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Executive Function Mediates the Association between Toddler Negative Affectivity and Early Academic Achievement

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Abstract

Research Findings—We examined the nature of association between toddler negative affectivity (NA) and later academic achievement by testing early childhood executive function (EF) as a mediator that links children's temperament and their performance on standardized math and reading assessments. One hundred eighty-four children (93 boys, 91 girls) participated in our longitudinal study. Children's NA was measured at age 2 and EF at age 4. At age 6, academic achievement in reading and mathematics were assessed using the Woodcock Johnson III Tests of Achievement (Woodcock, McGrew, & Mather, 2001). Results indicated that NA at age 2 negatively predicted EF at age 4, which positively predicted mathematics achievement and reading achievement at age 6. Age 4 EF mediated the relation between age 2 NA and age 6 academic achievement on both reading and math. These findings highlight the significance of considering both NA and EF in conversations about children's academic achievement.

Practice or Policy—For children with temperamentally high NA, focusing on efforts to enhance emotion regulation and EF during the preschool years may benefit their later mathematics and reading achievement.

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Keywords

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Wide-ranging factors, including cognitive ability (Alloway & Alloway, 2010), physical exercise (Castelli, Hillman, Buck, & Erwin, 2007), and parenting behaviors (Englund, Luckner, Whaley, & Egeland, 2004), contribute to early academic competence. Child temperament, defined as individual differences in emotional reactivity and the self-regulation of that reactivity (Rothbart & Ahadi, 1994), may be especially important in predicting academic achievement (Colom, Escorial, Shih, & Privado, 2007; Valiente et al., 2011). Temperament influences developmental outcomes by affecting within-individual cognitive and personality characteristics and, as a result, shaping individual experiences (Rothbart, Ahadi, & Evans, 2000). Thus, there is the potential that children with different temperamental characteristics will have distinct school experiences and varying academic outcomes (Rothbart & Jones, 1998).

Temperament is comprised of three broad dimensions during early development, with negative affectivity (NA) and surgency/extroversion (i.e., positive affectivity and activity; SE) representing the reactivity components and effortful control (EC) the regulatory component of temperament (Putnam, Gartstein, & Rothbart, 2006). The perspective that EC plays an important role in children's academic achievement has received considerable theoretical and empirical support (e.g., Deater-Deckard, Mullineaux, Petrill, & Thompson, 2009; Sánchez-Pérez, Fuentes, Pina, López-López, & Gonzalez-Salinas, 2015). Similarly, many studies have shown that some of the components (e.g., impulsivity) within the broader SE dimension are correlated with academic achievement (Merrell, & Tymms, 2001; Rudasill, Gallagher, & White, 2010; Vigil-Coleț, & Morales-Vives, 2005). The NA aspect of temperament has received less attention in research on academic achievement. It is important, however, to develop models that integrate emotion and cognition in predicting key academic outcomes in order to have a more comprehensive understanding of factors and experiences that influence children's development (Blair, 2002; Valiente, Swanson, & Eisenberg, 2012).

Negative Affectivity and Academic Achievement

As a higher-order factor of temperament, NA includes various aspects of negative emotion, such as discomfort, sadness, shyness, fear, motor activation, perceptual sensitivity, anger/frustration, and non-soothability (Putnam et al., 2006). Some previous research suggests that negative emotionality adversely affects academic performance (Ashcraft, 2002; Duchesne, Vitro, Larose, & Tremblay, 2008; Pekrun, Elliot, & Maier, 2009). There are inconsistencies in this association, however. For example, teacher reports of child sadness negatively predicted academic achievement in a short-term longitudinal study of 5- to 6-year-old children (Valiente, Lemery-Chalfant, & Swanson, 2010), but child NA failed to predict academic outcomes across a 5-year time span from 18-24 months to 6-7 years of age in another study (Supplee, Shaw, Hailstones, & Hartman, 2004). During middle childhood, temperamental anger/frustration did not directly predict academic achievement

longitudinally, but indirectly affected academic outcomes through social competence and externalizing problems from 6 to 9 years of age (Zhou, Main, & Wang, 2010). Thus, the impact of NA on academic achievement may best be understood using mediational models and longitudinal methodology (Valiente et al., 2012). We propose that a cognitive mediator, specifically executive function, is important for understanding the potential impact of NA on academic outcomes (e.g., Christianson, 2014).

