Interaction and Nonlinear Effects of Temperament Reactivity and Regulation on Adjustment Problems in Preadolescence

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Abstract

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Dimensions of child temperament related to reactivity and self-regulation are often studied in relation to child adjustment. Yet despite theory on interactive and nonlinear effects of dimensions of temperament, few studies have tested these. We examined quadratic and interactive effects of child temperament on adjustment. Interactive and nonlinear effects of temperament (fear, frustration, and executive control) on emotional and behavioral problems (anxiety, depression, and conduct problems) were investigated in a sample of 214 children aged 9-13. Using behavioral measures of temperament, we predicted concurrent problems, as well as problems one year later in hierarchical regression analyses. Executive control was consistently related to fewer problems. We observed a quadratic effect of executive control on depression, and an interaction between frustration and executive control predicting conduct problems. Low levels of executive control were associated with heightened risk for concurrent depression, whereas moderate to high levels of executive control were associated with similarly low levels of depression. Higher executive control was associated with fewer conduct problems for those moderate to high in frustration, and unassociated with conduct problems for those low in frustration. Examination of interactive and nonlinear effects of dimensions of temperament can clarify understanding of risk for child adjustment problems.

Introduction

Individual differences in child temperament are consistently related to adjustment problems and psychopathology, both concurrently and prospectively (Compas et al., 2017; Rothbart & Bates, 2006). Two broad facets of child temperament – negative emotionality (NE) and executive control (EC) – are viewed as the key contributing biologically-based individual differences that describe how young children differ from one another in the successful regulation of their emotions (Eisenberg, Fabes, Guthrie, & Reiser, 2000; Muris, 2006; Nigg, 2006). In Rothbart & Bates' formulation of temperament (Rothbart & Bates, 2006), NE consists of a child's general level of emotional and behavioral reactivity to stimuli experienced as unpleasant or threatening, and EC indexes a largely cognitive ability to inhibit and control one's attention and impulses. NE is closely related to the adult personality factor of neuroticism (Shiner, 1998; Soto & Tackett, 2015; Tackett, Krueger, Iacono, & Mcgue, 2008) and has been linked to both internalizing and externalizing problems in school-age youth (Eisenberg et al., 2001; Eisenberg, Valiente, et al., 2009). EC has been shown to precede the adult personality factor of constraint or conscientiousness and predict internalizing problems, externalizing problems, shyness, resiliency, and sympathy (Eggum-Wilkens, Reichenberg, Eisenberg, & Spinrad, 2015; Eisenberg, Haugen, et al., 2009; Lengua & Long, 2002; Spinrad et al., 2006).

NE is considered an important higher-order factor in a hierarchical view of child temperament (Soto & Tackett, 2015; Tackett et al., 2008), yet for purposes of differentially predicting specific aspects of children's adjustment, differentiating between lower-order constructs (i.e., fear and frustration) is important (Lengua, 2008; Nigg, 2006). Fear and frustration are believed to stem from relatively distinct physiological systems and may differentially predict internalizing and externalizing problems. Fear is thought to arise from activity in the behavioral inhibition system which underlies sensitivity to threat, and may confer risk for anxiety problems (Leve, Kim, & Pears, 2005; Muris, 2006). Frustration, which arises when an individual is blocked in obtaining a goal or reward, reflects activity in the behavioral activation system which underlies reward sensitivity and approach, and is related to both conduct problems and depression (Dennis, 2007; Eisenberg et al., 2001; Muris, 2006; Nigg, 2006).

EC measures index several interrelated cognitive abilities that underpin the ability to exert cognitive control over prepotent responses, including attentional control and behavioral inhibition. EC is measured using tasks that engage different aspects of the ability to inhibit, plan, and modulate responses. However higher scores on EC measures generally indicate lower risk for adjustment problems (Carlson, 2005; Nigg, 2017; Razza, Martin, & Brooks-Gunn, 2010). Some research on EC combines these cognitive control dimensions with reward delay, and there is some empirical support for the two loading on a single latent factor (Allan & Lonigan, 2011; Sulik et al., 2010). However, EC and delay often exhibit differential relations with adjustment outcomes, with EC sometimes emerging as the stronger predictor in studies controlling for delay ability (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Kim, Nordling, Yoon, Boldt, & Kochanska, 2013; King, Lengua, & Monahan, 2013; Li-Grining, 2007). Whereas EC tasks tend to elicit activity in the prefrontal cortex, reward delay also involves activation in reward circuits (Dixon, 2010). Thus, in examining the impact of EC on adjustment, it is potentially important to control for the impact of reward delay.

Some theory and evidence suggest a nonlinear effect of EC, such that both very low and very high EC confer heightened risk for adjustment problems (Derryberry & Rothbart, 1997; Robins, John, Caspi, Moffitt, & Stouthamer-Loeber, 1996). Murray & Kochanska (2002) found evidence for a quadratic relation between EC and broadband adjustment problems, such that both low-EC and high-EC children experienced more internalizing and externalizing problems. Jonas & Kochanska (2018) reported further evidence of a quadratic effect of EC, such that both low EC and high EC were associated with greater externalizing problems. In addition to the intuitive explanation that lesser abilities to control and direct attention would lead to more externalizing behavior, these findings also suggest that high EC (sometimes termed “behavioral overcontrol”) may reflect a focus on delayed rewards or attentional control that precludes developmentally normative goal-directed behavior. Moreover, omitting quadratic effects from model testing may lead to spurious interaction findings in general (Belzak & Bauer, 2019; Lubinski & Humphreys, 1990; MacCallum & Mar, 1995). Thus, we tested for a quadratic effect of EC on adjustment.

Interactions between Negative Emotionality and Executive Control

In addition to direct effects of individual temperament facets, interactions between temperament facets are predicted by temperament theory (Eisenberg & Fabes, 1992; Lengua, 2003; Nigg, 2006; Rothbart & Bates, 2006). Rothbart & Bates (2006) described two ways in which temperament facets might exhibit joint effects on adjustment via trait-by-trait interactions. The first is that self-regulation of a temperament extreme might qualitatively change its expression. For example, a child with high frustration and low EC might exhibit overt reactive aggression, whereas a child high in both frustration and EC might display internalizing problems via constant effortful inhibition of strong emotional impulses. The second is via one temperament trait protecting against the risk consequences of another. In this process, a high-frustration child who lashes out at peers might be protected from the social consequences of her frustration by having higher EC, allowing her to apologize and reconcile with peers successfully. Nigg (2006) formalized some of these predictions, hypothesizing that low EC and high NE might lead to heightened risk for anxiety disorders, whereas low EC and high frustration (especially with low fear) might lead to heightened risk of conduct disorder.

