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Trait and State Anxiety: Relations to Executive Functioning in an at Risk Sample

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Abstract

Prior research with adults suggests mixed evidence for the relations of state and trait anxiety to prefrontal executive functions. Trait anxiety is hypothesized to impair the efficiency of prefrontal areas and goal directed attention and has been largely associated with poorer performance on executive functioning tasks. Fewer studies have investigated state anxiety and findings have been mixed. As studies of these processes in children have been limited by small sample sizes and a focus on working memory, we examine whether state and trait anxiety are associated with performance on two executive function tasks in a sample of urban, low-income children, ages 9 to 12. Results indicated that higher trait anxiety predicted lower executive functioning on both tasks. In addition, higher state anxiety was related to better performance on the Stroop task. Results demonstrate that, consistent with the adult literature, higher trait anxiety is related to lower executive functioning in children.

Keywords

state anxiety; trait anxiety; executive function

Executive functions (EF), cognitive skills involved in organizing information and planning goal-directed action, have been shown in many studies to be an important correlate of children's academic performance in literacy and math as well as school competence (ex. Blair & Diamond, 2008). Executive functions include processes of working memory, the ability to manipulate information held in mind; inhibitory control, the ability to stop a prepotent response in favor of a more reflective one; and attention shifting, the ability to switch between mental frames of reference. Executive functions, however, are only one aspect of self-regulation and the development of EF may best be understood in the context of other more automatic self-regulatory processes. On a neurobiological level, fearful emotionality such as anxiety allows for the detection and swift response to threat, and as such, is an evolutionarily significant aspect of automatic self-regulation. Limbic centers of fearful emotionality, in turn, are linked to prefrontal centers of executive function in order to allow for more reflective evaluation of potentially threatening situations and volitional control of automatic responses. As outlined below, these connections bring tradeoffs (or

potential cost) to executive functioning, however: High levels of fear may lead to biased processing toward limbic centers in order to facilitate faster behavioral responses, and in the process may inhibit prefrontal cortical function (Luu, Tucker, & Derryberry, 1998). Given these neurobiological and evolutionarily important connections between fearful emotionality and EF, theoretical and empirical research has investigated the ways in which anxiety may influence prefrontal executive processes.

One major theoretical perspective, Attention Control Theory, suggests that trait anxious individuals' automatic attention systems, those associated with limbic brain structures, play a stronger role in directing attention than do more reflective, goal-directed systems associated with prefrontal brain structures (Eysenck, Derakshan, Santos, & Calvo, 2007). Because the efficiency of goal-directed executive attention is impaired, anxiety is hypothesized to be associated with deficits in EF, particularly in the domains of attention shifting and inhibitory control (Eysenck & Derakshan, 2011). Several empirical studies of adults have provided evidence for this hypothesis that trait anxiety impairs executive attention control processes (Pacheco-Unguetti, Acosta, Callejas, & Lupianez, 2010) and performance on set-shifting tasks (Visu-Petra, Miclea, & Visu-Petra, 2012; Orem, Petrac, Bedwell, 2008 (perceived stress); Caselli, Reiman, Hentz, Osborne, & Alexander, 2004; Ansari, Derakshan, & Richards, 2008). Similarly, neuroimaging work has demonstrated that anxiety is associated with greater activation in prefrontal areas during working memory tasks (Fales, Barch, Burgess, Schaefer, Mennin, Gray, & Braver, 2008).

Whereas Attention Control Theory focuses on the ways in which more trait-like aspects of anxiety impair executive processes, individuals may also experience mood or state-related anxiety which could theoretically either impair, or alternately, facilitate EF. On the one hand, state anxiety could function similarly to trait anxiety and lead to decrements in EF. Consistent with this hypothesis, state anxiety has been related to deficits in attention shifting and working memory in a context of social evaluation (Visu-Petra et al., 2012) and to deficits in attention shifting in participants with high-levels of obsessive-compulsive symptoms (Goodwin & Sher, 1992). On the other hand, a heightened bottom-up process of alerting attention, which has been associated with state anxiety (Pacheco-Unguetti et al., 2010), could focus individuals' attention on the task at hand and thus facilitate performance on EF tasks. Consistent with this hypothesis, Kofman, Meiran, Greenberg, Balas, & Cohen (2006) found that end of the semester exams, which were related to slightly higher levels of state anxiety, predicted higher shifting abilities and faster performance on all conditions of the Stroop task. Yet others have found support for a third alternative, that there is no relation of state anxiety to inhibitory control as measured by interference on a traditional version of the Stroop task (Visu-Petra, et al., 2012, Kofman et al., 2006) or to executive control of attention (Pacheco-Unguetti et al., 2010). Thus, the current adult literature does not conclusively support a single hypothesis of the relation between state anxiety and EF.

