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Cumulative risk, teacher-child closeness, executive function and early academic skills in kindergarten children☆

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ABSTRACT

We tested the role of teacher-child closeness in moderating the associations between early childhood adversity, measured as a cumulative risk index, and child outcomes during the kindergarten year. Using the ECLSK:11, a national dataset of kindergarteners in the 2010–11 academic year, we examined three dimensions of executive function (cognitive flexibility, inhibitory control, working memory), as well as early reading and math scores, as key skills that facilitate the transition to school. Cumulative risk was negatively associated with all outcomes, and teacher-child closeness was positively associated with all outcomes. Teacher-child closeness moderated the relation between cumulative risk and working memory and cumulative risk and reading scores in a protective manner, but not cognitive flexibility, inhibitory control, or math scores. Implications for research in early childhood adversity and education are discussed.

1. Introduction

Children draw on a range of skills in their transition and adaptation to school (e.g., Blair & Razza, 2007; McClelland, Morrison, & Holmes, 2000). Executive function (EF) and early academic skills (e.g., reading and math) are particularly important for school success (Blair & Raver, 2015; Duncan et al., 2007). EF skills allow children to control their behavior, organize thoughts, manage emotions, and focus their attention to accomplish desired tasks and goals (Diamond, 2013), which facilitate learning in a classroom environment. Moreover, children's reading and math skills at school-entry are powerful predictors of later academic achievement (Duncan et al., 2007) and have been shown to develop in concert with EF over time (e.g., Skibbe, Montroy, Bowles, & Morrison, 2018; Wolf & McCoy, 2019).

Exposure to risk factors can disrupt children's transition to school and the development of EF and academic skills (Blair, Granger, & Peters Razza, 2005), which may partially explain the negative associations between early adversity and later academic achievement. The link between early adversity and disparities at school entry has been well-established and can be consequential for children's academic trajectories (e.g., García, 2015). Early disparities are particularly troublesome because early educational gaps are persistent throughout elementary school and even widen with time (Bradbury, Corak, Waldfogel, & Washbrook, 2015). At the same time, there is accumulating evidence demonstrating that positive early teacher-child relationships can significantly benefit children's academic success, with close relationships improving children's academic trajectories (Hughes & Kwok, 2007) and conflictual relationships having negative effects on schooling outcomes (Hamre & Pianta, 2001; O'Connor, 2010). Teachers' provision of interpersonal support to children, beyond pedagogy alone, has been posited to be particularly important for the development of complex,

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higher-order thinking skills such as EF and early academic outcomes (Crosnoe, Leventhal, et al., 2010; Crosnoe et al., 2010). Less is known, however, about the specific protective effects of close teacher-child relationships in high-risk populations, though one quasi-experimental study found that high-quality teacher-child relationships improved academic achievement for low-income, racial/ethnic minority students attending urban schools (McCormick, O'Connor, Cappella, & McClowry, 2013).

In the current study, we applied a cumulative risk framework (Evans, Li, & Whipple, 2013) to develop a risk index representing early experiences associated with disadvantage and adversity. We examined the association between cumulative risk with EF and emerging academic skills, as well the promotive and protective role of teacher-child closeness, during the kindergarten school year in a national sample of kindergarteners. The majority of studies to date on teacher-child relationships have focused on academic outcomes; we expanded this literature to also consider EF.

1.1. Executive function and emerging academic skills as key school readiness indicators

1.1.1. Executive function

EF is a domain-general, multidimensional construct that is composed of three core elements: *working memory* (allows children to hold on to information and access it for use), *inhibitory control* (ability to focus on the present stimuli), and *cognitive flexibility* (ability to think flexibly and consider multiple concepts concurrently; Diamond, 2013). These three dimensions are distinct but interconnected, and typically operate in tandem to support children's early school success (e.g., Blair & Razza, 2007). EF skills help children control impulses, maintain and shift attention, and manipulate information in working memory (Blair, 2002; Miyake et al., 2000), all important skills for successful classroom engagement and learning. Increasingly, EF and self-regulatory behaviors are seen as central for children's successful adaptation to kindergarten, as such skills have been linked to children's growth in academic achievement (e.g., Bull & Lee, 2014; Jacob & Parkinson, 2015) and even prosocial skills (Wolf & McCoy, 2019). EF is susceptible to both the negative impact of early adversity and positive inputs, because the brain regions that support these skills have a prolonged developmental trajectory (Phillips & Shonkoff, 2000; Zelazo & Carlson, 2012).

1.1.2. Emerging academic skills

Early reading and *early math* are domain-specific skills that children develop through a cumulative and iterative process. Children are continuously refining and building on previous knowledge in order to learn new, more advanced material (Cunha & Heckman, 2007), which highlights the need to master foundational content early in their schooling. In a large study using six national datasets, early reading and math skills were the strongest predictors of later reading and math achievement (Duncan et al., 2007). Some studies have found that early reading skills also predict later social and behavioral outcomes. Herbert-Myers, Guttentag, Swank, Smith, and Landry (2006), for example, found that children's reading skills at age three were predictive of social competence at age eight, whereas Miles and Stipek (2006) found negative links between first grade reading skills and third grade aggression. In addition, mastering early foundational math skills in kindergarten is critical to grasp advanced concepts in subsequent grades (Jordan, Kaplan, Ramineni, & Locuniak, 2009).

1.1.3. EF and early academic skills develop together

The development of EF and emerging academic skills is intertwined and begins prior to school entry. A broad body of correlational research suggests that children's early EF skills are predictive of their academic outcomes, both cross-sectionally and longitudinally (e.g., Bull, Espy, Wiebe, Sheffield, & Nelson, 2011; Matthews, Ponitz, & Morrison, 2009; Ponitz, McClelland, Matthews, & Morrison, 2009; Rimm-Kaufman, Curby, Grimm, Nathanson, & Brock, 2009). For example, prior work has shown positive associations between different EF subskills and math achievement in preschoolers across diverse populations (e.g., Lan, Legare, Ponitz, Li, & Morrison, 2011; McClelland et al., 2014; Welsh, Nix, Blair, Bierman, & Nelson, 2010). A smaller but growing body of evidence has examined associations between EF and reading outcomes. Several recent studies have found evidence of bidirectionality between EF (measured as a single construct) and young children's language skills, with language being a stronger predictor of EF development than vice versa (Meixner, Warner, Lensing, Schiefele, & Elsner, 2019; Slot & von Suchodoletz, 2018; Wolf & McCoy, 2019). The family environment has a strong impact on children's acquisition of reading-related skills (Christian, Morrison, & Bryant, 1998). To support the development of these skills, parents can create learning opportunities for children by providing stimulating and developmentally appropriate spaces at home, including joint reading time.