Basic research on emotion and decision-making supports the notion that children who experience high levels of negative emotions may need to combat stronger cognitive biases and have an especially difficult time deploying their cognitive resources. A wealth of experimental evidence demonstrates that decision-making can become biased toward the negative under conditions of heightened negative emotion (see Drevets & Raichle, 1998; Leppänen, 2006 for review). For example, negatively-valenced information is more readily attended to than positively-valenced information and the probability of negative events happening is overestimated (Schwarz, 2000). If these resources are already limited (low-EC), efforts to regulate emotions and impulses are likely to be unsuccessful, precipitating higher levels of ineffective emotion regulation behaviors and adjustment problems.

A small body of research on toddlers and preschool-age children has found direct evidence that the combination of high NE and low EC is associated with especially poor adjustment, above and beyond additive effects of the two constructs. In several studies of 3-year-olds, a NE-by-EC interaction was observed such that high NE and low EC predicted high levels of externalizing problems (Belsky, Friedman, & Hsieh, 2001; Diener & Kim, 2004; Moran, Lengua, & Zalewski, 2013). In two of these studies, social competence was also predicted by this interaction (Belsky et al., 2001; Diener & Kim, 2004). In one study, the effects of mother-reported fear and observed frustration on externalizing problems were highest among those low in EC (Moran et al., 2013). Moran et al. also found that high observed fear interacted with low delay ability in predicting the highest levels of externalizing problems. Another study of 3-year-olds by Belsky, Friedman, & Hsieh (2001) did not find effects on adjustment problems, but did replicate the NE-by-EC interaction for social competence. Children who were high in NE and low in EC had the lowest social competence. In a study of 5- to 8-year-olds, Eisenberg, Guthrie, et al. (2000) found that attentional control was most strongly associated with externalizing behavior among children for whom NE was high, suggesting the importance of strong attentional control in maintaining behavioral control when NE is elevated.

Some preliminary support for an NE-by-EC interaction in preadolescence has been noted in a follow-up study with the Eisenberg, Guthrie, et al. (2000) sample when the children were four years older (9- to 12-year-olds) by Valiente, Smith, Fabes, Guthrie, & Murphy (2003). In Valiente and colleagues' work, EC was again most strongly linked to externalizing behavior for children high in NE. Meesters, Muris, & Van Rooijen (2007) also found modest support in a preadolescent sample for an interaction between NE and EC in predicting symptoms of anxiety and reactive aggression, with high-NE, low-EC individuals again at the highest risk for problems. All measures in this study were reported by the child. Despite these suggestive findings, neither preadolescent study disaggregated NE into fear and frustration, and temperament was measured primarily using child-report.

Negative Emotionality and Executive Control in Preadolescence

Preadolescence is an important developmental period during which to study the effects of temperament on adjustment because it is a period when temperament stabilizes and develops into adult personality, when emotion regulation becomes more independent, and when parental or school interventions are still quite feasible. Preadolescence represents a time during which broad tendencies captured by temperament start to differentiate into more specific personality traits (Shiner, 1998; Soto &

Tackett, 2015; Tackett et al., 2008). For example, conscientiousness and openness are much more interrelated in youth than in adults. By preadolescence, emotion regulation efforts have become largely internalized and independent (Altshuler & Ruble, 1989; Kliewer, 1991) and show within-person stability (Raffaelli, Crockett, & Shen, 2005). Thus, the effects of temperament on emotion regulation and adjustment are most likely to represent meaningful, pervasive differences. Understanding temperament and adjustment during preadolescence is especially important because preadolescence is a time when children are able to implement emotion regulation strategies independently, but are also embedded in a school and family context where high-frequency intervention is feasible. We are only aware of the two studies (Meesters et al., 2007; Valiente et al., 2003) that have tested NE-by-EC interactions in preadolescence, and findings have thus far been inconsistent as to potentially divergent roles of components of NE and EC.

The Current Study

In summary, a growing body of evidence suggests that children who are both high in NE and low in EC are at especially high risk for emotional and behavioral problems. However, the majority of research on child temperament reports findings on reactivity and self-regulation dimensions individually or additively, rather than interactively. Many of these studies aggregate across different expressions of negative affect, smoothing over differences which may reflect distinct biological substrates. Moreover, little research has examined these associations in preadolescence, a critical period during which child temperament begins to be canalized into particular emotion regulation styles. To deepen understanding of individual differences in reactivity and regulation as they relate to adjustment problems, we aimed in the current study to characterize relations between these patterns and adjustment problems.

Our study aimed to address these gaps by studying interactive effects of fear, frustration, EC, and difficulty with reward delay on both concurrent problems and change in problems over time in 9- to 13-year-old children. We tested several hypothesized relations between temperament and adjustment:

We hypothesized that higher fear would predict higher levels of depression and anxiety, higher frustration would predict higher levels of depression and conduct problems, and higher EC would predict lower levels of all problems. We expected greater delay difficulty to predict more externalizing problems. We also hypothesized quadratic effects of EC on depression and conduct problems, such that both low- and high-EC would predict higher problems. Finally, we hypothesized that high EC would attenuate the relations of fear and frustration with problems.

Methods

Participants

A risk-stratified community sample of 214 children and their families in a major Pacific Northwest city underwent an in-depth interview and completed several tasks designed to tap child temperament. The families were recruited from 3rd, 4th, and 5th grade public school classrooms and were drawn equally from six income strata which represented a broad range of socioeconomic status, ranging from <\$20,000 per year to >\$100,000 per year. The sample represented the ethnic and racial diversity of the region from which they were drawn (72% Caucasian, 14% African-American, 2% Asian/Pacific Islander, 3% Hispanic/Latino, 3% Native American, 6% multiple/other ethnicities). Follow-up assessments with similar measures were conducted at one year and two years after the initial assessment. Analyses were completed on the Time 1 sample who completed all behavioral temperament measures, which includes 196 children (43% female; mean age = 10.5, SD=1.0, range=9-13).

Procedure

Families were assessed in their homes and received \$50 for completing a structured interview and behavioral tasks over the course of 2.5 hours. Mothers' informed consent and child assent were obtained prior to conducting assessments. Demographics were reported by mothers during the interview. Mothers and children were interviewed separately to ensure the validity of responses. Following the interviews, children completed the behavioral tasks, which were videotaped and later coded by two independent research assistants. 20% of videos were coded by both research assistants to obtain reliability estimates. All recruitment and data collection procedures were approved by the Institutional Review Board at the affiliated university.