In children, studies examining relations between anxiety and EF are few in number and most of the literature tends to use only one EF task and focus on only one aspect of EF, namely, working memory. Several studies have found that higher trait anxiety was associated with lower working memory skills (Cheie, Visu-Petra, Miclea, 2012; Hadwin, Brogan, & Stevenson, 2005; Ng & Lee, 2010; Owens, Stevenson, Hadwin, & Norgate, 2012). All of

these samples, however, were fairly small and a number of other studies have offered contrasting evidence. For example, in a study of 60 preschool children, although anxiety was related to slower performance on a visual working memory task with emotional stimuli, anxiety was unrelated to spatial working memory (Visu-Petra, Tincas, Cheie, & Benga, 2010). Moreover, another study comparing 34 children with an anxiety disorder to 31 children with depression and to 33 healthy controls found no working memory differences among the groups (Gunther, Holtkamp, Jolles, Herpetz-Dahmann, & Konrad, 2004). Additionally, only one study assessed state anxiety and found that children with higher state anxiety took longer to perform the working memory tasks (Hadwin et al., 2005).

Some preliminary evidence for relations of anxiety to other aspects of EF comes from two additional studies. In one study of 38 9–11 year old boys selected for very high or very low scores on scales of both anxiety and depression, high anxious-depressed boys made more errors and took longer to complete the Trail Making test, a measure of EF (Emerson, Mollet, & Harrison, 2005). More general EF deficits as measured by the Wisconsin Card Sorting Test were also found for a sample of 19 clinically anxious children (age 6–18) as compared to 14 age matched controls (Toren, Sadeh, Wolmer, Eldar, Koren, Weizman, & Laor, 2000). Given differences in methodology and concerns regarding statistical power across these prior studies, it is difficult to draw firm conclusions about the role of anxiety for children's EF.

Thus, the aim of this study is to fill this empirical gap by examining relations of state and trait anxiety to performance on EF tasks in a large sample of low-income children. In order to more rigorously test the relation of anxiety to EF, the current study uses two direct assessments of EF in order to determine whether effects are consistent across tasks. We chose the Stroop task and the Hearts and Flowers task in order to include measures that went beyond working memory skills to also tap inhibitory control and set-shifting aspects of EF. In keeping with prior research with adults, our first hypothesis was that higher levels of trait anxiety would interfere with higher-order cognitive function among children ages 9 to 12, as reflected by lower performance on multiple measures of EF. Given mixed results in the prior adult literature and a paucity of research with children, we had no specific hypotheses for the relation of state anxiety to performance on the two EF tasks. As discussed above, both positive and negative relations of state anxiety to EF constitute plausible hypotheses. We chose to test these hypotheses with a sample of children from low-income households, given our own and others' recent consideration of the ways that relations between emotion regulation and prefrontal functioning may be exacerbated in conditions of high environmental adversity (Blair & Raver, 2012; McEwen, 2012). We utilized a field-based approach to data collection, assessing children's anxiety and EF with individually-administered, computerized, laptop-based assessments as a way to contribute to a growing body of research on the normative processes of anxiety and EF among children facing high risk (see also Hackman & Farah, 2009).

Method

Sample and Procedures

The Chicago School Readiness Project (CSRP) was a multifaceted intervention that was designed to improve urban, low-income children's school readiness through increasing self-regulation skills and reducing behavior problems. The program was evaluated in a cluster-randomized controlled trial in which 35 Head Start classrooms in Chicago's poorest neighborhoods were randomly assigned to either the intervention or control groups. Classrooms were assigned in 2 cohorts and were followed up when the majority of children in the sample were enrolled in kindergarten, 1st, 3rd, and 5th grades. Data for the primary analyses in this study come from the 369 children, ages 9 to 12 years (mean = 10.58, S.D. = .60) who had EF reaction time data at the 5th grade follow up.

