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Early cumulative risk and outcomes in adolescence and adulthood: The role of executive function and behavioral regulation

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Abstract

This study examined the extent to which early cumulative risk predicts a range of behavioral and psychological outcomes (i.e., depression, future orientation, risky behavior, educational attainment, and socioeconomic outcomes) measured at ages 15 and 26 and whether executive function (EF) and/or behavioral regulation mediated and/or moderated these associations. Data for this study came from the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development (NICHD SECCYD) and included a sample of 1,364 participants (52% male) born in 1991 and followed through age 26. Results indicated that early cumulative risk was related to depression and risky behavior at age 15 as well as depression, income, future orientation, and educational attainment at age 26. Further, both EF and behavioral regulation mediated relations among cumulative risk and academic achievement at age 15 and between cumulative risk and income and educational attainment at age 26. Finally, three significant interactions emerged for age 15 outcomes, indicating that EF and behavioral regulation may change relations between cumulative risk and depression, reading, and future orientation. Implications for future research are discussed.

Keywords

cumulative risk; executive function; behavioral regulation; adolescent outcomes; adult outcomes

Early exposure to contextual risk factors such as maternal stress and poverty can have long-term developmental consequences (Evans et al., 2013). Critically, when early risk exposure is cumulative (i.e., co-occurring risks), negative effects on outcomes are compounded (Atkinson et al., 2015). Although numerous studies have shown the negative impact that

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This study was not preregistered.

Data for all study waves with the exception of the age 26 data are available at ICPSR https://www.icpsr.umich.edu/icpsrweb/ICPSR/series/00233.

early cumulative risk exposure can have on development in early childhood through adolescence (Evans et al., 2013; Mason et al., 2019), fewer studies have linked early exposure to adult outcomes (Atkinson et al., 2015; Pungello et al., 2010; Raposa et al., 2014). Further, although research has begun focusing on the mechanisms through which early cumulative risk may influence later outcomes (Holochwost et al., 2016; Pungello et al., 2010), limited work has tested the extent to which childhood cognitive or behavioral characteristics play a role in these longitudinal relations. In order to further our understanding of the developmental processes through which early risk matters for subsequent health and well-being, identifying potential mechanisms and moderating factors is critical. The purpose of the present study was twofold. First, we examined the extent to which early cumulative risk (measured between birth and age three) predicted a range of behavioral and psychological outcomes (i.e., depression, future orientation, risky behavior, educational attainment, and socioeconomic outcomes) measured at ages 15 and 26. Second, we investigated whether executive function (EF) and/or behavioral regulation measured at 4 ½ years mediated and/or moderated these associations.

Cumulative Risk Exposure and Adolescent and Adult Health and Well-Being

Although a great deal of work has been dedicated to understanding the effects of singular contextual risks early in life for later outcomes such as educational attainment, cognitive functioning, and psychopathology (Davis-Kean et al., 2021; Elovainio et al., 2012; Hoyt et al., 2019; Jensen et al., 2014; Letourneau et al., 2013; Schoon et al., 2002), fewer studies have examined the longitudinal associations of cumulative risk exposure (i.e., co-occurring risks) in early childhood for later outcomes, and the majority of this work has focused on middle childhood and adolescent outcomes (Evans et al., 2013). Evidence from this research suggests that higher scores on various cumulative risk indices in early childhood predict cognitive, language, and socio-emotional outcomes in these periods of life (Brooks-Gunn et al., 1995; Furstenberg, 1999; Luster & McAdoo, 1994; Mason et al., 2019). For example, Appleyard et al. (2005) found that cumulative risk measured by socioeconomic status, parental stress, inter-parental violence, family disruption, and child maltreatment in early childhood predicted internalizing and externalizing behaviors at the age of 16. As another example, Gutman et al. (2003) found that a composite of ten risk factors (e.g., father absence, family stress, maternal mental health) measured at the age of 4 significantly predicted lower grade point average from 1st through 12th grade.

There are fewer studies examining relations between early cumulative risk and adult health and well-being. This is likely due to a dearth in longitudinal datasets that follow children from birth into adulthood. The longer-term studies that have been conducted generally indicate deleterious effects of cumulative risk exposure across a range of adult outcomes (Atkinson et al., 2015; Pungello et al., 2010; Raposa et al., 2014). Some of this work has focused on single outcomes such as health and others have focused on multiple outcomes. For instance, in a prospective study, Raposa et al. (2014) linked a composite of five risk factors (i.e., parental separation, family income, maternal relationship discord, maternal stress, and maternal depression) during the first five years of life with depressive symptoms

between ages 15 and 20 (Raposa et al., 2014). Atkinson et al. (2015) found that a cumulative risk index comprised of six risk factors (socioeconomic status, maternal age at birth, family size, maternal depression, maternal marital status, and parental conviction) was related to numerous adult outcomes measured at age 25 or 26, including, depression, educational attainment, arrests, and chronic disease. Similarly, using a six-item cumulative risk index (i.e., teen mother, maternal education, parent marital status, non-resident father, and high mobility), Pungello et al. (2010) documented significant connections between cumulative risk from birth to age five and educational attainment, high school graduation, employment, and teen parenthood for individuals ages 20–25.

In summary, extant research indicates that various conceptualizations of early cumulative risk are related to poorer outcomes across multiple domains in adolescence, and accumulating evidence suggests similar effects on adult outcomes. Notably, the majority of research examining longitudinal links between cumulative risk in early childhood and subsequent outcomes has focused on risk exposure in the first five years. Although the first five years of life collectively are certainly important for later development, in this study, we were interested in testing the extent to which risk exposure during *the first three years of life* was related to a host of later outcomes, some of which have not been included in previous studies (e.g., future orientation defined as degree of future consideration and planning). This decision was prompted by findings out of the neuroscience literature indicating that brain development is occurring rapidly during the first three years, and thus, may be particularly sensitive to external factors (e.g., contextual risk; Shonkoff & Phillips, 2000; Troller-Renfree, et al., 2022).

The Potential Role of Executive Function and Behavioral Regulation

Some studies have begun to examine potential mechanisms underlying or affecting the relations between early risk exposure and later outcomes; however, the majority of this work has focused on proximal contextual mechanisms, such as the home environment. For example, Pungello et al. (2010) found that the quality of the home environment within a low-income sample mediated associations between early cumulative risk and likelihood of graduating high school. Fewer studies have examined the role of individual child factors for longitudinal relations among early cumulative risk and outcomes. In this study, we examine the extent to which EF and behavioral regulation are involved in these relations. Specifically, we test whether cognitive EF (as measured by *direct assessments* of short-term memory, inhibitory control, and sustained attention), and/or behavioral regulation (as measured by *parent reports* of attentional focusing, inhibitory control, and attention problems) at 54 months mediate and/or moderate predictive relations between early cumulative risk and adolescent and adult outcomes. Understanding both EF and behavioral regulation as separate constructs is in line with perspectives suggesting they are distinct, both conceptually and methodologically (e.g., Jones et al., 2016) and will allow us to test for differential relations among our target predictor and outcomes. This approach is also consistent with Bornstein's Specificity Principle, which suggests that in order to truly understand the nuances of human development, scholars must include specific mechanisms and outcome variables in their models (Bornstein, 2019).