Measures

Cumulative risk score. Given that contextual risk factors tend to co-occur and impact development in the same direction, a useful index of the degree of risk a child experiences is a cumulative risk score. Our cumulative risk score is a count of up to 11 stable demographic, psychosocial, and environmental risk factors. Demographic risk factors were measured as educational risk (mothers had not completed high school), single-parent status, adolescent parent status (mother under 19 years old at child's birth), poverty (income below the 1998 federal Health and Human Services Guidelines), and family density (ratio of individuals living in the home to number of rooms in the home). Psychosocial risk factors were past-month maternal depression status, and family history of mental health problems. Environmental risk included indices of both home environment and neighborhood environment. The Post-Visit Inventory (Dodge, Bates, & Pettit, 1990) had mothers and children each report on the cleanliness, amenities, safety, and size of the house. quality of the home environment Research has demonstrated that cumulative risk predicts child outcomes equally well or better than consideration of any one factor (Deater-Deckard, Dodge, Bates, & Pettit, 1998; Sameroff, Seifer, Zax, & Barocas, 1987). Internal consistencies in this sample were all above $\alpha = .66$ and are published elsewhere (Lengua, Bush, Long, Kovacs, & Trancik, 2008; Thompson, Lengua, & Garcia, 2016).

Fear. Behavioral fear was observed and coded while children played a commercially-available form-board game called Perfection™. Children were given pegs of different shapes and sizes, and asked to place each peg in its corresponding shaped hole. An undisclosed amount of time into the task, the game unexpectedly popped up and made a loud noise. Children were given an insufficient amount of time (50 seconds) to complete the task, ensuring that they would experience the pop-up. Trained coders rated children's fearful anticipation (e.g., facial grimacing, body tension, pauses in activity, cowering) and nervous fidgeting (e.g., hand shaking and flustered movements). Each of nine behaviors was coded on a 0 (none) to 2 (high) scale and summed to create an overall fear score with a potential range of 0 to 18. To assess reliability, 20% of the anxiety task cases were coded twice by independent coders. Because scores were continuous, reliability was assessed using an intraclass correlation, which was .74 for the fear task.

Frustration. Behavioral frustration was observed and coded during a locked-prize task adapted from the laboratory temperament assessment battery (Lab-TAB; Goldsmith, Reilly, Lemery, Longley, & Prescott, 1995). Children were asked to open a locked container with a dollar bill inside within 3 minutes and given a key ring with 12 keys, none of which fit the lock. After 3 minutes, the experimenter returned with the correct key, the bag was unlocked, and children were given the $1 prize. Frustration was coded by independent raters and codes were assigned based on behavioral signs of frustration (e.g., setting keys down hard), facial expressions (e.g., furrowed brow), frustrated vocalizations (e.g., sighs, grunts, statements to the experimenter such as “I can’t get these to work”) and annoyance toward the experimenter (e.g., glares toward interviewer). Scores reflected both frequency and intensity of frustration behaviors – sum scores were computed, with the number of occurrences of each behavior during the task weighted by the intensity of the behavior (low = 1, high = 2). Inter-rater reliability was high, with an intraclass correlation of .85. These lower-order codes were then organized into four domains: overall frustration, overall vocalizations, overall annoyance/anger with experimenter, and overall vocalizations to the experimenter. Frequency and intensity of behaviors were combined to create 4 domain scores ranging from 0 (no frustration) to 3 (high frustration). Finally, these 4 scores were averaged to create a mean score with a range of 0 to 3. The internal consistency of these 4 categories was $\alpha = .67$.

Executive Control. EC was assessed with two tasks reflecting inhibitory control and attention regulation. **Inhibitory control** was measured using the Simon Says task (Kochanska, Murray, & Coy, 1997), which involved the child inhibiting behavior in order to follow directions correctly The experimenter gives a series of 37 commands, which a child is supposed to follow only if the experimenter precedes the command by stating “Simon Says.” Interviewers performed all of the commands immediately after asking the child regardless of whether the trial was a “Simon Says” trial. Behavior was coded to assess how accurately children followed the rules. For each non-Simon Says item, raters assigned the child 2 points for fully inhibited movement, 1 point for partially enacted movement, or 0 points for completely enacting the movement. A sum score (0-26) was thus created for the 13 non-Simon Says items. Inter-rater reliability for the sum score was high, with an intraclass correlation of .95.

Attention Regulation was measured using the Stroop Color Word Test (Golden & Freshwater, 1978), which assesses attention regulation and resistance to cognitive interference. The test requires a child to read a list of words aloud, saying the color of the ink the word is printed in rather than the word itself. Children participated in three trials. In the first trial (word), children read aloud the words ‘blue,’ ‘red,’ and ‘green’ listed 100 times in varying order. In the second trial (color), the character string ‘XXX’ was presented 100 times printed in blue, red, and green. Children said the ink color aloud for each trial. In the third trial (color-word), children were presented with the words ‘blue,’ ‘red,’ and ‘green’ which were printed in a different color from the word (e.g., the word ‘blue’ printed in red), and asked to name the color of the ink instead of reading the word. Children performed this task with an experimenter in the room, reading words from a list and receiving no feedback when mistakes were made. Scores are the number of words read in the 45 seconds of the third trial (color-word). Scores ranged from 10-52 words. As the two measures of EC were moderately correlated ($r = .36$), and we did not have particular hypotheses related to specific executive functions, we combined them into a single index of EC by standardizing each and taking a mean score.

Difficulty with Delay of Gratification. Difficulty with delay was coded by experimenters observing the child during a prize delay task. Children were asked to wait before opening a prize placed immediately in front of them, and if children waited successfully, they were told they would be awarded with a more appealing prize. Each child’s amount of difficulty with the task was coded using a composite score of time to opening the prize, combined with behavioral measures of restlessness or difficulty. These scores were live-coded by experimenters according to a coding system based on a count of fidgeting, distraction, questioning the interviewer, facial grimaces, tensing, and boredom & annoyance behaviors. Specific behaviors included the child mouthing words to oneself, asking the interviewer how much time is left, scrunching one’s face, restraining one’s hands, and hitting the table, among others. These behaviors were scored such that higher scores indicate greater difficulty with delay: performing 0 of these behaviors resulted in a code of 0; 1 or 2 behaviors were coded as 1; 3 or 4 behaviors were coded as 2; more than 4 behaviors were coded as 3.