1.2. Defining exposure to risk

1.2.1. Early risk and school readiness

Childhood adversity refers broadly to experiences that pose a risk to optimal development. Early experiences of risk are relatively common in the U.S. Population-based estimates indicate that about 50% of children are exposed to at least one form of adversity (e.g., Green et al., 2010). Importantly, there is not widespread agreement on how to define risk factors, and the way risk is operationalized varies across studies (Evans et al., 2013; Green et al., 2010) and disciplines (e.g., Bethell, Simpson, & Solloway, 2017). At the core is a lack of stimulation, safety, and nurturance for the child, which requires significant psychosocial adaptations to unexpected stressful environments (i.e., adjusting to deviations from an “expectable environment;” Fox, Levitt, & Nelson III, 2010). Experiences of early risk can jeopardize children's development of emerging academic skills and executive functioning, which could have substantial implications on academic achievement given their predictive strength (Duncan et al., 2007).

A rich body of literature exists linking a wide-range of adverse childhood experiences to children's learning, including economic

hardship (e.g., Kainz, Willoughby, Vernon-Feagans, & Burchinal, 2012) and exposure to physical abuse and inter-parental aggression (Perkins & Graham-Bermann, 2012; Towe-Goodman, Stifter, Coccia, Cox, and Family Life Project Key Investigators, 2011). Similarly, studies grounded in developmental neurobiology have reached parallel conclusions: early—but not later—experiences of economic-related stress are negatively associated with areas of the brain responsible for memory and implicit learning (Humphreys et al., 2018). Lastly, children's early academic skills are malleable and burgeoning in the preschool years, and become increasingly stable around third grade (Lonigan, Burgess, Anthony, & Barker, 1998). This suggests that the first years of school may serve as a critical window of opportunity for improving children's longer-term schooling outcomes.

1.2.2. Cumulative risk

Exposure to a *single* risk factor typically does not pose significant harm to child development. However, children exposed to *multiple* risk factors are much more likely to be susceptible to psychopathology (Green et al., 2010), suggesting that the number of adverse experiences can compromise the psychological and physiological ability to adapt. A cumulative risk model is the most common approach to assessing the effects of multiple risks; this approach examines the number of risks experienced, rather than the type, severity, or frequency (Evans et al., 2013). To do this, a risk factor, such as poverty, is dichotomized based on its presence (e.g., household income is below the federal poverty line equals risk; household income above the federal poverty line equals no risk). The next step would be to sum all risks for a cumulative risk score.

There are several strengths to this approach, including that it is a straightforward and powerful method for assessing the likelihood of a child to be at risk for a range of poor outcomes. Risk assignment can be based off of a particular statistical cut-off point or previously established theories (e.g., poverty). We used a combination of both risk assignment techniques in this study. Importantly, this approach also has drawbacks. For example, dichotomizing risk factors ignores variation in the severity and frequency of risk experiences. Nonetheless, decades of research have consistently documented the strength of measuring multiple risks through this additive model (for a full review, see Evans et al., 2013).

1.3. Teacher-child closeness and school adjustment

Teacher-child closeness is generally measured through the teacher's perspective of his / her relationship with their students. Kindergarten teacher reports of children's academic and social competencies have been shown to predict children's trajectories through later academic years and are an important source of information on children's adaptation to the school environment (Hamre & Pianta, 2001; Jones, Greenberg, & Crowley, 2015). For many children, close teacher-child relationships—high levels of warmth, and open and responsive communication—can ease the adaptation to school (Pianta, Steinberg, & Rollins, 1995). Like parent-child relationships, teacher-child relationships are bidirectional (Bronfenbrenner & Morris, 1998; Pianta, 1999) and vary in quality. An attachment theory perspective on teacher-child relationships proposes that children who experience high-quality relationships (defined by high levels of closeness and low levels of conflict; McCormick et al., 2013) are able to depend on teachers for guidance, fostering a sense of psychological security (Howes, Phillipsen, & Peisner-Feinberg, 2000).

As kindergarten children spend more time in the school environment, teachers can become an important resource that may improve children's learning potential and engagement in the classroom. Close teacher-child relationships can promote learning for all children, but this appears to be the case particularly for children considered to be at risk (Birch & Ladd, 1997). At the same time, teachers tend to report more conflictual and less close relationships with disadvantaged students (Jerome, Hamre, & Pianta, 2009), highlighting the ways in which disadvantage impacts interpersonal contexts.

Individual student differences can also moderate how children from economically disadvantaged backgrounds, measured as a cumulative risk index, benefit from quality teacher-child interactions. For example, children's language development and temperament are associated with the quality of teacher-child interactions (Moritz Rudasill, Rimm-Kaufman, Justice, & Pence, 2006), and this leads to a unique interplay between cumulative risk, child temperament, and the type of teacher support (e.g., emotional, instructional) needed to most effectively enhance children's academic performance (Rudasill, Hawley, LoCasale-Crouch, & Buhs, 2017).

Likewise, prior research also suggests that individual teacher qualifications can buffer against the negative association family-based cumulative risk can have on children's reading levels. More specifically, teacher experience in grade-level moderated the association between cumulative risk and reading skills in a protective manner, in that teachers who had more experience teaching within grade-level could, perhaps, better meet the needs of disadvantaged children (Crosnoe & Cooper, 2010). Taken together, evidence to date points towards the potential promotive and protective role that school-based factors can have both on the quality of the teacher-child relationship and children's learning skills. Yet notably, few studies have used a cumulative risk framework to assess disadvantage in the school-based literature.

1.4. The present study

In the current study, we bridged the literature on teacher-child relationships and cumulative risk and contributed to the literature on early adversity and children's transition to kindergarten in several ways. First, using a large sample of kindergarteners, we applied a cumulative risk approach to assess how an index of risk factors related to a lack of stimulation, safety, and nurturance (e.g., Fox et al., 2010) affected skill development during the first year of school. Second, by testing the moderating role of teacher-child relationships on EF and early academic outcomes, this study provided new information on how teachers can support learning in the classroom on fundamental skills related to the transition to school. Third, this study expanded on the dearth of literature that examines how teacher-child relationships can support EF and early academic outcomes, all of which are important predictors of

academic success. Like other educational research, our motivation for this study was to identify mechanisms that when targeted by intervention and policy have the potential to interrupt this cycle of cumulative disadvantage (Ceci & Papierno, 2005).

Controlling for children's fall skill level for each outcome, we hypothesized that by the spring of kindergarten:

Hypothesis 1. Cumulative risk would negatively predict EF and early reading and math skills.

Hypothesis 2. Teacher-child closeness would positively predict EF and early reading and math skills.

Hypothesis 3. Teacher-child closeness would moderate the association between cumulative risk and outcomes. More specifically, higher levels of closeness would buffer the negative associations between risk factors and early learning skills (e.g., EF, reading, math).

2. Methods

2.1. Participants and protocol

Data come from the Early Childhood Longitudinal Study-Kindergarten (ECLS:K) 2010–2011 Cohort, a longitudinal (following children from kindergarten through fifth grade) study of a nationally representative sample of 18,200 U.S. kindergartners (Mulligan, Hastedt, & McCarroll, 2012). Children were randomly selected from a representative sample of schools, and we accounted for this nesting in our analyses. We used data from the first two waves of the panel, the fall and spring of the kindergarten school year, respectively. In the fall, children were an average of 5.6 years old, 48.8% female, 46.9% White, 13.2% Black, 25.3% Hispanic, 8.3% Asian, and 6.1% were of another race.

