Journal of Experimental Child Psychology 188 (2019) 104676

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Age differences in electrocortical reactivity to fearful faces following aversive conditioning in youth

Katie L. Burkhouse [a,*], Max Owens [b], Kiera James [c], Brandon E. Gibb [c]

[a] Department of Psychiatry, University of Illinois at Chicago, Chicago, IL 60608, USA
[b] Department of Psychology, University of South Florida St. Petersburg, St. Petersburg, FL 33701, USA
[c] Department of Psychology, Binghamton University (State University of New York), Binghamton, NY 13902, USA

ARTICLE INFO

Article history:
Received 4 January 2019
Revised 29 May 2019

Keywords:
Attention bias
Conditioning
Children
Event-related potential
Development
Late positive potential

ABSTRACT

Although biases in the processing of affectively salient stimuli are thought to increase risk for psychopathology across the lifespan, questions remain regarding how these biases develop. The current study tested an aversive conditioning model for the development of children's sensitivity in detecting fearful faces at varying levels of emotional intensity and their facilitated attention to fearful faces assessed via the late positive potential (LPP) event-related potential component. Participants ($N = 144$, ages 7–11 years) were randomly assigned to one of three conditions: an active training condition in which an 85-dB white noise burst was paired with fearful faces, an active control condition in which the white noise was presented randomly throughout the task, and a no-sound condition. Children completed a separate task in which they viewed happy, sad, and fearful child faces at varying levels of emotional intensity while electroencephalography (EEG) was recorded. Although there were no conditioning group differences in children's sensitivity in detecting facial displays of emotion, there were group differences in LPP magnitude that were moderated by children's age. Among younger children, those in the active conditioning group exhibited smaller LPP amplitudes to high-intensity fearful faces than children in the control groups. However, among older youth, those in the active conditioning group exhibited larger LPP amplitudes to high-intensity fearful faces than children in the

* Corresponding author.
E-mail address: kburkho@uic.edu (K.L. Burkhouse).

https://doi.org/10.1016/j.jecp.2019.104676
0022-0965/© 2019 Elsevier Inc. All rights reserved.

control groups. These findings provide insight into how attentional biases may develop in children and how period of development may influence these patterns.

© 2019 Elsevier Inc. All rights reserved.

Introduction

According to cognitive models of psychopathology (e.g., Clark & Beck, 2010; Williams, Watts, MacLeod, & Matthews, 1988), biases in the processing of affectively salient information contribute to the development and maintenance of several forms of psychopathology. These biases are hypothesized to be disorder specific such that anxiety is characterized by biases specifically for threat-relevant stimuli and depression is characterized by biases specifically for stimuli reflecting themes of loss. Supporting these models, there is evidence from studies of children, adolescents, and adults that symptoms and diagnoses of anxiety are associated with attentional biases for threat-relevant stimuli (e.g., angry or fearful faces), whereas symptoms and diagnoses of depression are associated with attentional bias for depression-relevant stimuli (e.g., sad faces) (for reviews, see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Gotlib & Joormann, 2010; Peckham, McHugh, & Otto, 2010; Platt, Waters, Schulte-Koerne, Engelmann, & Salemink, 2017; Puliafico & Kendall, 2006). There is also evidence that attentional biases predict prospective changes in symptoms of depression and anxiety (Beevers & Carver, 2003; Beevers, Lee, Wells, Ellis, & Telch, 2011; Gibb, Benas, Grassia, & McGeary, 2009; Osinsky, Lösch, Hennig, Alexander, & MacLeod, 2012; Platt et al., 2017; Van Bockstaele et al., 2014; Woody, Owens, Burkhouse, & Gibb, 2016).