At the 5th grade follow up, parents completed a series of questionnaires including demographic information. Children individually participated in a 35-minute battery of direct assessments during the regular school day. Assessments were administered in the following order: emotion knowledge tasks, surveys measuring risk, strengths, and friendship quality, a Stroop task assessing EF, a dot probe task assessing attentional bias to threatening and positive stimuli, the STAIC State anxiety scale, the STAIC Trait anxiety scale, the Iowa Gambling Task assessing risk taking behavior, and the Hearts and Flowers task assessing EF. This study uses data from the direct assessments designed to tap children's EF as well as children's self reports of state and trait anxiety.

Measures

Income to needs ratio—Parents reported monthly household income as well as the number of people living in the household. The income-to-needs ratio was then calculated according to established guidelines.

State and Trait Anxiety—The State-Trait Anxiety Inventory for Children (STAIC; Spielberger, Edwards, Montuori, & Lushene, 1973) consists of two 20-item scales that measure state and trait anxiety in children between the ages of 8 and 14. The Trait scale measures longer-term trait anxiety which has to do with how the child generally feels. It prompts the child to rate 20 statement such as "I have trouble making up my mind" from hardly ever true to often true. The State scale examines the shorter-term state anxiety that is commonly specific to situations. It prompts the child to complete 20 "I feel..." statements on a scale of 1 to 3 with response options such as: 1 = not worried, 2 = worried, 3 = very worried. Both scales were highly reliable in this sample with $\alpha = .85$ and $\alpha = .77$ for the Trait and State subscales, respectively. When children completed at least 75% of a subscale, we calculated the mean score for that subscale. This method is equivalent to replacing missing item-responses with the mean response for each child and allowed us to calculate scores even for those who completed most but not all of the subscale (29 children on the State subscale and 17 children on the Trait subscale). The moderate correlation ($r = .25$) between these scales in this sample, indicated that Trait and State Anxiety are related but separable constructs.

Executive Functioning—Executive functioning was measured using the Hearts and Flowers task and the Color-Word Stroop task. In the Hearts and Flowers task (Davidson, Amso, Anderson, & Diamond, 2006), participants are told that when a heart appears on the screen, they should press the button that is on the same side as the heart, and when a flower appears on the screen, they should press the button that is on the opposite side of the flower. The first 12 trials were only hearts trials, the next 12 trials were only flowers trials, and the next 33 trials were mixed hearts and flowers. Stimuli were presented for 2000ms with an interstimulus interval of 1000ms. Trials were excluded from calculation of latency and accuracy aggregates if the response latency was less than 200ms as this indicates that participants were responding before they could have consciously seen the stimulus. Incorrect responses were also excluded from the calculation of latency aggregates. Accuracy aggregates were calculated as percent correct on valid trials. Mean latencies for each trial type were calculated by averaging the latency to respond across all trials of a given type. All aggregates were calculated only when at least 75% of trials were useable. In order to control for baseline reaction times, we created a difference score by subtracting mean reaction time on the hearts only trials from mean reaction time on the mixed trials. A lower difference score is indicative of higher EF. This score provides a measure of EF that captures all three components of working memory, inhibitory control, and attention set shifting.