Mediation.

There is evidence to suggest that both EF and behavioral regulation could act as mechanisms underlying associations between early cumulative risk exposure and particular adolescent and adult outcomes. Indeed, studies indicate that early cumulative risk is related to EF and behavioral regulation development (Hughes & Ensor, 2005; Lengua et al., 2007; Suntheimer & Wolf, 2020). For instance, in a recent study, early cumulative risk was negatively related to three regulatory outcomes in kindergarten (Suntheimer & Wolf, 2020). Specifically, these investigators found effects on EF as measured by direct assessments of working memory and cognitive flexibility and behavioral regulation as measured by teacher report of inhibitory control. In another study, early cumulative risk exposure predicted effortful control (as measured by direct assessments of delay of gratification and inhibitory control) six months later (Lengua et al., 2007).

Moreover, previous research points to pathways between childhood EF and behavioral regulation and later outcomes. For instance, Moffitt et al. (2011) found that childhood self-control (comprised of observer, adult, and child ratings and akin to our conceptualization of behavioral regulation) predicted a host of adult outcomes, including involvement in the criminal justice system and substance dependence (perhaps indicative of risky behaviors), as well as financial well-being. No significant effect was found for depression. Studies have also demonstrated connections between EF and behavioral regulation and academic and educational outcomes both in adolescence and adulthood. With regard to EF, using data from the NICHD Study of Early Child Care and Youth Development (SECCYD), Ahmed et al. (2019) found that EF measured at 54 months predicted academic achievement at age 15. Similar longitudinal relations were found at age 26 educational attainment using the same data set (Ahmed et al., 2021). With regard to behavioral regulation, McClelland et al. (2013) found that parent-reported attention at age 4 was related to academic achievement in young adulthood and college completion by the age of 25. Thus, both EF and behavioral regulation are likely related to later educational outcomes.

There is some emerging research examining EF as a mediator underlying certain risk factors and later outcomes. For example, studies have shown that EF during early and middle childhood mediates relations between socioeconomic factors and later academic outcomes (Deer et al., 2020; Lawson & Farah, 2017; Waters et al., 2021). Further, in a recent study looking specifically at cumulative risk, results indicated that EF measured at age 9 significantly mediated the effect of cumulative risk exposure from birth to age 9 on math achievement at age 11 among Ghanian children (Suntheimer et al., 2022). Thus, it is expected to do the same in models examining earlier cumulative risk and later educational outcomes.

In sum, previous literature suggests that the pathways for a mediating effect of EF and behavioral regulation for relations between early cumulative risk and outcomes are likely and may depend on the specific aspect of EF. For example, extant studies indicate that both EF and behavioral regulation may mediate the effects of risk on educational and socioeconomic outcomes (Deer et al., 2020; Lawson & Farah, 2017; McClelland et al., 2013; Moffit et al., 2011; Suntheimer et al., 2022; Waters et al., 2021). However, the literature base suggests that perhaps only behavioral regulation may mediate the effect

on risky behaviors and that neither EF nor behavioral regulation will mediate effects on depression (Moffitt et al., 2011). We offer no hypotheses for future orientation given the lack of literature on this outcome in adolescence and adulthood.

Moderation.

Similar to the potential for EF and behavioral regulation to act as mediators underlying longitudinal associations between early cumulative risk and subsequent outcomes, it is possible that EF and behavioral regulation could also moderate these relations. Indeed, EF has been identified as a potential compensatory factor or a marker of resilience for children experiencing early risk (McClelland et al., 2016), and there is some empirical evidence to support this claim with regard to behavioral regulation (Obradovic, 2010; Sektnan et al., 2010). For example, in one study using the NICHD SEYCCD data, results showed that when experiencing the same number of risk factors between birth and 54 months, children who had stronger behavioral regulation measured at 54 months fared better academically in 1st grade (Sektnan et al., 2010). As another example, a recent study found that behavioral regulation at age 4 moderated relations between cumulative risk between birth and age 6 and internalizing problems at age 7 (de Maat et al., 2022). To our knowledge, there have been no studies that have empirically tested the extent to which EF or behavioral regulation may moderate longitudinal associations between early cumulative risk and outcomes in adolescence or adulthood. However, given the theoretical and limited empirical evidence for such associations in childhood, we expect that behavioral regulation may also moderate relations between early risk and adolescent and adult outcomes.

Present Study

The goals of the present study were to examine 1) longitudinal relations between early cumulative risk (between birth and three years of age and comprised of eight risk categories: maternal education, income-to-needs ratio, maternal depression, maternal social support, whether the father lives with the mother, maternal parenting stress, mother's reported intimacy, and maternal personality) and a range of behavioral and psychological outcomes (i.e., depression, future orientation, risky behavior, educational and socioeconomic outcomes) at ages 15 and 26, and 2) the extent to which EF and behavioral regulation at 54 months mediate and/or moderate these associations. Given extant literature (Appleyard et al., 2005; Atkinson et al., 2015; Evans et al., 2013; Pungello et al., 2010; Raposa et al., 2014), we hypothesized that early cumulative risk would be significantly related to all of our target outcomes in adolescence and adulthood. Further, based on previous evidence (Lawson & Farah, 2017; Suntheimer et al., 2022; Waters et al., 2021), we expected that both EF and behavioral regulation would mediate relations between early cumulative risk and later educational and financial outcomes. We also expected that behavioral regulation would mediate associations between cumulative risk and risky behaviors, but not depression (Moffitt et al., 2011). We did not have a priori hypotheses for mediating effects on future orientation. With regard to moderating effects, we expected that behavioral regulation, not EF, would moderate relations between early cumulative risk and adolescent and adult outcomes (de Maat et al., 2022; Sektnan et al., 2010).

Method

Participants

The current study uses data from the NICHD Study of Early Child Care and Youth Development (SECCYD), an archived dataset available at https://www.icpsr.umich.edu/icpsrweb/ICPSR/series/00233. Participants were recruited during hospital visits conducted with mothers shortly after the birth of a child in 1991 at 10 locations in the United States (Little Rock, AR; Irvine, CA; Lawrence, KS; Boston, MA; Hickory, NC; Philadelphia, PA; Pittsburgh, PA; Charlottesville, VA; Seattle, WA; Madison, WI). During selected 24-hr intervals, all women giving birth (N = 8,986) were screened for eligibility. Of those families, 3,142 were excluded due to a priori criteria such as not speaking English or plans to move within the next 3 years. At a follow-up telephone interview at 2 weeks, 1,353 could not be contacted or refused to participate. Families were randomly selected among the remaining pool of eligible participants. A total of 1,364 families were recruited, completed a home interview at 1 month, and became the study participants. Overall, this constituted a 52% response rate from the original approach to families in the hospital to successful recruitment in the study. At recruitment, 26% of the mothers had no more than a high school education; 21% had incomes no greater than 200% of the poverty level; and 22% were of minority race or ethnicity (i.e., not non-Hispanic White). See Table 1 for descriptive statistics. For more details about the sample and sample recruitment, see NICHD ECCRN (2005). Phase I of the study includes data during the first three years of childhood, Phase II includes data collected at age 4 ½, Phase IV includes data on age 15 outcomes, and Phase VI includes data on age 26 outcomes. All phases of the SEYCCD study were approved by an Institutional Review Board. This study was not preregistered.

