The influence of emotional stimuli on attention orienting and inhibitory control in pediatric anxiety

Mueller, Sven, Hardin, Michael, Mogg, Karin, Benson, Valerie, Bradley, Brendan P., Reinholdt-Dunne, Marie Louise, Liversedge, Simon Paul, Pine, Daniel and Ernst, Monique

Published in final edited form as:
J Child Psychol Psychiatry. 2012 August ; 53(8): 856–863. doi:10.1111/j.1469-7610.2012.02541.x.

The Influence of Emotional Stimuli on Attention Orienting and Inhibitory Control in Pediatric Anxiety

Sven C. Mueller, Ph.D.[1,2], **Michael G. Hardin, Ph.D.**[1], **Karin Mogg, Ph.D.**[3], **Valerie Benson, Ph.D.**[3], **Brendan P. Bradley, Ph.D.**[3], **Marie Louise Reinholdt-Dunne, Ph.D.**[4], **Simon P. Liversedge, Ph.D.**[3], **Daniel S. Pine, MD.**[1], and **Monique Ernst, Ph.D., MD.**[1]

[1]Section of Developmental and Affective Neuroscience, National Institute of Mental Health, Bethesda, MD, USA

[2]Department of Experimental-Clinical and Health Psychology, Ghent University, Belgium

[3]School of Psychology, University of Southampton, Southampton, UK

[4]Department of Psychology, University of Copenhagen, Copenhagen, Denmark

Abstract

Background—Anxiety disorders are highly prevalent in children and adolescents, and are associated with aberrant emotion-related attention orienting and inhibitory control. While recent studies conducted with high-trait anxious adults have employed novel emotion-modified antisaccade tasks to examine the influence of emotional information on orienting and inhibition, similar studies have yet to be conducted in youths.

Methods—Participants were 22 children/adolescents diagnosed with an anxiety disorder, and 22 age-matched healthy comparison youths. Participants completed an emotion-modified antisaccade task that was similar to those used in studies of high-trait anxious adults. This task probed the influence of abruptly appearing neutral, happy, angry, or fear stimuli on orienting (prosaccade) or inhibitory (antisaccade) responses.

Results—Anxious compared to healthy children showed facilitated orienting towards angry stimuli. With respect to inhibitory processes, threat-related information improved antisaccade accuracy in healthy but not anxious youth. These findings were not linked to individual levels of reported anxiety or specific anxiety disorders.

Conclusions—Findings suggest that anxious relative to healthy children manifest enhanced orienting towards threat-related stimuli. Additionally, the current findings suggest that threat may modulate inhibitory control during adolescent development.

Keywords

Anxiety; Development; Children; Emotion; Orienting; Inhibition; Bias; Saccade

Introduction

Anxiety disorders are among the most prevalent of all pediatric psychiatric disorders and convey vulnerability for both adult anxiety and other adult psychopathologies (e.g., Beesdo, Pine, Lieb, & Wittchen, 2010; Bittner et al., 2007). Particularly, late childhood and early adolescence are prime periods for the onset of anxiety disorders, an association attributed to

Correspondence: Monique Ernst, M.D., Ph.D., NIMH/NIH, 15K North Drive, Bethesda MD 20892, Tel.: 301-402-9355, Fax: 301-402-2010, ernstm@mail.nih.gov.

the significant behavioral and neurobiological developments occurring during this transition period (Paus, Keshavan, & Giedd, 2008).

Cognitive models of anxiety have focused on attention orienting, particularly on orienting bias for threat stimuli (see Bar-Haim et al., 2007; Cisler & Koster, 2010; Mogg & Bradley, 1998). Other models of anxiety emphasize compromised inhibitory control processes (Eysenck & Derakshan, 2011). These models have been tested mostly in adults (Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009), and parallel work is warranted in youths (Waters & Valvoi, 2009; Waters, Henry, Mogg, Bradley, & Pine, 2010). The current study examines in anxious and healthy adolescents the influence of emotion-related stimuli on attention-orienting as well as on the integrity of inhibitory control processes.

Anxiety in both adults and children is commonly associated with biased allocation of attentional resources toward threat-related emotional information (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Puliafico & Kendall, 2006; Waters, et al., 2010). According to recent theory and empirical evidence, these biases occur as anxiety impacts the balance between stimulus-driven processes and regulatory attention control processes, such as inhibition (e.g., Browning, Holmes, & Harmer, 2010; Cisler & Koster, 2010; Eysenck & Derakshan, 2011; Derakshan et al., 2009). In particular, anxiety is believed to facilitate the processes that underlie the detection of, and orienting towards, threat stimuli (see Bishop, 2008), while simultaneously hindering the inhibitory processes that regulate the allocation of attentional resources to salient, but task-irrelevant, stimuli (Eysenck & Derakshan, 2011).

The antisaccade task (Hallett, 1978) is a conceptually simple task that allows for both orienting and inhibitory processes to be studied concomitantly. The typical task includes both prosaccades and antisaccades. Prosaccades are rapid ballistic eye movements that involve the automatic detection of and the orienting towards abruptly appearing peripheral stimuli. Antisaccades are slower eye movements that involve the inhibition of prepotent prosaccades towards an abruptly appearing peripheral stimulus, and instead, require the generation of volitional saccades to the opposite direction (see Luna, Velanova, & Geier, 2008; Munoz & Everling, 2004). Typical saccade tasks use neutral stimuli, such as shapes (e.g., circle, cross). By virtue of its simplicity, the antisaccade task can easily be modified to examine the influence of emotional information on orienting (prosaccades) and inhibitory processes (antisaccades). For example, while some researchers have added a performance–dependent monetary incentive cue prior to the appearance of the peripheral stimulus (e.g., Jazbec, McClure, Hardin, Pine, & Ernst, 2005; Mueller, Ng, Temple, Hardin, et al, 2010; Mueller, Hardin, Korelitz, Daniele, Bemis, et al., *in press*), others have begun to substitute the central cue or peripheral target with an emotional stimulus (e.g., angry face) to assess its influence on response execution (e.g., Derakshan et al., 2009; Reinholdt-Dunne, Mogg, Benson, Badley, Hardin, Liversedge, Pine, & Ernst, in press).