In the Stroop task (Stroop, 1935), participants are instructed to name the color of the ink in which stimuli are presented. In this computerized version, there are 84 trials, in which the words “green” “blue” “black” or “red” appear in congruent or incongruent ink color. On the child’s keyboard, the button “d” is marked with a red star, “f” with a green star, “j” with a blue star, and “k” with a black star. The child is instructed to “name the color in which the word is printed while ignoring what the words actually say,” to respond as quickly and as accurately as they can, and to place their middle and index fingers on the red, blue, black, and green star keys on the keyboard. The child responds to each trial by choosing the key with the corresponding star of his/her color choice. The control condition consists of neutral words or non-words and provides a baseline for assessing the accuracy and speed with which participants carry out the basic task of naming the ink color. In the incongruent condition, however, the stimulus is a color word that is printed in a different color from the one it designates (e.g., the word blue printed in green). Comparisons of response times in these two conditions typically reveal an interference effect where participants have longer reaction times in the incongruent condition than in the control condition. Stimuli were presented until the subject made a response, and the interstimulus interval was 200ms. Presentation of stimuli was completely randomized for each child except that each of the 12 trial types was presented 7 times during the 84 trials. An ‘x’ was displayed for 400ms when an incorrect response was made. The first 6 trials were considered to be practice trials and were not scored. Latency and accuracy aggregates were calculated for trials with response times greater than 200ms and less than 2000ms. Additionally, incorrect trials were excluded from latency aggregates. Aggregates were calculated when at least 75% of trials were valid. The interference effect was calculated by subtracting mean reaction time in the control condition from mean reaction time in the incongruent condition. A smaller interference effect is indicative of higher EF.

Preliminary Data Processing

385 children participated in the Hearts and Flowers task and 388 children participated in the Stroop task. Of these children, we were able to calculate accuracy scores for 384 on the mixed hearts and flowers trials and 345 on the Stroop incongruent trials. Mean levels of accuracy on both the Hearts and Flowers mixed trials ($M = .85$, $S.D. = .16$) and the Stroop incongruent trials ($M = .87$, $S.D. = .17$) were high: As indicated by these descriptive data for both EF tasks, there was too little performance variability to use these measures as indicators of EF in our analyses (see Diamond, Barnett, Thomas, & Munro, 2007 for further discussion and guidelines). For this reason, we used the reaction time based interference and difference scores as our outcomes of interest for the Stroop and Hearts and Flowers tasks, respectively.

Furthermore, preliminary analyses demonstrated that there were no differences in mean levels (control mean, treatment mean, t-test) of state anxiety (1.41, 1.41, $t(377) = -.26$, $p = .797$); trait anxiety (1.86, 1.84, $t(382) = .35$, $p = .725$); Hearts and Flowers difference score (432, 427, $t(311) = .28$, $p = .777$); or Stroop task interference (177, 163, $t(318) = .76$, $p = .447$) associated with treatment status in the Head Start year. For this reason, our analyses did not differentiate children on the basis of treatment status in the Head Start year.

Missing EF Data

We limited our sample to those children who had valid data on our outcomes of interest. The Hearts and Flowers difference score was available for 313 children, and the Stroop interference score was available for 320 children. We conducted independent samples t-tests in order to examine whether there were differences in child characteristics including age, state anxiety, and trait anxiety between those included and those excluded from the reaction time analyses. Results indicated that children excluded from Stroop analyses were more likely to be younger ($t(386) = -3.30$, $p = .001$). Neither state ($t(377) = -.49$, $p = .627$) nor trait anxiety ($t(382) = .18$, $p = .858$) were associated with being excluded from Stroop interference analyses. Younger children were also more likely to be excluded from analysis of the Hearts and Flowers difference score ($t(383) = -3.40$, $p = .001$) and excluded children also had higher levels of state ($t(375) = 2.03$, $p = .044$) and trait ($t(380) = 2.17$, $p = .031$) anxiety.

Analysis Plan

Linear regression models were used to examine the extent to which state and trait anxiety predict the difference score (mixed trials mean latency - hearts only trials mean latency) from the Hearts and Flowers task and interference (incongruent trials mean latency - control trials mean latency) on the Stroop task. All analyses controlled for child age, child sex, child race, and family income to needs ratio, and all predictors were mean centered. Linear multiple regression models were estimated using full information maximum likelihood with robust standard errors in MPLUS 6.12 to avoid bias associated with missing predictor variables.

Results

Descriptive Statistics and Correlations

Descriptive statistics for the sample of 369 children who had valid reaction time scores on at least one task are presented in Table 1. Of the 369 children who had valid reaction time scores on either the Stroop task or the Hearts and Flowers task, 71% were African American, 24% were Hispanic, 2.4% were Biracial, 2.4% were White and less than 1% were either identified as Other or Native American. For analysis purposes, we coded race as “1” for African American and “0” for any other race.

