


NEW RESEARCH

Development of Proactive Control and Anxiety Among Behaviorally Inhibited Adolescents

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Objective: Behavioral inhibition (BI) is an infant temperament characterized by heightened reactivity and negative affect in response to novel people and situations. BI is among the earliest and strongest predictors of future anxiety problems. However, not all children with a history of BI will manifest anxiety problems. A growing body of evidence suggests that proactive control skills may help buffer youth with BI from future anxiety difficulties; yet, it remains unclear how temperament may interact with the development of cognitive control to influence anxiety risk. The present study tested whether enhancements in proactive control occurring during adolescence may reduce risk for anxiety among youth with a history of BI.

Method: Participants included 185 adolescents (56% female) whose temperament was assessed during toddlerhood. In adolescence, participants completed anxiety assessments and an AX Continuous Performance Test (AX-CPT) to assess cognitive control strategy. Both assessments were administered at age 13 years and again at 15 years.

Results: Latent change score modeling revealed that, on average, participants increasingly used proactive control strategies and experienced worsening anxiety from age 13 to 15 years. Early BI was associated with a smaller anxiety increase from 13 to 15 years, but only among participants whose proactive control skills improved at mean or greater rates.

Conclusion: The present findings suggest that greater proactive control development during adolescence protects youth with high BI from age-related increases in anxiety. Results support a framework that highlights cognitive control as a key moderator of anxiety risk among children with a history of high BI.

Key words: Adolescence, Anxiety, Behavioral inhibition, Cognitive control, Development

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Behavioral inhibition (BI) is an infant temperament characterized by heightened distress to and avoidance of novelty.¹ It is among the earliest and strongest risk markers for future anxiety problems.² Nevertheless, only approximately half of all toddlers with high BI develop clinically significant anxiety problems.³ Understanding factors that moderate the BI–anxiety relation may help identify youth who are at particularly elevated risk for anxiety and inform prevention efforts.

Across at least 4 independent samples, children's cognitive control skills (ie, skills involved in monitoring and adapting behavior in accordance with behavioral goals) have consistently been shown to modulate anxiety risk for children with BI⁴⁻⁷ (for a recent review, see Fox *et al.*⁸). The dual mechanisms of control theory⁹ differentiates 2 temporally distinct and complementary modes of cognitive control: proactive and reactive. Proactive control involves early selection and maintenance of goal-relevant

information over time, whereas reactive control involves in-the-moment recruitment of resources, often in response to conflict. For example, a child who is about to engage in play with a peer must proactively select and maintain in working memory their goal of playing, which includes information about the selected activity, such as the rules of the game to be played. Reactive control, in contrast, may be recruited in response to unexpected events. For example, the sudden appearance of a peer's angry facial expression may trigger reactive control processes that shift attention away from the game and toward the peer's expression, thus disrupting proactive goal maintenance and potentially increasing anxiety risk.

An emerging view of the neurophysiological profile of BI recognizes heightened detection of salient stimuli (eg, threatening faces) as a core feature of the temperament.⁸ According to this view, some children with BI learn to regulate their responses to such cues via improved proactive

control skills.^{8,10-13} This increased proactive control likely helps the child resist goal-irrelevant demands on their attention (eg, ignoring the peer's potentially threatening facial expression) or, otherwise, more efficiently recover their goal-oriented attention (eg, quickly refocusing attention back toward the game), thereby reducing risk for anxiety. To date, cross-sectional evidence suggests that typically developing youth gradually transition from greater reliance on reactive control to greater reliance on proactive control from childhood to early adulthood.¹⁴⁻²¹ However, to the authors' knowledge, no study to date has examined proactive control development longitudinally. Moreover, no known study has examined how proactive development may relate to early temperament or to changes in anxiety over time. Adolescence is a time of markedly elevated neurocognitive development²² and a time when the most prevalent anxiety disorders (eg, social anxiety disorder) typically emerge.²³ Understanding how developmental changes in cognitive control and anxiety relate to one another may inform the assessment and identification of youth who are at heightened risk of manifesting anxiety difficulties and may also highlight potential target mechanisms for intervention.