Here, we examined the effect of emotion stimuli on saccadic responses in anxious and healthy youth. We selected emotional faces rather than words to avoid potential confounds of literacy in our young sample. We also opted for faces rather than scenes to avoid the complexity and, at times, ambiguity of emotional scenes. In addition, emotional faces have been widely and successfully used to test attention bias in anxiety (Mogg, Millar, & Bradley, 2000), reflecting their sensitivity to the construct under scrutiny.

To our knowledge, two studies to date have employed such emotion-modified versions of the antisaccade task using emotional faces. Both studies examine the influence of threat-related stimuli (angry faces) on orienting and inhibitory processes in high-trait anxiety adults (e.g., Derakshan et al., 2009; Reinholdt-Dunne et al., in press). Their findings indicate that, in the context of the antisaccade task, threat-related information presented as abruptly appearing central cues or peripheral targets hinders inhibitor control in anxious adults. Specifically, both studies report longer antisaccade latencies away from threat stimuli (angry faces) in high-anxious adults than in low-anxiety adults, but no group differences in antisaccade latencies away from positive or non-emotional stimuli. In addition, these studies did not detect emotion-related orienting differences during prosaccades in high-trait anxious vs. low-trait anxious adults.

Although these previous findings in high-anxiety adults are quite promising, parallel research has not been conducted in pediatric anxiety. This absence of research in youth is surprising given (1) the high prevalence of pediatric anxiety (Costello et al., 2003; Kessler, et al., 2005); (2) evidence indicating both orienting (Lonigan, Vasey, Phillips, & Hazen, 2004; Puliafico & Kendall, 2006) and inhibitory anomalies in pediatric anxiety (Ladouceur et al., 2006; Waters & Valvoi, 2009); and (3) behavioral and neural developmental changes associated with orienting and inhibition during late childhood and adolescence (e.g., Casey, Jones, & Hare, 2008; Luna, Padmanabhan, & O'Hearn, 2010; Paus at al., 2008).

The current study was designed to address this gap in pediatric anxiety research by examining the influence of emotion information on the behavioral responses of clinically anxious and healthy control children/adolescents during an emotion-modified antisaccade task. Emotion stimuli in the current task were presented as abruptly occurring peripheral targets. Participants were required to either orient towards these targets with prosaccades or generate an eye movement away from these targets with antisaccades. Given previous theory (e.g., Bishop, 2008; Eysenck & Derakshan, 2011) and empirical findings reported in adult and pediatric anxiety (Derakshan et al., 2009; Reinholdt-Dunne et al., in press), we tested the following specific, *a priori* hypotheses. In comparison with healthy youth, anxious youth in the current study were expected to show (1) an attention bias in orienting towards threatening (angry) faces, indexed by relatively faster prosaccade response latency to angry relative to neutral faces; and (2) deficient inhibitory control of antisaccade responses away from angry relative to neutral faces, indexed by relatively slower antisaccade response latency to angry relative to neutral faces. Thus, we predicted a significant group × face emotion interaction for saccade latency in each saccade type separately. We also explored whether similar biases exist for other types of emotional stimuli, namely, fearful faces (which are threat-relevant but not threatening per se) and happy faces, each relative to neutral faces.

Methods

Participants

Participants included 22 (8 female) children/adolescents diagnosed with an anxiety disorder (*M*=11.97 years, SD=2.95 years), and 22 (9 female) age-matched healthy, typically developing, non-anxious youth (*M*=12.51 years, SD=2.16 years). All participants were medication free at the time of the study. Of the anxious youth, 7 had a primary diagnosis of Social Phobia, 10 Generalized Anxiety Disorder (GAD) and 5 Separation Anxiety Disorder. Individual anxiety level was assessed with the Trait State Anxiety Inventory for Children (STAI-C, Spielberger, Gorsuch, Lushene, 1970), and, as expected, anxious participants scored significantly higher on both State ($t(42)=3.22$, $p=.002$) and Trait ($t(37)=5.26$, $p<.001$) anxiety than the healthy group (Table 1). Participants were recruited through local newspaper advertisements and word of mouth. The National Institute of Mental Health Institutional Review Board approved the study. The parents of all participants gave informed consent, and child participants provided informed assent.

Inclusion criteria for healthy control youth included: (1) age between 8 and 17 years; (2) absence of acute or chronic medical problems; and (3) absence of current or past psychiatric disorders. Inclusion criteria for anxious youth included: (1) primary diagnosis of an anxiety disorder based on a semi-structured diagnostic interview (Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version [K-SADS-PL]) (Kaufman et al., 1997); (2) Children's Global Assessment Scale's score < 60 (CGAS) (Shaffer et al., 1983); (3) Pediatric Anxiety Rating Scale score > 9 (RUPP, 2001); (4) desire for outpatient treatment; and (5) age between 8 and 17 years. Exclusion criteria for all participants included: (1) current use of any psychoactive substance; (2) current Tourette's syndrome, obsessive-compulsive disorder, Post Traumatic Stress Disorder (PTSD), conduct disorder, exposure to extreme trauma, or suicidal ideation; (3) lifetime history of mania, psychosis, or pervasive developmental disorder; or (4) IQ<70. All child diagnoses were based on semi-structured interviews using the K-SADS. Interviews were conducted by experienced clinicians, and demonstrated excellent inter-rater reliability (κ>0.75).

Emotion Saccade Task (Figure 1)

The Emotion Saccade Task (EST) probed the emotion-related influence of abruptly appearing peripheral stimuli on prosaccade and antisaccade generation. This approach allowed for the trial-by-trial examination of the influence of emotional information on orienting or inhibitory processes. Prosaccade responses provided information on orienting processes, while antisaccade responses provided information on inhibitory processes.