Executive function (EF) is comprised of a series of higher order, top-down cognitive processes (i.e., inhibitory control, set-shifting, working memory; Miyake et al., 2000) that are critical for school success (e.g., Blankenship, Keith, Calkins, & Bell, 2017; Bull, Espy, & Wiebe, 2008; Clark, Pritchard, & Woodward, 2010; Cutting, Materek, Cole, Levine, & Mahone, 2009; Espy et al., 2004). There are correlations between NA and EF in young children. For example, the level of anger shown by preschool age children is negatively related to concurrent EF ability (Hughes, White, Sharpen, & Dunn, 2000), whereas shyness at 3 years is negatively associated with EF at 4 years (Wolfe, Zhang, Kim-Spoon, & Bell, 2014).

Previous research has suggested that EF mediates the link between NA and academic performance for typically developing children during early adolescence (Owens, Stevenson, Hadwin, & Norgate, 2012). To the best of our knowledge, our study is the first that examines EF as a potential cognitive mechanism linking general NA and academic achievement during early childhood.

The Mediating Role of Executive Function

There is evidence in research with adults that the presence of task-irrelevant emotional stimuli interferes with EF task performance because some of the cognitive resources required for EF may be diverted to the processing of the emotion, especially if negative stimuli are present (Padmala, Bauer, & Pessoa, 2011). Related to this resource argument, college students who are high on NA show significant increase in response time after trials on which they made errors compared with individuals with low NA (Luu, Collins, & Tucker, 2000). Cognitive resources may also be diverted when young children with temperamental NA are using EF. For example, in a study of 3- and 4-year-old children, Jones and colleagues (2003) reported a positive correlation between NA and response time following an error during an EF task. They proposed that children high in NA are more sensitive to errors, which caused them to perform poorly on the EF task.

Consistent with this perspective, Blair (2002) proposed that young children's emotional responses inhibit the use of higher order cognitive processes. Specifically, he suggested that when children respond in reactive ways, such as expressing frustration, sadness, or other aspects of NA, their abilities to apply effortful cognitive processes involving memory, attention, planning, and problem solving are typically impaired. An important implication from a developmental perspective is that children characterized by high NA may have difficulties in applying complex cognitive skills, so these EF skills do not get used to their capacity and thus remain underdeveloped (Blair, 2002). Because EF is an important early

predictor of academic achievement, the implications are that early NA affects EF, which in turn positively influences academic achievement.

Children display developmental changes in EF abilities throughout early development (Zelazo et al., 2003), with evidence of greatest improvements between 3 and 4 years of age (Carlson, 2005; Hughes, 1998). This pattern of EF development coincides with longitudinal and cross-sectional studies demonstrating some stability in executive attention skills linked with EF by 4 years of age (Jones et al., 2003; Kochanska & Knaach, 2003). Thus, we focused on EF at age 4 as the cognitive mediational mechanism between early NA and later academic achievement.

Executive Function and Academic Achievement

Early childhood is a period of development associated with rapid acquisition of many foundational skills that act as precursors to more complex school-related abilities (Romano, Babchishin, Pagani, & Kohen, 2010). For example, the preschool precursors to mathematics achievement include number recognition and counting (Geary, Hoard, & Hamson, 1999), whereas the fundamentals for reading achievement include rhyming, phonemic awareness, and letter knowledge. Foundational academic skills during preschool and the early years of formal education rely heavily on children's capacities for memorizing and holding materials in working memory, as well as inhibiting irrelevant information and activities (Bull et al., 2008; Gathercole, Tiffany, Briscoe, Thorn, & the ALSPAC team, 2005).

Thus, there is strong evidence that the emergence and rapid development of EF during early childhood sets the foundation for formal learning (Blair & Razza, 2007; Farrar & Ashwell, 2008). For example, Epsy and colleagues (2004) reported that EF is concurrently correlated with preschool mathematical skills even after controlling for child age, child intelligence, and maternal education level, all of which are predictors of academic achievement (e.g., Fergusson & Horwood, 1995). More importantly, the link between EF and early mathematics achievement can be seen longitudinally. Clark and colleagues (2010) reported that performance on EF measures at age 4 predicts math achievement at age 6.