Children, parents, teachers, and school administrators participated in the study at the beginning of the kindergarten school year (Fall 2010) and again at the end of the school year (Spring 2011). One parent was interviewed at both fall and spring assessments and were asked a set of questions pertaining to different aspects of the target child's social-emotional development, family characteristics, parenting practices, and household dynamics. Some interview questions were asked in both fall and spring waves, whereas other questions were only asked at one particular point in the kindergarten year; these details are provided below with each specific risk factor. Teachers completed survey questionnaires to assess children's social-emotional competence in the fall and spring. School administrators provided information on school characteristics and policies through self-administered, hard-copy questionnaires. Direct assessments of children's skills (including: reading, math, cognitive flexibility, and working memory, respectively) were measured by trained assessors and subsequently entered into a computer-assisted interview program (Mulligan et al., 2012).

The assessment items detailed below were identified for inclusion by a panel of experts who pieced together the most appropriate measures, items, and format for the ECLS-K (Tourangeau et al., 2015). Reliability statistics were drawn from either the ECLS-K User's Manual for the public version of the ECLS-K:2011 Kindergarten Data File (Mulligan et al., 2012), or from the specific instruments' technical reports.

2.2. Measures

2.2.1. Child outcomes

Child outcomes included direct assessments of their reading, math, working memory, and cognitive flexibility competencies and teacher-reported levels of inhibitory control. In this study, all scores were standardized to have a mean of 0 and a standard deviation of 1 to ease interpretation of results. More information on task descriptions are available in Mulligan et al. (2012).

2.2.2. Reading skills

The reading test assessed knowledge of basic preliteracy skills such as letter and word recognition, beginning and ending sounds, vocabulary, and passage comprehension ($\alpha = 0.95$ in the fall and spring). The two-stage assessments were adaptive and consisted of 40 items, routing children to the next stage based on their performance in the previous section. First, children's English basic language skills were evaluated from two tasks from the Preschool Language Assessment Scale (*pre*LAS, 2000). Next, all children received the first set of reading-related items, regardless of their score on the *pre*LAS tasks. Finally, if the children passed a previously determined threshold, they were routed to more difficult reading assignments in English depending on their scores in the first set of tasks (or Spanish, if they were routed out of the English language pathway). We used the transformed theta scores, which represent latent ability scores (Mulligan et al., 2012).

2.2.3. Math skills

The math test evaluated understanding of numbers, geometry, spatial relations, and problem-solving skills ($\alpha = 0.92$ fall, 0.94 spring). Like the reading assessment, a set of items were administered to all children, and this initial score was used to further route them to the appropriate next set of questions. Children were offered paper and pencil to work through the math problems. Moreover, if children did not pass the English language screener, they progressed through the math portion in Spanish. We used the transformed theta scores, which represent latent ability scores (Mulligan et al., 2012).

2.2.4. Executive function

To measure *cognitive flexibility*, children were administered the Dimensional Change Card Sort (DCCS; Zelazo, 2006). This task has

been found to have excellent test-retest reliability, and to be age-appropriate for kindergarteners (Beck, Schaefer, Pang, & Carlson, 2011). Children were asked to sort 22 picture cards into the appropriate tray by color and then by shape. If the child successfully sorted at least four of the six cards by shape, they were advanced to a third and final round of sorting. In this final and most challenging round, there was an additional rule to sorting the cards (range = 0–6). In this study, we used the final combined score of the task which reflects the total across the three rounds (color, shape, and border). This approach is in line with the recommendation put forth by the developer in order to assess children's overall ability.

To measure *working memory,* the Numbers Reversed task was used, a subtest of the Woodcock-Johnson III Tests of Cognitive Abilities (Mather, Wendling, & Woodcock, 2001). Numbers Reversed required children to repeat strings of numbers orally in the reverse order in which they were presented. The number sequence became increasingly longer and concluded when the child got three consecutive sets of the same length incorrect or completed all number sequences (a maximum of 30 items). (The reliability for this assessment was not provided in the ECLS-K User's Manual, but according to the Woodcock-Johnson III technical report (Schrank & McGrew, 2001), $\alpha = 0.87$).

To measure *inhibitory control,* teachers reported on each child using the *Children's Behavior Questionnaire (CBQ) Short Form Inhibitory Control Sub-Scale* (Putnam & Rothbart, 2006). This scale captures ability to focus on the present environmental stimuli and refrain from responding inappropriately in the moment. The CBQ is a commonly used measure in examining EF and school readiness (e.g., Blair & Razza, 2007). The CBQ inhibitory control sub-scale consists of six items, and the score was calculated by taking the mean across items if at least four of the six were answered. A higher score represents that children were demonstrating greater levels of staying on task and controlling their behaviors ($\alpha = 0.87$ in the fall and spring).

2.3. Cumulative risk index

The cumulative risk index was comprised of items from the fall and spring parent interviews, and one item reported by the school administrator. To be as inclusive as possible in defining risk factors (ranging from neighborhood disadvantages to parent involvement in education-related activities), we created an extensive list of variables available in the public-use dataset. No rigid rules or guidelines exist to qualify an experience as adverse, and so we draw upon the existing body of research on disadvantages and child development to ground our selection of risks (e.g., Brooks-Gunn & Duncan, 1997; Gershoff, Aber, Raver, & Lennon, 2007; Kainz et al., 2012; Rhoades, Greenberg, Lanza, & Blair, 2011). Our selection of risk factors is guided by previous research showing important inputs for early development, and builds on a previous study examining the index in detail (Wolf & Suntheimer, 2019). Specifically, we included experiences that could be a threat to the child's physical safety (such as corporal punishment) and a lack of expected environmental inputs (such as low parental warmth). This range of risks is in line with the two distinct dimensions of risks put forth by McLaughlin and Sheridan (2016). While many of the risk factors are related conceptually, bivariate correlations among the dichotomized risks range from 0 to 0.31, indicating that each risk may indeed represent a unique factor. Table 1 presents the risk variables, definitions, and sample prevalence.

Most risks were compiled from parent interview questions throughout the child's kindergarten year, with crime in the school neighborhood being the one exception which was asked of the school administrator. Eighteen risks were considered (though no child had more than thirteen reported risks) and were summed to represent a cumulative risk index. Some of the risks were asked in both the spring and fall waves of data collection. We use the value from the fall wave whenever available, in order to capture how risks are associated with children's adaption throughout the kindergarten year. However, if the risk was only collected in the spring, we used this value.

Table 1
Risk factors, definitions, and sample prevalence for risk factors.