Anxiety, Depression, and Conduct Problems. Symptoms of anxiety, depression, and conduct problems were reported by both children and parents using validated and widely-used measures of child problems. **Mothers reported** on child symptoms of anxiety, depression, and conduct problems on the Child Behavior Checklist (CBCL; Achenbach, 1991) using a 3-point scale for each item (0 = not true, 1 = somewhat/sometimes true, 2 = very/often true). Subscales for anxiety and depression were scored in a way that allowed the internalizing problems scale to be separated into distinct depression and anxiety symptoms (see Lengua, Sadowski, Friedrich, & Fisher, 2001). Conduct problems scores were based on the aggression and delinquent behavior subscales of the CBCL. **Children reported** on their own symptoms of anxiety using the Revised Children's Manifest Anxiety Scale (RCMAS; Reynolds & Richmond, 1978), depression using Child Depression Inventory (CDI; Kovacs, 1981), and conduct problems using the Youth Self-Report (YSR: Achenbach, 1991), which is the child self-report version of the CBCL. The RCMAS consists of yes/no measures designed to tap child anxiety, and a count is computed for the number of anxiety symptoms. Each item of the CDI asks children to select one of three options reflecting severity of depression symptoms; these items are added together to create a sum score. The YSR is reported on the same scale as the CBCL (0 = not true, 1 = somewhat/sometimes true, 2 = very/often true), and a conduct problems sum score was computed for each child.

To address the effects of shared measurement variance and potential reporter bias on results, and following the approach of prior analyses of these data (Lengua, 2008), mother and child scores were combined to form a combined anxiety score, a combined depression score, and a combined conduct problems score. Correlations between mother- and child-reports for the scales were small to moderate: .12 for anxiety, .13 for depression, and .45 for conduct problems. Scores for anxiety and depression were first standardized and then averaged. Conduct problems were computed with a sum score because they were measured with comparable instruments. This is consistent with prior literature reporting more consistency in externalizing than in internalizing problems during childhood (e.g., Lengua, 2008).

Analysis Plan

We conducted hierarchical multiple linear regression using R (Team, 2016) and the lm.beta package (Behrendt, 2014) to calculate standardized regression coefficients to test hypotheses. For each outcome (anxiety, depression, and conduct problems), we ran a series of nested models. To test hypothesis 1, we tested linear effects of three covariates (age, gender, and cumulative risk) and four temperament measures (fear, frustration, EC, and difficulty with delay). To test hypotheses 2 and 3, we evaluated three additional models for each outcome. The first model included all terms in step 1 and a single interaction term between fear and EC. The second model instead included an interaction term between frustration and EC. The third model instead included a quadratic effect of EC. We assessed appropriateness of including second-order terms using statistical significance of the interaction term and F-tests for assessing improvement in variance explained. Several methodologists (see Belzak & Bauer, 2019; Ganzach, 1997; Lubinski & Humphreys, 1990; MacCallum & Mar, 1995) have demonstrated the dangers of omitting quadratic effects when testing interactions (and vice versa), showing that omission of either effect can greatly influence estimates of its counterpart. As such, we tested both interactions and quadratic effects for each set of hypotheses. We adjusted p-values for each second-order term for multiple a priori comparisons using the Benjamini-Hochberg correction (Benjamini & Hochberg, 1995). The Benjamini-Hochberg correction minimizes the false discovery rate by adjusting p values such that positive estimates in a sample are not likely to be true negative effects in the population, and vice versa.

To visualize data, we used the R package ggplot2 (Wickham, 2016) and the interActive web app developed by McCabe, Kim, & King (2018). The interactive app makes use of small multiples (Tufte, 2001) to display regression predictions with uncertainty at several user-specified levels of a moderator. interActive also outputs regions of significance plots using the Johnson-Neyman approach (Johnson & Neyman, 1936), which displays the slope of the focal predictor across levels of the moderator. Plots for quadratic effects were produced with ggplot2. All plots display raw data either as points or as a marginal rug. Predictors were centered such that coefficient estimates represent the effect for an individual who is 8 years old, female, at the mean of cumulative risk, and at the mean of each temperament variable.

Results

Descriptive statistics

Zero-order correlations indicated associations between frustration and EC (r = -.16) and frustration and difficulty with delay (r = .19). EC was negatively related to measures of adjustment problems (rs -.36 to -.20), while cumulative risk was positively related to measures of adjustment problems (rs .18 to .31). Adjustment problems showed stability over time, with test-retest reliabilities of .61 to .70. Boys had higher levels of frustration, difficulty with delay, and conduct problems, as well as lower levels of EC. Age and cumulative risk were associated with EC such that younger and higher-risk children had lower EC. Correlations and descriptive statistics are presented in Table 1.

Regression Analyses

Anxiety. Controlling for covariates and other predictors, EC was associated with fewer concurrent anxiety symptoms (β = -.23, p = .001), while higher cumulative risk was associated with greater anxiety (β = .24, p < .001). Fourteen percent of variance in concurrent anxiety was explained by observed temperament and demographic variables (age, gender, cumulative risk). Forty-nine percent of variance in anxiety was explained at T2, but neither demographic nor temperament variables predicted T2 anxiety above and beyond T1 anxiety. See Table 2.

In both cross-sectional and longitudinal models, the Fear x EC, Frustration x EC, and quadratic effect of EC were not statistically significant.

Depression. Fear was associated with greater concurrent depressive symptoms (β = .15, p = .027) while EC was associated with fewer symptoms (β = -.31, p < .001). Fifteen percent of variance in concurrent depression was explained by observed temperament and demographic variables. At T2, 51% of the variance in depression was explained, but there was no evidence for temperament or demographic variable effects on T2 depression above and beyond the effect of T1 depression. See Table 3.

There was a statistically significant quadratic effect of EC on concurrent depression (β = .19, adjusted p = .040), such that those lowest in EC experienced the most depression, and those moderate or high in EC experienced lower and comparable levels of depression. This relation is portrayed in Figure 1.

No interactive or quadratic effects were found when predicting T2 depression. Fear x EC and Frustration x EC interactions were not significant for depression.

Conduct Problems. Cumulative risk was associated with greater levels of concurrent conduct problems (β = .24, p < .001), while EC was associated with fewer problems both cross-sectionally (β = -.27, p < .001) and longitudinally (β = -.13, p = .039). Twenty-six percent of the variance in conduct problems was explained by observed temperament and demographics, while 44% of the variance was explained at T2. See Table 4.