Task trials were comprised of three phases: (1) the cue phase (1000–1500ms) informed participants of the type of saccade to perform; (2) the target response phase presented the peripherally appearing emotional stimulus (1000ms); and (3) the feedback phase informed the participant of the correct response location (500ms). An inter-trial-interval (ITI) of 500ms separated each trial. Participants were instructed to fixate the cue during the cue phase, to respond with the appropriate eye movement during the response phase, and to fixate the performance feedback symbol during the feedback phase.

Each task trial began with the presentation of one of two possible cues. Cues were an "X" or an "O" presented in yellow font. For half of the participants the "X" signaled prosaccade, and "O" signaled antisaccade. This saccade-cue pairing was reversed for the other half of participants. The participant order for saccade-cue pairing was randomly determined. Cues were located at the horizontal and vertical screen center and subtended 1°. Participants were instructed to fixate the saccade cue for its full duration.

The target response phase immediately followed the cue phase. During the target response phase, an emotion face appeared on the left or right side of the screen. Face images were 4.5° × 6.25° and the inner edge was located 2° from the screen center. The emotion-face stimuli comprised 16 images (8 male, 8 female) from the NimStim picture set (http://www.macbrain.org/resources.htm). Each face was presented with four distinct emotional expressions, which defined four emotion conditions (neutral, happy, angry, fear) and resulted in 64 total face images (16 faces × 4 expressions). Depending on the saccade condition, participants were instructed to direct their gaze to the face image (prosaccades), or to the opposite side of the screen (antisaccades). Participants were instructed to respond as fast as possible and to maintain their gaze on the correct location for the duration of the face target.

The feedback phase directly followed the target response phase. During the feedback phase, a solid green square appeared in the location of a correct response. The square was 1° × 1° and was located at the spot where the participant should be gazing for a correct response. Thus, during prosaccade trials, the feedback square replaced the emotion face image. During antisaccade trials, the emotion face disappeared while the feedback square appeared on the opposite side of the screen. Participants were instructed to look at the feedback square for its entire duration, and then to shift their gaze back to the screen center during the ITI.

The EST consisted of 32 trials per saccade-by-emotion condition (256 trials total). All conditions were randomly presented, and participants were trained on the task prior to study participation. Non-task face stimuli were used during training. Participants were informed they would be financially compensated for successfully completing the task.

Eye Movement Recording

Eye movements were recorded with an ASL Model 504 eye tracking system (Applied Science Laboratories, Boston, MA) at 240Hz temporal resolution and 0.25° spatial resolution. Raw eye movement data was analyzed off-line with ILAB software (Gitelman, 2002). Saccades were defined as movements greater than 30°/second that lasted for a minimum duration of 25ms. When determining correct and incorrect movements, only the first saccade following onset of the target stimulus was considered. Saccade accuracy was indexed as the percent of saccades directed to the correct location (target side for prosaccade; opposite side from target for antisaccade). Saccade latency was the time elapsed between target onset and the initiation of a saccade. To ensure only task-relevant saccades were analyzed, analyses were restricted to saccades occurring 80 to 700ms after target onset.

Data Analyses

The statistical approach was as follows. Despite an absence of age differences between groups, age was used as a covariate of no interest in all analyses based on a) continuous development of the saccadic system in the first two decades of life (Munoz, Broughton, Goldring, Armstrong, 1998), and b) to reduce variance in performance due to age and, thus, increase statistical power (Miller & Chapman, 2001). Furthermore, as saccadic data tends to be positively skewed, latencies to correct responses were $\log_{10}$-transformed (mean latencies [in msec] are provided in Figure 2). Because of our theory-driven hypotheses specific to the independent processes of orienting and inhibition, we conducted two separate analyses of the performance scores on the prosaccades and antisaccades, respectively.

The influence of emotional information on orienting was assessed with a two-way (Group [Healthy, Anxiety] repeated over Emotion [neutral, happy, angry, fear]) analysis of co-variance (ANCOVA) conducted on these log-transformed latencies to correct prosaccade responses and on prosaccade accuracy. Similarly, the influence of emotional information on inhibition was assessed with a two-way (Group [Healthy, Anxiety] repeated over Emotion [neutral, happy, angry, fear]) ANCOVA conducted on log-transformed latencies to correct antisaccade responses and on antisaccade accuracy.

Additional analyses were conducted to estimate the impact of individual anxiety disorders, as well as symptom severity, on the findings. To this aim, a post-hoc regression analysis assessed the contribution of individual anxiety disorders (GAD, SAD, or Phobia) to the findings. Specifically, a linear regression was performed with latency to angry faces as the dependent variable and anxiety disorder type as a dichotomous (yes/no) independent variable. To assess the contribution of individual differences and severity of psychopathology, post-hoc correlation analyses were performed between State/Trait anxiety scores and latency to angry faces. The critical statistical threshold for all analyses was set at $p<.05$.

Results

Mean Response Latency

Prosaccades—With respect to orienting processes, as predicted, the 2 (Healthy vs. Anxious) by 4 (neutral, angry, happy, fear) ANCOVA on correct prosaccade latency revealed a significant interaction of Group by Emotion, $F(3,123) = 2.86$, $p < .05$, power = 0.67 (Figure 2a). A follow-up test of this interaction showed that anxious children oriented significantly faster towards angry faces relative to neutral faces, $t(21) = 2.74$, $p = .01$, an effect that was absent for healthy children, $t(21) = 0.47$, $p = .64$. No other effects were significant.

This ANCOVA also revealed a main effect of age, $F(1,41) = 6.66$, $p = .01$, power = 0.71, which indicated faster latencies with increasing age regardless of Group status or emotion condition

Antisaccades—With respect to inhibitory processes, the 2 (Healthy vs. Anxious) by 4 (neutral, angry, happy, fear) ANCOVA on $\log_{10}$-transformed latencies of correct antisaccade responses did not yield any significant main effects or interactions.

Mean Response Accuracy

The percent of correct prosaccade and antisaccade responses in the neutral, happy, angry, and fear emotion conditions are presented for anxious and healthy participants in Table 1.