Measures

Early cumulative risk.—A composite variable representing cumulative risk between the ages of 0–3 was created using eight domains: maternal education, income-to-needs ratio, maternal depression, maternal social support, whether the father lives with the mother, maternal parenting stress, mother's reported intimacy with a spouse or romantic partner, and maternal personality. Selection of these variables was based on previous studies that have examined relations between early cumulative risk and developmental outcomes using the SECCYD data (Belsky & Fearon, 2002). *Maternal education* was obtained during the 1-month interview where the mothers disclosed the number of years of education they received. *Income-to-needs ratio* was assessed at 1, 6, 15, 24, and 36 months when the mothers provided the amount of income and household size. *Maternal depression* was assessed at 1, 6, 15, 24, and 36 months using the Center for Epidemiological Studies Depression Scale (Radloff, 1977). *Maternal social support* was assessed at 1, 6, 15, 24, and 36 months using the Relationships with Other People measure (Marshall & Barnett, 1993). Additionally, information about *whether the father lives with mother* was obtained at 1, 6, 15, 24, and 36 months during the home interviews and telephone surveys (1 (*Father present*), 0 (*Father not present*)). *Maternal parenting stress* was assessed using the Parenting Stress Index (PSI; Abidin, 1982) at 1 and 6 months and was assessed using the Parent Role Quality Scale (Barnett & Marshall, 1991) at 15, 24, and 36 months. *Maternal intimacy* was assessed using the Love and Relationships Part A: Personal Assessment of Intimacy in

Relationships (Schaefer & Olson, 1981) at 1 and 36 months. Lastly, *maternal psychosocial adjustment* was assessed at 6 months. Extraversion and neuroticism were assessed using the NEO Personality Inventory (Costa & McCrae, 1985), and maternal agreeableness was assessed using the NEO Five-Factor Inventory (Costa & McCrae, 1989).

Once all eight domains had been created as aggregates of the available data during the first three years, each domain score was centered and standardized, with positive values representing lower risk (e.g., higher income, higher education, less maternal depression). Then a cumulative variable of these eight domains was created by taking the average of all of them (i.e., positive values still representing lower risk), with each of the eight domains equally weighted (all contributed equally to the aggregate). Finally, we multiplied this aggregate variable by −1 to reverse the scale so it reflect greater cumulative risk for interpreting the model estimates (i.e., positive values characterize children experiencing poorer scores on the aggregate of cumulative risk). Refer to Supplementary Table 1 for more details about the cumulative risk measure and how it was coded.

EF.—A composite variable was created using three variables that were assessed at 54 months: short-term memory (also called simple working memory; Best & Miller, 2010; Garon et al., 2008), inhibitory control, and sustained attention. *Short-term memory* was assessed using the Memory for Sentences Test of the Woodcock-Johnson Psycho-Educational Battery (WJ-R; McGrew, 1993)*, inhibitory control* was assessed using the Children's Stroop Task (Gerstadt et al., 1994), *Sustained attention* was assessed using the omission errors of the Continuous Performance Task (CPT; Halperin et al., 1991). The Memory for Sentences Test of the WJ-R (McGrew, 1993) measures the ability to remember and repeat simple words, phrases, and sentences presented auditorily by use of a tape player or, in special cases, by the examiner. The test items are arranged in order of difficulty, with the easiest item presented first and the most difficult item last. The task is scored by placing 2 (*Superior response*), 1 (*Standard response*), or 0 (*Inadequate response*) points in the Test Record. The scoring software generated standard scores, which are based on a mean of 100 and a standard deviation of 15, and the equivalent percentile rank.

For the Stroop Task (Gerstadt et al., 1994), just before beginning the test, the child is shown Card A (Black Card) and told to say 'day'. The child is then shown Card B (White Card) and told to say 'night'. These instructions could be said a total of three times. If the child understood the instructions and answered correctly on the first set of practice trials, no further repetition of the instructions was necessary. If, however, the child did not get the first two trials correct, then the tester repeated the instructions and the practice trials a second time. If the child answered correctly on the second set of practice trials, then the tester continued with the test. If, however, the child again failed to correctly answer the second set of practice trials, then the instructions were given a third time, but the practice trials were not repeated. The child must answer correctly on both day and night in one of the two sets of practice trials for the data to be counted as usable. After the practice trials, the tester continues with trials 3 through 16. Inhibitory control was calculated using the incorrect percentage variable from the dataset to create the percentage correct out of the total number of non-missing responses.

With respect to the computer-generated CPT (Halperin et al., 1991), dot matrix pictures of familiar objects (e.g., butterfly, fish, flower) were presented on a 2-inch square screen in front of the child. The child was asked to press a button each time a target stimulus appeared. Once the test session began, the stimuli were presented in 22 blocks. Ten stimuli were presented in each block. The stimulus duration was 500 msec and the interstimulus interval was 1500 msec. The target stimulus (a dot matrix picture of a chair) was randomly presented within each block and appeared twice in each block. The computer automatically compiled the omission errors which were the number of targets to which the child did not respond when the target stimulus was present. Total omission errors represented sustained attention in the analysis. This variable was multiplied by −1 to reverse the scale so that positive values represented higher EF (e.g., higher sustained attention)

Each of the three variables was centered and standardized. Then, a cumulative variable of these three domains was created by taking the average of all of them (i.e., positive values still representing higher EF), with each of the three variables equally weighted (all contributed equally to the aggregate).

Behavioral regulation.—A composite variable was created using three variables that were assessed using maternal report at 54 months: attentional focusing, inhibitory control, and attention problems. *Attentional focusing* and *inhibitory control* were assessed using the Children's Behavior Questionnaire (CBQ; Rothbart et al., 1994), and *attention problems* was assessed using the Child Behavior Checklist (CBCL; Achenbach, 1991). For the CBQ (Rothbart et al., 1994), mothers responded to 80 items that described their children's reactions to different situations. The items were rated on a 7-point scale ranging from 1 (*Extremely untrue*) to 7 (*Extremely true*) to reflect the child's reactions during the previous six months. Sample items include 'tends to run rather than walk from room to room', and 'gets quite frustrated when prevented from doing something he or she wants to do'. Scores for attentional focusing consisted of the mean of eight items. Scores for inhibitory control consisted of the mean of 10 items. With respect to the CBCL (Achenbach, 1991), mothers responded to a series of items (about 100 items per version) on 3-point scales from 0 (*Not true of the child*) to 2 (*Very true of the child*), and attention problems were scored with standard computer programs. Sample items include 'feelings are easily hurt', and 'disturbed by any change in routine'.