In concurrent analyses, we found evidence of a frustration x EC interaction (β = -.18, adjusted p = .040). There was a similar trend toward an interaction effect predicting T2 conduct problems (unadjusted p-value was significant, where as adjusted value was not). Figure 2 depicts the T1 frustration x EC interaction, and indicated a protective effect of EC, but only for those moderate to high in frustration. The simple slope of EC on conduct problems was significant and negative when frustration was 0.55 standard deviations below the mean or higher. 72% of observations are within this region. For individuals lower than .55 SD below the mean in frustration, the effect of EC on conduct problems was not significant. See Figure 3 for marginal effects plot. No other interactive or quadratic effects were found when predicting T2 conduct problems.

Discussion

We sought to characterize interactive and nonlinear relations between temperament traits and adjustment outcomes, and found evidence of an interaction between frustration and EC in predicting conduct problems, as well as a quadratic effect of EC on depression. Higher EC was linked to fewer conduct problems, but only for individuals who were moderate to high in frustration. Children low in EC were especially prone to depressive symptoms, while those moderate or high in EC experienced similar lower levels of depressive symptoms. Higher fear was associated with more depression problems, and higher EC was related to lower anxiety. Overall, EC was associated with all three types of psychopathology, whereas fear related to depression and frustration related to conduct problems.

Low EC was most strongly associated with elevated conduct problems for children high in frustration. This is consistent with adolescent and adult models which consider impulse control and emotionality in conjunction, particularly those studying the construct of urgency (Cyders & Smith, 2008; Whiteside & Lynam, 2001). Urgency has been described as a "reflexive responsivity to emotion" which may manifest as rash action or ill-advised inaction, and is closely related to a broad range of adolescent/adult psychopathology, including depression, anxiety, substance use, binge eating, problem gambling, and non-suicidal self-injury (Berg, Latzman, Bliwise, & Lilienfeld, 2015; Carver, Johnson, & Joormann, 2008; Cyders & Smith, 2008; Whiteside & Lynam, 2001). In the current study, EC was unrelated to conduct problems for those low in frustration. This finding fits with two-mode models of self-regulation (Barrett, Tugade, & Engle, 2004; Carver et al., 2008; Kahneman, 2003), which highlight the role of EC as inhibiting prepotent, dominant, non-adaptive responses, in favor of subdominant, goal-oriented, and adaptive responses. When emotional reactions to blocked goals are high, non-adaptive prepotent responses may be reinforced over time and may become more salient. Compounding this effect, fewer cognitive resources may be available to inhibit behavior in these emotional situations. Our study highlights the potential importance of the confluence of emotionality and impulse control (underpinned by EC) even relatively early in development.

Incremental differences in child EC may impact adjustment outcomes more strongly at the low end of EC than at the high end. Lower levels of EC were associated with symptoms of depression, whereas moderate/high-EC children did not have elevated levels of depression. Notably, we did not observe a u-shaped effect as might be expected given ideas of behavioral under- and overcontrol (Block & Kremen, 1996; Murray & Kochanska, 2002; Rothbart & Bates, 2006). Instead, we observed a negative relation between depressive symptoms and EC at the low end of EC, which weakened as EC rose. In other words, lower EC was a risk for depressive symptoms, but as EC rose, this effect weakened and disappeared, such that children at mean and high levels of EC exhibited no differential risk for depression. Visual inspection of raw data shows a number of individuals in the upper-left quadrant of Figure 1: that is, children who are far from the mean on both EC (very low) and depression symptoms (very high).

Taken together, our results support the idea that low EC (behavioral undercontrol) predicts depression, but do not support the idea that high EC (behavioral overcontrol) is also a risk factor for depression.

Research on temperament and adjustment can be meaningfully advanced by examining nonlinear and joint effects of temperament facets. Rothbart & Bates (2006) called for examination of temperament by temperament interactions, citing promising research in infant through elementary school samples. Our research builds on a growing literature supporting interactions specifically between NE and EC. NE and EC are thought to be underpinned by distinct neural systems, with emotionality governed by orbitofrontal and amygdalar circuits and EC governed by lateral prefrontal areas and the anterior cingulate. Given some level of neurological separation between these areas, it may well be that different combinations of NE and EC manifest very differently behaviorally than one might expect from either alone. For example, the same level of fear reactivity stemming from amygdalar threat circuits, representing bottom-up reactions to threat stimuli, might be modulated by top-down cognitive regulation reflecting activity in the prefrontal cortex, resulting in modulated fear reactions and behaviors in individuals with higher executive control abilities, or more pronounced and ostensible fear behaviors in those with lower executive control. Still, it is important to exercise caution in interpreting interaction and quadratic effects, as these results need replication in a variety of samples before being seen as consistent.

Understanding temperament predictors of adjustment problems is critically important during preadolescence, a period during which temperament begins to canalize into adult personality and adjustment problems become more stable. Traditionally, work on temperament has focused on infancy through preschool (e.g., Thomas & Chess, 1977). Preadolescent temperament displays strong stability with prior child temperament (Komsi et al., 2006; Maziade, Cote, Boudreault, Thivierge, & Boutin, 1986; Rothbart, Derryberry, & Hershey, 2000) as well as adult personality (Rothbart, Ahadi, & Evans, 2000; Tackett et al., 2008). Models predicting adjustment outcomes with gender, age, environmental risk, and temperament measured using brief lab tasks explained approximately 15-30% of the variance in outcomes. Preadolescent problems are remarkably stable, with stability coefficients ranging from .59-.74 between age 10 and age 12 (Guerin & Gottfried, 1994; Guerin, Gottfried, & Thomas, 1997). Moreover, preadolescent internalizing and externalizing problems precede and predict subsequent teen and adult problems with a high degree of certainty (Merikangas et al., 2010; Nock, Kazdin, Hiripi, & Kessler, 2007). Altogether, temperament work in preadolescence holds strong promise for identifying children who are at risk at a time when intervention is feasible.

Strengths of the current study included its use of behavioral measures of temperament, an analytic approach which characterized nonlinear and interactive effects of temperament, and a sample which sampled children from a broad range of levels of socioeconomic status. Task measures provide a unique opportunity to obtain data independent of well-known reporter biases (Achenbach, McConaughy, & Howell, 1987), as well as showing behavior in a highly controlled situation, constrained to be the same across each child. Task measures do come with their own limitations, such as a potential confounding of trait and state effects (Campbell & Fiske, 1959), yet they provide a unique opportunity to test theory across measurement method.