One of the few available tasks used to measure proactive control processes is the AX Continuous Performance Test (AX-CPT).²⁴ The AX-CPT presents a series of letter pairs dissociable into 4 trial types (AX, AY, BX, and BY). The task enables measurement of proactive control via contextual cues (eg, the letters A or B) that indicate to the participant how they should respond to an upcoming probe (eg, the letters X or Y). The task also involves differential probabilities of trials (ie, some trial types are more common than others), making some trial types relatively expected and others relatively unexpected. Participants are instructed to press a target button only when they see the letter A followed by the letter X. As such, accurate performance depends, in part, on proactively attending to the cue identity and maintaining it in working memory until the probe letter appears. Recently, we used the AX-CPT in a longitudinal study examining cognitive control factors in the context of BI-anxiety relations. We found that 13-year-old children with a history of high BI during toddlerhood tended to rely less on proactive control, as indicated by lower d' context scores computed from their AX-CPT behavioral responses, than children without a history of high BI.²⁵ The d' context score is a behavioral index based on signal detection theory and involves comparing hit rate on AX trials to false alarm rate on BX trials; thus, the d' context score reflects the extent to which participants discriminate between target and nontarget trials as a

function of the cue identity, with higher scores indicating greater proactive control use.²⁴ In addition to the association between BI and less proactive control use, we found that youth with BI who used less proactive control had greater parent-reported total anxiety than youth with BI who used more proactive control.²⁵ In a later follow-up of the same cohort involving the AX-CPT combined with electroencephalogram (EEG), BI was associated with elevated anxiety specifically among youth using a cognitive control strategy characterized by the combination of low proactive control and high reactive control as measured via event-related potentials.¹³ Overall, there is emerging evidence based on both behavioral and neural data suggesting that children with BI who engage less in proactive control may be at greater risk for anxiety difficulties.

However, as noted earlier, all known studies to date examining the development of proactive control have been cross-sectional. Cross-sectional analyses using only one time of measurement per participant can usefully generate hypotheses about longitudinal change. However, these approaches often seriously misrepresent developmental processes.²⁶ This is largely because cohort effects have nonintuitive and cumulative impacts on group means and standard deviations (for examples illustrated with simulated data, see Kraemer *et al.*²⁶). Therefore, making correct developmental inferences requires longitudinal research designs paired with analyses that capture change over time.

Additionally, none of the existing cross-sectional studies of proactive development have examined relations with anxiety or examined the role of early temperament. Thus, it remains unclear how early temperament may interact with developmental changes in proactive control to influence anxiety risk. To address this question and the problem of relying on cross-sectional analyses, the present study applied a novel latent change score modeling approach to data from a relatively large longitudinal study examining anxiety risk among adolescents with a history of BI. BI was assessed during toddlerhood, and AX-CPT behavior and anxiety measures via multi-informant report were obtained at 13 and again at 15 years of age.^{13,25} This is an especially important age window that captures the mean onset for the most prevalent anxiety disorders (eg, social anxiety disorder, which has a mean age of onset of 14.3 years²³). Understanding developmental factors that relate to increases in anxiety during this key period may help identify youth with particularly elevated risk for anxiety disorders and may inform prevention and intervention efforts that target these factors. It was hypothesized that youth with a history of high BI who experience higher levels of proactive control development (ie, greater increases in d' context score) from

13 to 15 years would experience smaller increases in anxiety than youth with a history of high BI who experience lower levels of proactive control development.

METHOD

Participants

Participants included 189 adolescents (56% female) enrolled as part of a longitudinal study examining relations between infant temperament and the emergence of anxiety who were administered the AX-CPT at either the 13- or 15-year assessments. Four adolescents were excluded because they did not have valid AX-CPT data at either time point, for a final sample size of 185 (see AX-CPT section below for more details). The recruitment strategy and screening methods of this study have been described in detail elsewhere.^{27,28} Briefly, infants (N = 779; age 4 months) completed a laboratory temperament screening for emotional and motor reactivity toward novel auditory and visual stimuli. From these, infants with high motor and high positive or high negative reactivity were oversampled to reflect a range of temperamental reactivity that is wider than would be found in a randomly selected community sample. The selected infants (n = 291) continued to participate in assessments of cognitive and socioemotional development throughout childhood and adolescence. Informed consent and assent were obtained at each assessment, and each visit protocol was approved by the institutional review board of the University of Maryland, College Park. Race/ethnicity was rated by parents at the time of infant recruitment and was as follows: 17% African American, 5% Hispanic/Latino, 3% Asian, 72% White, and 3% Other. The mean (SD) age at the 13-year assessment was 13.2 (0.6) years and at the 15-year assessment was 15.4 (0.6) years. The attrition rate from infancy (n = 291) to the adolescent assessments (n = 189) was 35.1%. Using χ^2 and t tests revealed no significant differences between participants who did vs did not participate in the adolescent assessments in terms of race/ethnicity, sex, BI, or maternal education level (all *ps* > .30).