The Hearts and Flowers difference score and Stroop interference score were uncorrelated ($r = .02$, $p = .730$). Bivariate correlations revealed that trait anxiety ($r = .15$, $p = .007$) but not state anxiety ($r = .05$, $p = .432$) was significantly correlated with performance on the Hearts and Flowers task. Correlations of trait anxiety ($r = .09$, $p = .130$) and state anxiety ($r = -.09$, $p = .106$) with interference on the Stroop task were opposite in direction but did not reach statistical significance.

Preliminary Analyses of Change in Variance Predicted

Our preliminary analyses indicated that demographic characteristics accounted for 6% of the variance in the Hearts and Flowers measure ($R^2 = 0.06$, $S.E. = 0.03$, $p = .024$), but that 8% of the variance was accounted for when anxiety measures were added to the model ($R^2 = .08$, $S.E. = 0.03$, $p = .003$). Demographic characteristics accounted for 3% of the variance in Stroop interference scores ($R^2 = 0.03$, $S.E. = 0.02$, $p = .136$), but the addition of anxiety measures led to 6% of the variance being accounted for ($R^2 = 0.06$, $S.E. = 0.03$, $p = .048$).

Hearts and Flowers Regression Analysis

As shown in Table 2, higher trait anxiety significantly predicted lower EF on the hearts and flowers task ($\beta = 0.14$, $S.E. = 0.06$, $p = .013$) such that a 1 standard deviation higher mean trait anxiety score was related to a .14 standard deviation higher difference score. State anxiety, however, was unrelated to performance on the hearts and flowers task. Sex was also associated with performance on the hearts and flowers task ($\beta = -0.18$, $S.E. = 0.05$, $p = .001$) indicating that boys on average had higher EF scores than girls. Older children also had higher EF on average as indicated by a significant negative effect of age ($\beta = -0.15$, $S.E. = 0.05$, $p = .004$). Income to needs ratio and ethnicity were not significantly related to the hearts and flowers EF measure.

Stroop Regression Analysis

As shown in Table 2, higher trait anxiety was significantly related to lower EF as measured by the Stroop task ($\beta = 0.12$, $S.E. = 0.06$, $p = .025$) such that being 1 standard deviation higher in mean trait anxiety was associated with a .12 standard deviation higher interference score. Higher state anxiety, however, predicted higher EF ($\beta = -0.13$, $S.E. = 0.06$, $p = .018$) such that 1 standard deviation higher on the state anxiety scale was associated with a .13 standard deviation lower interference score. Ethnicity was also related to interference ($\beta = -0.18$, $S.E. = 0.06$, $p = .002$) such that being African American was also associated with a

higher EF score. Neither sex, age, nor income-to-needs ratio was related to EF as measured by the Stroop task.

To check the robustness of these results, we replicated the analyses using a subset of 10 items on the state anxiety scale that were phrased to avoid social desirability effects. These items were worded in a way that generated more variability as compared to the other items. The pattern of results using only these items was the same as the pattern of results generated by using the entire state anxiety scale (which consisted of 20 items).

Discussion

This study demonstrated that higher levels of trait anxiety are associated with lower levels of executive function in childhood. Trait anxiety was associated both with a higher difference score on the Hearts and Flowers task as well as greater interference on the Stroop task. Our findings with regard to trait anxiety in childhood are consistent with an adult literature largely demonstrating deficits in executive functioning processes in adults with anxiety (Eysenck & Derakshan, 2011; Visu-Petra, et al., 2012; Caselli, et al., 2004; Ansari, et al., 2008). Moreover, our findings are consistent with past studies of these relations in childhood, which demonstrated that trait anxiety was associated with poorer performance on working memory tasks (Cheie, et al., 2012; Hadwin, et al., 2005; Ng & Lee, 2010; Owens, et al., 2012). Similarly, they are consistent with the results of two studies that provided some evidence of relations between anxiety and broader measures of EF (Emerson et al., 2005; Toren et al., 2000).