The study also had several limitations. Though our study is one of the first to examine nonlinear and interactive effects of temperament in preadolescents, our sample size may have limited power to detect effects in longitudinal analyses. Though observational tasks provide measurements which are less likely to be biased by desirability effects or other biases, it is unknown to what degree these measures reflect state variability in addition to trait variability. Moreover, they do not capture cognitive processes that are not behaviorally enacted, but may be available to introspection. Another limitation of lab-administered tasks is the extent to which they reflect behavior in ecologically-valid settings.

The richness of individual differences in children's temperament and developing personalities impacts their development and their emotional experience of the external world. While single-trait approaches are necessary and important, it is also important to examine to what extent temperament traits might work in concert to influence children's adjustment. In the current study, we used a multi-trait approach to describe child temperament, and found evidence of important trait-by-trait interactions and nonlinear effects in predicting later adjustment problems. Given the importance of managing emotionality and regulating impulses to successful functioning as an adolescent and adult (Cole, Marin, & Dennis, 2004; Compas et al., in press; Eisenberg & Spinrad, 2004; Gross, 2013; Rothbart, Sheese, & Posner, 2007), more nuanced knowledge on the contributions of temperament to adjustment is necessary to inform etiological models of psychopathology and intervention efforts.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (include name of committee + reference number) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Conflict of interest: The authors declare that they have no conflicts of interest.

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Table 1. Means, standard deviations, and correlations of demographic, temperament, and adjustment variables.

Variable	*M (SD)* or *%*	1	2	3	4	5	6	7	8	9	10	11	12
1. Gender (1=male)	57%												
2. Age	9.52 (1.01)	.11											
3. Cumulative risk	0.90 (1.28)	.08	-.04										
4. Fear	3.92 (3.41)	-.06	-.04	**.18**									
5. Frustration	1.52 (0.67)	**.14**	-.13	-.10	.05								
6. Executive control	28.64 (7.00)	**-.21**	**.20**	**-.19**	-.01	**-.16**							
7. Delay difficulty	1.58 (1.08)	**.23**	.01	.06	.10	**.19**	-.04						
8. T1 Anxiety	-.02 (1.48)	-.01	-.03	**.30**	.12	-.08	**-.25**	.01					
9. T1 Depression	-.01 (1.52)	.05	-.07	**.19**	**.18**	.03	**-.32**	.13	**.67**				
10. T1 Conduct problems	3.26 (2.82)	**.31**	-.04	**.31**	.03	.09	**-.36**	**.19**	**.44**	**.48**			
11. T2 Anxiety	-.04 (1.51)	-.03	-.14	**.27**	.11	.07	**-.20**	-.03	**.67**	**.56**	**.32**		
12. T2 Depression	-.01 (1.52)	.04	-.08	**.18**	.14	.04	**-.27**	.02	**.44**	**.70**	**.35**	**.59**	
13. T2 Conduct problems	2.80 (2.23)	**.29**	.03	**.27**	.12	**.18**	**-.36**	.11	**.33**	**.35**	**.61**	**.39**	**.47**

Note. Boldface indicates p < .05. M and SD are used to represent mean and standard deviation, respectively.

Table 2. Hierarchical regressions predicting anxiety from temperament and covariates.

	T1 Anxiety										
	Step 1 model					Step 2 models					
	β (std)	B	SE(B)	p	R^2	*β* (std)	B	SE(B)	p	adj. p	R^2
Gender	-.06	-.18	.21	.401	.14						
Age	.02	.03	.10	.752							
Cumulative risk score	**.24**	**.27**	**.08**	**<.001**							
Fear	.07	.11	.10	.299							
Frustration	-.08	-.12	.10	.246							
Delay difficulty	.00	.00	.10	.972							
Executive control	**-.23**	**-.34**	**.11**	**.001**							
Fear x EC						-.00	-.01	.10	.959	.959	.15
Frustration x EC						-.07	-.11	.10	.281	.460	.16
EC^2						.11	.13	.08	.120	.270	.16

	T2 Anxiety										
	Step 1 model					Step 2 models					
	β (std)	B	SE(B)	p	R^2	*β* (std)	B	SE(B)	p	adj. p	R^2
T1 Anxiety	**.65**	**.66**	**.06**	**<.001**	.49						
Gender	-.02	-.05	.18	.768							
Age	-.10	-.15	.08	.071							
Cumulative risk score	.09	.11	.07	.113							
Fear	.01	.02	.09	.850							
Frustration	.10	.15	.09	.094							
Delay difficulty	-.06	-.09	.08	.303							
Executive control	-.01	-.01	.09	.912							
Fear x EC						.09	.14	.09	.104	.268	.50
Frustration x EC						-.03	-.04	.08	.608	.684	.49
EC^2						.11	.13	.07	.055	.164	.50

Note: All Step 1 β *values change by less than .05 in subsequent steps and are not reported in Step 2 analyses. Bolded values indicate* p *< .05 for main effects and Benjamini-Hochberg corrected* p *< .05 for interaction and quadratic terms.*