Behavioral Inhibition

BI was assessed at ages 24 and 36 months via behavioral coding of laboratory assessments.^{27,28} During laboratory observations, children were presented with an unfamiliar person and various novel toys (ie, robot, inflatable tunnel) during 3 episodes. Measures of interest were proximity to mother and latency to vocalize, to approach and touch the toys, and to approach a stranger. Additionally, maternal report of social fear was collected using the Toddler

Behavior Assessment Questionnaire.²⁹ Each questionnaire and observation measure was z-scored, and then all z-scores were averaged to create a composite BI score that combined ratings across informants and time points. Results when using a measure of BI that included only observational scores and excluded maternal report measures are presented in Figure S1 (available online) and were similar to those based on the combined BI measure.

AX Continuous Performance Task

To measure proactive control, participants completed the AX-CPT.^{9,24} The AX-CPT presents a continuous series of letter pairs (ie, a cue letter followed by a probe letter) dissociated into 4 trial types: AX, AY, BX, and BY. AX trials were the target trials, meaning that when participants saw an A cue followed by an X probe, they were to press a different button in response to the probe than during the other 3 trial types. Specifically, participants were instructed to press a nontarget button (eg, 1) following every cue and following most probe types; however, if an A cue was followed by an X probe, participants were to press a target button (eg, 4) on seeing the probe.

At age 13 and consistent with past behavioral studies of the AX-CPT, AX trials were presented 70% of the time, and the other trial types (ie, AY, BX, and BY) were each presented 10% of the time.²⁵ Participants completed 150 trials presented in random order. Each trial began with a center fixation cross appearing for 200 ms, followed by the presentation of the cue stimulus appearing for 500 ms. Next, a center fixation cross appeared during a 1,000-ms response window and during a subsequent 3,900-ms delay. The probe stimulus was then presented for 500 ms followed by another 1,000-ms response window with a fixation cross. At age 15, the task was modified to facilitate simultaneous collection of EEG (for EEG results from the 15-year assessment, see Valadez *et al.*¹³). In line with past EEG studies involving the AX-CPT,^{30,31} the breakdown of trial types was changed to 55%/15%/15%/15%, and the total number of trials was increased to 319. To accommodate the larger number of trials, the total delay between cue and probe onset was reduced to an interval randomized to between 1,400 and 1,600 ms. These changes were made to acquire enough trials to achieve adequate EEG signal-to-noise ratio in each condition. Critically, because AX trials were still by far the most frequent and comprised the majority of trials, behavioral predictions remained the same as in the 13-year version of the task.

Letter stimuli were presented in boldface 60-point Courier New font on a black background. To make clear the distinction between cues and probes, cues were

TABLE 1 Descriptive Statistics and Pearson Correlations Among Continuous Measures of Interest and Demographics

Measure	N	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Behavioral Inhibition (Standardized)	182	0.0	0.8													
2. SCARED Total Anxiety Parent Report: 13-year	159	10.3	8.8	0.25**												
3. SCARED Total Anxiety Child Report: 13-year	168	17.9	11.4	0.04	0.40***											
4. SCARED Total Anxiety Parent Report: 15-year	171	11.1	9.7	0.15	0.74***	0.35***										
5. SCARED Total Anxiety Child Report: 15-year	157	20.5	12.2	0.07	0.47***	0.47***	0.52***									
6. AX-CPT d' Context: 13-year	128	1.8	1.3	-0.07	-0.02	-0.11	0.10	-0.09								
7. AX-CPT d' Context: 15-year	164	3.1	0.7	0.02	-0.05	-0.04	-0.02	0.00	0.45***							
8. AX-CPT BX Probe Interference Effect: 13-year	129	0.09	0.17	0.15	0.10	0.12	-0.08	0.14	-0.54***	-0.22*						
9. AX-CPT BX Probe Interference Effect: 15-year	164	0.03	0.06	-0.14	0.05	0.04	0.04	-0.05	-0.16	-0.56***	0.12					
10. Sex (% male)	185	44.3%	—	-0.10	-0.20*	-0.33***	-0.32***	-0.38***	-0.08	-0.11	0.04	0.03				
11. Pubertal Development Scale: 13-year	156	2.5	0.5	0.07	0.19*	0.14	0.17*	0.18*	0.06	-0.05	-0.05	0.00	-0.53***			
12. Pubertal Development Scale: 15-year	130	3.1	0.5	0.08	0.10	-0.13	0.04	-0.03	0.16	0.12	0.00	-0.09	-0.08	0.25**		
13. Race/ethnicity (% White)	185	71.9%	—	-0.09	-0.06	-0.08	0.07	0.05	0.17	0.28***	-0.13	-0.03	-0.07	-0.08	0.13	
14. Maternal education	175	1.2	0.7	-0.01	-0.24**	-0.19*	-0.18*	-0.14	-0.10	0.07	-0.05	-0.07	0.01	-0.05	-0.08	0.22**