Overall, the current study offers several strengths that improve upon past studies to provide stronger evidence of trait anxiety-related impairments in children's executive functioning. In contrast to several prior studies, we utilize multiple assessments of EF and demonstrate similar sized effects of trait anxiety on both tasks. Moreover, our tasks capture multiple aspects of EF, and thus our results provide some evidence that anxiety associated impairments in EF are not solely limited to impairments of working memory. Although we did not aim to test which specific components of EF are related to anxiety, our results may suggest that higher trait anxiety is associated with lower inhibitory control in children as this component of EF was specifically tapped by the Stroop task. Additionally, our sample is much larger than those in past studies and is unique in that it is drawn from a demographically at risk population that is typically not involved in laboratory research. Moreover, our participants were not selected for clinically high or particularly low levels of trait anxiety, and thus our results may have greater generalizability to typically developing children, at least those who are in demographically risky contexts.

The fact that these relations of higher trait anxiety to lower executive functioning were obtained in a sample of participants that were not selected for clinical levels of anxiety warrants consideration. These results are especially interesting and important to consider in the context of school-related anxiety since many children have habitual anxiety to academic test taking, especially in the context of mathematics, which has been associated with poorer academic performance (Hembree, 1988). Importantly, executive functioning skills are necessary for learning and successfully completing assessments more generally and for

understanding and solving complex mathematical problems specifically. Given the associations found in the current study, children who experience high trait anxiety may be more at risk for academic difficulties because they have lower levels of executive functioning skills. Consistent with this prediction, recent work has demonstrated that working memory significantly mediated the relation between trait anxiety and academic performance (Owens et al., 2012). Future work should explore whether EF mediates anxiety related performance deficits on academic assessments.

Additionally and surprisingly, we found that state anxiety was associated with higher EF as measured by the Stroop, but was not associated with performance on the hearts and flowers task. These findings with regard to state anxiety add to a mixed adult literature. The findings for the Stroop task are somewhat consistent with one study that found that higher state anxiety is related to higher EF as measured by a shifting task (Kofman, et al., 2006). They contrast, however, with two other studies finding no relation of state anxiety to interference (Visu-Petra et al., 2012; Kofman et al., 2006) on a classic version of the Stroop task. In the child literature, one study found that state anxiety was associated with slower performance on the backward digit span task, a task tapping working memory (Hadwin, et al., 2005). That study, however, did not include any control for processing speed, and thus it is difficult to determine whether these findings were specific to differences in executive functioning or to simple speed of processing differences.

Theoretically, state anxiety has been hypothesized to be differentially related to attentional processes such that although trait anxiety impairs executive attention processes, state anxiety leads to an over-functioning of bottom-up attention processes such as alerting attention (Pacheco-Unguetti et al., 2010). Based on this mechanism of heightened alerting attention, higher state anxiety may help children to focus on the task at hand, which may in turn facilitate performance on the Stroop task as children need to consistently focus their attention on pressing the key that corresponds to the color of the stimulus presented. On a broader theoretical level, this finding is also consistent with the Yerkes-Dodson (1908) inverted U relation of arousal to complex cognition in which moderate increases in arousal are hypothesized to be associated with better performance on complex tasks. Notably, participants exhibited low to moderate levels of state anxiety, and thus the results may differ if participants were to instead experience highly intense levels of state anxiety or stress. Moreover, although we found a main effect of state anxiety on Stroop performance, it is possible that the effect of state anxiety may differ for children who have different temperaments or who have been exposed to differing levels of poverty related risk. Investigating these questions will be a productive avenue for our future work.

Limitations and Future Directions

Although the results of this study are intriguing, there are several limitations to the conclusions that can be drawn. The correlational nature of the study makes it impossible to draw any causal inferences. While it is impossible to randomly assign children to have various levels of trait anxiety, future work could be done with longitudinal data to model changes in trait anxiety and changes in executive functioning which could provide some insight into answering the causal question. Alternatively, interventions aimed at treating

anxiety could measure executive functioning as an outcome across groups of children randomly assigned to treatment and control conditions. It would be particularly interesting to know whether the EF deficits associated with trait anxiety are experimentally lowered when other anxiety symptoms are clinically reduced or whether they persist because the underlying neurocircuitry takes longer to re-organize.