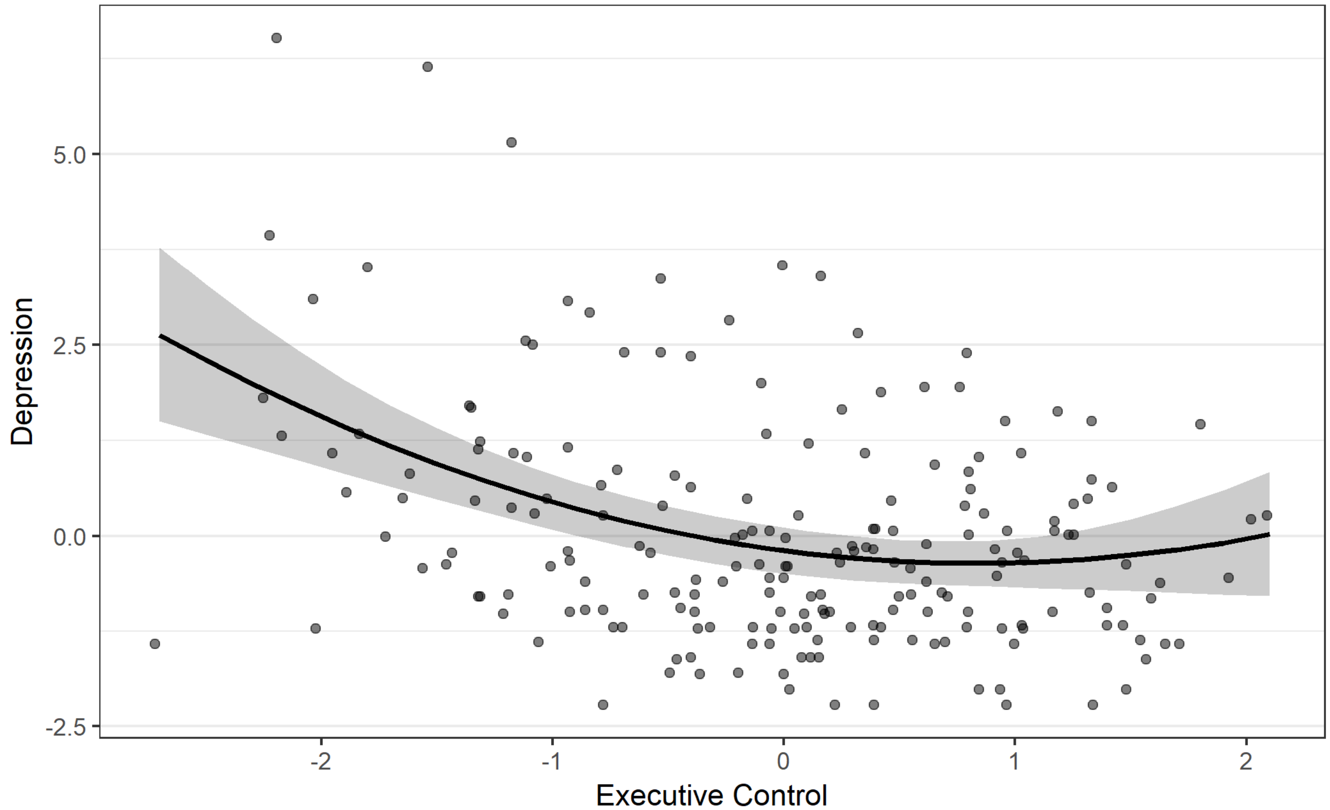
Table 3. Hierarchical regressions predicting depression from temperament and covariates.

	T1 Depression										
	Step 1 model					Step 2 models					
	β (std)	B	SE(B)	p	R^2	*β* (std)	B	SE(B)	p	adj. p	R^2
Gender	-.03	-.10	.22	.658	.15						
Age	.00	.01	.10	.956							
Cumulative risk score	.09	.11	.08	.177							
Fear	**.15**	**.23**	**.10**	**.027**							
Frustration	-.03	-.05	.11	.617							
Delay difficulty	.11	.16	.11	.124							
Executive control	**-.31**	**-.46**	**.11**	**<.001**							
Fear x EC						-.05	-.08	.11	.448	.611	.16
Frustration x EC						-.05	-.07	.10	.475	.611	.16
EC^2						**.19**	**.24**	**.08**	**.005**	**.040**	**.19**

	T2 Depression										
	Step 1 model					Step 2 models					
	β (std)	B	SE(B)	p	R^2	*β* (std)	B	SE(B)	p	adj. p	R^2
T1 Depression	**.69**	**.68**	**.06**	**<.001**	.51						
Gender	.01	.04	.17	.832							
Age	-.02	-.02	.08	.768							
Cumulative risk score	.07	.09	.07	.192							
Fear	-.01	-.01	.09	.885							
Frustration	.01	.02	.09	.795							
Delay difficulty	-.08	-.12	.08	.171							
Executive control	-.03	.05	.09	.610							
Fear x EC						-.01	-.02	.09	.791	.837	.51
Frustration x EC						-.07	-.11	.08	.166	.299	.51
EC^2						.06	.07	.07	.322	.483	.51

Note: All Step 1 β values change by less than .05 in subsequent steps and are not reported in Step 2 analyses. Bolded values indicate p < .05 *for main effects and Benjamini-Hochberg corrected* p < .05 *for interaction and quadratic terms.*

Figure 1. Quadratic effect of executive control on concurrent depression.



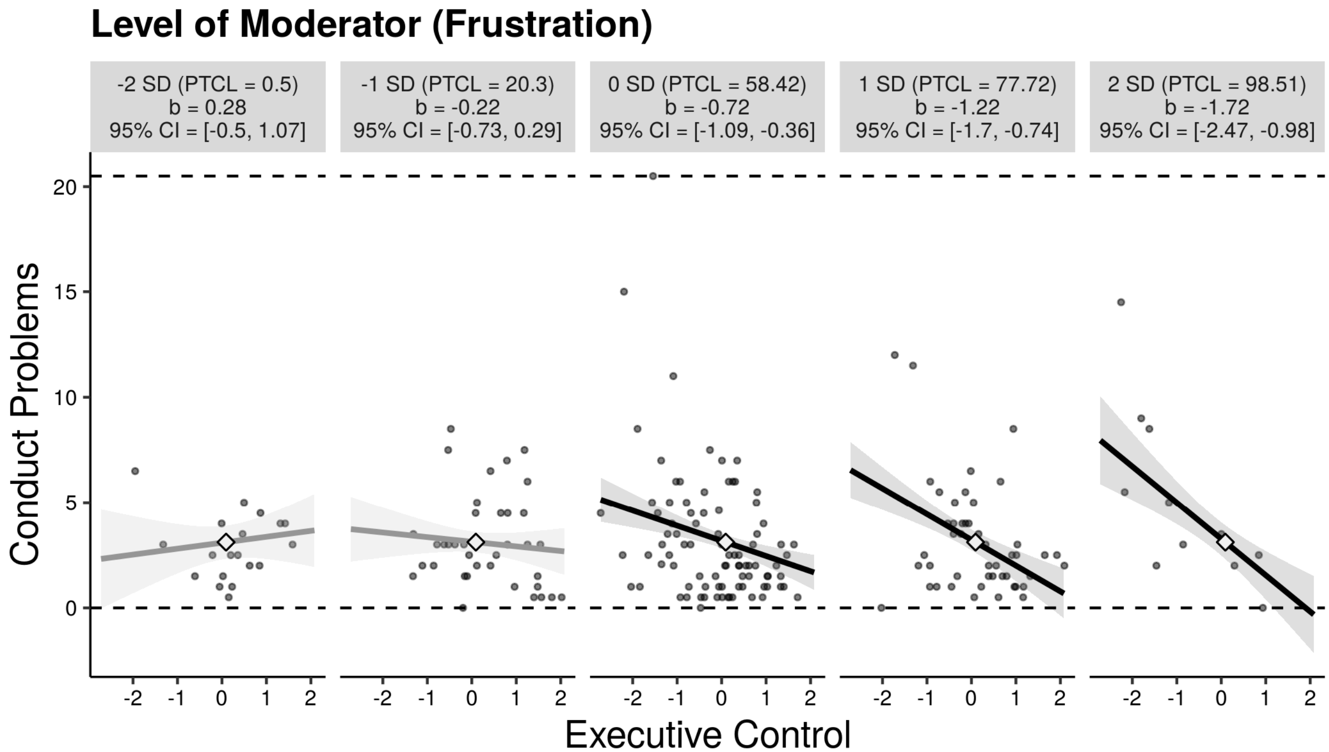
Solid line represents model-predicted depression scores. Shaded area represents 95% confidence interval for scores. Points represent all raw data.