EF has also been linked with success in reading development. EF measured at the start of prekindergarten year significantly predicts growth of literacy skill over the prekindergarten year. EF also makes unique contributions to kindergarten reading achievement (Welsh, Nix, Blair, Bierman, & Nelson, 2010). In a review paper, Cartwright (2012) noted that EF significantly influences reading development, including word-reading proficiency and passage comprehension, throughout preschool and early elementary school years. These results suggest that EF is not only a correlate of concurrent reading skills, but subsequently predicts future reading achievement as well.

The Present Study

There are early, persistent individual differences in emotional reactivity that negatively impact later EF performance (e.g., Jones et al., 2003); in turn, EF affects future academic achievement (Clark et al., 2010; Welsh et al., 2010). We combined these areas of research to test a model that EF mediates the association between early NA (age 2) and later reading and

math achievement (Valiente et al., 2012). A unique contribution of our study is that we controlled for other aspects of temperament (i.e., SE & EC), in order to demonstrate the distinctive effect of NA on EF and academic achievement. Furthermore, given reports that gender can affect cognitive performance and academic achievement, and is likely to modify the association between temperament and academic achievement (Kerkman, Wise, & Harwood, 2000; Mullola et al., 2011), we also controlled for gender in our analyses. For this study, our methodology was longitudinal and we examined EF and academic outcomes in early childhood (ages 4 and 6, respectively). Examining these associations in early childhood is important because during this developmental period, children experience salient transitions to a more formal school environment, with the challenges of adapting to increased social relations and stricter rules (Rimm-Kaufman & Pianta, 2000).

In sum, we hypothesized that NA would negatively predict EF, which in turn would positively predict academic achievement, including both mathematics and reading. We did not make specific hypotheses about the direct effect of NA on academic achievement given that previous findings are inconsistent (Supplee et al., 2004; Valiente, et al., 2010). In addition, we hypothesized that EF would mediate the relation between NA and academic achievement, controlling for gender, SE, and EC (see Figure 1).

Method

Participants

Children visited the research laboratory when they were 2, 4, and 6 years of age. Children represent two cohorts (approximately 75% of the participants) of a larger longitudinal study focused on individual differences in the development of cognition and emotion across early development. The remaining 25% of the larger longitudinal study represent a third cohort who did not have a research visit at age 6. The cohorts were recruited by two research locations (Blacksburg, VA; Greensboro, NC), with half of the original sample recruited by the Blacksburg research location and half by the Greensboro location. The children in the larger study were initially recruited as infants via commercial mailing lists, flyers, newspaper advertisements, and word of mouth.

At the age 2 visit, participants included 256 children ($M = 2.07$ years, $SD = 24.79$ days; 125 boys, 131 girls; 75% Caucasian, 18% African American, 7% Asian, Other, and Multi-Racial; 7% Hispanic, 93% not Hispanic). With respect to education, 97% of their mothers completed high school education (27% high school, 7% technical degree, 42% bachelor's degree, 21% graduate degree).

At the age 4 visit, 195 children (76% retention rate from age 2 visit) visited the lab. The children included 101 boys and 94 girls ($M = 4.07$ years, $SD = 25.96$ days; 76% Caucasian, 18% African American, 6% Other and Multi-Racial; 9% Hispanic, 93% not Hispanic).

At the age 6 visit, 184 children (94% retention rate from age 4 visit) visited the lab. The children included 93 boys and 91 girls ($M = 6.50$ years; $SD = 81.12$ days). With respect to race and ethnicity, 76% were Caucasian, 17% were African American, and 7% were Other and Multi-Racial; 8% were Hispanic, 92% were not Hispanic. Children who contributed age

6 outcome data to the analyses were no different with respect to sex, race, and maternal education from those in the original group at age 2 who did not contribute outcome data (all p 's > .05).

Procedure

Data were collected at both research locations using identical protocols. Research assistants from each location were trained together by the project's Principal Investigator on protocol administration, as well as on behavioral data collection and coding. To ensure that identical protocol administration was maintained between the labs, the Blacksburg site periodically viewed DVD recordings collected by the Greensboro lab. To ensure that identical coding criteria were maintained between labs, the Blacksburg lab provided reliability coding for behavioral data coded by the Greensboro lab.

Upon arrival at the research lab, children and mothers were greeted by research assistants, study procedures were described, and signed consent was obtained from the mothers and verbal assent from the children. For each assessment, children received a small gift and mothers were given an honorarium.

