normal speed and each slow speed trial was computed and these differences were averaged. Higher scores indicated a greater slowing of motor activity (or higher motor control).

Approaches to learning—Kindergarten teachers rated children's approaches to learning in kindergarten using the scale of this name drawn from the Early Childhood Longitudinal Study -1998 Kindergarten Cohort. This scale consisted of 6 items (α = .93) capturing children's typical behaviors during learning activities. Sample items included "persists in classwork without being told," and "works independently." Teachers rated how true each statement was using the following 3-point scale: 1 (*never*), 2 (*somewhat or sometimes true),* and 3 (*very true or often true*). Scores were averaged across items.

Attention problems—Kindergarten teachers rated children's attention problems using 9 items (α = .87) selected from the Attention Problems subscale of the Teacher Report Form (Achenbach, 1991). Sample items included "can't concentrate, can't pay attention for long" and "is confused or seems to be in a fog." Teachers rated how well each item described the focal child using a 3-point scale: 1 (*not true)*, 2 (*somewhat or sometimes true*) and 3 (*very true or often true*). Scores were averaged across items.

Behavior problems—Kindergarten teachers rated children's aggressive behavior using 19 items (α = .93) from the Aggression subscale of the Teacher Report Form (Achenbach, 1991). Sample items included "gets in many fights" and "threatens others." Responses used the same 3-point scale as the Attention Problems scale and were averaged across items. Teachers rated children's social problems using 6 items (α = .67) drawn from the subscale of that name from the Teacher Report Form (Achenbach, 1991). Sample items included "gets teased a lot" and "is not liked by other kids." Responses used the same 3-point scale as the Attention Problems scale and were averaged across items. Because the scales of aggressive behavior and social problems were highly correlated (r = .90), they were averaged to create a composite representing behavior problems.

Low birth weight—An indicator variable was created to denote whether the child had been born low birth weight (<2500 g.). Birth weight was gathered at baseline through hospital records.

Control variables—Characteristics of the child and his or her family were included as controls in all multivariate models. These characteristics were selected based on previous literature showing their associations with EC and school readiness. The child's negative emotionality during infancy was captured at the age 1 phone interview using 3 items (α = .60) drawn from the Emotionality scale of the EAS Temperament Survey for Children (Buss & Plomin, 1984). Mothers were asked to rate how well three items described their child ("often fusses and cries," "gets upset easily," "reacts intensely when upset") on a 5-point scale (1 = *not at all like my child*, 5 = *very much like my child*); items were averaged. Race was coded according to maternal self-report as European American non-Hispanic, African American non-Hispanic, Hispanic or other. An indicator variable denoted whether the child was male. Maternal education (less than high school, high school graduation or GED, or some college or more) and marital status (married, cohabiting, or single) were collected during the home visit at age 3. An indicator variable denoted that the family was in poverty at age 3 if the household income fell below the federal poverty threshold for the preceding calendar year. The child's receptive vocabulary, a proxy for general cognitive ability, was assessed by the PPVT-III (Dunn & Dunn, 1997), administered at the age 3 home visit. Scores are standardized by age against a national norming sample ($M = 100$, $SD = 15$). Finally, mother-child attachment security was also assessed at the age 3 home visit using the MAS-39 (Bimler & Kirkland, 2005), an attachment Q-sort procedure for toddlers.

Data Analyses

Some control variables were missing on up to 5% of cases. Based on the assumption that data were missing at random (Allison 2009), we conducted multiple imputation in Stata 13 to create five complete data sets with control and predictor variables. The ICE command in Stata (Royston 2007) conducts multiple imputation based on a regression switching protocol using chained equations. While the dependent variables were used in imputation models for other missing variables, they themselves were not imputed per von Hippel (2007). The five data sets were analyzed using the *mi beta* prefix for regression analyses in Stata, which combines coefficients and standard errors across imputed data sets and estimates standardized regression coefficients. Robust standard errors adjusted for clustering by city.

Results

Descriptive statistics for all study variables are presented in Table 1. Bivariate correlations between age 3 motor control and kindergarten classroom behaviors appear in Table 2. As expected, age 3 motor control was significantly correlated with greater approaches to learning as well as lower levels of attention problems and problem behaviors in kindergarten.

