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Fearful Faces Influence Attentional Control Processes in Anxious Youth and Adults

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This study examined the effects of trait anxiety and age on performance of an emotional working memory task designed to investigate attentional control processes in the context of emotion. Participants included children, adolescents, and adults (8–30 years old). They performed the Emotional Face *N*-Back (EFNBACK) task, a modified *n*-back working memory task with four emotional distracter types (no picture, neutral, fearful, and happy) and two memory-load conditions (0-back and 2-back), and completed self-report trait anxiety measures. Results indicated that participants high in trait anxiety had slower reaction times on the fearful 2-back memory-load condition. A significant interaction with age indicated that this effect was greater in the younger participants. These findings suggest that anxious individuals, particularly younger ones, exhibit difficulty resisting interference from threat-related stimuli when greater attentional resources are being recruited.

Keywords: emotional distracters, attentional control, trait anxiety, children, youth, adults

Modulating attention toward or away from emotionally salient information plays an integral role in the processing and regulation of emotion (Phillips, Ladouceur, & Drevets, 2008), and this aspect of attentional control has been shown to be impaired in anxiety and mood disorders (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburgh, & van Ijzendoorn, 2007; MacLeod, Mathews, & Tata, 1986; Mogg, Bradley, & Williams, 1995). There is mounting evidence indicating that one of the key characteristics of anxiety in youth and in adults is a tendency to disproportionately allocate attentional resources toward potential threats (Williams, Watts, MacLeod, & Mathews, 1997) or to have some difficulty in disengaging attention away from threat-related stimuli (Mogg, Bradley, De Bono, & Painter, 1997; Williams et al., 1997), or both. Some have proposed that such a tendency may be mediated by deficits in attentional control processes when processing emotionally salient information (i.e., threat-related stimuli; Derryberry & Reed, 2002). Most of the research in this area, however, has been conducted in adults. Very little research has been conducted in children and adolescents, particularly with regard to examining attentional control processes in the context of emotion (Bar-Haim et al., 2007). Elucidating such processes in youth will provide important information regarding early intervention during key early periods in the development of anxiety disorders. One way to address this issue is to use tasks that examine attentional control processes with emotional distracters that can be used in both youth and adults. Such an approach has the potential to advance our understanding of the mechanisms underlying the development of anxiety and mood disorders in ways that can help to inform early intervention strategies.

Cognitive theories of anxiety have put forward different accounts to explain attentional biases to threat, which have been documented in numerous adult studies in clinical and nonclinical samples (Bar-Haim et al., 2007; Bradley, Mogg, White, Groom, & de Bono, 1999; Mogg et al., 1995). One view is that anxious individuals are abnormally sensitive to threat-related stimuli and that such individuals tend to quickly and automatically direct their attention toward threatening information (Williams et al., 1997), which is consistent with the theoretical view that stimulus emotional valence is processed early, automatically, and in the absence of awareness (LeDoux, 2000). Another view is that anxious individuals tend to avoid threatening stimuli perhaps related to an inhibition in the processing of detailed information related to threat, which occurs later in the processing stream and which would manifest itself by a tendency to direct attention away from threat-related stimuli (Mogg et al., 1997; Williams et al., 1997). Others have focused on the delay taken to disengage attention away from threat-related stimuli, suggesting that the primary deficit in anxiety is associated with deficits in the modulation of the

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maintenance of attention on the source of the threatening information (Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002). Finally, an alternative view, which highlights the role of cognitive control processes in the monitoring and regulation of attention, is to focus on how automatic and voluntary processes work together by proposing that anxiety may be related to deficits in voluntary attentional control processes in the context of threatening information (Derryberry & Reed, 2002). According to this view, anxiety-related biases are not solely attributed to automatic attention-orienting processes to threatening information. Rather, it is proposed that anxiety is associated with impairments in the ability to flexibly control attention, particularly in the context of threatening information. Supporting evidence comes from findings showing that adults high in attentional control were better in shifting attention away from threatening information (Derryberry & Reed, 2002). More recent studies in cognitive neuroscience provide supporting evidence for this view. For instance, Bishop, Duncan, and Lawrence (2004) reported that the level of activation in the rostral region of the anterior cingulate cortex (ACC), an important component of the neural circuitry underlying attentional control processes while processing emotional information (Bush, Luu, & Posner, 2000), was lower in response to unattended threat-related stimuli (i.e., fearful faces) in highly anxious individuals than in healthy controls (Bishop, Duncan, & Lawrence, 2004).