Although these biases are thought to develop during childhood as a function of both environmental and genetic influences (Gibb, Beevers, & McGeary, 2013), relatively few studies have examined how the biases may develop in children. This said, there is evidence that different forms of negative environmental influences may lead to different patterns of biased emotion processing. For example, physically abused children, compared with children with no history of abuse, exhibit increased sensitivity in detecting facial displays of anger and attentional biases specifically for angry facial expressions (Pine et al., 2005; Pollak & Tolley-Schell, 2003; Pollak, 2003). Similar findings have been observed for other forms of parental influence. For example, children of mothers who exhibit high levels of expressed emotion–criticism exhibit attentional biases specifically for angry faces (Gibb et al., 2011). In addition, children of depressed mothers exhibit attentional biases specifically for sad facial expressions (Gibb et al., 2009; Gibb, Pollack, Hajcak, & Owens, 2016; Joormann, Talbot, & Gotlib, 2007; Kujawa et al., 2011). Other studies have shown that children whose parents are more overprotective perceive ambiguous situations as more threatening (Chorpita & Barlow, 1998; Pereira, Barros, Mendonça, & Muris, 2014) and exhibit biased attention toward threat-relevant stimuli (Perez-Olivas, Stevenson, & Hadwin, 2008). Although biased attention toward threat-relevant stimuli (i.e., fear or angry faces) may be adaptive in the short term (i.e., signaling the need to act in response to threat in the environment), these biases likely become maladaptive if they are chronically activated even in objectively nonthreatening contexts, which may lead to increased anxiety as a result of heightened fear circuits that increase vigilance for threat and danger.

These prior studies provide preliminary support for the presence of experience-specific information-processing biases in which the specific focus of children's information-processing bias (e.g., biases for threat-relevant vs. sad faces) is dependent on their prior exposure to affectively salient cues in their environment (Pollak, 2003). Despite the strengths of prior research, a key limitation is that focusing on parent behavior or characteristics may confound genetic and environmental influences. In addition, because these studies were observational, they cannot rule out third variable explanations for their findings. Therefore, to adequately evaluate an environmental model for development of children's information-processing biases, children must be randomized to receive different environmental experiences within the laboratory.

In the current study, therefore, our goal was to use a laboratory-based conditioning paradigm to examine the acquisition of experience-specific information-processing biases in children. In doing so, we sought to extend prior research using aversive conditioning paradigms in children and adults. For example, in Lau et al. (2008) "screaming lady" paradigm, participants learn to associate an aversive unconditioned stimulus (UCS) (i.e., a shrieking female scream and a fearful face) with a paired neutral face (CS+). Children in the study developed greater fear responses to the CS+ relative to the CS− (no noise paired with neutral face). Although several studies have used this paradigm to examine fear-conditioning responses at the behavioral and physiological levels in children and adults (Glenn, Klein, et al., 2012; Glenn, Lieberman, & Hajcak, 2012; Lau et al., 2008), no studies to date have examined how conditioning tasks influence information-processing biases in children. This said, researchers have used conditioning paradigms in the laboratory to evaluate the acquisition of attention biases among adults. For example, by pairing cues with the presence (CS+) or absence (CS−) of a potential aversive white noise burst, researchers demonstrated that the CS+ cues strongly captured visual attention in comparison with the CS− cues among a sample of college undergraduates (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2005). In a separate study, researchers demonstrated that healthy control adults who received aversive conditioning (i.e., aversive shock) exhibited preferential allocation of attention toward angry faces paired with the shock compared with a CS− (angry face with CS− stimuli) and neutral faces (Pischek-Simpson, Boschen, Neumann, & Waters, 2009). Together, these findings confirm the interplay between learning-based mechanisms and attention processes. However, as noted above, additional research is needed to understand these patterns in younger populations.