Hierarchical regression models were computed to examine the association between age 3 motor control and children's classroom behaviors in kindergarten. To test whether these associations were moderated by low birth weight, models followed a two-step procedure. For each kindergarten classroom behavior, motor control, low birth weight and all control variables were entered in Step 1. In Step 2, the interaction term (motor control × low birth weight) was added to the regression model; motor control was mean-centered.

As shown in Table 3, there was a main effect of motor control at age 3 on kindergarten approaches to learning ($\beta = .06$, $p < .05$). Specifically, children who demonstrated greater motor control at age 3 were reported by teachers to evidence more adaptive learning behaviors in kindergarten. Although low birth weight was not a significant predictor of approaches to learning, it moderated the association between motor control and approaches to learning. There was a positive interaction between motor control and low birth weight ($\beta = .04$, $p < .05$). This was indicative of a compensatory model, in which motor control was more beneficial for approaches to learning among children who were vulnerable due to low birth weight than for children who were normal birth weight. The difference in simple slopes for motor control between normal and low birth weight children is displayed in Figure 1. Both simple slopes were significantly greater than zero but the slope for low birth weight children was steeper ($\beta = .19$, $p < .01$) than the slope for normal birth weight children ($\beta = .06$, $p < .05$).

Results did not support a main effect of age 3 motor control on teacher-reported attention problems in kindergarten. Low birth weight was only marginally associated with greater attention problems ($\beta = .06$, $p < .10$), but the interaction between low birth weight and motor control was statistically significant ($\beta = -.07$, $p < .01$). As was true for approaches to learning, a compensatory model was found in which motor control was more beneficial for reducing attention problems among children who were at risk due to low birth weight. In fact, the non-significant main effect of motor control should be interpreted as indicating that it was not protective against attention problems among children who were normal birth weight. The difference in simple slopes for motor control between normal and low birth weight children is displayed in Figure 2. Only the simple slope for low birth weight children is significantly different from zero, ($\beta = -.26$, $p < .01$).

There was a main effect of motor control at age 3 on behavior problems in kindergarten ($\beta = -.05$, $p < .05$). Specifically, children who showed greater motor control at age 3 were reported by teachers to have lower levels of behavior problems in kindergarten. Low birth weight was not a significant predictor of behavior problems, nor did it moderate the association between motor control and behavior problems. Thus, the link between greater motor control and fewer behavior problems did not vary according to birth weight status. .

Discussion

This study found that motor control at age 3, as measured by a walk-a-line task, predicted better learning-related behaviors in kindergarten, although associations varied by birth weight status. Specifically, children who displayed better motor control at age 3 were reported by their kindergarten teachers to have better approaches to learning, particularly if they had been born low birth weight. Children with better motor control at age 3 were also reported to have fewer attention problems, but only if they had been born low birth weight. Finally, children with better motor control at age 3 were reported to have fewer behavior problems in kindergarten. Collectively, these findings suggest that for learning-related behaviors, motor control followed a compensatory model of development for children born low birth weight. By contrast, all children, regardless of birth weight, benefited equally from motor control in predicting behavior problems.

As hypothesized, toddlers who demonstrated greater motor control at age 3 evidenced higher levels of approaches to learning in kindergarten. This finding is consistent with previous studies linking composite measures of EC with teacher-reported learning behaviors (Campbell & von Stauffenberg, 2009; Murray & Kochanska, 2002) and provides additional insight into how motor control, in particular, may contribute to this association. One previous study found that motor control, but not delay of gratification, was uniquely associated with learning-related behaviors in kindergarten (Brock et al., 2009). Thus, our findings are the second to specify a link between early motor control, an aspect of behavioral inhibitory control, and work habits and attitudes toward learning in kindergarten. Past research has found that greater motor control predicts higher academic achievement in preschoolers (Bierman et al., 2008; Maccoby et al., 1965; but see Liew et al., 2010). Future research with measures of motor control, learning behaviors, and academic achievement should explore the possibility that the association between motor control and academic achievement is mediated in part or whole by more adaptive learning behaviors. It is possible that children who are better able to control their motor movements have an easier time participating in seat work, which allows them to absorb instructional content and complete group and individual learning activities.