Each of the three variables was centered and standardized, and the attention problems variable was multiplied by −1 to reverse the scale such that positive values represented higher behavioral regulation (e.g., higher parent-reported attentional focusing and inhibitory control, lower parent-reported attention problems). Then, a cumulative variable of these three domains was created by taking the average of all of them (i.e., positive values still representing higher behavioral regulation), with each of the three variables equally weighted (all contributed equally to the aggregate).

Outcomes at age 15

Depression.—The depression score was assessed using the Children's Depression Inventory (Short Form; Kovacs, 1992), which consists of a 10-item questionnaire. The

adolescents were presented with ten sets of three statements, and they selected the one that best describes the way they felt over the previous two weeks. The items tap dysphoric mood, lack of pleasure, and low self-esteem. Each set of statements is scored on a 0 to 2 scale where higher scores indicate more child depression. Scores above 8 for girls and above 10 for boys are considered “well above average”. The raw items used to create the depression score have moderate internal reliability (Cronbach’s alpha = 0.81).

Future Orientation.—Future orientation was assessed using the Future Outlook Inventory (Cauffman & Woolard, 1999), which consists of an 8-item scale. The scale assesses the adolescent’s ability to foresee short- and long-term consequences. Adolescents are asked to respond according to what is most true for them. The scale ranges from 1 (*Never*) to 4 (*Always*). Responses on the eight items are summed to form the global measure of future orientation, with higher scores indicating a greater degree of future consideration and planning. The items used to create the final score have moderate internal reliability (Cronbach’s alpha = .72).

Risky behavior.—Adolescent risky behavior was assessed using the Risky Behavior Questionnaire that was developed for use in the NICHD SECCYD, and it draws on work from Conger and Elder (1994). In the first part of the questionnaire the adolescent is asked how many times in the past year they engaged in 55 different risky behaviors. These items use the following response scale: 0 (*Not at all*), 1 (*Once or twice*) and 2 (*More than twice*). Sample items include ‘ridden in a car without a seatbelt’, and ‘taken part in a gang fight’. The 53 items used to create the final score have high internal reliability (Cronbach’s alpha = .89). Two items that measured sex-related experience outcomes rather than actual behavior were not included in the final score. The scores are computed as the sum of response values to child items, after recoding the items to be 0/1 variables (0 [*Never*], 1 [*Once or twice and more than twice]*), with higher values indicating more risk-taking by the adolescent.

Achievement.—Adolescents were assessed on their reading and math skills using the Passage Comprehension and Applied Problems subscales of the WJ-R respectively (McGrew, 1993). The Passage Comprehension subscale assesses the adolescent’s understanding of written text. The initial items measure the adolescent’s ability to match a picture symbol with an actual picture. The next set of items requires adolescents to match a short phrase to the appropriate picture when given three choices. Most items require the adolescents to supply a missing word to sentences and then paragraphs of increasing complexity. The Applied Problems subscale assesses the adolescent’s ability to solve mathematical problems that include basic counting, addition, subtraction, and multiplication primarily through word problems read to the child. The raw scores were used for both subscales, which is the number of correct responses plus a score of 1 for every item in the test below the basal level, which is the set of consecutive items below which the subject has essentially a 100% chance of responding correctly to all items.

Refer to Supplementary Table 2 for more details about the outcomes and how they were coded.

Outcomes at age 26

Depression.—Adult's depression was assessed using the Center for Epidemiologic Studies Depression Scale (Corcoran & Fisher, 1987). The items used to create the final score have high internal reliability (Cronbach's alpha = .94).

Future Orientation.—Future orientation was assessed using the Future Outlook Inventory (Cauffman & Woolard, 1999), which was also used to assess adolescents at age 15. The items used to create the final score have moderate internal reliability (Cronbach's alpha = .73).

Risky Behavior.—Adults' risk behavior was assessed using the Risky Behavior Questionnaire based on Conger & Elder (1994), which was also used to assess adolescents at age 15. The items used to create the final score have moderate internal reliability (Cronbach's alpha = .77).

Income.—Adults entered the amount of their paycheck in a format (hourly, weekly, biweekly, monthly, yearly) that was most convenient for them. Salary was computed in 10 percentiles and data were excluded for those individuals who had no income. Sensitivity analyses were conducted for salary: 1) Using 10 percentiles where the data for individuals with no income was not excluded; 2) Using log annual salary. The results remained consistent for all three ways that salary was computed.

Educational attainment.—Adults reported on the highest degree attained based on eight options that included: no high school, General Equivalency diploma, high school diploma, some college but no college degree, Associate's degree, Bachelor's degree, some graduate school but no graduate degree, Master's degree, and Doctoral degree.

Refer to Supplementary Table 2 for more details about the outcomes and how they were coded.

Analytic Plan

All analyses were run using Stata 17 (StataCorp, 2021). All models were run using the *sem* function in Stata, which allows for Full Information Maximum Likelihood (FIML), estimating direct, indirect, and total effects, and correlated error terms of the dependent variables (done in all models). FIML was used to handle missing data in all models and provides less biased estimates than listwise deletion (Acock, 2012). In addition to FIML, all models used bootstrapped and clustered standard errors due to the mediation analyses and the 10 sites participants were recruited from. Finally, in all models, we controlled for sex, race/ethnicity, and mother's vocabulary, and for age 15 and 26 year outcomes, we controlled for EF and behavioral regulation at 54 months. All code and output, including how variables were coded/created and analytic models, are available by request.

To answer the mediation questions, we first ran a series of models that estimated the main effects of cumulative risk on mediators (EF and behavioral regulation) and age 15 or age 26 outcomes. We report on the direct, indirect, and total effects from these models without the interaction terms included (i.e., the indirect and total effects would change as a function

of the interaction if it were included). Indirect effects represent the mediating effects of EF and/or behavioral regulation.

To answer the moderation question, we then ran a series of models that estimated the prior models but with interaction terms for cumulative risk and EF and behavioral regulation at 54 months (2 interaction terms in total) on each of the age 15 and 26 outcomes. In models where the interaction was statistically significant, we provide and plot the simple slopes of cumulative risk at low (−1 *SD*), average (*M*), and high (+1 *SD*) levels of EF or behavioral regulation to aid in interpretation.