Prosaccades—With respect to orienting processes, the ANCOVA on prosaccade accuracy yielded no significant effects or interactions. This finding indicated that all participants, regardless of group membership or emotion condition, were equally capable of making correct prosaccade responses.

Antisaccades—With respect to inhibitory processes, the ANCOVA on antisaccade accuracy produced a main effect of emotion, $F(3,123) = 4.11$, $p = .008$, power =.84, and critically revealed an Emotion by Group interaction, $F(3,123) = 4.81$, $p =.003$, power = 0.86 (Figure 2b). A follow-up test of the significant Group by Emotion interaction revealed that healthy youth were more accurate during angry stimuli, $t(21) = 2.53$, $p = .02$ and happy stimuli, $t(21) = 2.35$, $p = .03$, relative to neutral stimuli. This effect was not significant for anxious children (both $p >.16$).

With regards to developmental effects, the main effect of age, $F(1,41) = 8.29$, $p = .006$, as well as the interaction of Emotion by Age were also significant, $F(3,123) = 3.93$, $p = .01$, power = .82. To examine the significant Age by Emotion interaction, Pearson Product Moment Correlations were conducted between the accuracy rates to each emotional valence and age for the entire sample and adjusted for multiple comparisons. The results revealed a significant decrease in accuracy with age during angry faces ($r^2(44)=-.50$, p=.001) (Figure 3). By comparison, the corresponding correlations for the other emotional valences were not significant. These data suggest that inhibitory control selectively to angry faces declines with development.

Finally, the main effect of Group was not significant, $F(1,41) = .002$, $p = .97$.

Additional analyses

Diagnostic specificity—Additional regression analyses were conducted to determine the contribution of the different anxiety disorders (GAD, SAD, Phobia) to the effects of angry faces on latency of prosaccades or antisaccades. No significant effects emerged (all $t < 0.27$, $p > .78$).

Severity of psychopathology—State/Trait anxiety scores were not significantly correlated with prosaccade latency to angry faces, either for the pooled group (trait: $r^2(39)$-.25, p=.13; state: $r^2(44)$-.19, p=.21) or for each group separately (anxious: trait $r^2(21)=-.16$, p=.48; state: $r^2(22)$-.15, p=.49; or controls: trait $r^2(18)=-.19$, p=.44; state: $r^2(22)$-.03, p=.89).

Discussion

The current study was designed to examine the influence of emotional information, particularly threat information, on both orienting and inhibitory processes in pediatric anxiety.

The present data support our primary theory-driven hypothesis of an anxiety-related bias in orienting to threat. This effect consisted of a speeded prosaccade latency towards threat stimuli in anxious relative to healthy youth. Our secondary hypothesis, predicting impaired inhibitory processes by a threat stimulus (as reflected by antisaccade latency data), was not confirmed. Nevertheless, threat information did appear to affect inhibitory processes differently in anxious relative to healthy youth. Antisaccade accuracy was improved during angry-face trials compared to neutral-face trials in the comparison group, but not in the anxiety group.

Previous work using an emotion-modified antisaccade task has been conducted in healthy adults characterized as high or low on trait anxiety (Derakshan, et al., 2009; Reinholdt-Dunne, et al., in press). Similarly to the present study, participants were required to either orient their gaze towards abruptly appearing emotional stimuli (prosaccade, orienting process), or to inhibit a prepotent response, and instead generate a response away from emotional stimuli (antisaccade, inhibitory process). These studies reported that high-anxious adults were uniquely affected by threat stimuli (angry faces), showing abnormally long antisaccade latency to threat. The current study represents the first of its kind conducted with anxious youth.

With respect to orienting processes, in contrast to these previous adult anxiety studies using pro-and anti-saccade tasks, anxious youth in the current study were faster and more efficient than healthy youth to orient their attention towards angry emotional information. This difference between anxious and healthy youth in the latency to orient towards angry emotion faces occurred despite similar response latencies when orienting towards neutral, happy, or fear faces. While similar results have not been reported for high-trait anxious adults on saccade tasks, this finding is highly consistent with the well-documented attentional biases reported in anxiety. Indeed, facilitated orienting towards angry emotional stimuli by anxious youth is consistent with selective attention studies in both anxious youth and adults that describe attention biases for threat-related information (e.g., Bar-Haim et al., 2007; Puliafico, & Kendall, 2006; Waters et al., 2010).

One possible explanation for a lack of anxiety-related orienting biases to threat on prosaccade performance in adult studies (Derakshan, et al., 2009; Reinholdt-Dunne, et al., in press), in contrast to the present youth study, may be methodological, based on the difference in maturity of the visual attentional system in youth and adults (e.g., Klein & Foster, 2001). Developmental work has shown that prosaccades tend to be performed at floor level by adults, preventing further improvement, in contrast to youth who show more variable and poorer performance (e.g., Klein & Foster, 2001). This developmental effect is consistent with the shorter mean prosaccade latency in the most recent adult study (≈160

NIH-PA Author Manuscript

NIH-PA Author Manuscript

ms) (Reinholdt-Dunne, et al., in press) compared to the present mean prosaccade latency of our youth sample (≈220 ms). The less mature visual attentional system in youth would allow more sensitivity to emotion-related effects on prosaccade latency. Another important difference is the level of anxiety manifested by participants in these studies. Adults were healthy individuals with various levels of trait-anxiety, whereas our youth were affected by an anxiety disorder, for which they sought treatment. Since this effect of severity is fully confounded with the age effect, it is not possible to elaborate further on the implication this clinical difference.