Surprisingly, we did not find a link between early motor control and teacher-reported attention problems in kindergarten for normal birth weight children. One possible explanation is that the attention problems scale used in this study did not sufficiently capture the problems most likely to reflect poor motor control. The attention problems scale included more items that were cognitively-based (e.g., is confused or daydreams) than behaviorally-based (e.g., can't sit still or is impulsive). Future studies should include a scale of ADHD symptoms that are likely to be more sensitive to variation in motor control. Indeed, there is evidence that motor ability is compromised in children with ADHD (Kalff et al., 2003; Piek, Pitcher, & Hay, 1999; Pitcher, Piek, & Hay, 2003). Our measure of attention problems may also have been underestimated if teachers are less able to report cognitive than behavioral manifestations of attention problems because the former are less observable.

As with EC more broadly measured (Gartstein & Fagot, 2003; Olson et al., 2005), early motor control predicted teacher-reported behavior problems in kindergarten. Although motor control may be considered a facet of cool EC and thus unlikely to predict behavior problems, we hypothesized that poor motor control may exclude children from play with peers and signal non-compliance to teachers, both of which could undermine socioemotional competence. Previous empirical evidence was mixed, as one study reported links between motor control and both social competence and aggression (Bierman et al., 2008), while another found a link between motor control and social competence but not externalizing behaviors (Dennis et al., 2007). Our measure of behavior problems combined social competence with aggression because the correlation between the two was too high to disaggregate them. Nevertheless, our finding suggests the possibility that motor control predicts aggression, as found by Bierman et al. (2008). It is possible that Dennis et al. (2007) failed to find that association because it used parent rather than teacher reports of behavior problems. Parents of children at risk for psychopathology may be biased in their reporting of externalizing behaviors. Additionally, children's behavior at home and at school are not identical, as the two contexts place different demands on children. Further research is needed to explicitly test whether motor control confers greater rewards for children's behavior in school than at home.

Relatedly, more research is needed to reveal the specific mechanisms through which children's ability to slow down motor activity predicts better social functioning in the classroom. It is likely that the ability to slow motor activity enhances children's capacity to suppress expressions of anger, frustration, and boredom. Young children who are perceived as aggressive or even merely disruptive are rejected by both peers and teachers (Hubbard, 2001; Olson, 1992; Wood, Cowan, & Baker, 2002). Motor control may also promote prosocial behaviors by allowing children to sustain participation in organized classroom activities and games with peers that are demanding of gross motor skills. Indeed, this possibility is supported by research indicating that gross motor skills (Gulay, Seven, &

Damar, 2010) and perceived athletic competence (Dunn et al., 2007) are important predictors of children's peer relations and social status.

In this study, motor control followed a compensatory model of development in predicting learning-related behaviors for children who were born low birth weight. Motor control was more strongly associated with better approaches to learning, and exclusively associated with fewer attention problems, for children born low birth weight. However, motor control was equally protective against behavior problems for low and normal birth weight children. Motor control may have been more advantageous for low birth weight children in promoting learning behaviors than in averting behavior problems because low birth weight is a bigger liability for achievement problems than it is for behavior problems. Klebanov et al. (1994) found that teachers rated low birth weight children higher than normal birth weight children on hyperactivity but equally on aggression. A few studies have directly linked low birth weight to behavior problems (Breslau et al., 1996; Gray et al., 2004; Rickards et al., 2001, but see Szatmari et al., 1990), but ample evidence links low birth weight, and especially very low birth weight, to cognitive delays and lower achievement (e.g., McCormick, Gortmaker, & Sobol, 1990; see Reichman, 2005, for a review). These problems implicate learning-related behaviors more than socioemotional problems like aggression for children born low birth weight; thus, motor control may be particularly protective against deficiencies in that domain.