Researchers have explored threat-related bias in anxiety by using various experimental paradigms that involve modified cognitive tasks incorporating emotionally salient stimuli, such as the emotional Stroop task, the dot-probe task, and the emotional spatial cueing task. The *emotional Stroop task* is a modified version of the classic color-naming interference paradigm (Stroop, 1935). In this task, participants are asked to name the color of a word as quickly as possible and to ignore the content of the word. Anxious individuals, in comparison with nonanxious individuals, are relatively slower in naming the color of threatening words than of neutral words. Such slow reaction times on these trials generally have been interpreted as reflecting greater allocation of attentional resources toward processing the threatening word, thereby reducing attentional resources necessary to perform the color-naming task (e.g., Williams, Mathews, & MacLeod, 1996). However, there remains some controversy regarding the interpretation of the performance of anxious individuals on this task (see Mogg & Bradley, 1998, p. 822). In the *dot-probe task*, participants are asked to stare at a fixation cross on the center of a computer screen. Two stimuli, one of which is neutral and the other of which is threatening, appear on either side of the screen. A dot is then presented in the location of one of the former stimuli. Participants are asked to indicate via button press as fast as possible the location of this dot, which, when presented at the location of the threatening stimulus, can serve as an index of attentional bias toward threat (i.e., faster reaction times to the dot when it appears in the previous location of the threatening stimulus is interpreted as vigilance to threat). Anxious adults are relatively quicker than are nonanxious adults to detect the dots following threat-related stimuli than neutral stimuli (MacLeod et al., 1986; Mogg & Bradley, 1998). The *emotional spatial cueing task* was developed to address the question of whether anxiety is associated with overengagement of attention toward threatening stimuli versus difficulty disengaging attention from threatening stimuli. The task is a modified version of Posner's classical spatial cueing paradigm (Posner, 1980), which involves the presentation of a cue at one of two locations on a high percentage of trials (valid cue condition) and at a different location on a smaller percentage of trials (invalid cue condition). Participants are typically faster to identify the target on validly cued trials than on invalidly cued trials, which reflects attentional engagement and disengagement, respectively. In the emotional spatial cueing task, the cue is either a neutral stimulus or a threat-related stimulus. Findings using this task in adults suggest that anxiety is associated with increased attentional dwell-time and deficits in disengaging of attention from threat-related stimuli (E. Fox et al., 2001, 2002). Other studies, however, have not replicated these effects (Cooper, Rowe, Penton-Voak, & Ludwig, 2009; Koster, Leyman, Raedt, & Crombez, 2006).

In comparison with the number of studies published about adults, relatively few studies have examined aspects of threat-related bias using these tasks in anxious youth. Nevertheless, in general these studies suggest that, as with adults, anxious children and adolescents also exhibit threat-related attentional biases (for a review, see Bar-Haim et al., 2007). For instance, on a visual search task, researchers documented that trait anxiety was associated with faster detection of schematic threat faces in children aged 7–10 years (Hadwin et al., 2003). Others using the emotional Stroop task and dot-probe task in high-trait anxious children aged 7–10 years have also reported an association between trait anxiety and attention bias for threatening stimuli (Heim-Dreger, Kohlmann, Eschenbeck, & Burkhardt, 2006). Despite mixed findings on the relationship between trait anxiety and attention bias in youth and adults potentially because of methodological factors such as the type of task, the type of threat-related stimuli used, or evidence of poor reliability (Schmuckle, 2005), Bar-Haim et al. (2007) concluded from their extensive literature review and meta-analysis that the evidence of an anxiety-related bias in youth resembles for the most part that typically observed in adults.

Most of the studies investigating threat biases in anxiety, however, have focused on early and automatic attention processes, such as attention orienting (e.g., dot-probe task). Little work has been conducted to examine the ability to resist interference from emotional distracters while anxious individuals perform a cognitive task that recruits high-order cognitive control processes such as a working memory task. Moreover, few studies have included children, adolescents, and adults in the same study. As such, one of the goals of the current study was to use a task that would allow us to examine, in anxious children, adolescents, and adults, voluntary attentional control processes implicated in resisting interference from emotionally salient distracters while performing a task that engages cognitive control processes.

One paradigm that appeared promising in this regard was the emotional working memory paradigm, which is a modified working memory task that includes emotionally salient stimuli as distracters potentially impairing the ability to maintain focus on task-relevant information (e.g., Erk, Kleczar, & Walter, 2007; Ladouceur et al., 2005; Lavric, Rippon, & Gray, 2003; Perlstein, Elbert, & Stenger, 2002). For instance, Erk et al. (2007) used a delayed-match-to-sample emotional working memory task in which healthy volunteers first viewed a display of six capital letters followed by a delay period, during which they viewed simultaneous presentations of a series of emotional pictures, each paired with a single lowercase letter. During presentation of the latter, participants indicated whether the single letter was part of the initial letter set. In another study, Dolcos and colleagues also used a delayed-match-to-sample working memory task, but it included a set of three faces followed by emotional pictures in the delay period (Dolcos, Kragel, Wang, & McCarthy, 2006; Dolcos & McCarthy, 2006). Finally, Ladouceur et al. (2005) used an emotional *n*-back task that included the superimposition of a letter *n*-back task onto emotional pictures (i.e., neutral, negative, or positive; Ladouceur et al., 2005). Although all of these studies allowed for the examination of interference effects from emotional distracters on attentional resources required to perform the working memory task, the emotional stimuli used in these studies were emotional pictures taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997). Despite the fact that the pictures taken from the IAPS elicit emotional responses in adults (Lang, Bradley, Cuthbert, & Patrick, 1993) and children (McManis et al., 2001), it remains unclear whether attentional resources would be affected similarly across development and whether interference effects were due mainly to variations in valence or levels of arousal.

