Learning and Instruction 41 (2016) 85–93

Contents lists available at ScienceDirect

Learning and Instruction

journal homepage: www.elsevier.com/locate/learninstruc

Moderating effects of executive functions and the teacher–child relationship on the development of mathematics ability in kindergarten

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ARTICLE INFO

Article history:
Received 8 December 2014
Received in revised form
30 September 2015
Accepted 18 October 2015
Available online 2 November 2015

Keywords:
Mathematics
Early childhood
Executive functions
Self-regulation
Teacher–child relationship
Kindergarten

ABSTRACT

Academic preparedness, executive function abilities, and positive relationships with teachers have each been shown to be uniquely important for school readiness and success in the early elementary grades. Few studies, however, have examined the joint influence of these readiness variables on early school outcomes. Using data from a prospective longitudinal sample of 1292 children and families in predominantly low-income and rural communities, we found that executive function at child age 48 months and a higher quality relationship with the kindergarten teacher each uniquely moderated the effect of math ability in preschool on math ability at the end of kindergarten. This effect was seen for math ability as measured by the Early Childhood Longitudinal Study-Kindergarten (ECLS-K) mathematics assessment battery but not the Woodcock-Johnson III Tests of Achievement Applied Problems subtest. For children with lower math ability in preschool as assessed by the ECLS-K Math battery, higher executive function abilities and a more positive relationship with the kindergarten teacher were each associated with a higher than expected level of math ability in kindergarten. Conversely, lowest levels of math ability in kindergarten were observed among children with low math ability in preschool and poor executive function or a less positive relationship with the kindergarten teacher.

Early academic ability is a strong predictor of later academic ability. Children with greater knowledge and understanding of letters and number concepts at school entry achieve at higher levels academically in later grades than their less well prepared peers (Duncan et al., 2007). Although academic preparedness plays a prominent role in school readiness (Duncan et al., 2007; Pianta, La Paro, Payne, Cox, & Bradley, 2002), self-regulation abilities, including executive functions as well as social and emotional aspects of self-regulation are also important (Blair & Raver, 2015). For example, children who can effectively hold information in mind in working memory, selectively attend to stimuli, and inhibit irrelevant and distracting information – executive function abilities that in part undergird self-regulated learning and metacognitive skills (Zimmerman, 2008) – achieve at higher levels academically than children who are less adept at these abilities (Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008; McClelland et al., 2007; Raver et al., 2011). Similarly, children with positive relations and low levels of conflict with teachers, indicative of social-emotional competence, are more likely to demonstrate higher academic performance (Burchinal et al., 2008; Hamre & Pianta, 2001; Liew, Chen, & Hughes, 2010; Schmitt, Pentimonti, & Justice, 2012), particularly when receiving higher quality instruction (Crosnoe et al., 2010).

Predictors of school readiness and early academic progress are well established. Less is known, however, about relations among these predictors. No studies of which we are aware have examined the possibility that effects of aspects of self-regulation such as executive function abilities and the child's relationship with the teacher are most pronounced for children with initially low levels of academic preparedness for kindergarten. Whereas children entering school with well-developed academic skills will likely meet classroom learning goals, higher levels of executive function abilities and more positive relationships with teachers should in

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http://dx.doi.org/10.1016/j.learninstruc.2015.10.001
0959-4752/

theory help children with limited academic preparedness as assessed by standardized measures to capitalize on learning opportunities and to make larger gains than would be expected from preschool level of ability on its own. Executive function abilities would assist children in maximizing engagement in learning activities while close supportive relationships with teachers would provide an increased level of attention and support in learning activities. Teachers provide more explanation and scaffolding for children with whom they report being close (Allington, 1984; Nomi, 2009) and this increased instruction has been shown to be important for academic achievement (Hamre, Hatfield, Pianta, & Jamil, 2014; Hamre & Pianta, 2001). Thus, executive function abilities and positive relationships with teachers may help close an early achievement gap for children with initially low levels of measured academic ability at school entry.

The purpose of our study was to test the hypothesis that executive function abilities and the quality of the relationship with the kindergarten teacher will each individually interact with mathematics ability measured in preschool to predict mathematics ability measured at the end of kindergarten. We focus on early mathematics learning given the generally high metacognitive demand of early math learning and for reasons related to the measurement of early ability in math. Mathematics, even for very young children includes activities focusing on pattern completion and the identification of conceptual relations among problem elements that make substantial demands on reasoning and abstraction (Baker et al., 2010; Blair, Knipe, & Gamson, 2008). Early reading also makes demands on reasoning, for example holding in mind rules for spelling and syntax that are unique to specific letter or word combinations. Measures of early reading, however, tend to focus on knowledge of letters and words more so than on reasoning. In contrast, measures of early math ability generally include items assessing reasoning and conceptual skills as well as knowledge-based aspects of mathematics. Thus, for conceptual and methodological reasons, we focus our analysis on early mathematics learning but suggest that our approach is also relevant to early reading and to academic achievement more generally.