Results

Descriptive Statistics

Descriptive statistics, including means, standard deviations, and ranges are presented separately by participant age (age 15 and age 26) in Table 1. Bivariate correlations for the full sample are presented in Table 2. Cumulative risk was related to all the outcomes except future orientation at age 15. At age 26, cumulative risk was related to all outcomes. In terms of EF, it was related to risky behavior ($r = -.14$, $p < .001$), reading ($r = .38$, $p < .001$), and math ($r = .33$, $p < .001$) at age 15. At age 26, EF was related to income ($r = .17$, $p < .001$) and educational attainment ($r = .25$, $p < .001$). Lastly, with regards to behavioral regulation, it was related to future orientation ($r = .08$, $p = .025$), risky behavior ($r = -.14$, $p < .001$), reading ($r = .24$, $p < .001$), and math ($r = .26$, $p < .001$) at age 15. At age 26, behavioral regulation was related to risky behavior ($r = -.12$, $p = .001$), income ($r = .16$, $p < .001$), and educational attainment ($r = .24$, $p < .001$). For information about the cross-domain bivariate correlations at age 15 and 26 refer to Supplementary Tables 3–4.

Cumulative Risk During the First Three Years Predicts Outcomes at Age 15 and 26

When controlling for sex, race/ethnicity, and mother's vocabulary, mediation analyses revealed significant and positive direct effects between cumulative risk and depression (β = .11, do $p = .002$; Table 3) and risky behavior at age 15 (β = .14, $p < .001$; Table 3). At age 26, analyses indicated a significant direct effect between cumulative risk and depression (β = .15, $p = .003$; Table 4), income (β = −.12, $p = .007$; Table 4), and educational attainment (β = −.22, $p < .001$; Table 4) at age 26. Cumulative risk did not significantly predict future orientation or risky behavior at age 26. No other significant direct relations emerged in the data at age 15 or 26 (Tables 3–4). For information about the direct effects for the covariates at age 15 and 26 refer to Supplementary Tables 5 and 8.

Mediation Results

With regards to the mediation at age 15, there were two significant indirect effects (Table 3): reading (β = −.07, $p < .001$) and math (β = −.09, $p < .001$). In the case of reading, 68% of the indirect effect for cumulative risk was associated with EF and 32% was related to behavioral regulation. In terms of math, 45% of the indirect effect for cumulative risk was associated with EF and 55% was related to behavioral regulation. At age 26 there were two significant indirect effects: income (β = −.06, $p < .001$) and educational attainment (β = −.05, $p < .001$). In the case of income, 36% of the indirect effect for cumulative

risk was associated with EF and 64% was related to behavioral regulation. With regards to educational attainment, 42% of the indirect effect for cumulative risk was associated with EF and 58% was related to behavioral regulation. For information about the indirect and total effects for the covariates at age 15 and 26 refer to Supplementary Tables 6, 7, 9, and 10.

Moderation Results

There were three significant interactions, all that occurred for age 15 outcomes (see Figures 1, 2, and 3 for a visual depiction and simple slopes). There was a significant interaction between EF and cumulative risk on depression at age 15 ($\beta = -.11$, $p < .001$; Figure 1; Supplementary Table 9) such that cumulative risk was more strongly related to depression when children had low EF at 54 months. There was also a significant interaction between behavioral regulation and cumulative risk on future orientation at age 15 ($\beta = -.09$, $p = .010$; Figure 2; Supplementary Table 9). Future orientation at age 15 were highest for adolescents who experienced low levels of cumulative risk in the first three years and who demonstrated high behavioral regulation as preschoolers. Finally, there was a significant interaction between EF and cumulative risk on reading at age 15 ($\beta = .04$, $p = .04$; Figure 3; Supplementary Table 10), suggesting that reading scores were lower for children who experienced cumulative risk and had lower levels of EF. No other significant interactions emerged in the data at age 15 or 26 (Supplementary Tables 9–12). For information about the covariates in the moderation analyses at age 15 and 26 refer to Supplementary Tables 11–14.

Discussion

The goals of the present study were to examine the extent to which cumulative risk during the first three years was linked to adolescent and adult outcomes (i.e., depression, future orientation, risky behavior, educational and socioeconomic outcomes) and to investigate whether EF and/or behavioral regulation measured at 4 ½ years mediated and/or moderated these associations. Results indicated that early cumulative risk predicted the majority of our adolescent and adult outcomes. Specifically, higher early cumulative risk in the first three years was linked to higher depressive symptoms at both age 15 and age 26. Higher cumulative risk also predicted engaging in more risky behaviors at age 15 and less educational attainment at age 26.

In addition, we found evidence that both EF and behavioral regulation served as pathways linking early risk and educational and financial outcomes. Specifically, there were significant indirect effects of cumulative risk working through both EF and behavioral regulation for reading and math achievement at age 15 and for income and educational attainment at age 26. Our exploratory moderation analyses revealed three significant interactions all of which occurred for age 15 outcomes. First, results indicated that for children who experienced high levels of cumulative risk in the first three years, low EF at 54 months magnified this relation and was related to higher depression scores at age 15. Similarly, children who experienced high levels of cumulative risk in the first three years and had low EF at 54 months had the lowest reading scores at age 15. Finally, a significant interaction emerged between behavioral regulation and cumulative risk on future orientation at age 15 indicating that children who experienced low levels of cumulative risk

and who had higher behavioral regulation had the highest future orientation scores at age 15. Together, these findings indicate that early cumulative risk (measured between birth and age 3) matters for adolescent and adult functioning and shed light on the role of EF and behavioral regulation for these relations.

Direct Effects of Early Cumulative Risk on Adolescent and Adult Outcomes

In line with hypotheses, findings indicated that early cumulative risk (comprised of eight indicators) was related to the majority of our target outcomes at ages 15 and 26. Specifically, risk exposure predicted depression at both ages, risky behaviors in adolescence, and income, educational attainment, and future orientation in adulthood. These results are in line with other prospective studies examining early cumulative risk and later outcomes (Atkinson et al., 2015; Raposa et al., 2014). Indeed, and as others have found (e.g., Raposa et al., 2014), the stress that very young children and their families feel as a result of experiencing multiple adversities simultaneously likely explains, at least partially, why early risk exposure is predictive of later difficulties. Further, it is possible that early adversities impact the brain development that is occurring rapidly during the first three years (Shonkoff & Phillips, 2000; Troller-Renfree, et al., 2022), which in turn, leads to developmental challenges in adolescence and adulthood.

Unexpectedly, there were no significant direct effects of early cumulative risk on reading, math, or future orientation at age 15 or risky behaviors at age 26. With regard to the adolescent outcomes, it appears that the inclusion of EF in our models may help explain why direct effects did not emerge (see next section). It is unclear why there was no direct effect on risky behaviors in adulthood; however, the mean percentage of risky behaviors that adults reported was relatively low (8%), which is likely due to the items being focused primarily on severe risky behaviors (e.g., violent behaviors with weapons). Future research that utilizes measures of less severe risky behaviors (e.g., promiscuous or unsafe sexual behaviors) is needed to test whether early cumulative risk may be related to this outcome.