Note: Reported N values are the number of participants with valid scores for the given measure. Sex was dummy coded as female = 0 and male = 1. Maternal education was coded on an ordinal scale where high school diploma = 0, college degree = 1, and postgraduate degree = 2. Owing to small cell sizes for specific racial/ethnic groups, race/ethnicity was collapsed and dummy coded as Non-White = 0 and White = 1. Pubertal stage was assessed via self-report with the Pubertal Development Scale.³⁴ AX-CPT = AX Continuous Performance Test; SCARED = Screen for Child Anxiety Related Emotional Disorders.

*p < .05; **p < .01; ***p < .001.

presented in cyan, and probes were presented in white. Stimuli were presented on a 17-inch LCD monitor using E-Prime 2.0 Professional (Psychology Software Tools, Inc., Sharpsburg, Pennsylvania). Consistent with past work, individual trials were excluded from analysis if reaction time (RT) was >3 SDs above or below each participant's mean RT on correct trials,²⁵ resulting in exclusion of $<3\%$ of all trials at each assessment. After excluding outlier trials, accuracy and mean RTs were computed for each trial type. Consistent with other studies with children, participants needed at least 60% accuracy on BY trials for inclusion in analyses.^{13,20,25} This resulted in the exclusion of 4 participants who did not have valid behavioral data for at least one of the AX-CPT assessments (final $N = 185$). Within-subject trial type comparisons of RT and accuracy at age 13 and 15 years have been reported elsewhere.^{13,25} Briefly, at both assessments, B trials were generally faster and more accurate than A trials. AY trials were consistently the slowest and least accurate by a wide margin. This is in accordance with past studies of the AX-CPT in populations predominantly relying on proactive control.^{24,32,33} Behavior on all 4 trial types was significantly correlated across time (accuracy: AX: $r = 0.29$, AY: $r = 0.29$, BX: $r = 0.43$, BY: $r = 0.53$; RT: AX: $r = 0.42$, AY: $r = 0.39$, BX: $r = 0.41$, BY: $r = 0.33$; all $ps < .01$).

The d' context score, a commonly used behavioral index based on signal detection theory, provides a measure of the ability to discriminate between target and nontarget trials as a function of the cue.²⁴ The d' context scores were computed by comparing correct responses on AX trials (hits) relative to incorrect responses on BX trials (false alarms). A correction was applied in cases where there was a hit rate of 1 (hit rate = $2^{-(1/N)}$, where $N =$ number of target trials) or a false alarm rate of 0 (false alarm rate = $1 - 2^{-(1/N)}$, where $N =$ number of nontarget trials). The distribution of the d' context scores (13-year: skewness = -0.52 , kurtosis = 0.22 ; 15-year: skewness = -0.05 , kurtosis = 2.57) was inspected and determined to be normal (Table 1). Consistent with the broader literature involving the d' context score, higher scores were interpreted to indicate a more proactive style of cognitive control because the participant used the cue information to inform future responses.^{20,24,25}

Screen for Child Anxiety Related Emotional Disorders

Each participant and their parent separately completed the revised version of the Screen for Child Anxiety Related Emotional Disorders (SCARED)³⁵ at the 13- and 15-year assessments. The parent and child versions of SCARED included 41 items presented on a 3-point Likert scale (0 = never/hardly ever true, 1 = sometimes/