		Risk definition	Prevalence
1	Single parent	No parent or spouse living in household	22.7%
2	Financial hardship	Serious financial problems since child was born	26.8%
3	No parent school involvement	Parent had not attended a regularly scheduled parent-teacher conference	9.5%
4	Low parental warmth	Parent indicated “somewhat true” or “not at all true” on at least one of the four warmth items	12.3%
5	No cognitively stimulating activities	Family had not participated in any of the six stimulating activities	7.6%
6	Minimal reading	Parent indicated “never” or “only once or twice per week” to reading with child	9.1%
7	No extracurricular activities	Child did not participate in any activities outside of school	17.9%
8	Maternal depression	Bottom 15% of mothers who indicated “most of the time” or “moderate amount of time” on 11 depression indicators	15.6%
9	Household food insecurity	Household food insecure within the past year	21.3%
10	Nonstandard parental work hours	At least one parent works 60 h or more per week	11.3%
11	Household poverty	Living below the U.S. federal poverty threshold	25.5%
12	Safety of home neighborhood	Parent indicated “big problem” or “somewhat of a problem” to three items	7.6%
13	Crime near school	Crime is a big problem in the child's school neighborhood	5.6%
14	High parenting stress	Parent indicated “completely true” or “mostly true” to four stress items	26.8%
15	Corporal punishment	Parent spanked the child at least once within the past week	16.2%
16	Harsh discipline	Parent used at least one of four harsh discipline practices	29.3%
17	Parent substance use	At least one biological parent needed help for drug or alcohol use within the past year	6.4%
18	High child mobility	Child has lived in three or more places for four or more months since born	26.9%

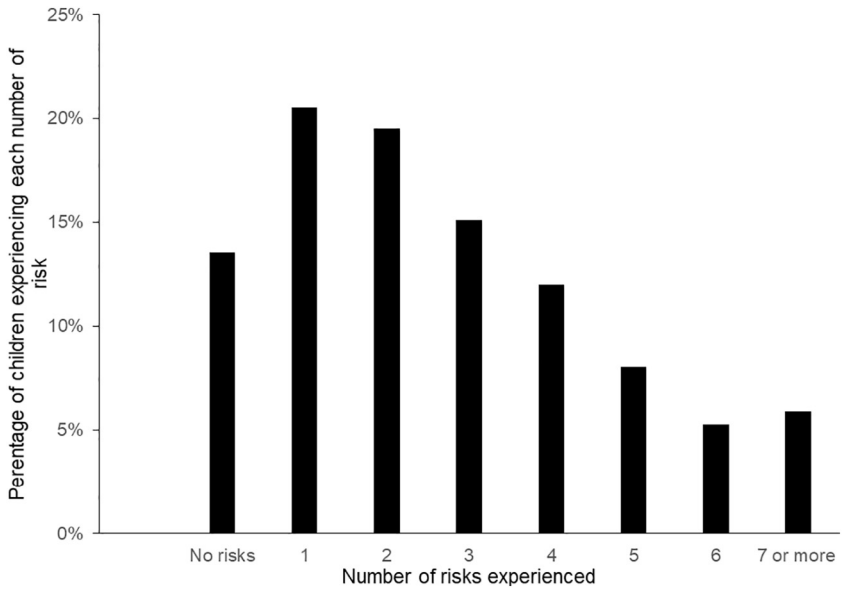

Fig. 1. Distribution of cumulative risks.

The risk index was positively skewed and children had experienced more than seven risks at a very low rate. Given this, we top-coded the cumulative risk index at seven (5.9% of the sample; and 3.0%, 1.6%, 0.7%, 0.4%, 0.1%, 0.1%, and < 1% for children who had experienced a total of 8–13 risks, respectively). Fig. 1 presents the distribution of risk index, ranging from no risks to seven or more risks.

2.3.1. Single parent

The parent indicated that there was no spouse or partner living in household. This item was asked in both spring and fall data collection waves for the kindergarten year.

2.3.2. Financial hardship

The family answered "yes" to having experienced serious financial problems or had trouble paying the bills since the child was born. This item was only asked in the fall.

2.3.3. Household poverty

Parents were asked to report their annual income, and when it was close to or lower than 200% of the U.S. Census Bureau poverty threshold for a household of its size, they were asked to provide their exact income. NCES used this information to create a household-level poverty variable to indicate whether or not a family's income was above or below the U.S. Census Bureau threshold. This item was only asked in the spring.

2.3.4. No parent school involvement

The parent had not attended a regularly scheduled parent-teacher conference or meeting. This item was only asked in the spring.

2.3.5. Low parental warmth

A four-point scale for each of the four items ranging from "*not at all true*" to "*completely true.*" We defined low levels of parental warmth if "*not at all true*" was selected for all for items. The items assessed the parents' levels warmth and affection towards the child (e.g., "Child and I often have warm, close times together") and is part of the parental warmth subscale from the Home Observation for Measurement of the Environment scale (HOME; Bradley & Caldwell, 1984; $\alpha = 0.63$). These four items were only asked in the spring.

2.3.6. No family participation in cognitively stimulating activities

Six "yes-no" questions related to family activities, such as visiting a zoo or library, and the child had not participated in any in the past month. These six items were only asked in the spring.

2.3.7. Minimal reading to child

Two questions related to the child's access to picture books or reading materials in the home. Each question was asked on a four-point scale: "*never,*" "*once or twice a week,*" "*three to six times a week,*" and "*everyday.*" It was considered to be a risk if the parent reported "*never*" or "*once or twice a week*" for both questions. These two items were only asked in the spring.

2.3.8. No participation in extracurricular activities

Twelve "yes-no" questions related to the child's involvement in out-of-school activities, such as organized athletic groups or academic activities, and the child was not involved in any over the past month. These twelve items were only asked in the spring.

2.3.9. Maternal depression symptoms

Eleven items from the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff & Locke, 1986) short form which assessed the mother's levels of sadness, loneliness, and lack of appetite or energy during the past week. Mothers could respond to each of the items using a four-point scale: "*never*," "*some of the time*," "*a moderate amount of time*," and "*most of the time*." We used the bottom 15% of the sample and considered those children with mothers who expressed the most severe depression symptoms to be at risk. These items were only asked in the spring.

2.3.10. Food insecurity

Parent reported "*usually true*" or "*sometimes true*" to all 3 items on a three-point scale, part of the standardized US Household Food Security Scale (Nord, Andrews, & Carlson, 2009). Questions were asked at the household level about the amount of food running out or not lasting and that the parents would not be able to buy more within the past 12 months. The third question assessed if finances were a barrier to eating well-balanced meals within the past 12 months. These three items were only asked in the spring.

2.3.11. Nonstandard parental work hours

One or both parents worked for pay for > 60 h per week, with a response range from zero to 80. These two items were only asked in the fall.

2.3.12. Neighborhood safety

On a three-point scale (ranging from "*big problem*" to "*no problem*"), the parent reported that public substance use and/or burglary or robbery was a "*big problem*" in their home neighborhood or that it was "*not at all safe*" (whereas "*somewhat safe*" or "*very safe*" was not considered a risk) for the child to play outside during the day. These three items were only asked in the spring.

2.3.13. Crime near school

School administrators reported that crime was a "big problem" near their school. This question was asked using a three-point scale with response options ranging from "big problem" to "no problem". This item was only asked in the spring.

2.3.14. High parenting stress

Four items from the Parenting Stress Index (Abidin, 1990) which asked the parent how true parent-stress related items felt. The parent was asked to respond on a four-point scale ("*completely true*" to "*not at all true*") to statements such as, "being a parent is harder than I thought it would be." We operationalized the high parenting stress risk if the parent answered, "*completely true*" or "*mostly true*" to all four stress items. These four items were only asked in the spring.