Limitations

An important limitation of our study is its exclusive focus on motor control and lack of measures that tap delay of gratification and suppress/initiate behavior, which may reflect cognitive inhibitory control. Ideally, all three of these facets of EC would be examined in one model, allowing for estimates of unique variance accounted for by motor control. Given that only motor control was assessed here, to an unknown degree, our findings may reflect confounding by delay of gratification or cognitive control. However, although motor control, cognitive control, and delay of gratification are all considered indicators of EC, they are not likely to strongly covary. For example, in Dennis et al. (2007), the correlations between the walk-a-line and two cognitive control tasks were .16 - .20 (not significant), and in Murray and Kochanska (2002), the motor control and the cognitive control factors had an r of .18. A recent meta-analysis found that motor inhibition, assessed using the slow drawing task, was only moderately correlated with executive function ($r = .17$) and delay of gratification ($r = .11$; Duckworth & Kern, 2011). Therefore, the associations reported here between motor control and classroom behaviors should reflect minimal confounding with unmeasured aspects of EC.

Another limitation of this study was its exclusive measurement of gross motor control. Ideally, assessments of motor control would also tap fine motor control, as this skill may also contribute to classroom behaviors that have implications for learning. For example, fine motor skills are essential for drawing and writing, and thus may facilitate independence and persistence in schoolwork, while curbing frustration and disengagement. Early fine motor skills predict kindergarten achievement (Cameron et al., 2012), and kindergarten fine motor skills predict subsequent achievement (Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010).

Early fine motor skills also buffer against the influence of negative teacher-student relationships on achievement (Liew et al., 2010). Fine motor skills may benefit children in social contexts, such as game playing or building, that require skill manipulating materials. Further research is needed to understand the specific mechanisms through which motor control, indexed by both gross and fine motor skills, influence children's classroom behaviors, as motor control may serve as a target for interventions to promote school readiness. Indeed, there is evidence that circle-time games that promote behavioral inhibition, like red light-green light, and mindful yoga, which includes basic breathing exercises and postures, can enhance self-regulation among preschoolers (Razza, Bergen-Cico, & Raymond, 2015; Tominey & McClelland, 2011). Thus, teachers may be able to help children develop motor control via simple and enjoyable group activities. Improving motor control may be an effective way of both enhancing learning behaviors and deterring behavior problems.

Acknowledgments

Funding: The Fragile Families and Child Wellbeing Study is funded by NICHD grant numbers R01HD36916, R01HD39135, and R01HD40421, as well as a consortium of private foundations and other government agencies.

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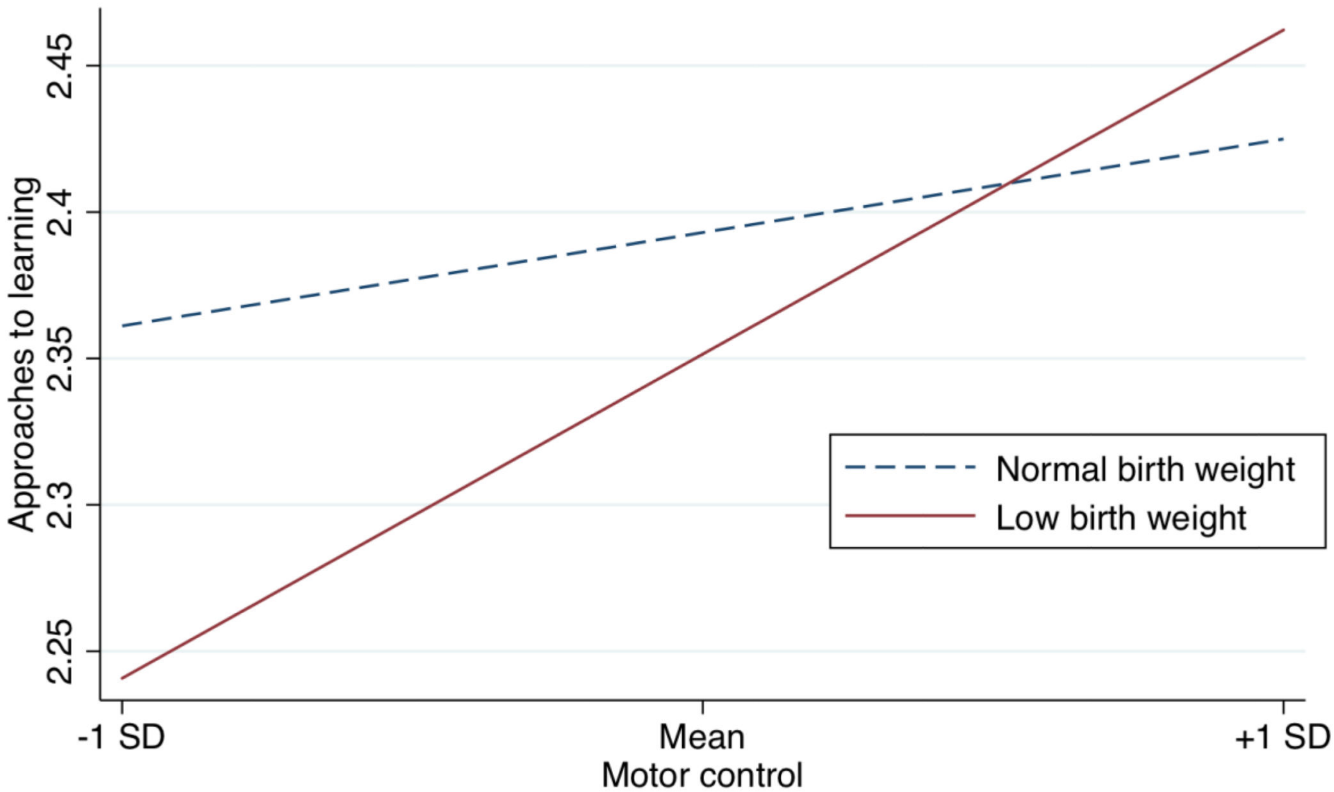