It is also important to note that our use of field-based administration of assessments limited our control and therefore our ability to rule out several potential confounds related to the timing and sequence of our administration of state and trait anxiety measures and EF tasks. One possible timing issue is that the state anxiety measure was administered immediately before the trait anxiety measure and thus participants' responses to the state questionnaire could potentially prime their responses to the trait questionnaire. The low correlation between responses to these two scales, however, demonstrates that this is less of a concern. It is also important to note that the Stroop task was administered sequentially prior to the STAIC whereas the hearts and flowers task was administered after the STAIC. With regard to trait anxiety, this is not an issue as trait anxiety represents a more stable, habitual construct. With regard to state anxiety, there is the likelihood that children's experience of higher versus lower levels of success on the Stroop task may have influenced their subsequent reports of state anxiety. Had this been the case, however, it seems more likely that those who did more poorly would have reported higher, rather than lower levels of state anxiety, as compared to those who performed better. Moreover, we note that the assessment was only 35 minutes long and that the two tasks were only 12 minutes apart. Furthermore, children generally were reported by assessors to enjoy the challenge of the Stroop and Hearts and Flowers assessments, and none of the tasks elicited observable child distress, although it is possible that anxiety related distress occurred internally. Thus, the measure of state anxiety may best be described as representing children's levels of *reported* anxiety across the assessment situation. Future research using emotion induction procedures might also provide an alternative, experimental method of testing the associations between state anxiety and EF. Although this was not feasible in the current study because of the practical and ethical constraints of administering short assessments to a large number of children in school settings, this represents a productive direction for our future work.

Finally, we note that for the analysis of the Hearts and Flowers data, those children who were excluded had higher levels of state and trait anxiety on average than did those who were included. On the one hand, this sample selection further supports our claim that these data show important differences in EF associated with trait anxiety even in a sample of students with relatively low levels of anxiety. On the other hand, however, although this sample selection does not weaken the pattern of results obtained, it does raise an important direction for future research in that future studies would benefit from sampling students with a wide range of anxiety levels in order to determine the extent to which relations of state and trait anxiety to EF are similar or different across a wider range of anxiety levels.

Conclusion

In sum, this study examined relations of state and trait anxiety to executive functioning in a large sample of minority, low-income children. Our results indicating that higher trait

anxiety was associated with lower executive functioning as measured by both the Hearts and Flowers task and the Stroop task greatly strengthen an emerging literature that has previously identified relations of trait anxiety to EF in children. These findings have important implications for our understanding of the role of two different types of anxiety and higher-order cognitive processing. These findings also have important implications for applied contexts (such as clinical services and education) for children facing high environmental adversity, as the field moves forward in establishing neuropsychological and behavioral linkages between these key domains of cognition and emotion.

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Table 1

Descriptive Statistics

	N	Mean	S. D.
Child Age (months)	369	127.21	7.21
Ethnicity (1 = African American)	369	71%	--
Sex (1 = male)	361	47%	--
Income-to-needs Ratio	331	0.86	0.85
State Anxiety (mean)	362	1.41	0.25
Trait Anxiety (mean)	365	1.85	0.36
Hearts and Flowers hearts only RT	363	402.17	99.48
Hearts and Flowers mixed RT	314	831.62	161.70
Hearts and Flowers difference score	313	429.28	141.40
Stroop Control RT	365	1051.17	187.39
Stroop Incongruent RT	321	1205.93	235.16
Stroop Interference RT	320	169.49	162.66

Table 2

Regression Analyses

	Stroop Interference			HF Difference Score		
	β	S.E.	p-value	β	S.E.	p-value
State Anxiety mean	−0.13	0.06	0.018	0.03	0.06	0.558
Trait Anxiety mean	0.12	0.06	0.025	0.14	0.06	0.013
Boy	−0.02	0.06	0.713	−0.18	0.05	0.001
Age (months)	−0.02	0.05	0.725	−0.15	0.05	0.004
African American	−0.18	0.06	0.002	0.07	0.05	0.175
Income to Needs Ratio	−0.01	0.06	0.844	0.02	0.06	0.709
Intercept	1.04	0.06	<.001	3.05	0.16	<.001