The Role of Executive Function and Behavioral Regulation in Relations Between Early Cumulative Risk and Adolescent and Adult Outcomes

In this study, we tested the extent to which EF and behavioral regulation at 54 months mediate and/or moderate associations between early cumulative risk and our target outcomes in adolescence and adulthood. In line with our hypotheses, we found that both EF and behavioral regulation mediated relations between early cumulative risk and later educational and financial outcomes. Specifically, we found that both EF and behavioral regulation mediated associations between risk and reading and math at age 15 and between risk and income and educational attainment at age 26, but with the exception of reading, behavioral regulation contributed slightly more to the indirect effect than EF.

Our findings are consistent with other studies showing similar mediation effects in shorter-term longitudinal studies (Lawson & Farah, 2017; Suntheimer et al., 2022; Waters et al., 2021). For example, Lawson & Farrah (2017) found that EF partially mediated the effects of socioeconomic status and math development between the ages of 6 and 15. Similarly, Waters et al. (2021) found that working memory, a specific EF skill, mediated relations between

preschool parent education and 1st grade math achievement. Finally, our study is in line with the one other study examining EF as a mediator between cumulative risk and learning outcomes (Suntheimer et al., 2022). In that study, results indicated that EF measured at age 9 significantly mediated the effect of cumulative risk from birth to age 9 on math achievement at age 11. Overall, our findings suggest that EF and behavioral regulation, measured at age 4 ½, could be mechanisms underlying the long-term effects of early cumulative risk exposure on educational and financial outcomes, which has implications for our theoretical understanding of the processes through which risk impacts development, health, and well-being across the life span.

In contrast to educational and financial outcomes, we did not see evidence of EF or behavioral regulation as a mediator of early risk exposure for risky behaviors, depression, or future orientation. Because there is less evidence of associations between EF and behavioral regulation and these outcomes in the extant literature base, these findings are not surprising. Future research is needed to uncover alternative mechanisms underlying relations among early cumulative risk and these outcomes.

In addition to mediation effects, three significant interactions emerged in our data. First, EF at 54 months moderated associations between early risk exposure and depression, such that when children experienced high levels of cumulative risk, low EF exacerbated this relation and was linked to higher depression scores. Similarly, we found that low EF at 54 months was associated with magnified negative relations between early cumulative risk and reading scores at age 15. Indeed, experiencing multiple risks simultaneously while also not having the cognitive resources to potentially ward off external factors that could lead to mental health concerns and academic difficulties could certainly be at play here. Analyses also revealed a significant interaction between behavioral regulation and cumulative risk on future orientation at age 15. Here, adolescents who experienced low levels of cumulative risk and who had high behavioral regulation exhibited the greatest future orientation. This finding also makes sense in that children who do not experience many risks and are able to pay attention, focus, persist, and control their behaviors (i.e., have strong behavioral regulation) are also better able to plan for their futures, think in goal-oriented ways, and consider long-term consequences of their actions (all components of future orientation).

In sum, both EF and behavioral regulation play a role in several of the links between early cumulative risk and adolescent and adult outcomes. These findings have implications for our theoretical understanding of the developmental processes through which early risk affects later development, health, and well-being and for future research. Indeed, prior work has identified contextual mechanisms, such as the quality of the home environment, that underlie the effects of early risk for later outcomes. Our study adds to this work by identifying possible child-level mechanisms for these relations, and particularly for educational and financial outcomes. Moreover, our study adds to the shorter-term longitudinal studies that examined EF as a mediator of risk and developmental outcomes during middle childhood (Deer et al., 2020; Lawson & Farah, 2017; Waters et al., 2021) by including EF and behavioral regulation in our models and several outcome variables during two developmental periods (adolescence and adulthood). Further, our study is the first to explore potential child-level moderators of these associations, although our findings did

not indicate a protective effect of EF in the context of early risk exposure as other studies have (de Maat et al., 2022; Sektnan et al., 2010). Future research should continue to build our understanding of these pathways (both contextual and child-level) to develop a comprehensive theoretical model of how early risk may influence later outcomes. Subsequent work should also consider other individual child factors that could exert a buffering effect on impacts of early risk.

Limitations and Future Directions

Although this study has many strengths, including the utilization of a large, longitudinal data set, limitations must be noted. First, data are correlational and thus, causal claims cannot be made with regard to associations between early cumulative risk exposure and outcomes in adolescence and adulthood. Second, although our measures of EF and behavioral regulation cover both cognitive and behavioral components and are measured differently (i.e., EF is measured with direct assessments, behavioral regulation is measured with maternal report), there is some conceptual overlap among the measures. For example, inhibitory control is included as both a component of EF (directly assessed) and behavioral regulation (maternal report). Future research would benefit from including more distinct measures of EF and behavioral regulation. Third, the SECCYD did not have a measure of cognitive flexibility at 54 months, which is an important component of EF (Garon et al., 2008). We also did not have a measure of complex working memory and had to rely on a measure of simple working memory (i.e., short-term memory) as a proxy (Best & Miller, 2010; Garon et al., 2008). A direction for future research is to incorporate more components of EF to clarify how different components are related to developmental outcomes.

Finally, although the SEYCCD study began in 1991, the study findings are still relevant to the environment that today's racially and ethnically diverse teenagers and adults are attempting to navigate. Current research suggests that the accumulation of educational advantages in early childhood (e.g., having parents with high levels of education and high socioeconomic status) result in higher educational attainment and income, and subsequently fewer health problems (Walsemann et al., 2013). However, much more research is needed to identify mechanisms that support the education of racially, ethnically, and economically diverse children in early childhood through to secondary school with the aim of promoting educational attainment, and thereby furthering health outcomes and income earned in adulthood.

Despite the continued relevance of the SEYCCD data, any long-term longitudinal study such as SEYCCD, by definition, reflects a lag between the measures used to assess various constructs in early childhood and contemporary measures. The demographic characteristics of the U.S have changed since 1991 when the SECCYD sample was recruited, and although the SECCYD sample was similar to the U.S. population in 1991 (NICHD ECCRN, 2005), it is less ethnically diverse than the U.S. population today. Thus, there is a clear need for a comparable longitudinal study to be undertaken to reflect the current U.S. population.

Conclusion

The goal of this study was to examine longitudinal relations between early cumulative risk and several outcomes at age 15 and age 26 and explore the extent to which EF and/or behavioral regulation at 54 months mediate and/or moderate these associations. Results indicated that early exposure to cumulative risks predicted the majority of our adolescent and adult outcomes and that some of these relations were mediated and moderated by EF and behavioral regulation measured during early childhood. This study lays a foundation for subsequent empirical work dedicated to building a comprehensive theoretical framework for how and why early cumulative risk exposure has a long-term impact on developmental, health, and socioeconomic outcomes. Furthering our understanding of these processes could eventually lead to practical solutions for mitigating the negative impacts of early risk exposure for outcomes across the life span.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Public Significance Statement:

This study found that early cumulative risk was related to depression and risky behavior at age 15 as well as depression, income, future orientation, and educational attainment at age 26. Further, results indicated that executive function and/or behavioral regulation mediated and/or moderated relations among cumulative risk and outcomes at age 15 and 26. These findings have implications for our theoretical understanding of the developmental processes through which early risk affects later development, health, and well-being.