2.3.15. Corporal punishment

Parent was asked how many times the child was spanked, if at all, in the past week. If the parent reported spanking the child one or more times, we considered that to be a risk. This item was only asked in the spring.

2.3.16. Harsh discipline

The parent was presented with a vignette about how they would respond if their child became so angry that they hit the parent. Eleven different discipline strategies were provided as options, four of which we considered to be harsh. If the parent indicated that they would use at least one of the four harsh discipline practices (e.g., hit the child back; make fun of the child) we coded this as a risk. These four items were only asked in the spring.

2.3.17. Parent substance use

The parent was asked to report, by answering "yes" or "no" if anyone suggested that they seek professional help for drug or alcohol use within the past year. The same question was asked in reference to the child's biological father. If either or both parents indicated "yes", this was coded as a risk. These two items were only asked in the spring.

2.3.18. High child mobility

One item inquiring about the number of places the child has lived for four months or more since birth. The parent was provided a range from 0 to 10, and risk was considering if the child lived in three or more residences since birth. This item was only asked in the fall.

2.4. Teacher-child closeness

The Student-Teacher Relationship Scale (STRS; Pianta, 2001) is an instrument frequently used with preschool and elementary-aged children and is grounded in attachment theory which provides insight on how children form relationships with adults. The STRS is a teacher-reported measure designed to evaluate levels of closeness and conflict between the teacher and student. This scale

includes seven items assessing relationship closeness and consists of descriptive statements in which teachers were asked to indicate how closely each statement corresponded with the child using a five-point scale ranging from "*definitely does not apply*" to "*definitely applies*." Teachers completed the questionnaire in the spring data collection wave. The *closeness scale score* consists of the average rating across the items, and mean sores were computed only if teachers had provided ratings on at least five of the seven items. The measure captures the level of the affection, warmth, and open communication between the teacher and the child. A high score indicates that the teacher perceived the relationship to be characterized by high closeness ($\alpha = 0.89$).

2.5. Covariates

We included a set of covariates that measure family characteristics related to risk and children's outcomes. These characteristics were selected because they are largely considered "fixed" characteristics in that they are unlikely to rapidly change as a function of risk or disadvantage. Covariates included primary parent's education level (less than high school 12.6%; high school diploma or equivalent 20.8%; some college / vocational technical program 31.3%; bachelor's degree or higher 35.4%), if English was the primary language spoken in the home (96.7%), urbanicity of the school (city 31.6%; suburb 37.3%; town 7.9%; rural 23.2%), child's race (White 51.0%; Black 11.1%; Hispanic 23.7%; Asian 8.0%; Other 6.2%) and sex (49.0% female), household income ($M = 10.5$, $SD = 5.6$ on a scale of 1–18 in $5000 increments), child's age ($M = 73.4$ months, $SD = 4.4$ months) mother's age ($M = 34.5$ years, $SD = 6.7$ years), and number of children living in the household ($M = 2.5$, $SD = 1.1$).

2.6. Analytic strategy

We use two-level hierarchical linear models, with children (Level 1) nested in schools (Level 2), to estimate the associations between cumulative risk, teacher-child closeness (Model 1), and their interaction (Model 2), on child outcomes. Separate models were run for each of the five outcomes, with the fall score for each outcome included in the respective models, and the full set of covariates included in each model. Ten models were run in total. Because the outcome data was measured in the exact same way in both the fall and spring waves, we followed an approach recommended by NICHD ECCRN and Duncan (2003) to implement lagged models (controlling for children's fall outcome scores), which reduces selection bias in the models. The equations are as follows:

Level 1 (Child-level) Model:

$$Y_{ij} = B_{0j} + B_{1j}\text{CRIndex}_{ij} + B_{2j}\text{TchClose}_{ij} + B_{3j}Y_{(t-1)ij} + B_{4j}'Z_{ij} + e_{ijk}$$

Level 2 (School-level) Model:

$$B_{0j} = \gamma_{00} + u_{0j}$$

where B_{1j} represents the mean effect for the cumulative risk index on outcome Y for child i in school j; B_{2j} represents the mean effect for teacher closeness; B_{3j} is the mean effect of the fall score for each respective outcome; and Z_{ij} is a vector of child-level covariates. γ_{00} is the school-level random intercept. For Model 2, an interaction term between $CRIndex_{ij}$ and $TchClose_{ij}$ is added to the Level 1 equation to examine the moderating effect of Teacher Closeness for the relationship between cumulative risk and outcome Y.

2.6.1. Missing data

Children who were missing more than half (ten or more) risks were excluded from the analyses ($N = 4878$, 26.9%). Additionally, children who were missing outcome data were excluded (12.37% for inhibitory control; 5.64% for cognitive flexibility; 5.65% for working memory; 5.44% for reading; and 5.67% for math). The proportion of children missing data on inhibitory control is likely much higher than the other four outcomes because it is the only teacher-reported outcome, whereas the others are direct child assessments.

To address missing covariate and teacher-child closeness data, we used Stata's multiple imputation by chained equations technique (Royston, 2004) and created 20 imputed datasets. An average of 2.4% of cases were missing covariate data on each variable (ranging from 0 to 11.8%) and 12.17% were missing closeness data. Following recommendations by Johnson and Young (2011), we included the full set of covariates and dependent variables in the imputation modeling. Prior to running the regression models, children who were missing the specific dependent variable were excluded from the analysis (multiple imputation then deletion, or MID), resulting in a sample size between 11,100 and 11,800, depending on the outcome. All multilevel regression analyses were conducted using Stata's "mi estimate" command.

Children missing outcome or risk data, and thus excluded from our analysis, were slightly more disadvantaged than those with data. Most notably children who were excluded had parents with lower levels of education, were less likely to be White, and more likely to reside in a city. This may skew the representativeness of the findings. To test the sensitivity of the results, we ran the same models using the imputed values for the 26.9% of children that were missing risk values; the results (not shown) change slightly. For Model 1, cumulative risk negatively predicted inhibitory control, reading, and math (as in the main models), but not cognitive flexibility and working memory. In addition, the interaction terms between cumulative risk and teacher-closeness were in the same direction as the main models, but no longer statistically significant. Thus, the results were sensitive to the exclusion of this part of the sample.

Table 2
Multilevel results of children's executive function and early academic outcomes as spring scores as an interaction of cumulative risks and teacher-child closeness.