In the present study, we aimed to examine the effects of trait anxiety and age on performance of a task designed to investigate attentional control processes in the context of emotion. We used the *Emotional Face N-back* (EFNBACK) *task*, an emotional working memory task designed to test the impact of emotionally salient distracters on attentional control processes implicated in working memory. In contrast to previous studies, we used emotional facial expressions, instead of pictures, as distracters. We decided to use facial expressions as emotional distracters for a number of reasons. First, several studies use facial expressions because they tend to engage basic neural and psychological processes in humans (Haxby, Hoffman, & Gobbini, 2002). Second, facial expressions are emotionally meaningful nonverbal stimuli, particularly for children and adolescents (Herba & Phillips, 2004). Third, the developmental literature on face processing has shown that the ability to discriminate among discrete facial expressions is relatively well developed early in childhood (Kolb, Wilson, & Taylor, 1992; Taylor, McCarthy, Saliba, & Degiovanni, 1999). We incorporated into the EFNBACK task two memory-load conditions—no memory load (0-back) and memory-load (2-back)—which allowed us to examine the role of task difficulty (i.e., more or less attentional resources being recruited) for the impact of emotional distracters on attentional control processes implicated in working memory. Additionally, unlike previous studies, we recruited a sample with a wide age range, including children, adolescents, and adults, which allowed us to examine the effects of age on the ability to resist interference from emotionally salient information in anxious individuals.

Hypotheses

We hypothesized that participants high in trait anxiety would exhibit slower reaction times on trials that included fearful face distracters and recruited greater attentional resources (i.e., 2-back). Although few studies have examined the normal development of attentional control processes in the context of emotion, there is evidence to suggest that there is a process of protracted functional maturation of the neural systems implicated in cognitive control and emotion regulation processes (Galvan et al., 2006; Herba & Phillips, 2004; Monk et al., 2003). Thus, we also hypothesized that reaction times to the fearful distracters on the 2-back memory-load condition in the high–trait anxiety group would be related to age.

Method

Participants

A total of 64 participants between 8 and 30 years old were recruited into the study; the data from 4 participants could not be included in the analyses because of technical errors yielding data for a total of 60 participants (mean age = 15.3 years, $SD = 4.9$; 28 male participants). Participants were subclassified into two groups: high trait anxiety ($n = 31$; mean age = 15.9 years, $SD = 4.9$; 16 male participants) and low trait anxiety ($n = 26$; mean age = 15.2 years, $SD = 4.8$; 11 male participants). Trait anxiety groups were formed using a median-split of the standardized scores on the State–Trait Anxiety Inventory for Children (STAIC; Spielberger, Edwards, Lushene, Montuori, & Platzek, 1973) and State–Trait Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970): low–-trait anxiety group (mean Z score = −.83, $SD = .44$) and high–trait anxiety group (mean Z score = .70, $SD = .76$), $t(55) = -9.5$, $p < .001$. There were no significant differences between the trait anxiety groups on any of the demographic variables (i.e., age, sex, socioeconomic status, and IQ; $p > .1$). All were free of neurological, developmental, or psychiatric disorder. The study was approved by the University of Pittsburgh Institutional Review Board. After a detailed description of the study and before participation, parents gave written informed consent for their child's participation in the study. Children gave written informed assent.

Measures

Demographic information. A sociodemographic questionnaire was used to obtain sociodemographic information from adults, parents, and their children. This questionnaire included information regarding basic sociodemographic information such as age, sex, family history of affective disorders, and socioeconomic status (SES; Hollingshead, 1975).

Psychiatric symptomatology. To screen for Axis I psychiatric disorders in this normative sample of children, parents completed a paper-and-pencil psychiatric screening inventory about child symptomatology. Parents of children 12 years of age and older completed the Adolescent Symptom Inventory—4 (ASI–4; Gadow & Sprafkin, 1998a), and parents of children less than 12 completed the Child Symptom Inventory—4 (CSI–4; Gadow & Sprafkin, 1998b). The ASI–4 and CSI–4 both inquire about child behavior over 17 categories related to *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM–IV*; American Psychiatric Association, 1994) diagnostic categories. The ASI–4 and CSI–4 demonstrate convergent and discriminant validity with corresponding scales of the Child Behavior Checklist (Achenbach, 1991) and with clinician diagnoses. The CSI–4 has also been shown to correlate with *DSM–IV* diagnoses (Gadow, Devincent, Pomeroy, & Azizian, 2005). Adult participants completed the Adult Self-Report Inventory—4 (ASRI–4; Gadow, Sprafkin, & Weiss, 2004), which is a 135-item self-report inventory. It has satisfactory internal consistency and test–retest reliability and can differentiate patients with or without specific diagnoses and between clinical and nonclinical samples.

Trait anxiety. The State–Trait Anxiety Inventory for Children (STAIC; Spielberger et al., 1973) consists of 20 items that assess trait anxiety in children and adolescents. Items were answered on a 3-point scale to indicate whether they were *hardly ever*, *sometimes*, or *often* true. The State–Trait Inventory (STAI; Spielberger et al., 1970) was used to assess trait anxiety in adults.

