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Cognition and classroom quality as predictors of math achievement in the kindergarten year

A. Nayena Blankson [a, *], Clancy Blair [b]

[a] Spelman College, United States
[b] New York University, United States

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ABSTRACT

Using a sample of 171 children, we examined classroom quality as a potential moderator of the link between three distinct but related aspects of cognition (fluid intelligence, crystallized intelligence, and executive functioning) and math achievement across the kindergarten year. Multilevel modeling analyses were conducted to account for nesting of students within classrooms. Results revealed significant aptitude by treatment interactions for fluid and crystallized intelligence, suggesting that classroom practices may affect children differently depending on their abilities. Children with higher levels of fluid intelligence and of crystallized intelligence fared better in higher quality classrooms. Results also provide some support for Cattell's investment hypothesis. Implications of the results are discussed.

1. Introduction

In an increasingly technological world, there is greater need for individuals who are skilled in math. Math skills are relevant for many career fields, and they are also important in personal health and decision making (Reyna & Brainerd, 2007). Moreover, math skills are necessary to allow the US to become more competitive in the global economy (US Department of Education, 2007), highlighting the importance of math achievement in our nation. Although US high school students won the International Mathematical Olympiad for the first time in 21 years in 2015, (Washington Post, 2015), concerns have been raised regarding math achievement in American students because American students continue to lag behind East Asian countries and several European nations in math achievement (Provasnik, Gonzales, & Miller, 2009; Provasnik et al., 2013). It has been observed that math achievement in the kindergarten year is a strong predictor of later achievement (Claessens & Engel, 2013; Duncan et al., 2007).

Although children in the United States are not required to begin school until first grade, which generally occurs around age 6 in most states (National Center for Education Statistics, 2010), the kindergarten year, occurring around age 5, is the first year of formal school entry for most children (La Paro et al., 2009). Thus, investigation of factors that predict math achievement in the kindergarten year is of national import. Cognitive abilities are the strongest predictors of early academic achievement (Watkins, Lei, & Canivez, 2007). However, we do not yet have a full understanding of the contexts under which there might or might not be relations between various aspects of cognition and academic achievement in the early years. In the present research, we examine whether classroom quality moderates the link between distinct aspects of cognition and math achievement in the kindergarten year.

1.1. Cognition and math achievement

Current research indicates that human abilities consist of many different components that are interrelated, but that would be expected to have unique effects on a given outcome (Horn & Blankson, 2012), such as math achievement. Therefore, it has been argued that increased attention should be paid to examination of specific cognitive abilities to increase our understanding of the factors that predict achievement (McGrew & Wendling, 2010). A growing number of studies focus on distinct cognitive constructs, primarily fluid intelligence, crystallized intelligence, and executive functioning, in the examination of achievement outcomes (e.g., Blair & Razza, 2007). Fluid intelligence is reasoning to arrive at

* Corresponding author. Department of Psychology, Spelman College, 350 Spelman Lane, S. W., Box 259, Atlanta, GA 30314, United States.
E-mail address: ablanks1@spelman.edu (A.N. Blankson).

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understanding relations among stimuli, comprehending implications, and drawing inference (Horn & Blankson, 2012). Fluid intelligence is often exhibited in matrix reasoning tests. Elements of the matrix reasoning tests are figures such as circles, squares, and triangles, which are equally familiar to all. The relationships among the elements in the matrix are those of order and size that run across the rows and down the columns of the matrix. The task is to comprehend the relationships in order to fill in an element that is missing in the matrix. Relationships among elements in the matrices are not much taught in school settings. Mathematical questions often require one to figure out a problem, come up with possible ways to solve a problem, select one or more of the possible ways to solve the problem, and implement the selected strategy to arrive at a solution. The reasoning involved is inherent in the conceptualization of fluid intelligence. Children with strong fluid reasoning skills have been found to perform well on tests of math achievement (Flanagan, Ortiz, Alfonso, & Mascolo, 2006; McGrew & Wendling, 2010).

Crystallized intelligence, which is related to but independent from fluid intelligence, represents knowledge acquired through social transmission. Such knowledge can be acquired through schooling and is often measured by tests of vocabulary (Blair, 2006; Horn & Blankson, 2012). Crystallized knowledge has also been found to be related to math achievement (Floyd, Evans, & McGrew, 2003).