With respect to inhibitory processes, group differences in antisaccade performance scores manifested in the accuracy data rather than response time. This result is relevant to our prediction of an effect of anxiety on inhibitory processes, but, this effect manifested differently from what we predicted. Rather than the predicted slowed antisaccade response during angry trials, anxious youth failed to show the performance improvement on these trials that was exhibited by their healthy comparisons. Although valence effects in the accuracy data have not been reported in high-trait anxiety adults (i.e., Derakshan, et al., 2009; Reinholdt-Dunne et al., in press), they are consistent with a modulation of threat-related information during saccadic inhibition. When comparing our youth data with adult studies, the well-documented developmental changes of inhibitory control processes (see Casey et al., 2008; Luna et al., 2010; Paus, 2005) are critical to consider. For example, the antisaccade accuracy rates observed for youth in the current study were substantially lower than accuracy rates observed in adult studies. Yet, they are consistent with accuracy rates in similar age cohorts (Munoz et al., 1998) and in youth with mood disorder (Mueller, et al. 2010). Moreover, these accuracy rates were sensitive to a modulation by valence demonstrating a paradoxical reduction in accuracy with increasing age selectively during angry trials. These findings may point toward developmental differences in threat processing when inhibitory control is required. This unexpected finding needs to be replicated before further consideration.

While the current findings provide evidence of facilitated orienting towards threat-related stimuli, and lack of strengthened inhibitory control to threat stimuli in pediatric anxiety, some limitations must be considered. The present study utilized a relatively small sample size that did not allow us to examine the effects of sex or age adequately. Future studies that address this limitation will be important, particularly given the discrepancies between the current findings and those reported in high-trait anxious adults. The age-related paradoxical reduction in antisaccade accuracy to threat may contribute to these findings in youth. In addition, the lack of differential effects of various anxiety disorders in the present work does not rule out that differences exist, particularly given the relatively small sample size. To test this question substantially larger samples are needed.

Conclusion

The current study suggests that anxious relative to healthy youth manifest enhanced orienting towards threat-related stimuli. Regarding inhibitory control, threat-related information may improve inhibitory control in healthy youth but not in anxious youth. This finding is in contrast to results documented in adult studies using similar emotion-modified antisaccade tasks (which did not detect anxiety-related biases in antisaccade accuracy data), and may represent developmental differences between the processes underlying pediatric and adult anxiety. We hope that these findings will stimulate further cross-sectional and longitudinal studies to examine the impact of development on orienting and inhibitory processes in anxiety. Specifically, an important next step will be to directly compare different age groups with and without anxiety on saccade tasks, to inform developmental differences of the effects of anxiety on orienting and inhibitory processes.

Acknowledgments

This study was supported by the Intramural Research Program of the National Institute of Mental Health.

References

Bar-Haim Y, Lamy D, Pergamin L, Bakermans-Kranenburg M, van IJzendoorn M. Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. Psychol Bull. 2007; 133(1):1–24. [PubMed: 17201568]

Beesdo K, Pine DS, Lieb R, Wittchen HU. Incidence and risk patterns of anxiety and depressive disorders and categorization of generalized anxiety disorder. Archives of General Psychiatry. 2010; 67(1):47–57. [PubMed: 20048222]

Bishop S. Neural mechanisms underlying selective attention to threat. Ann N Y Acad Sci. 2008; 1129:141–152. [PubMed: 18591476]

Bittner A, Egger HL, Erkanli A, Costello JE, Foley DL, Angold A. What do childhood anxiety disorders predict. Journal of Child Psychology and Psychiatry. 2007; 48(12):1174–1183. [PubMed: 18093022]

Browning M, Holmes EA, Harmer CJ. The modification of attentional bias to emotional information: A review of the techniques, mechanisms, and relevance to emotional disorders. Cogn Affect Behav Neurosci. 2010; 10(1):8–20. [PubMed: 20233952]

Casey B, Jones R, Hare T. The adolescent brain. Ann N Y Acad Sci. 2008; 1124:111–126. [PubMed: 18400927]

Cisler JM, Koster EHW. Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. Clinical Psychology Review. 2010; 30(2):203–216. [PubMed: 20005616]

Eysenck MW, Derakshan N. New perspectives in attentional control theory. Personality and Individual Differences. 2011; 50:955–960.

Derakshan N, Ansari TL, Hansard M, Shoker L, Eysenck MW. Anxiety, inhibition, efficiency, and effectiveness: An investigation using antisaccade task. Experimental psychology. 2009; 56(1):48–55. [PubMed: 19261578]

Everling S, Fischer B. The antisaccade: a review of basic research and clinical studies. Neuropsychologia. 1998; 36(9):885–899. [PubMed: 9740362]

Gitelman D. ILAB: a program for postexperimental eye movement analysis. Behav Res Methods Instrum Comput. 2002; 34(4):605–612. [PubMed: 12564563]

Hallett P. Primary and secondary saccades to goals defined by instructions. Vision Research. 1978; 39(16):1279–1296. [PubMed: 726270]

Hardin MG, Ernst M. The adolescent development of behavioral and neural correlates of reward, emotion, and regulatory control. Prevention Science. (in press).

Hardin MG, Mandell D, Mueller SC, Dahl RE, Pine DS, Ernst M. Inhibitory control in anxious and healthy adolescents is modulated by incentive and incidental affective stimuli. Journal of Child Psychology and Psychiatry. 2009; 50(12):1550–1558. [PubMed: 19573033]

Jazbec S, McClure E, Hardin M, Pine DS, Ernst M. Cognitive control under contingencies in anxious and depressed adolescents: an antisaccade task. Biological Psychiatry. 2005; 58:632–639. [PubMed: 16018983]

Kaufman J, Birmaher B, Brent D, Rao U, Flynn C, Moreci P, Williamson D, et al. Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL): Initial reliability and validity data. Journal of the American Academy of Child and Adolescent Psychiatry. 1997; 36(7):980–988. [PubMed: 9204677]

Klein C, Foerster F. Development of prosaccade and antisaccade task performance in participants aged 6 to 26 years. Psychophysiology. 2001; 38(2):179–189. [PubMed: 11347863]

Ladouceur CD, Dahl RE, Williamson DE, Birmaher B, Axelson DA, Ryan ND, Casey BJ. Processing emotional facial expressions influences performance on a Go/NoGo task in pediatric anxiety and depression. Journal of Child Psychology and Psychiatry. 2006; 47(11):1107–1115. [PubMed: 17076749]