Prior to the age 2 assessment, mothers were mailed the Early Childhood Behavior Questionnaire (ECBQ; Putnam et al., 2006). Mothers brought the completed questionnaire with them when they visited the laboratory for a series of tasks focused on child cognition, emotion, and mother-child interaction (not part of these analyses). For the age 4 assessments, children completed a series of cognition, emotion, and mother-child interaction tasks, with EF tasks used in these analyses. For the age 6 assessment, children again completed a similar series of tasks in addition to Woodcock Johnson (WJ) III Tests of Achievement (Woodcock, McGrew, & Mather, 2001).

Measures

Temperament at age 2—The Early Child Behavior Questionnaire (ECBQ; Putnam et al., 2006) is a widely used parent-report for children's temperament from ages 1.5 to 3 years old. Mothers responded to 201 questions about their children's behavior by using a 7-point Likert scale ranging from 1= never to 7= always. NA was calculated as the mean score of 8 subscales (i.e., discomfort, fear, sadness, shyness, perceptual sensitivity, motor activation, non-soothability, and frustration). Sample items targeted such temperament traits as sadness (e.g., When another child took away his/her favorite toy, how often did your child sadly cry?), shyness (e.g., When approached by an unfamiliar person in a public place (for example, the grocery store), how often did your child pull back and avoid the person?), soothability (reversed score; e.g., After getting a bump or scrape, how often did your child forget about it in a few minutes?), and frustration (e.g., When told that it was time for bed or a nap, how often did your child get irritable?). In the present study, the Cronbach's alpha for NA was .93.

SE was calculated as the mean score of 5 subscales (i.e., impulsivity, activity level, high-intensity pleasure, sociability, and positive anticipation). EC was calculated as the mean score of 5 subscales (i.e., inhibitory control, attention shifting, attention focusing, low-

intensity pleasure, and cuddliness). In the present study, the Cronbach's alpha for SE and EC was .92 and .89 respectively.

Executive function at age 4—Simon-says task and Dimensional Change Card Sort (DCCS) were used to measure child EF at age 4. The Simon-says task followed the Bear/ Dragon procedure (Carlson, Moses & Breton, 2002) and is detailed in Wolfe and Bell (2007). In brief, the experimenter introduced “nice” pig and “mean” bull puppets to the child. Children were instructed to do what the nice pig says to do and to not do what the mean bull says. For example, if the pig said “touch your nose,” then child should touch his or her nose. If the bull said “touch your ears,” the child should not touch his or her eyes. Performance was the proportion of correct responses in the bull (i.e., inhibitory) trials as an assessment of the inhibitory control aspect of EF (Marshall & Drew, 2014).

For the DCCS task (Zelazo, Frye & Rapus, 1996), children were instructed to sort cards based on two dimensions (i.e., color or shape). Children first sorted six cards by one dimension (pre-switch; counterbalanced across participants) and then were instructed to switch and to sort the remaining six cards by the other dimension (post-switch). Performance was the proportion of correct post-switch responses as an assessment of the set shifting or cognitive flexibility aspect of EF (Doebel & Zelazo, 2015). Inter-rater reliabilities (intraclass correlations; 25% coding overlap) were acceptable for both EF tasks (ICC's = .99 and 1.00, respectively).

Academic achievement at age 6—Woodcock Johnson (WJ) III Tests of Achievement (Woodcock et al., 2001) were administered. To assess mathematics achievement, we used math fluency, applied problems, and calculation subtests. To assess reading achievement, we used reading fluency, letter-word identification, and passage comprehension subtests. The variables of interest were age-normed scores on each test.

Data Analysis Strategy

Structural equation modeling (SEM) analysis of the 184 children with academic achievement assessments was undertaken using Mplus 7.4 (Muthén & Muthén, 2015). SEM was selected as a statistical methodology because it has several advantages over regression modeling, including use of confirmatory factor analysis to reduce measurement error by having multiple indicators per latent variable, the desirability of testing overall models rather than individual coefficients, and the ability to handle missing values with sophisticated methods. Missing values on predictor variables were handled with full information maximum likelihood (FIML).