	Model 1					Model 2				
	Executive function			*Early academic skills*		*Executive function*			*Early academic skills*	
	Inhibitory control	Cognitive flexibility	Working memory	Reading scores	Math scores	Inhibitory control	Cognitive flexibility	Working memory	Reading scores	Math scores
Spring kindergarten scores										
Cumulative risk index	−0.018***	−0.020***	−0.016***	−0.013***	−0.016***	0.005	−0.042	−0.068**	−0.059**	−0.044*
	(0.004)	(0.005)	(0.005)	(0.003)	(0.003)	(0.022)	(0.030)	(0.025)	(0.019)	(0.019)
Teacher-child closeness	0.258***	0.115***	0.077***	0.068***	0.079***	0.260***	0.113***	0.074***	0.065***	0.077***
	(0.011)	(0.014)	(0.013)	(0.009)	(0.009)	(0.011)	(0.014)	(0.013)	(0.009)	(0.009)
Closeness × Cumulative risk	–	–	–	–	–	−0.005	0.005	0.012*	0.010*	0.006
	–	–	–	–	–	(0.005)	(0.007)	(0.006)	(0.004)	(0.004)
Lagged outcome	0.635***	0.263***	0.489***	0.761***	0.795***	0.635***	0.263***	0.489***	0.760***	0.794***
(Fall score)	(0.007)	(0.010)	(0.008)	(0.006)	(0.006)	(0.007)	(0.010)	(0.008)	(0.006)	(0.006)
Constant	−1.419***	−0.938***	−1.033***	−0.076	−0.271*	−1.472***	−0.987***	−1.064***	−0.101	−0.191
	(0.137)	(0.178)	(0.155)	(0.113)	(0.114)	(0.136)	(0.177)	(0.154)	(0.112)	(0.123)
Sample size (children)	11,100	11,800	11,800	11,800	11,750	11,100	11,800	11,800	11,800	11,750
Sample size (schools)	822	855	855	855	855	822	855	855	855	855

Note. All models control for child and family covariates (coefficients not shown). All outcomes are standardized within the sample to have a mean of zero and a standard deviation of 1. Sample sizes computed by rounding the original sample size to the nearest 50 per NCES guidelines.

*** $p < .001$.

** $p < .01$.

* $p < .05$.

3. Results

Table 1 displays the sample prevalence of each of the individual risks that comprise the cumulative risk index. In this sample of kindergarteners, 13.6% had no risks; 40.1% had 1–2 risks (low risk); 27.2% had 3–4 risks (moderate risk); and 19.2% had 5 or more risks (high risk). Results from the multilevel regression analyses are presented in Table 2.

3.1. Main effects of cumulative risk and teacher-child closeness

In Model 1 (first row in Table 2), the cumulative risk index was negatively predictive of all five outcomes as hypothesized ($b = -0.018$, $SE = 0.004$, $p < .001$ for inhibitory control; $b = -0.020$, $SE = 0.005$, $p < .001$ for cognitive flexibility; $b = -0.016$, $SE = 0.005$, $p < .001$ for working memory; $b = -0.013$, $SE = 0.003$, $p < .001$ for reading scores; and $b = -0.016$, $SE = 0.003$, $p < .001$ for math scores). Because all outcome scores were standardized, the coefficients represent an association of 0.01–0.02 standard deviations for each additional risk factor experienced by the child.

Teacher-child closeness (second row in Table 2) positively predicted all five outcomes, also as hypothesized ($b = 0.258$, $SE = 0.011$, $p < .001$ for inhibitory control; $b = 0.115$, $SE = 0.014$, $p < .001$ for cognitive flexibility; $b = 0.077$, $SE = 0.013$, $p < .001$ for working memory; $b = 0.068$, $SE = 0.009$, $p < .001$ for reading scores; and $b = 0.079$, $SE = 0.009$, $p < .001$ for math scores). These results confirmed our first and second hypotheses.

3.2. Interactive effects of cumulative risk and teacher-child closeness

Our third hypothesis was that teacher-child closeness would moderate the association between cumulative risks and children's EF and early academic outcomes. This hypothesis was partially confirmed. Specifically, teacher-child closeness moderated the association between cumulative risk with working memory ($b = 0.012$, $SE = 0.006$, $p < .05$) and early reading scores ($b = 0.010$, $SE = 0.004$, $p < .05$). Figs. 2 and 3 illustrate graphically these interactive relationships in predicting both outcomes in the spring of kindergarten, respectively. In both figures, high and low levels of teacher-closeness are represented by one SD above and below the mean for illustrative purposes. For all children, scores decline as children have higher levels of cumulative risk. Teacher-child closeness moderated this association such that the with higher levels of teacher-child closeness, the slope between risk and outcomes was less steep.

Predictions of the two other measures of EF—cognitive flexibility and inhibitory control—and math scores did not bear out as hypothesized; inhibitory control, cognitive flexibility, and math scores were not significantly moderated by teacher-child closeness.

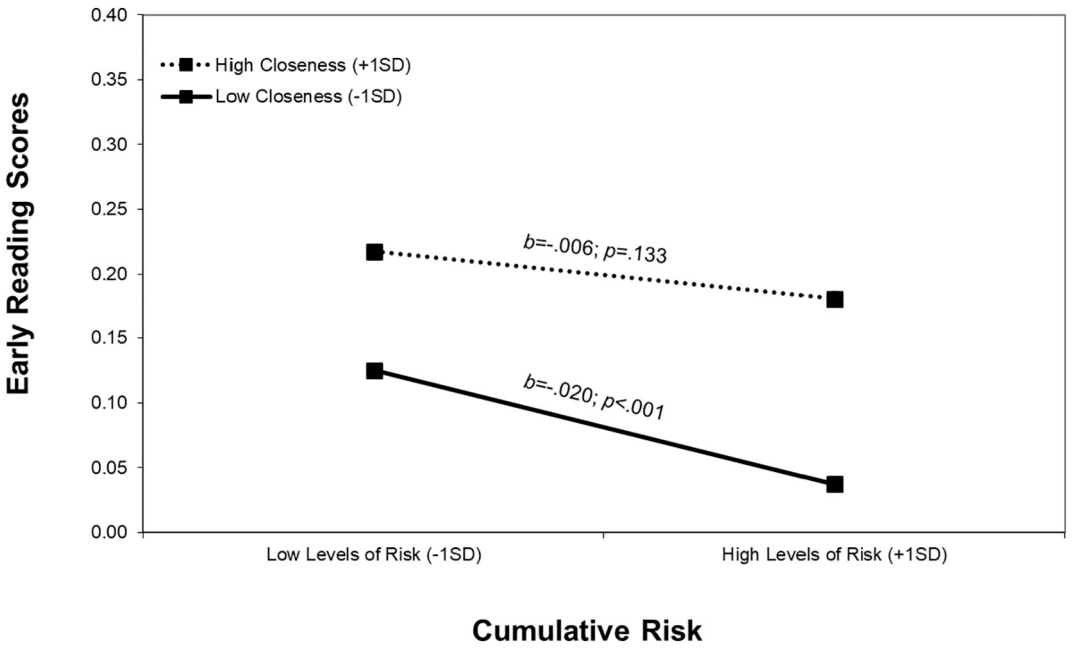

Fig. 2. Moderation of cumulative risks and children's early reading scores by teacher-child closeness
Note. Graph created using the multi-level regression results with standardized outcomes; graphic created with ModGraph (Jose, 2013). Teacher-child closeness mean = 4.35, SD = 0.64. "High" teacher-child closeness refers to +1SD above the mean (4.99), whereas "Low" teacher-child closeness refers to -1SD below the mean (3.71).