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Lonigan CJ, Vasey MW, Phillips BM, Hazen RA. Temperament, anxiety, and the processing of threat-relevant stimuli. Journal of Clinical Child & Adolescent Psychology. 2004; 33(1):8–20. [PubMed: 15028537]

Luna B, Padmanabhan A, O'Hearn K. What has fMRI told us about the Development of Cognitive Control through Adolescence. Brain and Cognition. 2010; 72(1):101–113. [PubMed: 19765880]

Luna B, Velanova K, Geier C. Development of eye-movement control. Brain Cogn. 2008; 68(3):293–308. [PubMed: 18938009]

Miller GA, Chapman JP. Misunderstanding analysis of covariance. J Abnorm Psychol. 2001; 110(1):40–48. [PubMed: 11261398]

Mogg K, Bradley BP. A cognitive-motivational analysis of anxiety. Behavior Research and Therapy. 1998; 36:809–848.

Mogg K, Millar N, Bradley BP. Biases in eye movements to threatening facial expressions in generalized anxiety disorder and depressive disorder. J Abnorm Psychol. 2000; 109(4):695–704. [PubMed: 11195993]

Mueller SC, Ng P, Temple V, Hardin MG, Pine DS, Leibenluft E, Ernst M. Perturbed reward processing in pediatric bipolar disorder: an antisaccade study. J Psychopharmacology. 2010; 24(12):1779–1784.

Munoz DP, Broughton JR, Goldring JE, Armstrong IT. Age-related performance of human subjects on saccadic eye movements. Experimental Brain Research. 1998; 121:391–400.

Munoz D, Everling S. Look away: The anti-saccade task and the voluntary control of eye movement. Nat Rev Neurosci. 2004; 5(3):218–228. [PubMed: 14976521]

Paus T. Mapping brain maturation and cognitive development during adolescence. Trends Cogn Sci. 2005; 9(2):60–68. [PubMed: 15668098]

Paus T, Keshavan M, Giedd J. Why do many psychiatric disorders emerge during adolescence. Nature Reviews Neuroscience. 2008; 9:946–957.

Puliafico AC, Kendall PC. Threat-Related Attentional Bias in Anxious Youth: A Review. Clin Child Fam Psychol Rev. 2006; 9(3–4):162–180. [PubMed: 17053961]

Shaffer D, Gould M, Brasic J, Ambrosini P, Fisher P, Bird H, Aluwahlia S. A children's global assessment scale (CGAS). Archives of General Psychiatry. 1983; 40(11):1228–1231. [PubMed: 6639293]

Somerville LH, Jones RM, Casey BJ. A time of change: behavioral and neural correlates of adolescent sensitivity to appetitive and aversive environmental cues. Brain and Cognition. 2010; 72(1):124–133. [PubMed: 19695759]

Spielberger, CD.; Gorsuch, RL.; Lushene, RE. Manual for the state-trait anxiety inventory. Palo Alto, CA: Consulting Psychologists Press; 1970.

Tabachnick, BG.; Fidell, LS. Using Multivariate Statistics. 3rd ed.. New York: Harper Collins; 1996.

Waters AM, Valvoi JS. Attentional bias for emotional faces in paediatric anxiety disorders: an investigation using the emotional Go/No Go task. Journal of Behavior Therapy and Experimental Psychiatry. 2009; 40(2):306–316. [PubMed: 19159866]

Waters AM, Henry J, Mogg K, Bradley BP, Pine DS. Attentional bias towards angry faces in childhood anxiety disorders. Journal of Behavior Therapy and Experimental Psychiatry. 2010; 41(2):158–164. [PubMed: 20060097]

Key Points

- Pediatric anxiety is highly prevalent and has been associated with aberrant emotion-related attention orienting and inhibitory control.
- Emotion-modified antisaccade studies have been conducted with high-trait anxious adults to examine the influence of emotion information on orienting and inhibition.
- Despite evidence indicating behavioral and neural development in orienting and inhibitory processes during childhood and adolescence, emotion-modified antisaccade studies that parallel adult studies have not been conducted with anxious children
- The current study demonstrates that, contrary to findings from this saccade task in adults, threat-related information facilitates orienting for anxious relative to healthy youth, and may improve inhibitory control in healthy relative to anxious youth.
- These findings may represent a development-related difference between pediatric and adult anxiety that could influence future approaches to treat pediatric anxiety.