SEM includes two parts: the measurement model and the structural model. In order to reduce measurement error and test the reliability of the indicators, we first tested the measurement model by conducting a confirmatory factor analysis (CFA). Then we tested the structural model and examined relations among the different latent variables. Specifically, we tested the direct effect of NA on EF and academic achievement (reading and mathematics), the direct effect of EF on academic achievement (reading and mathematics), as well as the indirect effect of NA on academic achievement after controlling for gender, SE, and EC.

To evaluate the overall goodness of fit the model, we report chi-square goodness-of-fit statistics, degrees of freedom (*df*), corresponding *p* value, comparative fit index (CFI), and root mean square error of approximation (RMSEA; McDonald & Ho, 2002). Hu and Bentler (1999) suggested that for continuous variables, RMSEA < .06 and CFI > .95 are indicative of good model fit. We tested the significance of the mediated effects using the confidence interval (CI) method because it provides greater statistical power than the commonly used Baron and Kenny (1986) approach and Sobel's test (Sobel, 1982; MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002). A mediated effect is considered significant if the CI does not include zero.

Results

Preliminary Analysis

Descriptive statistics for all measures are presented in Table 1. Word-letter identification was positively skewed. Word-letter identification, passage comprehension, and math applied problems were leptokurtic. Because of the presence of non-normal variables, we conducted the SEM analyses using the MLR estimator of Mplus 7.4 (Muthén & Muthén, 2015), which provides outcomes robust against non-normality (see Muthén & Muthén, 2006).

Confirmatory Factor Analysis

The model fit of the measurement model was good, $\chi^2 = 25.66$, $df = 17$, $p = .08$, CFI = .98, RMSEA = .05. Table 2 presents the factor loadings and the variances of the residuals of the indicators of the latent variables. All the factors loadings were significant.

A correlation matrix of all the variables is presented in Table 3. As expected, NA was significantly correlated with EF, which was significantly associated with mathematics and reading achievement. There was no correlation between NA and math or reading achievement.

The Mediating Model of NA: Structural Equation Modeling

The structural model was determined to fit the data well, $\chi^2 = 57.82$, $df = 37$, $p = .02$, CFI = .97, RMSEA = .06. After controlling for gender ($p = .68$), SE ($p = .11$), and EC ($p = .10$), NA predicted EF ($p = .00$; see unstandardized and standardized coefficients in Figure 2). EF predicted math achievement ($p = .00$) when controlling for gender ($p = 1.00$), SE ($p = .04$), and EC ($p = .25$). Similarly, EF predicted reading achievement ($p = .01$) when controlling for gender ($p = .79$), SE ($p = .02$), and EC ($p = .89$). In these analyses, 23% of the variance in EF was explained by the predictors; 37% and 21% of the variance in math achievement and reading achievement, respectively, were explained by the predictors.

The direct effects of NA on math achievement and reading achievement were not significant ($p = .17$ and $p = .16$ respectively for math and reading). However, there was an indirect effect of NA on both math achievement ($b = -.28$, $SE = .12$, $p = .02$, $\beta = -.23$; 95% CI [-.58; -.05]) and reading achievement ($b = -.27$, $SE = .13$, $p = .04$, $\beta = -.17$; 95% CI [-.59; -.03]) through EF.

Discussion

The purpose of our study was to examine the effect of NA on academic achievement, including both mathematics and reading, as well as to study EF as a potential mediator that underlies temperament and academic achievement association. As expected, NA at age 2 negatively predicted EF at age 4, which in turn positively predicted both mathematics and reading achievement at age 6. EF at age 4 mediated the association between NA and both reading and math academic achievement. NA directly predicted neither mathematics nor reading achievement.

Our finding that NA did not directly predict academic achievement in reading and math but indirectly predicted both through a mediator might be partly due to the inclusion of covariates SE and EC, where SE made direct negative contributions to both math and reading achievement, consistent with past research (Merrell & Tymms, 2001; Rudasill et al., 2010; Vigil-Coleţ, & Morales-Vives, 2005). Interestingly, EC was not related to math and reading achievement in our study. This unexpected finding may be because other temperament characteristics were included in our model. Indeed, in studies that have reported links between EC and academic achievement, EC has been the only temperament trait examined (e.g., Sánchez-Pérez et al., 2015) or one of only two traits examined (e.g., Deater-Deckard et al., 2009). By focusing on NA and including both SE and EC as covariates, we were able to tease apart the unique contribution of NA and its role in early reading and math achievement.