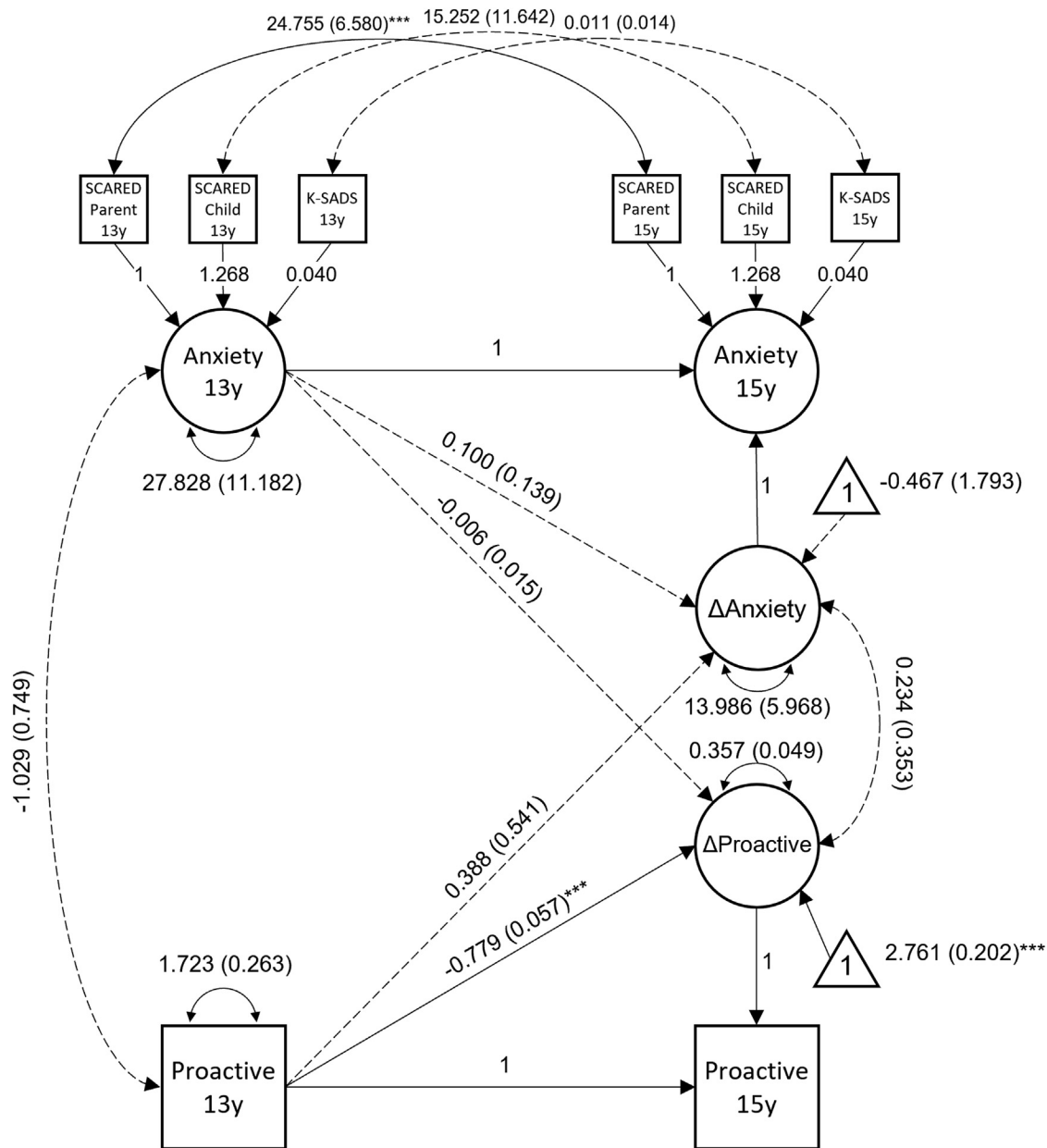
somewhat true, 2 = very/often true). Total SCARED scores at each time point and from each reporter were included as indicators in latent change score analyses. Internal consistency (Cronbach's α) of SCARED was high at both time points and for both reporters (13-year parent = 0.92 ; 13-year child = 0.92 ; 15-year parent = 0.93 ; 15-year child = 0.93).

Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version

Participants were administered the Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime version (K-SADS-PL)³⁶ at both time points. K-SADS-PL is a semistructured diagnostic interview for assessing current and past psychopathology among children and adolescents according to *DSM-5* criteria. It was administered by an advanced graduate student or doctoral-level clinician, under the close supervision of a board-certified child and adolescent psychiatrist and a licensed clinical psychologist. Of the 124 participants administered K-SADS-PL at age 13 years, 18 (14.5%) currently met criteria for at least one anxiety disorder. Specific anxiety diagnoses included social anxiety disorder ($n = 9$, 7.3%), generalized anxiety disorder ($n = 6$, 4.8%), specific phobia ($n = 3$, 2.4%), separation anxiety disorder ($n = 2$, 1.6%), and anxiety disorder not otherwise specified ($n = 1$, 0.8%). Of the 140 participants interviewed at age 15 years, 42 (30.0%) met criteria for at least one anxiety disorder. Specific anxiety diagnoses at age 15 included social anxiety disorder ($n = 22$, 15.7%), generalized anxiety disorder ($n = 18$, 12.9%), specific phobia ($n = 15$, 10.7%), separation anxiety disorder ($n = 1$, 0.7%), and panic disorder ($n = 1$, 0.7%).