Figure 1.
The association between motor control and approaches to learning as a function of birth weight.

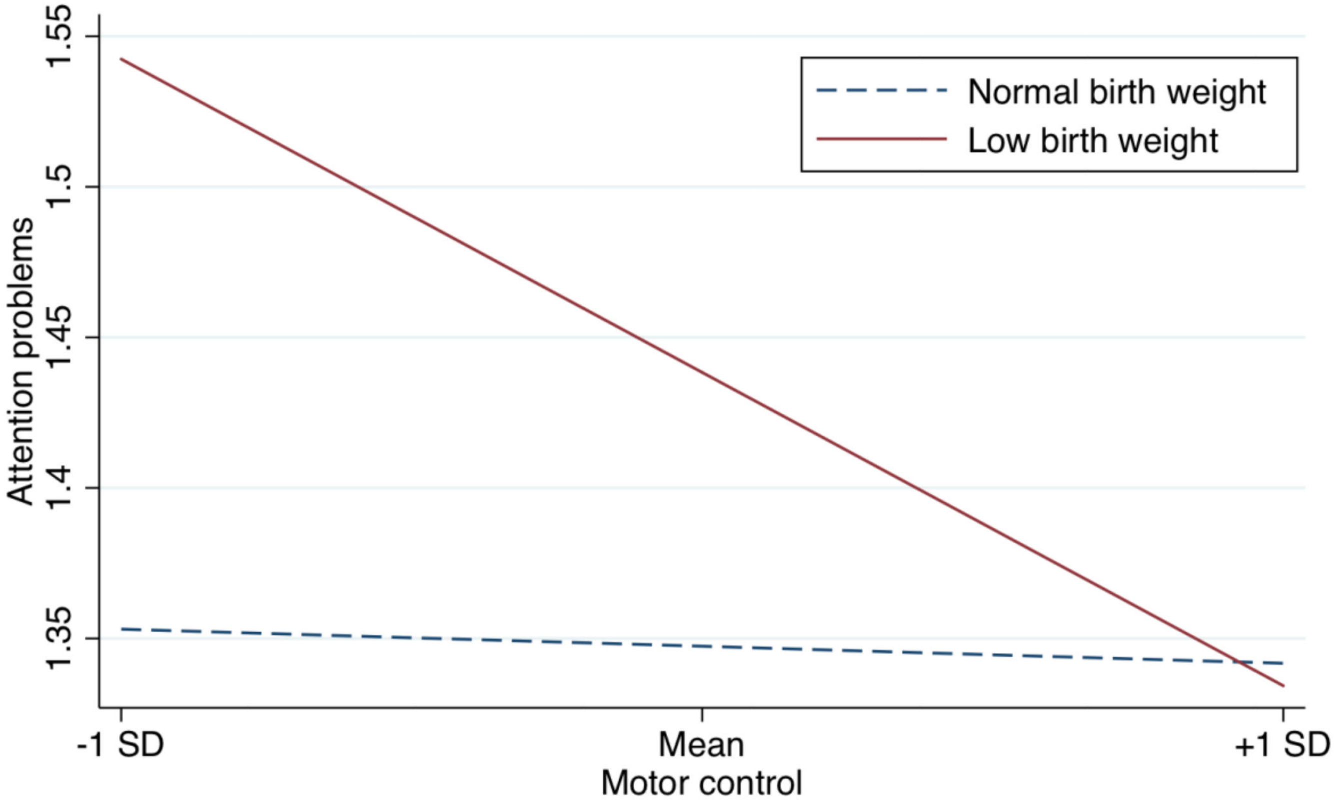

Figure 2.
The association between motor control and attention problems as a function of birth weight.

Table 1

Descriptive Statistics for Control, Predictors, and Outcome Variables

Variable	*M*	*SD*	%
Predictor and Moderator			
Motor control (age 3)	1.23	2.65	
Low birth weight			7.30
Controls			
Child male			47.67
Maternal race/ethnicity			
White			26.47
Black			45.30
Hispanic			24.23
Other			4.00
Maternal education			
Less than high school			26.98
High school graduation/GED			26.95
Some college or more			46.07
Maternal marital status			
Single			34.49
Cohabiting			29.16
Married			36.35
Family in poverty (<100% threshold)			38.08
Negative emotionality (age 1)	2.73	1.06	
Child receptive vocabulary	89.46	17.91	
Mother-child attachment security	−0.59	0.51	
Outcomes			
Approaches to learning	2.40	0.58	
Attention problems	1.36	0.48	
Behavior problems	1.19	0.34	

Note. Calculations are based on five multiple imputed data sets. $N = 751$.

Table 2

Correlations among Motor Control, Low Birth Weight, and Age 5 Outcomes

	1.	2.	3.	4.
1. Motor control	--			
2. Low birth weight	−.02	--		