Notably, our study is the first to examine the unique contributions of NA to EF and academic achievement independent of other aspects of temperament. Emotionality plays an important role in academic-related outcomes (Gumora & Arsenio, 2002); however, only a small body of research has examined when and how emotionality matters to academic achievement. Our study highlights the importance of considering emotionality, and specifically NA, as a precursor to children's early academic competence. Because of reported correlations between NA and cognition, we relied on the research literature to propose EF as a potential mediator that links NA with academic achievement. Indeed, our findings demonstrate that early NA (i.e., at age 2) can indirectly predict academic achievement 4 years later because of its impact on developing executive cognitive processes.

Our NA finding is consistent with previous research that showed only indirect links between NA and academic or related outcomes without controlling for SE and EC. For example, shyness during early childhood did not make unique direct contributions to vocabulary achievement, but indirectly predicted vocabulary through EF (Blankson, O'Brien, Leerkes, Marcovitch, & Calkins, 2011). Anger/frustration did not directly predict academic achievement, but indirectly predicted it through social competence and externalizing problems (Zhou et al., 2010). These findings call attention to the importance of examining potential mediators that link NA and academic outcomes. They also call attention to the value of controlling for other temperament characteristics in the model in order to examine unique contributions of the temperament of interest.

Our study extends previous research by focusing specifically on EF as the mediator between NA and academic achievement during early childhood. Children in our sample who had high levels of NA tended to perform poorly on EF tasks. This is consistent with previous work showing negative association between NA and EF in studies with preschool children (Jones et al., 2003) and adults (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013). For young children who experience high NA, there may be a greater impact of negative emotions on cognitive processes. Because higher order cognitive skills are undergoing rapid development during the preschool years, young children's emotional responses may overwhelm their cognitive regulatory mechanisms. Consequently, their cognitive skills may remain underused and underdeveloped (Blair, 2002).

The negative link between NA and EF has implications for the strong connections between EF and concurrent and subsequent mathematics and reading achievement that permeate the research literature (e.g., Blankenship, O'Neill, Ross, & Bell, 2015; Clark et al., 2010; Espy et al., 2004). EF incorporates fundamental cognitive processes underlying early skills required by mathematics and reading (Best, Miller, & Naglieri, 2011). Consistent with substantial previous findings, we showed that early EF significantly predicted later mathematics and reading achievement (e.g., Clark et al., 2010; Welsh et al., 2010). For example, Bull and colleagues (2008) reported that EF measured at 4 years predicted academic performance at 7 to 8 years. We showed that EF at age 4 predicted reading and math at age 6. Importantly, these findings suggest that young children with EF deficits are at risk for later significant impairments in academic performance (Biederman et al., 2004).

Conclusions

Our study had several methodological strengths. First, by using a longitudinal design across toddlerhood and early childhood, we were able to link early NA with later academic achievement, while examining a potential cognitive mechanism that underlies the association. Second, we used two age-appropriate EF tasks to cover wide-ranging EF skills, rather than focusing on single aspects of EF (Best & Miller, 2010; Miyake, et al., 2000). Third, our use of standardized assessment of mathematics and reading achievement allows for generalization of our findings to other research studies using this particular measure. Fourth, we controlled for gender, allowing our findings to generalize to both girls and boys. In addition, because our two site study recruited families from a rural university as well as a mid-sized southern city, 24% of the children at the age 6 visit were minority with respect to race and ethnicity.

Notwithstanding these strengths, some potential limitations should be noted. First, temperamental NA was measured by maternal report. Although parental report may be considered as a limitation of study, we consider it to be an advantage. Maternal reports assess children's behavioral patterns across a variety of natural contexts, thus enhancing the ecological validity of our findings. Ideally, future research may want to integrate multiple NA measures, including laboratory or school based assessments of NA, in a more comprehensive way. Second, NA is a higher order factor that includes different aspects of specific emotions (e.g. fear, frustration). Not all emotions are likely to contribute to academic achievement equally or through the same mechanism. Although it is important to

study the effect of overall NA on academic achievement as a first step, future research might benefit from examining how specific aspects of emotions relate to academic achievement. Third, there is little evidence indicating an association between positive emotions and academic achievement. Understanding how positive emotions affect cognitive processes and academic achievement would significantly advance our understanding of school readiness in early childhood (Valiente et al., 2012). Fourth, as there may be gender differences on cognitive performance and academic achievement (Kerkman et al., 2000; Mullola et al., 2011), future research could examine if the process is similar for boys and girls.