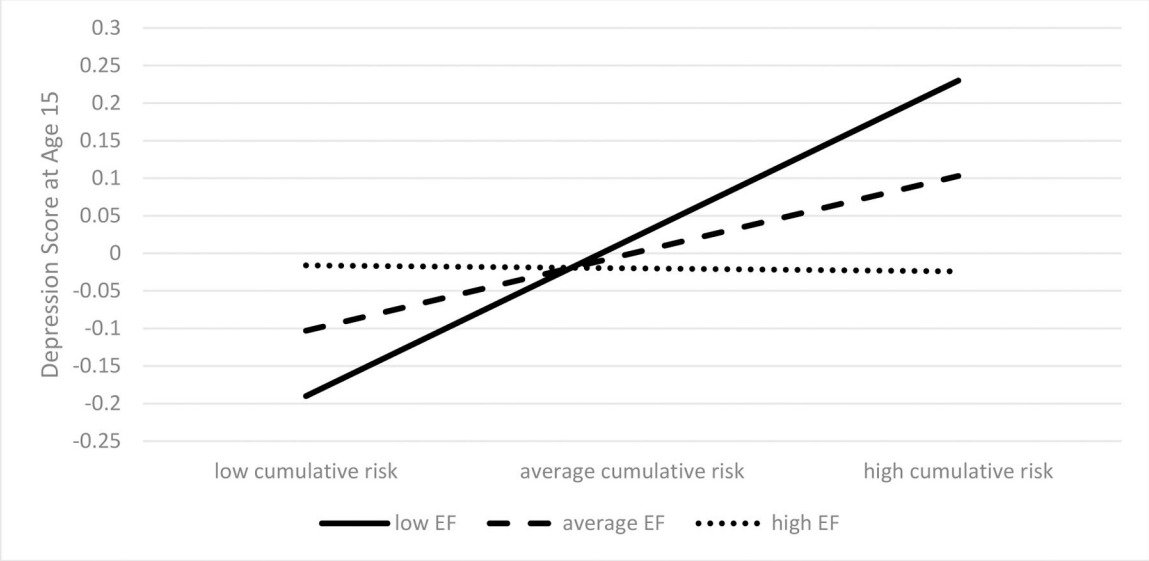

Figure 1. Interaction EF and Cumulative risk on Depression at Age 15.

Low refers to −1 *SD*, average refers to the *M*, and high refers to +1 *SD* for each variable. The simple slopes for cumulative risk and depression at age 15 based on levels of EF were the following: for −1 *SD* on EF, β = .21, $p < .001$, 95% CI [.11, .30], for *M* on EF, β = .10, $p = .013$, 95% CI [.02, .18], and for +1 *SD* on EF, β = −.00, $p = .968$, 95% CI [−.10, .09].

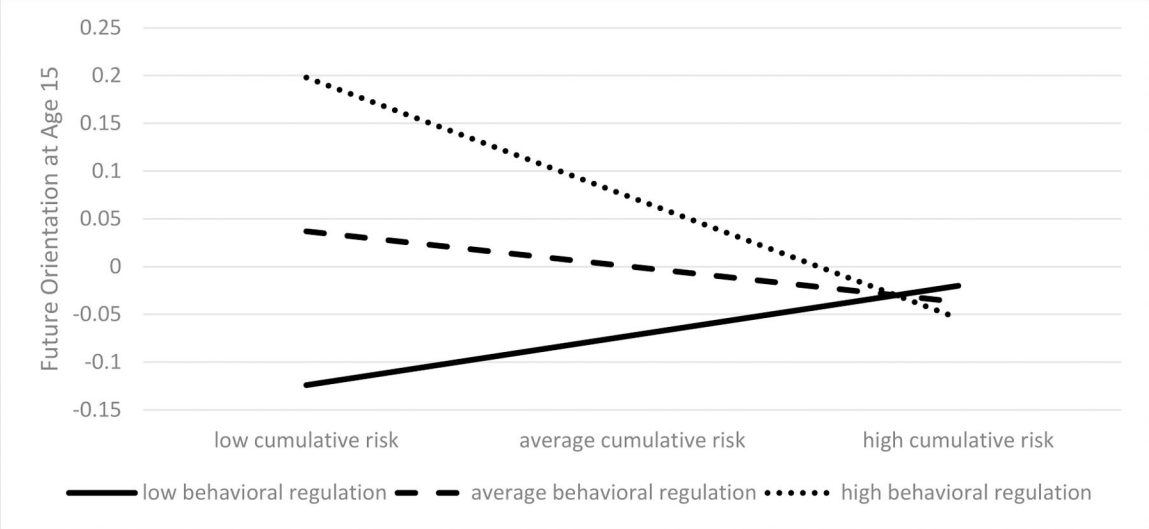

Figure 2. Interaction Behavioral regulation and Cumulative risk on Future Orientation at Age 15.

Low refers to −1 *SD*, average refers to the *M*, and high refers to +1 *SD* for each variable. The simple slopes for cumulative risk and future orientation at age 15 based on levels of behavioral regulation were the following: for −1 *SD* on behavioral regulation, β = .05, *p* = .184, 95% CI [−.02, .11], for *M* on behavioral regulation, β = −.04, *p* = .179, 95% CI [−.09, .02], and for +1 *SD* on behavioral regulation, β = −.12, *p* = .021, 95% CI [−.22, −.02].

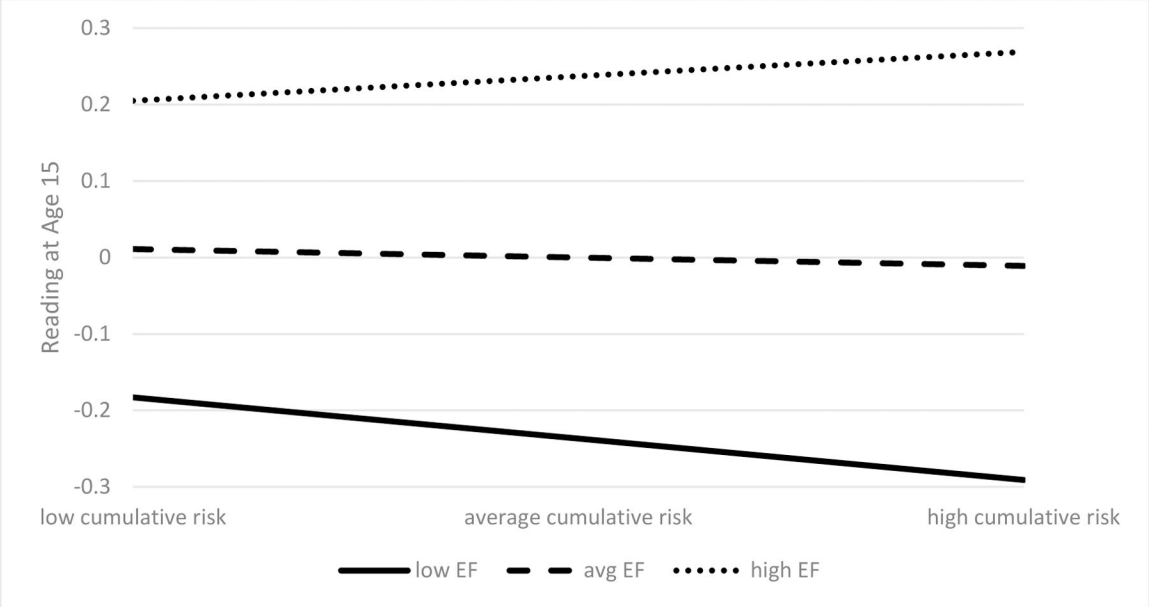

Figure 3. Interaction EF and Cumulative risk on Reading at Age 15.