Emotional Face N-Back (EFNBACK) task. The EFNBACK is a task designed to examine the interference effects of emotionally salient information on the performance of a visual *n*-back task (Cohen et al., 1994; see Figure 1). The EFNBACK task is a modified version of a visual sequential letter working memory *n*-back task. The visual *n*-back task consists of visually presenting a pseudorandom sequence of letters and asking participants to respond to a prespecified letter appearing on the computer screen. In this study, the *n*-back included two memory-load conditions: a no-memory load (0-back: e.g., press the button to a specific letter, e.g., *M*) and a memory load (2-back: e.g., press the button whenever the current letter is identical to the letter present two trials back, (e.g., *L-X-L*). The EFNBACK task consisted of presenting the visual *n*-back task flanked by affectively valenced faces. It included eight blocks comprising two memory-load conditions (i.e., 0-back and 2-back) by four emotional distracter-type conditions (no picture, neutral face, fearful face, or happy face). The "no-picture" condition served to control for the probable interference related to the presence of flankers and to examine differences on the performance of the original *n*-back working memory task. The "happy-face" condition served to control for the probable interference related to the emotional valence (i.e., fearful face) of the flankers. Each block included 12 trials. Each trial consisted of presenting a letter only (no-picture condition) or a letter flanked by two stimuli, which consisted of identical copies of a picture of an actor exhibiting a neutral, fearful, or happy facial expression. The stimuli were gray-scaled pictures of actors displaying fearful, happy, and neutral (mouth open) expressions (the identities of the actors were numbers: female participants: 2, 5, 6, 7, 8, 9, 13, 14, 18, and 19; male participants: 21, 23, 24, 27, 28, 30, 33, 37, 41, and 42) taken from the NimStim set available at www.macbrain.org (Tottenham et al., 2009). All images were 400 × 600 pixels, cropped into an oval shape and normalized for size and luminance. The modified pictures were then aligned according to the positioning of the eyes on each face. This alignment procedure ensured that all of the pictures appeared at the same location across trials. Trial duration was 500 ms. The intertrial interval (ISI) consisted of a fixation cross (flanked with the faces presented during the prior trial). The ISI was jittered, with a mean duration of 3,500 ms. During the data acquisition, participants were instructed to remain still and silent and to respond to target letters by pressing a button on a keyboard with their index finger as quickly as possible while ignoring the faces that flanked the letters. Participants completed three runs of the task, with a total duration of 21 min, 12 s. Within each run, blocks were presented in a pseudorandom order (i.e., each run began with a 0-back/no-picture block to help participants ease into the task). Brief instructions, informing participants about whether the block was a 0-back or a 2-back condition, were presented on the screen at the beginning of each block. More detailed instructions were provided to participants during a practice session.

Procedure

After completing the informed consent process, parents completed the CSI–4 or the ASI–4 about their children to screen for any Axis I psychiatric disorders. Participants older than 18 years of age completed the ASRI–4 Inventory. Participants were then invited to complete computer tasks designed to examine the influence of emotional information on attentional control processes.

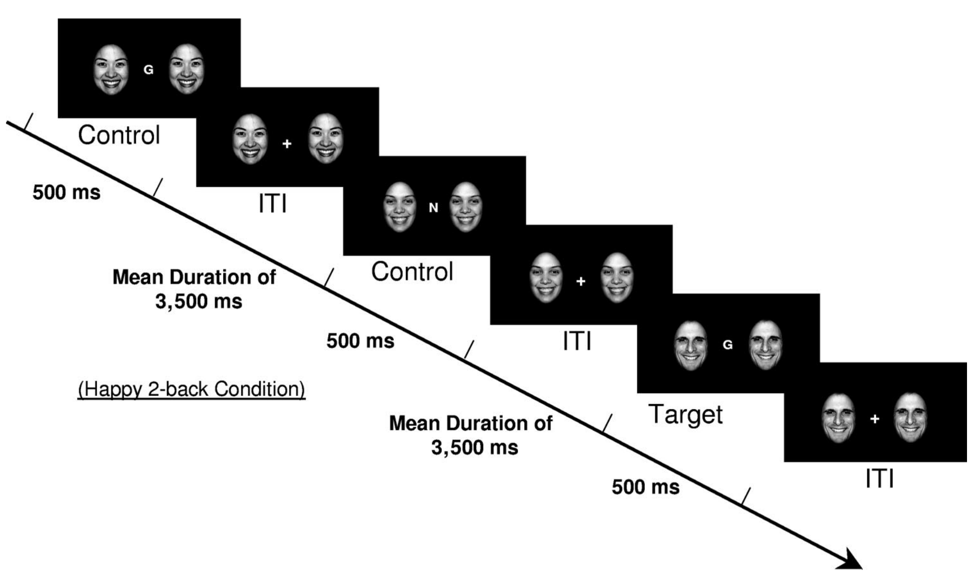

Figure 1. Illustration of the Emotional Face *N*-back (EFNBACK) task. Included is an example of the happy-face 2-back memory-load condition. The 0-back memory-load condition includes the same number of targets per block and involves responding to the letter *M*. Targets are trials in which a response is required. ITI = intertrial interval. Printed with permission.

One of the tasks was the EFNBACK task, which was completed in a counterbalanced order with another task. Stimuli presentation and response acquisition were controlled by a PC (Dell Dimension 8200) running E-prime software (Psychology Software Tools; PST; Pittsburgh, PA). Participants were tested individually. They sat in front of the computer screen at a distance of approximately 24 inches in a quiet room to perform the task. Before starting the task, participants completed a practice session, during which the experimenter read with the participants written instructions presented on the computer screen and gave feedback to participants during practice trials. The instructions informed participants that they were going to complete a computer task in which they were going to see a series of letters and that they would be asked to press a button on the keyboard when they saw either the letter *M* (0-back condition) or a letter that was preceded by the same letter two positions back (2-back condition). Finally, they were told that most of the time the letters would appear with faces on each side and that some of these faces would express an emotion while others would be neutral or "plain." Participants were also told that the task would be divided into blocks and that they would receive instructions before each block specifying whether the next series of trials was a 0-back condition or a 2-back condition. They were instructed to respond by pressing the number '2' on the keyboard with their index finger as quickly and as accurately as possible. Participants completed all previously described self-report measures after the computer tasks.