Despite these limitations, our study provides practical educational implications. Our findings highlight the significance of considering both temperament and EF in improving children's academic achievement. High NA, as well as EF deficits, might be informative in the early screening for children who might be at risk for difficulties in later reading and math achievement. Thus, early intervention programs targeted at either emotion regulation or EF (Diamond & Lee, 2011; Shields et al., 2001) may benefit early academic performance. For parents, previous research indicates that appropriate emotional socialization strategies, as well as maternal contingent engagement, responsiveness, and support, play important roles in early developing emotion regulation (Crockenberg & Leerkes, 2004; Spinrad, Stifter, Donelan-McCall, & Turner, 2004). For educators, professional development programs designed to improve children's EF have been shown as efficient ways to advance school readiness and academic achievement (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008). Given our longitudinal findings that age 2 NA impacts age 6 reading and math achievement through age 4 EF, perhaps there would be utility and not redundancy in targeting both NA and EF for early intervention.

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Figure 1.

Hypothesized model describing that age 2 NA indirectly predicts age 6 math and reading achievement through age 4 EF, controlling for age 2 SE and EC. NA = Negative affectivity; SE = Surgency/Extroversion; EC = Effortful control; EF = Executive function; BD = Bear-dragon; DCCS = Dimension Change Card Sorting; MF = Math fluency; AP = Applied Problems; CAL = Calculation; RF = Reading fluency; WL = Word-Letter identification; PC = Passage comprehension. For clarity of the presentation, indicators of the latent variables are not drawn.

Figure 2.

Structural equation model describing that age 2 NA indirectly predicts age-6 math and reading achievement through age 4 EF, controlling for age 2 SE and EC. Only significant paths are shown. Numbers represent unstandardized path coefficients (inside parentheses are standardized path coefficients). NA = Negative affectivity; SE = Surgency/Extroversion; EC = Effortful control; EF = Executive function; BD = Bear-dragon; DCCS = Dimension Change Card Sorting; MF = Math fluency; AP = Applied Problems; CAL = Calculation; RF = Reading fluency; WL = Word-Letter identification; PC = Passage comprehension. $*p < .05$, $**p < .01$.

Table 1

Descriptive Statistics (n=184)

Variables	Mean	SD	Skewness	Kurtosis
Negative Affectivity	3.11	.55	.37	.36
Bear-dragon	.58	.46	-.28	-1.83
DCCS	.82	.34	-1.61	.97
Math fluency	6.63	.82	.64	-.10
Applied problems	7.04	1.15	1.34	3.49
Calculation	7.07	.78	.19	-.04
Reading fluency	7.03	1.05	1.14	.05
Letter-word identification	7.52	1.02	2.47	11.02
Passage comprehension	7.05	.93	.98	3.23
Surgency/Extroversion	5.12	.58	-.30	1.47
Effortful Control	4.43	.50	-.23	-.04

Table 2

Factor Loadings and Variances of Residuals of the Indicators

Variables	Unstandardized Factor loadings	Standardized Factor loadings	Residual variances ^a
Executive function			
Bear-dragon	1.00	.42 **	.83
DCCS	1.17 **	.67 **	.56
Math achievement			
calculation	1.00	.87 **	.24
math fluency	1.10 **	.92 **	.16
applied problems	1.16 **	.69 **	.53
Reading achievement			
letter-word identification	1.00	.88 **	.22
reading fluency	1.04 **	.89 **	.20
passage comprehension	1.00 **	.97 **	.06

Note.

**
p < .01.

Table 3

Correlations among Variables

Variables	1	2	3	4	5
1. NA	1.00				
2. EF	-.37**	1.00			
3. Math	-.09	.56**	1.00		
4. Reading	-.05	.41**	.79**	1.00	
5. SE	.08	.16*	-.05	-.11	1.00
6. EC	-.19**	.30**	.06	.12	-.06

Note. NA = Negative affectivity; EF = Executive function; Math = Mathematics achievement; Reading = Reading achievement.

*
 $p < .05$,

**
 $p < .01$.