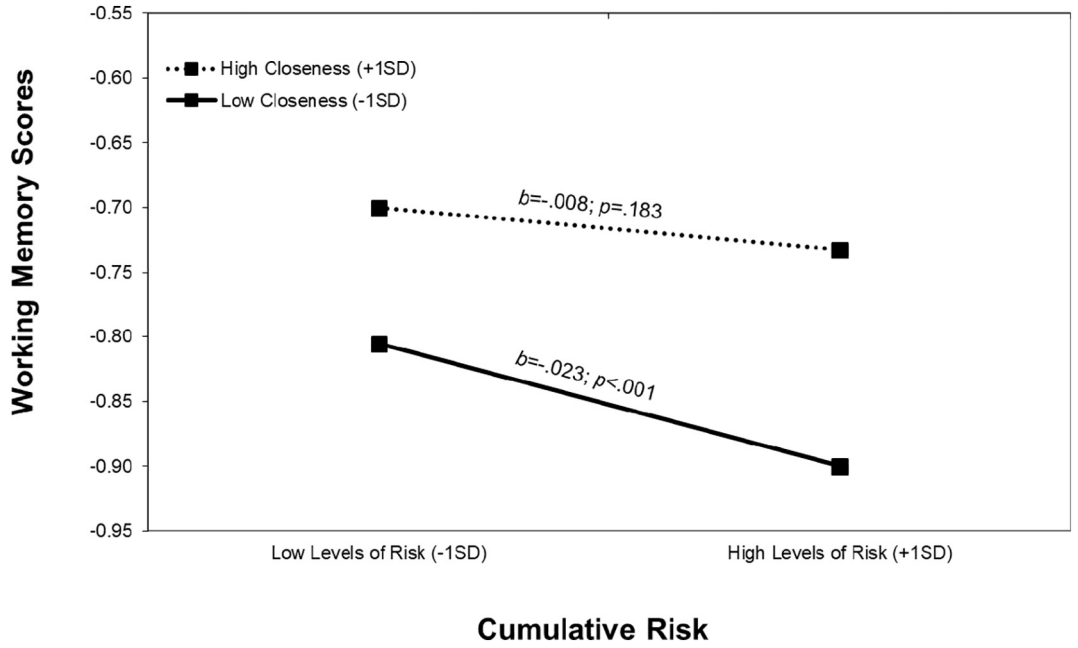

Fig. 3. Moderation of cumulative risks children's working memory scores by teacher-child closeness
Note. Graph created using the multi-level regression results with standardized outcomes; graphic created with ModGraph (Jose, 2013). Teacher-child closeness mean = 4.35, SD = 0.64. "High" teacher-child closeness refers to +1SD above the mean (4.99), whereas "Low" teacher-child closeness refers to -1SD below the mean (3.71).

3.3. Sensitivity analyses

Because many of the socio-demographic covariates used in our models are associated with children's disadvantage, such as parents' levels of education and the locale of the community, we ran two sets of sensitivity analyses. First, we ran all models without covariates. The pattern of results across all models were very similar. For Model 1, the coefficients for both cumulative risk and teacher-child closeness were similar, though slightly larger when no covariates were included. For Model 2, the results were nearly identical to the main models. Second, we ran a fully interacted model where we controlled for the interactions between each covariate with teacher-child closeness. The magnitude of the coefficients were very similar to the main models, but the standard errors were larger, and thus the interactive effects of cumulative risk and teacher-child closeness on working memory and reading scores were not statistically significant. (Results available upon request.)

4. Discussion

This study examined how cumulative risk and teacher-child closeness predicted the development of children's EF and early academic skills over the course of kindergarten, and whether teacher-child closeness moderated the association between cumulative risks and child outcomes. The large and representative nature of this data provides a unique opportunity to assess the cumulative risk experienced by kindergarten students in the United States, and advances knowledge about the ways in which teachers can protect the most vulnerable children from some of the negative effects associated with early risk experiences. This study contributed to the literature on how education research can be leveraged to disrupt intergenerational cycles of disadvantage, with the school environment serving as a plausible and practical way to intervene and to promote children's learning skills (Crosnoe & Cooper, 2010). It is important to note that because sampling weights were not used for analysis, we caution readers to understand our interpretation of the results in light of the fact that they are not nationally representative.

4.1. Cumulative risk, teacher-child closeness, and the development of executive function and early academic skills

A surprisingly large proportion of the sample (86%) experienced at least one risk factor, while almost half (47%) experienced three or more risk factors. Importantly, there is variability in how studies and disciplines operationalize risk. While we defined risk broadly, perhaps more than previous studies (Evans et al., 2013), this is still a large majority of young children in the U.S. For context, Hunt, Slack, and Berger (2017) found that in a high-risk sample of five-year-olds, 77% of children had experienced at least one of eight Adverse Childhood Experiences (ACEs), a measure of risk used widely in the fields of medicine and social welfare that focuses on experiences of abuse and neglect, as well as exposure to other potentially traumatic events. The risks included in our study depart from the ACE questions in that we included experiences related to children's learning opportunities and school readiness.

Cumulative risk negatively predicted all three domains of EF and reading and math skills, as was predicted by our first hypothesis. This replicated and extended previous work that documents a positive association between cumulative risk and academic-related problems in diverse samples of children (e.g., Hostinar, Stellern, Schaefer, Carlson, & Gunnar, 2012; Luster & McAdoo, 1994; Morales & Guerra, 2006). We extended this knowledge base by examining how the development of core aspects of EF were sensitive to cumulative risk, in addition to early academic skills. While these associations were small in magnitude – with each additional risk predicting 0.01–0.02 standard deviations (SD) lower on each skill –, for children with seven or more risks this amounts to 0.07–0.14 standard deviations. As a reference, children learn about one standard deviation in academic skills over the course of kindergarten (Hill, Bloom, Black, & Lipsey, 2008), and thus 0.1 SD is equivalent to about 1 month of learning.

On the other hand, teacher-child closeness served as a promotive factor for all kindergarteners' EF and early academic skills, regardless of their exposure to early risk. This suggests that teachers' perceptions of closeness with their students may promote important early learning during the school transition, supporting our second hypothesis. While several other studies have documented the role of teacher-child relationships in promoting children's transition to kindergarten (e.g., Pianta & Stuhlman, 2004), results have been mixed in regards to how relationship quality with teachers can foster academic achievement in kindergarten students. For example, one study found that teacher-child closeness predicted children's reading abilities but not math scores (Burchinal, Peisner-Feinberg, Pianta, & Howes, 2002). In contrast, another study found that the quality of the teacher-child relationship in kindergarten significantly affected first grade math achievement, but not reading achievement (McCormick et al., 2013). It is less understood how teacher-child closeness may promote various aspects of children's EF abilities.

In the current study sample, teacher-child closeness was promotive of both reading and math, and executive function development. Importantly, even with the lagged multilevel regression models we used, the direction of these associations cannot be determined. Thus, it is equally plausible that teachers report closer relationships with children who developed stronger EF and early academic skills, or with children who had individual additional attributes that contributed to more positive teacher-child interactions (e.g., Rudasill et al., 2017). Nonetheless, it is important to understand the environments and relationships that have the potential to shape the development of these academic abilities.