Methodologically, we focus on a sample at risk for early difficulty in school due to poverty. Children from low-income homes tend to enter kindergarten with less well developed academic abilities than their higher income counterparts (Brooks-Gunn & Duncan, 1997; Duncan & Brooks-Gunn, 1997). It is also well established, however, that children from poverty backgrounds are more likely to enter school not only less prepared academically but also with less developed self-regulation skills (Fitzpatrick, McKinnon, Blair, & Willoughby, 2014; Noble, McCandliss, & Farah, 2007). It may be that the combination of poor academic preparedness with poor EF or with a less positive relationship with the teacher is associated with the least positive learning trajectory into kindergarten. If so, this would indicate a group of children who are at high risk for early school difficulty.

1. Aims and hypotheses

The foregoing underscores the importance of understanding how initial math preparedness, executive functioning, and the quality of teacher–child relationships may uniquely and interactively predict academic outcomes in kindergarten. Although prior research has shown the importance of each domain independently, far less is known about relations among these aspects of children's early schooling. This study builds on prior research on school readiness by examining these relations in a large prospective, longitudinal sample in two regions of high poverty in the United States. In light of persistent and increasing gaps in academic achievement associated with poverty (Reardon, 2011), potential moderating effects of executive functions and positive relationships with teachers on the development of mathematics ability between preschool and kindergarten may provide some insight into ways in which to narrow the achievement gap and inform efforts to identify children at highest risk for early school difficulty.

Importantly, to address the foregoing points, we simultaneously examine two highly reliable and widely validated measures of early math ability, namely, the ECLS-K Math assessment from the Early Childhood Longitudinal Study – Kindergarten cohort study and the Applied Problems subtest of the Woodcock-Johnson III Tests of Achievement. The ECLS-K Math battery was developed in response to the need for a sensitive measure of the development of math skills in early childhood whereas the Applied Problems subtest was developed to assess mathematics ability across the lifespan from ages 2–90 years. As such, examination of the two measures provides a more complete understanding of the development of early math abilities with implications for mathematics assessment in early childhood.

2. Method

2.1. Participants

The Family Life Project (FLP) was designed to study young children and their families who live in two (Eastern North Carolina, Central Pennsylvania) of the four major geographical areas of the United States with high poverty rates (Dill, 2001). The FLP adopted a developmental epidemiological design in which sampling procedures were employed to recruit a representative sample of 1292 children whose families resided in one of the six counties at the time of the child's birth. Low-income families in both states and African American families in NC were over-sampled (African American families were not over-sampled in PA because the target communities were at least 95% non-African American). Full details of the sampling procedure appear elsewhere (Vernon-Feagans, Cox & the FLP Investigators, 2013).

Data in the current analysis ($N = 1005$) were collected during visits when the target child was 48 months old (n = 920; $SD = 2$ months), of preschool age (n = 907; age $M = 60$ months, $SD = 3$ months), and in kindergarten (n = 1005; age $M = 71$ months, $SD = 3$ months). Primary caregivers reported children as 54% Caucasian, 46% African American, less than 1% other ethnicities, and half of children were male (49%). Almost three-quarters of the families were low-income (72%). Half of the mothers were not married (52%), almost half of the mothers had a high school education or less (40%), and only 16% had at least 4 years of postsecondary education. At the preschool age data collection, 76% of the children were in child care or preschool classrooms with an average of 1.8 target children per classroom, and the remaining 24% were in home care. At the time of the kindergarten visit, children were nested in 487 classrooms, most of which had 1 target child (52%, range 1–10).

2.2. Procedures

At the 48-month home visit, two researchers visited the family's home and administered an executive function battery as part of a longer battery of tasks with parents and children. At the preschool and kindergarten visits, researchers visited children at school, or at home when in home care, and administered the ECLS-K Math battery, Applied Problems subtest, and the Peabody Picture Vocabulary Test (PPVT) as part of a larger battery of early academic achievement measures. Kindergarten teachers were given a packet of questionnaires to complete that included ratings of the quality of the teacher's relationship with the target child. Teacher questionnaires were distributed in the spring, providing ample time for