Data Analytic Strategy

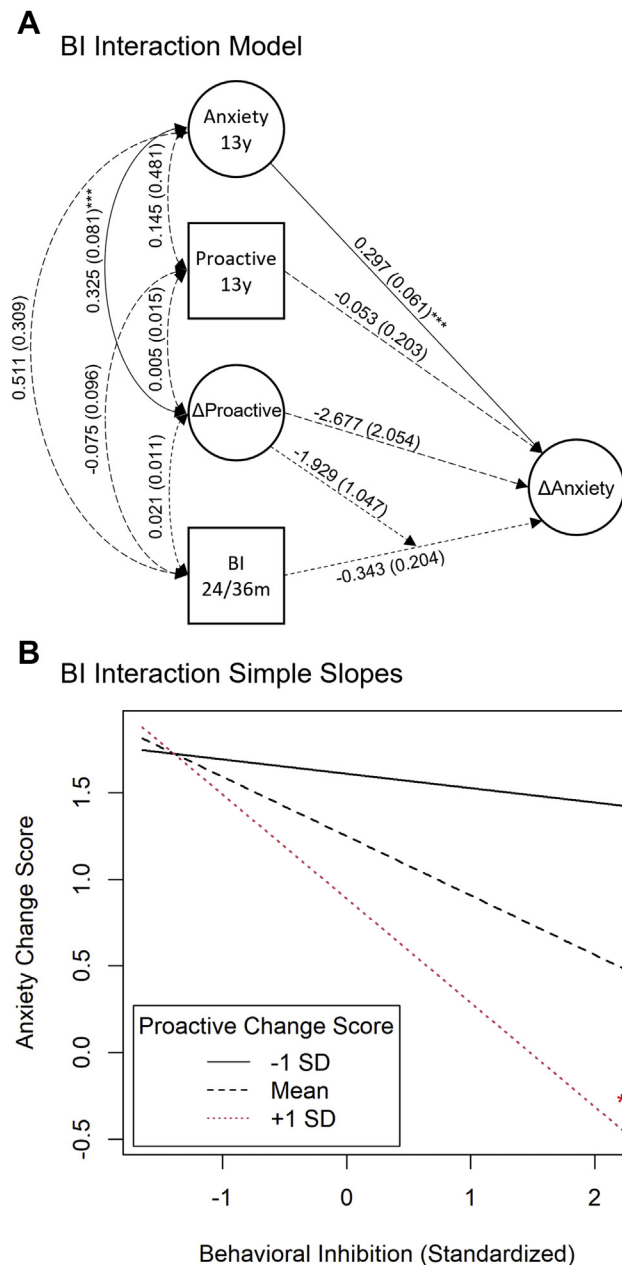
A series of latent change score models were tested to estimate changes in the d' context score and anxiety across ages 13 and 15 years (for models including a behavioral measure of reactive control, the BX probe interference effect,³⁷ see Figures S2-S3, available online). Latent change score models are a class of structural equation models enabling estimation of the complex relations between variables assessed at multiple time points. Anxiety at each time point was estimated as a latent score with the following indicators: parent-reported SCARED total score, child-reported SCARED total score, and current presence/absence of any anxiety disorder as assessed with K-SADS-PL (measured as a binary score). Little's missing completely at random test revealed missing data were likely missing completely at random

FIGURE 1 Bivariate Latent Change Score Model Including Anxiety and Proactive Control

Note: Parameter estimates are shown with standard error in parentheses. 13y = measured 13-year assessment; 15y = measured at 15-year assessment; K-SADS = Schedule for Affective Disorders and Schizophrenia for School-Age Children; SCARED = Screen for Child Anxiety Related Emotional Disorders. *** $p < .001$.