4.2. The protective role of teacher-child closeness

Our third hypothesis—that teacher-child closeness would moderate the negative associations between cumulative risk and child outcomes—was partially supported. Teacher-child closeness significantly moderated the association between cumulative risk and working memory and cumulative risk and early reading scores in a protective way, such that the negative association between cumulative risk and child outcomes was less steep for children with high teacher closeness. No protective effects were found for cognitive flexibility, inhibitory control, or math scores.

Recent research suggests that working memory is the component of EF that is most beneficial to academic skill development, including both reading and math achievement (Nguyen & Duncan, 2018). Working memory allows children to mentally store and manipulate information, which can facilitate the mastery of early academic sills (e.g., Alloway, 2006). Relational closeness has the potential to create an encouraging learning environment, which might facilitate children's working memory and ability to engage in complex thinking (Baker, 2006; Birch & Ladd, 1997; Crosnoe, Leventhal, et al., 2010; Crosnoe, Morrison, et al., 2010).

Second, like working memory, our findings indicated that close relationships with kindergarten teachers can buffer the negative effects of cumulative risk for children's reading abilities. Prior research has found that children displaying aggressive behaviors had better reading skills when they had a warm, supportive relationship with their teachers, in comparison to a group of children who did not benefit from relational support (Baker, Grant, & Morlock, 2008). Another possible explanation for teacher closeness' protective effect on children's reading could be that the positive relationship translated into teachers' warm engagement in reading activities with their students. This interpretation would be consistent with studies that have found that parents' active and affectionate engagement in shared reading time with children is positively association with reading outcomes (Bergin, 2001).

We did not find moderating effects for math scores, cognitive flexibility, and inhibitory control. While one previous study showed that teacher-child relationships impact math learning outcomes for at-risk children (McCormick et al., 2013), others have shown that reading skills are particularly sensitive to teacher interactions (Rudasill et al., 2017). This finding contributed to a growing area of literature on relationships and academic development. Regarding EF, while some have argued that in early childhood, the components of EF are best measured as a latent construct (Miyake et al., 2000), the lack of consistent results across the three dimensions of EF suggests that evaluating them separately is a helpful nuance in some cases. Moreover, across studies and in the current sample, the different elements of EF are not highly correlated and vary in strength when predicting children's academic achievement (Nguyen, Duncan, & Bailey, 2019). While the three components of EF are related, they are distinct processes. More research is needed to understand how teachers foster the development of different EF skills, and such an effort is currently underway (Bardack & Obradović, 2019).

4.3. Strengths, limitations and conclusions

This study has several strengths. First, four of the five outcomes examined were direct assessments administered by trained field staff, which minimizes any potential bias teachers might have had in rating both children's skills and their relationships with each child. Second, all outcomes were measured at the start of the school year and controlled for in the analysis, in addition to a set of child and family demographic characteristics. This lagged model approach has been found to limit selection bias and adjusts for unobserved or omitted variables associated with the lagged outcome in previous national studies (e.g., NICHD ECCRN & Duncan, 2003).

Third, by using a large sample of kindergarteners, children in the sample experienced a wide range of risk exposure. This allowed for an examination of the moderating role of teacher-child closeness across a range of home experiences. Lastly, in this study, we examined five outcomes, testing ten main effects and five interaction terms in total. Thus, the results should be interpreted in light of the multiple models examined. Of the ten main effects examined, all were statistically significant at $p < .001$ and in the expected direction; of the five interaction terms examined, two were statistically significant at $p < .05$. These results are well above chance, building confidence in the findings.

Nonetheless, it is important to interpret these findings in light of the study's limitations. First, the direction of the associations observed cannot be determined. Thus, it is not known if children displaying greater attention, social, and academic problems elicit different types of interactions with teachers (e.g., O'Connor, 2010), as opposed to resulting from teacher-child interactions. Second, measuring EF in young children has been identified as challenging (Blair et al., 2005). Our study did not evaluate the measures used to assess EF and early academic scores, and thus we cannot appraise the measurement or the administration of the outcomes. Third, assessment of children's risks were primarily from parent-reported interviews. It is possible that objective measures would more accurately capture children's experiences. Fourth, by dichotomizing risk scores with a cut-off point, we were unable to evaluate the severity and frequency of children's experience across each risk factor. Fifth, over one-quarter of children were excluded from this study due to missing more than half of the considered risks. Sixth, because we used multiple imputation and multi-level models, we were unable to apply sampling weights to our analyses in Stata. Lastly, we were not able to account for the additional level of nesting of children within classrooms (within schools) due to data restrictions, given that the teacher / classroom identification variable is not available in the public-use dataset.

The findings point to several areas for future research. First, future studies should explore the dynamic and evolving interplay between risks, teacher-child relationships, and child outcomes throughout later academic years. Prior research has shown the positive effects of the teacher-child relationship throughout childhood (Baker, 2006). While establishing a close teacher-child relationship in kindergarten has great value, many young children have several teachers throughout elementary school. Considering how children's relationships with their teachers may change across school years, and the implications for learning outcomes, is an important area for future research.

Second, future studies could consider the role of integrating targeted EF training in supporting disadvantaged children in their transition to school. Diamond and Lee (2011) found that children who performed the worst on EF tasks benefited the most from play-based intervention activities designed to build EF skills. Such early EF training may reduce achievement gaps at the start of school, with implications for later achievement gaps (e.g., Bradbury et al., 2015) and strengthen children's relationships with their teachers. Importantly, scholars suggest that solely focusing on improving EF may not suffice, and that attention should also be paid to addressing other developmental domains (Diamond & Lee, 2011).

Third, future research could consider the role of supportive peer relationships in conjunction with teacher relationships, as peer relationships have been shown to have a strong influence on classroom engagement and ease the transition to kindergarten (Ladd, Birch, & Buhs, 1999). Peer relationships also increasingly play a larger role throughout childhood and into adolescence (Ladd et al., 1999). Lastly, subsequent research could explore additional outcomes that have also been shown to be important for children's development and learning, including social and behavioral skills. One study found that close teacher-child relationships predicted less risky behavior in older elementary school children (Rudasill, Reio Jr, Stipanovic, & Taylor, 2010), and thus, future research could explore if a similar pattern exists in kindergarten children.

It is important to deepen our understanding of how kindergarten teachers can foster EF and early academic skills at the beginning of the school year, especially given the promising evidence that EF skills are malleable to intervention efforts in young at-risk children (Riggs, Blair, & Greenberg, 2004). The set of learning skills examined in this study are foundational and can be improved with effort and strategy; however, if left unaddressed, early adverse experiences can continue to contribute to a number of cognitive disadvantages through adolescence and adulthood (Geoffroy, Pereira, Li, & Power, 2016). Providing children from disadvantaged backgrounds with the supports to develop promotive relationships with teachers, and the skills to succeed academically, could alter their developmental trajectories in ways that have lasting impacts. While the protective effects of teacher-child closeness were relatively small, the results provide insight into a meaningful pathway to contribute to building resilience in young children.

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