Statistical Analyses

In order to examine the effects of trait anxiety and age on performance of the EFNBACK task, we conducted separate mixed multivariate analyses of covariance (MANCOVA) models, respectively, on accuracy and correct-trial reaction time measures. For both models, distracter type (no picture, neutral, fearful, and happy) and memory load (0-back and 2-back) were included as within-subject variables. Age was included as a covariate and interaction term in the models. The multivariate test statistic reported is Wilks' lambda. Greenhouse-Geisser and Bonferoni corrections were used where warranted. Univariate analyses and post hoc multiple comparisons were conducted to follow-up main effects and interactions. Simple contrasts were used to follow up within-subject main effects. Outlying reaction time data points less than 100 ms or greater than 3,000 ms were filtered out; this comprised less than 1% of the trials. The mean correct-trial reaction time was then calculated for each of the participants as a function of each of the factors in the design. Preliminary analyses did not reveal any significant effects related to sex or SES. Therefore, these variables were not considered further.

Results

Accuracy

Analyses did not yield any significant Trait Anxiety Group × Distracter Type × Memory Load interaction or any significant trait anxiety group interactions or main effects ($p > .1$). There was, however, a significant main effect of memory load, $F(1, 51) = 19.74$, $p < .001$, partial $\eta^2 = .28$, indicating that participants were more accurate on the 0-back than on the 2-back memory-load condition. Furthermore, there was a significant main effect of age, $F(1, 51) = 21.24$, $p < .001$, partial $\eta^2 = .29$, and a significant Memory Load × Age interaction, $F(1, 51) = 9.39$, $p < .005$, partial $\eta^2 = .16$. Correlational analyses indicated that age was significantly positively correlated with accuracy measures, $r(58) = .51$, $p < .001$, suggesting that the number of correct responses increased with age, and that this effect was stronger in the 2-back condition, $r(58) = .47$, $p < .001$, than in the 0-back condition, $r(58) = .37$, $p < .005$ (see Table 1).

Reaction Times

Analyses indicated a significant Trait Anxiety Group × Distracter Type × Memory Load interaction, $F(2, 123) = 5.4$, $p < .005$, partial $\eta^2 = .18$ (see Table 1). Post hoc simple contrast analyses with distracter type as a within-subject variable were conducted in each of the trait anxiety groups for each of the memory-load conditions separately. Results revealed that participants high in trait anxiety were significantly slower in the fearful face condition than in the neutral face condition in the 2-back memory-load condition, $F(1, 27) = 10.95$, $p < .01$, partial $\eta^2 = .29$ (see Figure 2b). There were no significant differences for the low–trait anxiety group ($p > .1$; see Figure 2a).

There was also a significant Trait Anxiety Group × Distracter Type × Memory Load × Age interaction, $F(2, 123) = 3.8$, $p < .05$, partial $\eta^2 = .13$ (see Table 1). In order to examine the Trait Anxiety Group × Distracter Type × Memory Load × Age interaction and to minimize the number of comparisons, we computed "negative bias" scores for each of the memory conditions by subtracting the correct-trial reaction times for neutral faces from those for fearful faces in the 0-back and 2-back conditions. We also computed "positive bias" scores by subtracting the correct-trial reaction times for neutral faces from those for happy faces in the 0-back and 2-back memory-load conditions. Correlational analyses revealed that age was significantly correlated with reaction times on the 2-back negative bias score in the high–trait anxiety group, $r(58) = -.44$, $p < .01$. No other significant correlations were observed ($p > .1$; see Table 2).

As for accuracy, results also indicated a significant main effect of age, $F(1, 51) = 11.12$, $p < .005$, $\eta^2 = .18$. Correlational analyses indicated that age was negatively correlated with overall reaction times, $r(58) = -.48$, $p < .001$, suggesting that response times were faster with age.

Discussion

The goal of this study was to examine the influence of emotional distracters on attentional control processes in high–trait anxious in relation to low–trait anxious children, adolescents, and adults, by using the EFNBACK task. We predicted that the high–trait anxiety group would exhibit greater interference effects (i.e., slower reaction times) on trials that included threat-related information and demanded greater attentional resources and that these effects would be related to age. Our hypotheses were supported in that participants in the high–trait anxiety group exhibited slower reaction times on the 2-back fearful face condition than on the 2-back neutral face condition. Results also showed that reaction times on those trials were negatively correlated with age in the high–trait anxiety group. These findings are consistent with the theoretical

Table 1
Estimated Marginal Means (and Standard Errors) of Correct-Trial Reaction Time and Accuracy as a Function of Trait Anxiety Group, Emotional Distracter Type, and Memory Load