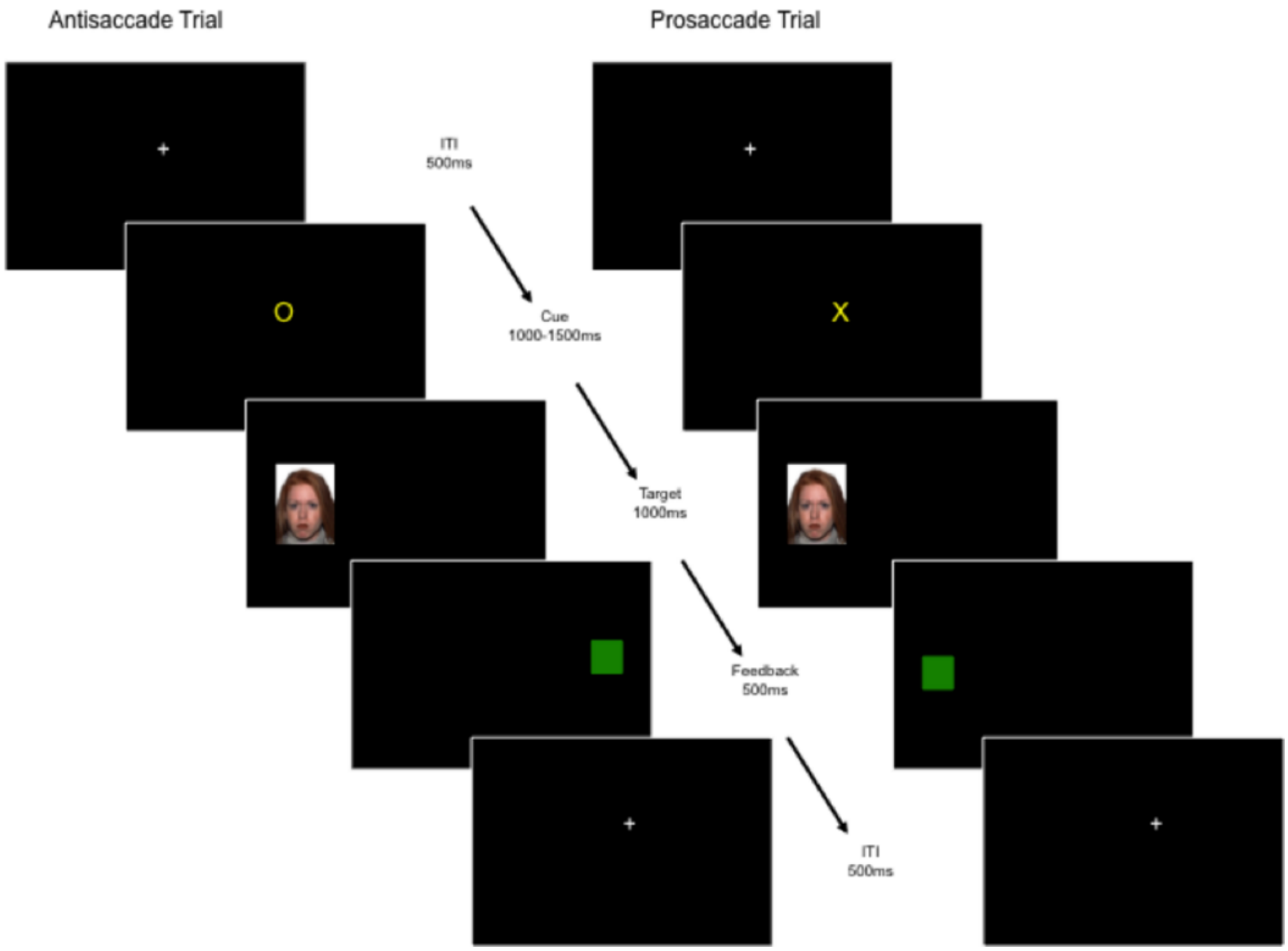

Figure 1.
A schematic representation of antisaccade and prosaccade trials from the Emotion Saccade Task (EST). The shape of the cues ("o" or "x") signals the type of response (antisaccade or prosaccade) to be generated when the target appears. Prosaccade trials require the participant to orient towards the target emotion stimulus. Antisaccade trials require the participant to inhibit a prepotent saccade towards the target emotion stimulus, and instead generate a saccade to the opposite periphery.

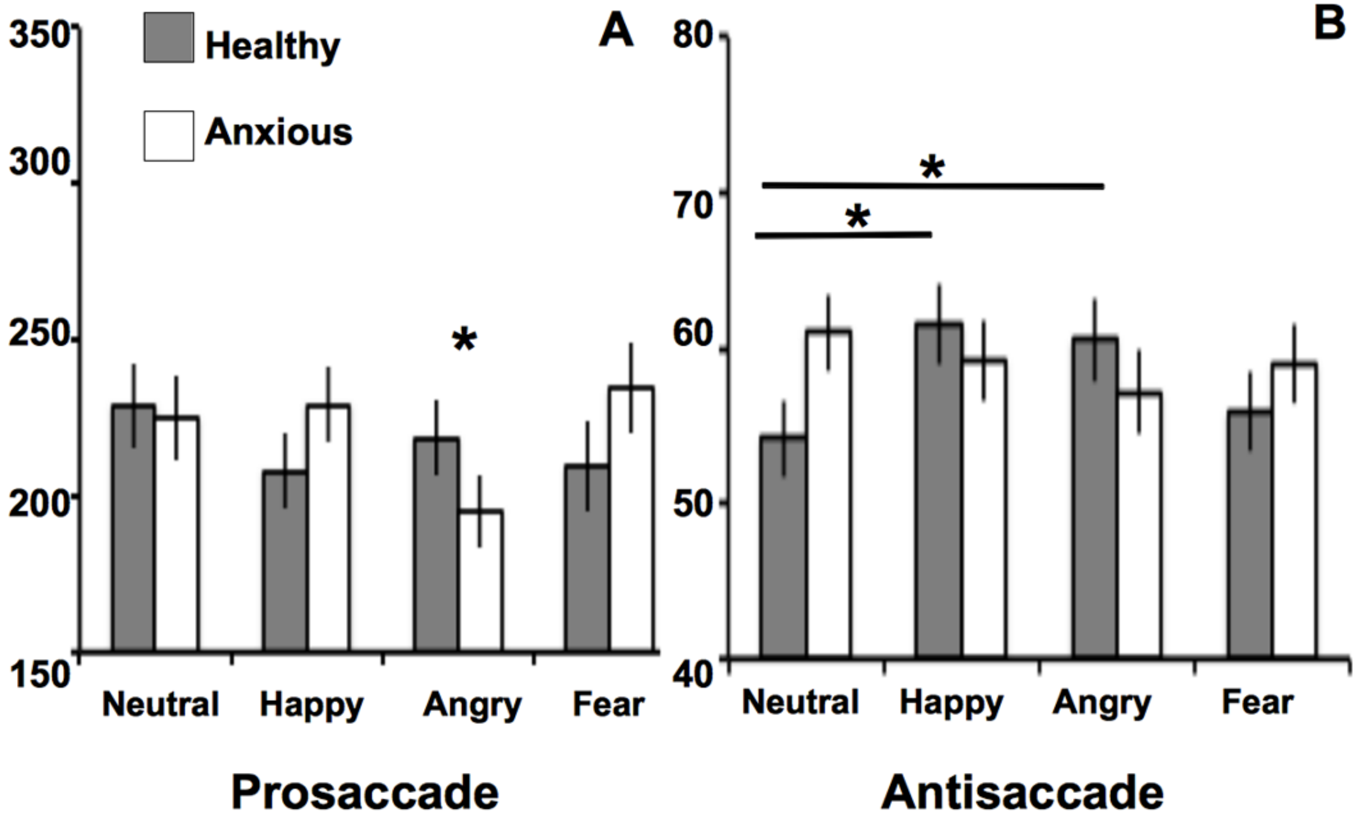

Figure 2.
A. Mean latency (milliseconds) to correct prosaccade responses for healthy and anxious children by emotion conditions. * Significant between group difference, $p < .05$. Error bars denote standard error of the mean (SEM). **B**. Mean accuracy (% correct) to antisaccades for healthy and anxious children split by emotion conditions. *Significant between emotion condition difference, $p < .05$. Error bars denote standard error of the mean (SEM).