Low refers to −1 *SD*, average refers to the *M*, and high refers to +1 *SD* for each variable. The simple slopes for cumulative risk and reading at age 15 based on levels of EF were the following: for −1 *SD* on EF, β = −.05, *p* = .092, 95% CI [−.12, .01], for *M* on EF, β = .−.01, *p* = .748, 95% CI [−.08, .06], and for +1 *SD* on EF, β = .03, *p* = .517, 95% CI [−.06, .13].

Table 1

Descriptive Statistics

Variables	*N*	Mean	*SD*	Min	Max	Missing %
Percent Male	1,364	51.69%				0
Percent White	1,364	80.43%				0
Percent Black	1,364	12.90%				0
Percent Hispanic	1,364	4.69%				0
Percent Other	1,364	1.98%				0
Maternal vocabulary	1,167	99.01	18.35	40	159	14
Cumulative risk						
Maternal education	1,363	14.23	2.51	7	21	0
Income-to-needs	1,302	3.62	2.87	0.14	22.47	5
Maternal depression	1,303	9.26	6.93	0	43	4
Maternal social support	1,363	4.98	.61	1	0	0
Father in the home	1,305	0.82	0.35	0	1	4
Parenting stress	1,275	50.23	9.90	26	83	7
Maternal intimacy	1,288	4.85	.97	1.78	7	6
Maternal personality	1,272	−0.00	.76	−2.28	2.18	7
EF						
Cognitive inhibitory control	838	25.34	20.53	0	87.5	39
Short-term memory	1,054	91.74	18.49	17	142	23
Sustained attention	1,002	9.13	7.59	0	41.07	27
Behavioral regulation						
Attentional focusing	1,023	4.71	.85	1.25	6.88	25
Behavioral inhibitory control	1,061	4.66	.78	2	6.7	22
Attention problems	1,061	53.68	5.29	50	79	22
Outcomes at age 15						
Depression	957	2.01	2.64	0	18	30
Future Orientation	952	2.62	.49	1	4	30
Reading	887	107.71	15.72	44	160	35
Math	887	102.92	14.22	48	168	35
Risky behavior	954	6.16	5.67	0	53	30
Outcomes at age 26						
Depression	808	1.74	.59	1	3.9	41
Future Orientation	807	3.01	.46	1	4	41
Risky behavior	804	.08	.09	0	.66	41
Income	745	5.12	2.42	1	10	45
Educational attainment	814	.63	.48	0	1	40

Table 2

Bivariate correlations for cumulative risk and children's outcomes at age 15 and 26

Variables	1	2	3	4	5	6	7	8	9
1. Cumulative risk	-								
2. EF	−.26***	-							
3. Behavioral regulation	−.43***	.26***	-						
4. White	−.28***	.15***	.15***	-					
5. Black	.27***	−.17***	−.15***	−.78***	-				
6. Hispanic	.10***	−.003	−.04	−.45***	−.08**	-			
7. Other race/ethnicity	.01	−.01	.01	−.29***	−.05*	−.03	-		
8. Male	−.01	−.09**	−.08**	.02	−.004	−.02	−.01	-	
9. Maternal vocabulary	−.38***	.29***	.27***	.39***	−.36***	−.10***	−.10***	−.03	-
Age 15									
Depression	.08*	−.01	−.002	.01	−.03	.03	.003	−.20***	.03
Future orientation	−.06	.02	.08*	.003	−.02	.01	.04	−.10**	.02
Risky behavior	.21***	−.14***	−.14***	−.21***	.22***	.08*	−.05	.18***	−.20***
Reading	−.27***	.38***	.24***	.28***	−.31***	−.04	−.01	−.04	.49***
Math	−.25***	.33***	.26***	.24***	−.27***	−.05	.06	.09**	.40***
Age 26									
Depression	.14***	−.02	−.05	−.10**	.07	.13***	−.06	−.02	.01
Future orientation	−.08*	−.05	.06	.03	−.002	−.06	.01	−.16***	−.04
Risky behavior	.08*	−.04	−.12**	−.14***	.20***	.01	−.04	.22***	−.11**
Income	−.21***	.17***	.16***	.14***	−.14***	−.07	.01	.08*	.15***
Educational attainment	−.33***	.25***	.24***	.16***	−.15***	−.06	−.001	−.10**	.28***

Note.

* $p < .05$

** $p < .01$

$^{***}p < .001$.

Table 3

Direct, indirect, and total effects for the mediation analyses at age 15

Variables	Depression			Future Orientation			Risky Behavior			Reading			Math		
	Direct β	Indirect β	Total β	Direct β	Indirect β	Total β	Direct β	Indirect β	Total β	Direct β	Indirect β	Total β	Direct β	Indirect β	Total β
Cumulative risk	.11**	.00	.11**	−.04	−.02	−.06*	.14**	.01	.14**	−.02	−.07***	−.08*	−.01	−.09***	−.10***
EF	−.02		−.02	−.01		−.01	−.04		−.04	.24***		.24***	.21***		.21***
Behavioral regulation	.01		.01	.06		.06	.00		.00	.05		.05	.12***		.12***

Note. β are the standardized coefficients.

* $p < .05$

** $p < .01$

*** $p < .001$.

Table 4

Direct, indirect, and total effects for the mediation analyses at age 26

Variables	Depression			Future Orientation			Risky Behavior			Income			Educational Attainment		
	Direct β	Indirect β	Total β	Direct β	Indirect β	Total β	Direct β	Indirect β	Total β	Direct β	Indirect β	Total β	Direct β	Indirect β	Total β
Cumulative risk	.15**	.00	.15***	−.10	−.00	−.11*	.01	.03	.03	−.12**	−.06***	−.18***	−.22***	−.05***	−.27***
EF	−.00		−.00	−.08*		−.08*	.03		.03	.11*		.11*	.12***		.12***
Behavioral regulation	−.01		−.01	.05		.05	−.08*		−.08**	.09**		.09*	.08*		.08*

Note. β are the standardized coefficients.

* $p < .05$

** $p < .01$

*** $p < .001$.