	Trait anxiety group			
	Low trait anxiety (n = 26)		High trait anxiety (n = 31)	
Condition	RT[a]	Accuracy[b]	RT[a]	Accuracy[b]
No picture				
0-back	468.33 (14.28)	35.14 (.28)	461.76 (13.50)	34.80 (.26)
2-back	584.29 (33.72)	32.84 (.65)	543.24 (31.87)	32.79 (.62)
Total	523.74 (21.40)	34.04 (.36)	502.85 (20.26)	33.84 (.34)
Neutral face				
0-back	517.60 (19.78)	34.87 (.26)	512.06 (18.70)	34.60 (.25)
2-back	643.49 (40.92)	32.58 (.64)	599.69 (38.67)	33.21 (.60)
Total	582.19 (28.18)	33.73 (.36)	557.17 (25.11)	33.91 (.34)
Fearful face				
0-back	519.58 (18.21)	35.03 (.25)	516.88 (17.22)	35.02 (.23)
2-back	597.68 (30.06)	32.84 (.61)	637.17 (34.08)	33.06 (.57)
Total	557.17 (25.11)	33.94 (.34)	575.83 (23.77)	34.04 (.32)
Happy face				
0-back	523.22 (19.95)	35.06 (.22)	514.51 (18.86)	34.77 (.21)
2-back	657.96 (49.22)	32.94 (.66)	584.09 (46.52)	33.05 (.62)
Total	594.11 (31.93)	34.00 (.35)	552.18 (30.22)	33.91 (.33)

Note. Standard errors are in parentheses. RT = reaction time.
[a] There was a significant Trait Anxiety Group × Distracter Type × Memory Load interaction, $F(2, 123) = 5.4$, $p < .005$. Post hoc simple contrast analyses with distracter type as a within-subject variable revealed that participants high in trait anxiety were significantly slower in the fearful face condition than the neutral face condition in the 2-back memory condition, $F(1, 26) = 8.95$, $p < .01$. [b] Data are presented as mean overall accuracy scores, which were calculated for each condition as (number of correct responses) + (number of correct omissions) with a maximum score of 36. All participants were more accurate on the 0-back memory-load condition than on the 2-back memory-load condition, $F(1, 51) = 19.74$, $p < .001$.

view that anxiety may be related to alterations in attentional control processes when processing threatening stimuli. In addition, they suggest that developmental factors, such as age, are important to consider when assessing attentional bias on cognitive control tasks in anxious individuals.

The present findings of an anxiety-related attention bias in trials that included fearful faces is consistent with previous findings from both adults and youth (Bar-Haim et al., 2007). In contrast to previous studies, however, the effect was specific to the 2-back memory trials, which demand greater attentional resources. In order to successfully perform the 2-back working memory component of this task, participants had to focus their attention on the target letter, keeping at least three letters in working memory while inhibiting engagement of attention by the emotional facial expressions flanking the target letters. The fact that participants high in trait anxiety exhibited difficulty resisting interference from these threat-related emotional distracters (i.e., fearful faces) while performing the 2-back memory-load condition suggests that trait anxiety may be associated with deficits in mobilizing sufficient attentional control resources to resist processing threatening or anxiety-provoking information without compromising goal-oriented behavior (Derryberry & Reed, 2002). Recent studies have suggested that such deficits may be associated with impairments in the recruitment of prefrontal attentional control mechanisms implicated in inhibiting or modulating activity in these subcortical regions (i.e., amygdale; Bishop, Duncan, Brett, & Lawrence, 2004).

Our findings that trait anxiety may be associated with impaired attentional control processes when processing threatening information are not consistent, however, with a recent theoretical proposal that anxiety is associated with deficits in attentional control processes in general (i.e., even when threat-related stimuli are absent; Eysenck, Derakshan, Santos, & Calvo, 2007). Eysenck et al. (2007) recently proposed a *processing efficiency theory* to explain findings from studies suggesting that anxiety may be associated with deficits in cognitive processing on difficult tasks (e.g., Eysenck, 1985). According to this view, anxious arousal may lead to worry or anxiety-related thoughts that are intended to dispel negative feelings but instead impair cognitive control processes because they mobilize valuable attentional resources. In addition, a high level of motivation to reduce the aversive state associated with anxiety-related physiological reactions may lead to a compensatory increase in cognitive effort in order to maintain an expected level of performance on a particular task. Thus, according to this theory, anxiety-related thoughts coupled with cognitive efforts aimed at suppressing negative affect associated with an anxiety-related state are thought to reduce processing efficiency in anxious individuals. If this account were valid, we should have observed a significant trait-anxiety group by memory-load interaction. That is, we should have observed in the high– trait anxiety group, in comparison with the low–trait anxiety group, lower accuracy scores or slower reaction times on the 2-back memory-load condition than the 0-back memory-load condition either in the no-picture condition or across the distracter-type conditions. In-