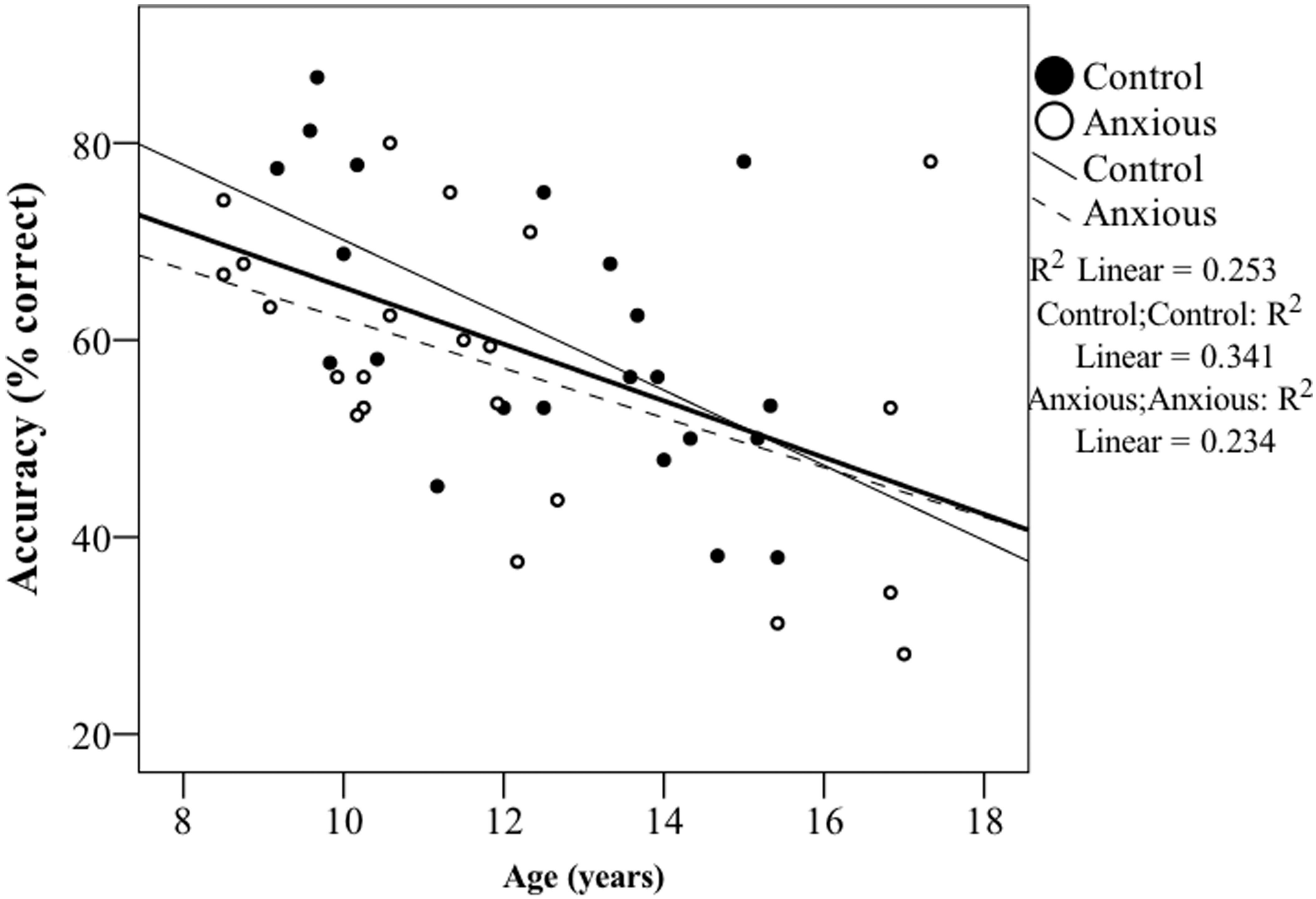

Figure 3.

Scatterplot showing the significant age by emotion interaction for antisaccade accuracy rates, which emerged for the angry faces. Note that the slope was similar for both anxious and controls, which may not explain the group difference in the latencies.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 1

Mean (*SD*) scores on the Spielberger State/Trait anxiety scale, which ranges in scores from 20–60. Saccade accuracy rates (%; SD) and latencies (ms; SD) in each emotion condition for healthy and anxious children.

	Healthy (N=22)	**Anxiety (N=22)**
Sex female (%)	9 (41%)	8 (36%)
Age, mean (SD)	12.51 (2.16)	11.97 (2.95)
STAI-C Trait	28.33 (5.14	40.19 (8.29)
STAI-C State	27.32 (4.34)	33.05 (7.12)
Prosaccade (accuracy)		
Neutral	80.07% (11.5)	79.49%(10.2)
Happy	80.11% (11.6)	78.99% (10.4)
Angry	80.05% (10.7)	79.92% (8.5)
Fearful	77.22% (9.9)	79.55% (9.7)
Antisaccade (latency)		
Neutral	275.98 (89.38)	257.64 (60.85)
Happy	260.79 (65.80)	245.24 (51.37)
Angry	298.83 (87.82)	244.48 (50.03)
Fearful	261.90 (78.29)	256.98 (75.16)