Table 4. Hierarchical regressions predicting conduct problems from temperament and covariates.

	T1 Conduct Problems										
	Step 1 model					Step 2 models					
	β (std)	B	SE(B)	p	R^2	*β* (std)	B	SE(B)	p	adj. p	R^2
Gender	**.20**	**1.16**	**.38**	**.002**	.26						
Age	.00	.01	.18	.965							
Cumulative risk score	**.24**	**.53**	**.14**	**<.001**							
Fear	-.02	-.04	.18	.809							
Frustration	.02	.05	.18	.788							
Delay difficulty	.12	.34	.18	.066							
Executive control	**-.27**	**-.75**	**.18**	**<.001**							
Fear x EC						.03	.10	.19	.588	.684	.26
Frustration x EC						**-.18**	**-.50**	**.17**	**.004**	**.040**	**.29**
EC^2						.14	.33	.15	.026	.153	.28
	T2 Conduct Problems										
	Step 1 model					Step 2 models					
	β (std)	B	SE(B)	p	R^2	*β* (std)	B	SE(B)	p	adj. p	R^2
T1 Conduct problems	**.51**	**.39**	**.05**	**<.001**	.44						
Gender	.09	.41	.28	.148							
Age	.10	.23	.13	.085							
Cumulative risk score	.10	.19	.11	.096							
Fear	.09	.21	.13	.111							
Frustration	.11	.24	.13	.076							
Delay difficulty	-.06	-.13	.13	.314							
Executive control	**-.13**	**-.29**	**.14**	**.039**							
Fear x EC						.09	.20	.14	.137	.274	.44
Frustration x EC						-.12	-.26	.13	.045	.163	.45
EC^2						.12	.22	.10	.035	.160	.45

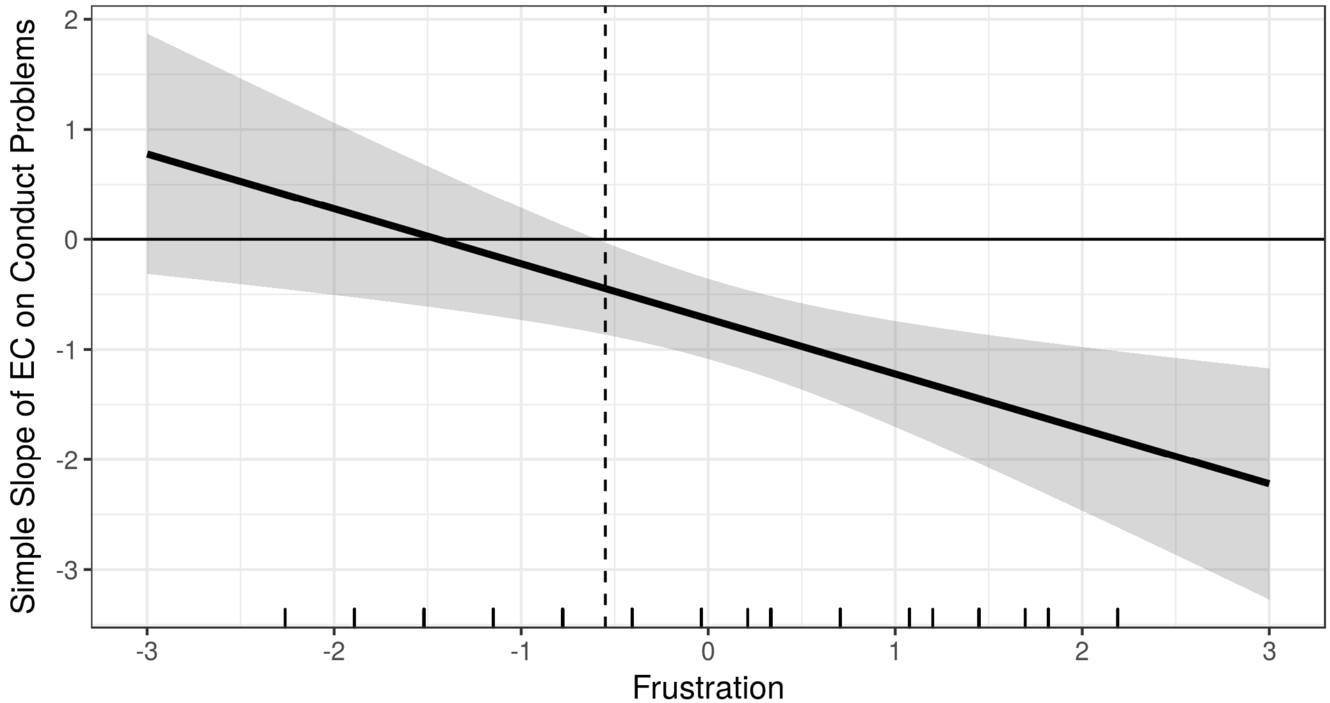
Note: All Step 1 β *values change by less than .05 in subsequent steps and are not reported in Step 2 analyses. Bolded values indicate* $p < .05$ *for main effects and Benjamini-Hochberg corrected* $p < .05$ *for interaction and quadratic terms.*

Figure 2. The effect of executive control on concurrent conduct problems is moderated by frustration.



Lines represent model-predicted conduct problems scores. Shaded areas represent 95% confidence intervals for scores. SD=standard deviation, PTCL=percentile, CI=confidence interval. Diamonds represent grand mean levels on both variables.

Figure 3. Marginal effects plot for interaction between frustration and executive control predicting conduct problems.



The linear effect (slope) of executive control (EC) on conduct problems is statistically significant and negative for individuals with frustration scores at or above .55 standard deviations below the mean.