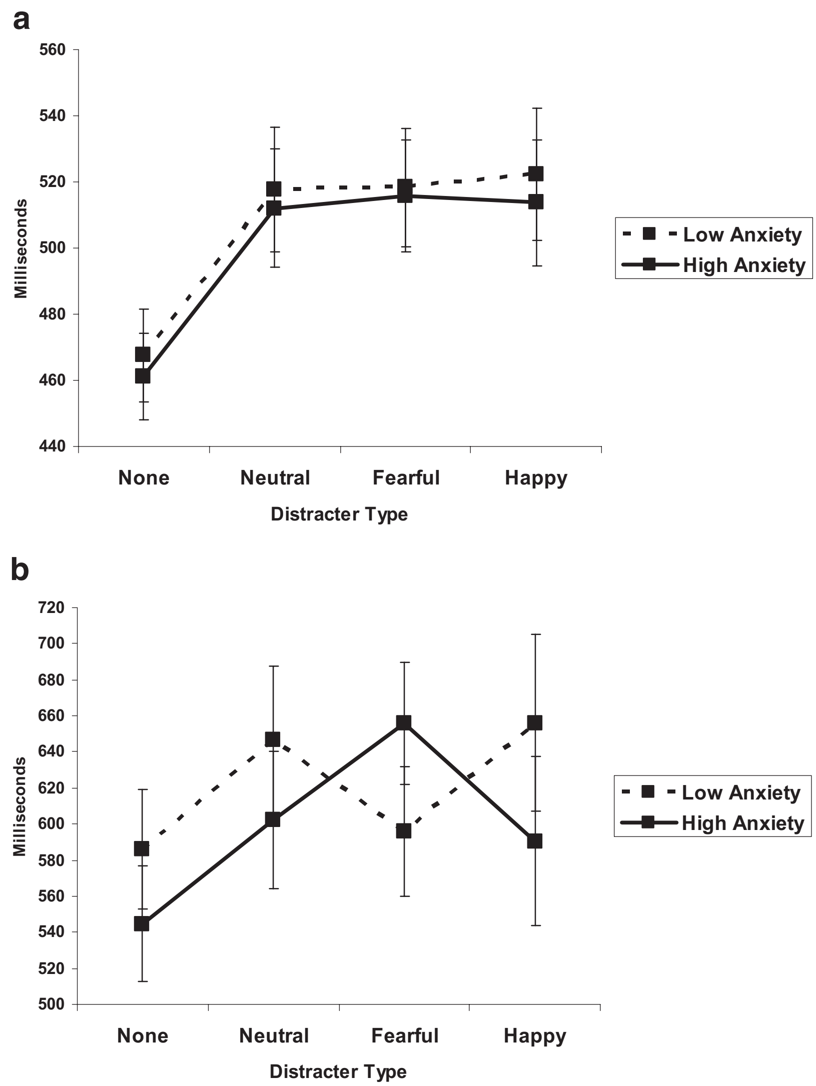

Figure 2. Reaction times and standard errors on the Emotional Face *N*-back (EFNBACK) task as a function of emotional distracter-type condition and trait-anxiety group (low or high) in the (a) 0-back memory-load condition and in the (b) 2-back memory-load condition. Note that participants high in trait anxiety were significantly slower in the fearful-face condition than in the neutral-face condition in the 2-back memory-load condition ($p < .01$).

stead, we found that slower reaction times in high–trait anxiety participants were specific to the 2-back memory-load condition with fearful face distracters. It is important to note that the impairments in cognitive control associated with trait anxiety in those studies were observed only on the more difficult levels of the cognitive tasks (Calvo & Ramos, 1989; Calvo, Ramos, & Estevez, 1992; Eysenck, 1985). By manipulating task difficulty to include higher levels of difficulty, it is possible that the task difficulty in those studies inadvertently induced anxiety in the high–trait anxiety participants. As such, the tasks may have not been completely devoid of threatening information (i.e., anxiety-related feelings and thoughts about performance, which they had to resist in order to successfully perform the task). Nevertheless, effects of anxiety on cognitive control processes may be more complex, and other factors may need to be taken into consideration (Fales et al., 2008).

When examining the effects of anxiety on performance, we also found that age was negatively correlated with reaction times in trials with fearful-face distracters in the 2-back memory-load condition in the high–trait anxiety group. Such a negative correlation suggests that the effect of threat-related information on attentional control processes is more prominent in youth than in adults. Recent evidence from studies using emotional working memory paradigms with functional magnetic resonance imaging (fMRI) suggests that attentional control processes involved in resisting interference from emotional distracters while performing a working memory task implicate lateral regions of the prefrontal cortex (i.e., ventrolateral prefrontal cortex; Erk et al., 2007). It is possible that such improvement in reaction times with age reflect the influence of maturation of prefrontal–subcortical connections in childhood and adolescence that can in turn impact threat-related biases in

Table 2
Correlations Between Age and Negative and Positive Bias Scores in the 0-Back and 2-Back Memory-Load Conditions

Bias score	Low trait anxiety group (n = 26)	High trait anxiety group (n = 31)
Negative bias 0-back	.30	−.11
Negative bias 2-back	.18	−.44**
Positive bias 0-back	.19	−.05
Positive bias 2-back	−.23	.23

** $p < .01$.

trait-anxious individuals (Hare et al., 2008). More developmental research in this area is needed, however, to address this question further. For instance, using the EFNBACK task in the fMRI scanner will help us determine whether anxious youth are as efficient as anxious adults in recruiting prefrontal–subcortical neural systems involved in modulating emotional information and whether such changes in efficiency with age may provide clues for early intervention.