3. Approaches to learning	.12***	−.06	--	
4. Attention problems	−.08*	.06	−.65***	--
5. Behavior problems	−.08*	.08*	−.49***	.50***

Note. Table presents bivariate correlations.

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 3

Results of Regression Models Predicting Classroom Behaviors at Age 5

	Step 1			Step 2		
	B	*SE*	β	*B*	*SE*	β
	Approaches to learning (*n* = 749)					
Motor control (MC)	0.01 *	0.00	0.06	0.01 *	0.00	0.05
Low birth weight (LBW)	−0.05	0.08	−0.02	−0.04	0.09	−0.02
MC × LBW				0.03 *	0.01	0.04
R^2 or ΔR^2		0.14 ***			0.01 *	
	Attention problems (*n* = 748)					
Motor control (MC)	−0.01	0.00	−0.03	0.00	0.00	−0.01
Low birth weight (LBW)	0.10	0.05	0.06	0.09	0.06	0.06
MC × LBW				−0.04 **	0.01	−0.07
R^2 or ΔR^2		0.13 ***			0.01 **	
	Behavior problems (*n* = 748)					
Motor control (MC)	−0.01 *	0.00	−0.05	−0.01	0.00	−0.05
Low birth weight (LBW)	0.11	0.09	0.06	0.11	0.09	0.06
MC × LBW				−0.01	0.02	−0.01
R^2 or ΔR^2		0.07 ***			0.00	

Note. Models include controls for child sex, maternal race/ethnicity, maternal education, maternal marital status, child receptive vocabulary, child negative emotionality, mother-child attachment security, and poverty status.

* $p < .05$;

** $p < .01$;

*** $p < .001$.