Executive functioning refers to a set of domain general cognitive skills that involve attentional focusing and flexibility, cognitive inhibitory control, and working memory (Diamond, Barnett, Thomas, & Munro, 2007; McClelland et al., 2007; Montgomery, Anderson, & Uhl, 2008). Research suggests that in the preschool and kindergarten years, executive functions are best represented as a unitary factor rather than distinct functions (Mungas et al., 2013; Wiebe, Espy, & Charak, 2008). Executive functioning may be especially relevant to the development of math skills. In solving mathematical problems, the individual is expected to not only come up with potential solutions, which would involve fluid reasoning skills, but also hold the potential solutions in their immediate short term awareness and manipulate this information prior to arriving at a final solution (Geary, Hoard, & Hamson, 1999).

Indeed, researchers are beginning to explore the effects of different cognitive abilities on math achievement (e.g., Parkin & Beaujean, 2011). Although the conclusion reached by Parkin and Beaujean (2011) was that a single factor model better predicted math achievement than did a model with multiple factors, in a research synthesis by McGrew and Wendling (2010), results indicated that there are differential relations between specific abilities and math achievement. For example, crystallized intelligence and fluid intelligence were related to arithmetic and computational skills, whereas short-term memory was not consistently related to arithmetic and computational skills. Fluid intelligence was also more strongly related to problem solving skills than was crystallized intelligence. Relatedly, Hale et al. (2008) examined a general cognitive ability construct as well as subcomponent scores as predictors of mathematics achievement in typically developing children and children with math disabilities. Results indicated greater predictive validity for the subcomponent scores, thus highlighting the need for assessing specific cognitive abilities in research on achievement outcomes.

Fluid intelligence, crystallized intelligence, and executive functioning have all repeatedly been found to be related to math achievement (e.g., Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008; Flanagan et al., 2006; Fuhs, Nesbitt, Farran, & Dong, 2014; McGrew & Wendling, 2010). However, no studies have examined these three cognitive ability variables as predictors of math achievement in the kindergarten year within the context of the classroom environment. From a contextual perspective (Bronfenbrenner, 1994), aspects of the child's environment interact with the child's own characteristics to produce adaptive or maladaptive outcomes. Next to the home environment, the classroom environment is the most proximal source of influence on a child's academic outcomes. Thus, examination of school entry cognition within the context of the classroom environment will lead to better understanding of the impact that early cognitive abilities and environmental factors play in math achievement.

1.2. The role of classroom quality

Classroom quality has garnered increased attention in recent years, with many states developing standards of excellence for kindergarten classrooms (e.g., New Jersey Department of Education, 2011). Several frameworks, such as the Classroom Assessment Scoring System (CLASS; Pianta, La Paro, & Hamre, 2006) have been developed for understanding the effects of classroom experiences on student outcomes. Elements of the classroom that have been observed to affect achievement range from the physical environment, such as the quality of learning materials in the classroom, to student–teacher relationships, such as emotional responsivity of the teachers toward their pupils (Hamre, Pianta, Mashburn, & Downer, 2007). Within these frameworks, three aspects of the classroom environment that have been identified are classroom organization, instructional support, and emotional support, each of which has been found to affect achievement (Pianta, La Paro, & Hamre, 2008). Classroom organization refers to the extent to which the teacher creates an atmosphere that is conducive to learning and provides opportunities and material for learning to take place. Instructional support refers to the extent to which teachers scaffold more complex thinking in pupils. Emotional support includes the emotional connection displayed by a teacher towards her students, the extent to which negative emotions are displayed by the teacher or students in the classroom, and the teacher's sense of awareness about student needs and perspectives (Pianta et al., 2006). When children are in classrooms that are more organized, this may maximize available opportunities for learning. If the classroom environment is organized, the teacher will spend more time on teaching the students and less time in preparing materials during the class time. Likewise, if teachers are warm and responsive, they may be better able to motivate children to learn (La Paro et al., 2009) and may have pupils who are better behaved (Raver et al., 2009). Classroom organization, instructional support, and emotional support have been found to be related to each other and are often measured using the CLASS (Pianta et al., 2006), which was used in the present study.

Theory and empirical research indicates that better classroom quality leads to greater achievement in young children. For example, Hamre and Pianta (2005) found that 5- to 6-year-old students who were at risk of failure performed as well as their low-risk counterparts when placed in classrooms with higher levels of instructional and emotional support. Perry, Donohue, and Weinstein (2007) found that students in classrooms with greater levels of instructional and emotional support made greater gains in math achievement than those in classrooms of poorer quality. These findings are consistent with other research that has highlighted the important role of classroom quality on student achievement (e.g., Cadima, Leal, & Burchinal et al., 2010; Reynolds & Ou, 2011; Weinert & Helmke, 1995). Moreover, effects of classroom quality have been observed not only in research on US samples (e.g., Pianta et al., 2008), but in European samples as well (e.g., van de Grift, 2007).

To date, no studies have considered whether classroom quality moderates the association between the cognitive abilities under