Several studies have documented the presence of threat-related bias associated with anxiety in children and adults (for a review, see Bar-Haim et al., 2007). To our knowledge, however, no study has specifically examined the effects of age within the same study. Results from the current study suggest that, on this task, younger participants in the high–trait anxiety group appeared to exhibit greater interference from the fearful face distracters in the 2-back condition than did older participants. Most of the research studies addressing questions related to the development of attentional control and emotion have focused typically on differences associated with temperament in infants, toddlers, and preschoolers (e.g., Fox & Calkins, 2003). Given the paucity of research on the development of attentional control and emotion in older children and adolescents, it is difficult to interpret the effects of age on this task, given that participants included children older than 8 years old. There have been, however, recent research studies in developmental cognitive neuroscience documenting differences in the recruitment of neural systems implicated in attentional control processes when processing emotional information in children and adolescents. Findings from these studies suggest that these neural systems undergo significant maturational changes in childhood and adolescence. For example, Monk et al. (2003) reported that during passive viewing of fearful faces, adolescents (ages 10–17 years) in comparison with adults showed greater activity in the amygdala, bilateral orbitofrontal cortex, and anterior cingulate cortex, which are neural regions implicated in processing emotionally salient information, suggesting that when attention is unconstrained, adolescents may be more sensitive to emotionally salient stimuli. In another study, Hare et al. (2008) examined the development of behavioral and neural responses in performance of an emotional go/no-go paradigm in children (ages 7–12 years), adolescents (ages 13–18 years), and adults (ages 19–32 years; Hare et al., 2008). In this study, participants were presented with two emotional facial expressions (either fearful, happy, or neutral faces) and were asked to respond to one of the emotional faces (e.g., fearful) and suppress their response to the other emotional face (e.g., neutral). In the context of the threat-related information (fearful faces), reaction times improved with age but were slower in children and adolescents when detecting fearful faces in relation to a neutral face or a happy face. Such slower reaction times to fearful faces were associated with increased activity in the amygdale, whereas faster reaction times were associated with activity in the ventrolateral region of the prefrontal cortex. These findings were interpreted as indicating that maturation of prefrontal regions implicated in the modulation of attention to emotional information may reflect more efficient suppression of emotional reactivity with age (Hare et al., 2008). In light of these recent findings, it is possible that the age-related effects observed on the EFNBACK task in the high–trait anxiety group indicate that as prefrontal–subcortical systems become more efficient with age, individuals become better able to overcome interference effects from emotional stimuli and focus more attention on task-relevant stimuli. Further research using this task with neuroimaging techniques will help elucidate underlying neural systems and advance our understanding of the developmental mechanisms.

A potential limitation of the current study is the extent to which our findings can be generalized to individuals with anxiety disorders or other affective disorders. Future studies examining performance on the EFNBACK task in individuals with an anxiety or mood disorder are needed to address this question. Moreover, although we examined the effects of age by including it as a covariate and as an interaction term in our model, replicating our findings with a larger sample that includes separate age groups—including children, young adolescents, older adolescents, and adults—will enable us to better address age-related effects on performance. The main effect of age, indicating improved accuracy and faster reaction times with age, reflects normal developmental changes in cognitive processing from childhood through adulthood. It is possible, however, that younger participants might have found the EFNBACK task more difficult than did older participants, and as such this experience might have generated a certain level of anxiety and possibly influence the effects of the emotional distracters on their performance. This seems unlikely, however, because our findings indicate that age was specifically related to reaction times on the fearful-face 2-back condition, but not on other conditions, and only in the high–trait anxiety group, not in the low–trait anxiety group. Furthermore, given findings that puberty may contribute to increased reactivity to emotionally salient stimuli in adolescents (Dahl, 2001; Nelson, Leibenluft, McClure, & Pine, 2005; Silk et al., 2009; Steinberg, 2005), examination of the specific effects of puberty on performance in anxious youth may further our understanding regarding the influence of developmental factors on attentional biases related to anxiety. In addition, to investigate the extent to which the fearful faces were more or less distracting in anxious youth versus adults, future studies could incorporate eye-tracking measures, which would allow us to examine the frequency with which participants look at the faces. Such data combined with neuroimaging data on this task will be useful to advancing our knowledge about the developmental mechanisms underlying attentional control processes involved in processing emotionally salient stimuli and how these processes may be altered in individuals with affective disorders. Furthermore, it is possible that pictures of adult facial expressions may not have the same distracting effect in youth compared to adults. Thus, including pictures of actors within the same age range as the participants may have a greater "distracting" effect, particularly in adolescence, when peer relationships become increasingly important (Nelson et al., 2005). Finally, given findings from prior studies raising questions regarding the reliability of the emotional Stroop task (Strauss, Allen, Jorgensen, & Cramer, 2005), the dot-probe task (Schmuckle, 2005), and the emotional spatial cueing task, future research is needed to assess the reliability and validity of the EFNBACK task. Such research studies will contribute in moving the field forward and set the stage for further studies using neuroimaging techniques to investigate underlying neural systems.

In summary, this study examined the effects of trait anxiety and age on performance of the Emotional Face *N*-back task, a novel task designed to investigate attentional control processes in the context of emotion. Results suggest that participants high in trait anxiety have more difficulty resisting interference from threat-related stimuli when they must recruit attentional resources to perform a cognitive control task and that such an effect is stronger in younger people. Findings from this study also suggest that the EFNBACK task has the potential to advance our understanding of the developmental mechanisms of cognitive control–emotion interactions. Because the task was designed to be used eventually with fMRI, it also has the potential to advance of our knowledge about the development of underlying neural systems of cognitive control–emotion interactions and how these systems may be altered in individuals at risk for or diagnosed with an anxiety or mood disorder (Phillips, Drevets, Rauch, & Lane, 2003; Phillips et al., 2008).

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