($\chi^2_{254} = 278, p = .144$). Owing to missing data and potential departures from multivariate normality, all models were estimated using a robust maximum likelihood estimator, which provides unbiased estimates when data are missing at random or missing completely at random.³⁸ For visualization of missing data patterns, see Figure S4, available online. Models were tested in R version 4.0.5 with the package lavaan version 0.6-8³⁹ according to the procedures described by Kievit et al.⁴⁰

Measurement models including only anxiety (ie, without d' context score) were tested for measurement invariance across time. There were no significant differences in model fit statistics when anxiety factor loadings were constrained to be equal across the 2 time points vs when they were unconstrained ($\chi^2_{diff2} = 0.09, p = .957$), indicating that the factor loadings were invariant across time. Additionally, the constrained model had good fit ($\chi^2_{robust7} = 10.14, p = .181$, root mean square error of approximation = .053 [90% CI:

FIGURE 2 Behavioral Inhibition Interaction Model and Simple Slopes

Note: (A) Model testing interaction between proactive control latent change score and BI, controlling for 13-year anxiety and 13-year proactive control. Parameter estimates are shown with standard error in parentheses. (B) Simple slopes from the BI \times d' context latent change score interaction. BI was associated with a smaller 13- to 15-year anxiety increase specifically among participants with proactive control change scores that were at least 1 SD above the mean. 13y = measured at 13-year assessment; BI = behavioral inhibition; BI 24/36m = BI averaged across 24 and 36 months of age.
* $p < .05$; ** $p < .01$; *** $p < .001$.

.000, .120], standardized root mean squared residual = 0.039, comparative fit index = 0.986, Yuan-Bentler scaling factor = 1.180). Thus, in all subsequent models involving

anxiety, anxiety factor loadings were constrained to be equal across both time points.⁴⁰

In the next step, separate latent change score models for anxiety and cognitive control strategy were tested to estimate mean levels of change in the absence of any covariates. These models were then combined into a bivariate latent change score model (Figure 1) to estimate relations between the 2 sets of measures.⁴⁰ Lastly, to test for a possible interaction between BI and the change in d' context score in predicting anxiety change, the latent change scores obtained from the bivariate latent change score model were extracted and included in a new path model that was also implemented in lavaan (Figure 2). The interaction test between BI and cognitive control change score was conducted in a separate model to reduce model complexity and improve interpretability of main effects. All predictors were mean-centered before computation of the interaction term. Anxiety and d' context score at age 13 years were included as covariates. The interaction was probed with the R package semTools version 0.5-4⁴¹.

RESULTS

The univariate latent change score model for anxiety revealed an anxiety latent change score significantly greater than zero (estimate = 1.23, SE = 0.56, $p = .028$), indicating that, on average, anxiety increased from 13 to 15 years. Similarly, the univariate latent change score model for d' context revealed a latent change score significantly greater than zero (estimate = 1.31, SE = 0.11, $p < .001$), suggesting that youth used more proactive strategies at age 15 than at age 13 years.

Bivariate latent change score model fit was good ($\chi^2_{\text{robust}15} = 24.07$, $p = .064$, root mean square error of approximation = 0.057 [90% CI: .000 .098], standardized root mean squared residual = 0.046, comparative fit index = 0.963, Yuan-Bentler scaling factor = 1.009) (Figure 1). Inspection of key parameters revealed that greater d' context score at 13 years was associated with a smaller d' context score change from 13 to 15 years ($p < .001$). There was no significant association between 13-year anxiety and anxiety change ($p = .470$), between anxiety and d' context 13-year scores ($p = .169$), or between anxiety and d' context change scores ($p = .507$).

The BI interaction model predicting 13- to 15-year anxiety change scores revealed a main effect of 13-year anxiety (Figure 2A). Greater anxiety at age 13 was associated with a larger anxiety increase from 13 to 15 years ($p < .001$). The hypothesized interaction between d' context change score and BI was not significant—albeit it was a nonsignificant trend ($p = .065$); however, this interaction did reach significance when using a measure of BI that excluded maternal report (Figure S1, available online), when controlling for

potential interactions with sex (Figure S5, available online), or when using change scores obtained from a model that included reactive control (Figures S2-S3, available online). Planned follow-up of this interaction revealed that BI was associated with a smaller 13- to 15-year anxiety increase specifically among participants with levels of d' context score change that were at least 1 SD above the mean ($p = .015$) (Figure 2B). The same pattern of results was also found when controlling for sex, race/ethnicity, maternal education level, and pubertal stage (Figure S6, available online). Supplemental analyses including the behavioral measure of reactive control revealed that the proactive and reactive control measures were strongly negatively correlated, as were their 2 change scores (Figure S2, available online). The interactions between BI and proactive and reactive control change were both significant and in opposite directions (Figure S3, available online). That is, BI was associated with a smaller anxiety increase among participants with larger proactive control increases or participants with smaller reactive control increases.

DISCUSSION

The present study tested whether the relations between early BI and changes in anxiety vary as a function of proactive control development during adolescence. This study benefited from several strengths, including a relatively large longitudinal sample beginning in infancy and the application of a novel structural equation modeling approach combining multi-informant assessments of psychopathology. The analytic approach was robust to data missingness typical of long-term longitudinal designs. It was hypothesized that youth with a history of high BI would be relatively protected against anxiety if they had higher levels of proactive control development compared with youth with a history of high BI with lower levels of proactive control development.^{8,13,25} On average, youth experienced worsening anxiety from age 13 to 15. However, youth with early BI were protected from this increase in anxiety if their proactive control skills developed at a relatively faster rate. Youth at the highest levels of both BI and proactive control development even experienced somewhat decreased anxiety from age 13 to 15. Because all models controlled for 13-year scores, this effect was not explained by potential individual differences in 13-year anxiety or proactive control. Age-related change in proactive control did not predict age-related change in anxiety among youth with low BI. Owing to the observed main effect of 13-year anxiety on the increase in symptoms from age 13 to 15, adolescents with high anxiety at age 13 faced elevated risk for even higher levels of anxiety by age 15. This pattern held for participants with low BI and/or with stable levels of proactive control. However, this was not the case for the unique subset of highly

anxious 13-year-old adolescents who also had a history of behavioral inhibition and showed an increase in proactive control between the ages of 13 and 15. For this unique subset of highly anxious 13-year-old adolescents, anxiety either did not change or decreased. According to an emerging framework, some children with BI learn to downregulate their responses to potentially threatening stimuli via increased proactive control.⁸ In line with the present results, an increase in the deployment of proactive control may help ameliorate BI-related risk for anxiety during adolescence.

The current findings have implications for understanding the development of cognitive control. First, youth tended to use increasingly proactive strategies between the ages of 13 and 15 years. Second, 13-year anxiety was associated with greater proactive control development from 13 to 15, suggesting that proactive control development may be, in part, a response to early anxiety. Third, youth who were already using predominantly proactive strategies by age 13 tended to exhibit less of a proactive control shift from age 13 to 15, indicating that some youth may have experienced their shift toward greater proactive control earlier in development. To address these last 2 possibilities, assessments of proactive control beginning before adolescence will be needed. An important caveat to these developmental findings is that the AX-CPT administered at age 15 had shorter delays between the cue and probe than the 13-year version (1,400-1,600 ms vs 4,900 ms). This may have made it easier to use proactive strategies at age 15 because the cue identity did not have to be maintained in working memory for as long as in the 13-year version. Furthermore, the 15-year task was administered with EEG. Thus, a portion of the observed proactive control increase from age 13 to 15 may have been due to these differences in the task and context, in addition to potential practice effects. Nevertheless, although previous work has found cross-sectional differences in proactive control use across child, adolescent, and adult age groups,¹⁴⁻²¹ the present study is the first to our knowledge to examine longitudinal increases in proactive control use. Though the changes in task parameters from age 13 to 15 years allow for only cautious interpretations of group-level development of proactive control, the fact that all youth experienced the same task changes permits confident interpretations of between-subject differences in proactive control development, which were the focus of the present study. Future work investigating the development of proactive control would benefit from a larger number of repeated assessments beginning earlier in childhood and, if possible, employing identical tasks across those assessments. Together, this would help provide greater temporal separation and inform a more comprehensive understanding of these processes across development, thus helping to distinguish between potential causes and consequences of anxiety.

Because proactive control development from age 13 to 15 years protected youth with BI from increased anxiety, the present findings may inform anxiety prevention and intervention efforts. Assessments of cognitive control strategy may eventually help identify children or adolescents with BI facing particularly elevated anxiety risk. These youth may benefit from existing psychosocial interventions designed for children with BI,^{42,43} from cognitive control training programs targeting proactive control directly,^{33,44-46} or a combination of the two. A key limitation, however, is that temporal precedence of proactive control development over anxiety onset has yet to be established, further underscoring the need for more longitudinal work in this area. Nevertheless, it is encouraging that anxiety risk among youth with BI has consistently been shown to be modulated by cognitive control processes.^{5,6,13,25,30,47-50}

In summary, the present findings indicate that among youth with a history of BI, a shift toward greater proactive control use during early adolescence may be associated with smaller increases in anxiety (and, in some cases, even decreased anxiety) during this key period for the emergence of anxiety disorders.²³ The present study contributes to an emerging understanding of how cognitive control factors may buffer anxiety risk that is otherwise associated with fearful temperament⁸ and, more generally, of plasticity in cognitive and emotional functioning during adolescence. Further longitudinal studies beginning earlier in childhood are needed to better understand the relations between proactive control skills and anxiety risk across development.

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