Therefore, in the current study, we examined whether pairing the presentation of a specific type of emotional stimulus (fearful faces) with an aversive stimulus (85-dB white noise burst) would alter children's processing of fearful stimuli in a separate information-processing task. The acquisition phase of the experiment was conducted within the context of a dot-probe task (MacLeod, Mathews, & Tata, 1986) in which emotional (fearful, happy, or sad) and neutral faces were presented on a computer screen. Children were randomly assigned to one of three conditions: (a) active training (AT), in which an 85-dB white noise burst was presented simultaneously with the appearance of fearful faces; (b) active control (AC), in which the white noise burst was presented the same number of times throughout the task but was not systematically paired with any stimulus type; and (c) no sound (NS), in which children completed a typical dot-probe task without any white noise bursts. Importantly, our goal in this task was not to differentially induce fear or anxiety in children; rather, we sought to examine the impact of pairing a mildly aversive stimulus with a specific facial expression of emotion (i.e., fear). To ensure that the task did not influence children's state affect, we assessed children's levels of state anxiety and sadness before and after the task.

To examine the impact of this task on children's information processing, children completed a separate task using a new set of emotional facial stimuli. Specifically, using a morphed faces paradigm (cf. Burkhouse, Siegle, & Gibb, 2014) in which children viewed a series of child faces, one at a time, that ranged from neutral to full-intensity emotion (fearful, happy, or sad), we examined children's sensitivity in detecting facial displays of emotion as well as their attention to these faces. We chose to use child faces, rather than adult faces, in the generalization task to provide a more conservative test of our hypotheses. Specifically, we sought to determine whether the conditioning effects would generalize not only to a novel stimulus set with different actors but also to a novel age group of actors (children vs. adults). We predicted that children assigned to the AT condition would exhibit increased sensitivity in detecting fearful facial expressions at lower levels of stimulus intensity compared with children assigned to the NS and AC conditions. In examining attention, we focused on the late positive potential (LPP) event-related potential (ERP) component. Research suggests that the LPP is enhanced in response to emotional faces, pictures, and words, and it is theorized to reflect the reflexive engagement of attentional resources toward motivationally relevant stimuli (Hajcak & Olvet, 2008; Lang, Bradley, & Cuthbert, 1997). Studies show that, in adult populations, the amplitude of the LPP is enhanced in conditioning paradigms (Baas, Kenemans, Böcker, & Verbaten, 2002; Böcker, Baas, Kenemans, & Verbaten, 2004; Bublatzky & Schupp, 2011; Nelson, Weinberg, Pawluk, Gawlowska, & Proudfit, 2015) and is sensitive to factors that make stimuli more salient (Weinberg, Ferri, & Hajcak, 2013). Thus, in the current study, we predicted that children assigned to the AT condition, compared with children assigned to the control conditions, would exhibit an enhanced LPP response to fearful facial expressions in the morphed faces paradigm.

Finally, we sought to examine potential age-related differences in these conditioning effects. Indeed, others have found evidence for age-related differences in children's detection of emotional stimuli (i.e., linear changes in children's ability to detect fearful faces from 6 to 16 years of age) (Lawrence, Campbell, & Skuse, 2015) and attention bias development (for a review, see Field & Lester, 2010). Similarly, there is evidence for developmental differences in fear conditioning processes, which may be explained by more complex forms of learning that are continuing to mature and interact with neural circuity changes. For example, in studies of youths aged 8 to 13 years, older children (10 years and above) exhibited greater fear learning (i.e., larger startle response during CS+ than during CS−) and were more likely to discriminate between gradations of an aversive stimulus in a generalization phase than younger children (Glenn, Klein, et al., 2012; Jovanovic et al., 2014). Similarly, in a study of 5- to 10-year-old children, older children demonstrated better discrimination of conditioned stimuli and reported more fear in response to resembling stimuli (Michalska et al., 2016). These data support developmental changes in conditioning responses, which may correspond to a shift in functional connectivity between the amygdala and prefrontal cortex that has been found to occur at around 10 years of age (Gee et al., 2013). Thus, based on these prior studies, we explored whether the conditioning effects on children's information-processing biases would be stronger among older versus younger children.

Method

Participants

Participants in this study were 144 children recruited from the community. All children were 7–11 years old and, per parent report, had no learning or developmental disorders that would preclude completing the study protocol. In addition, to avoid potential confounding effects with the conditioning task, all children were required to have no lifetime history of major depressive disorder (MDD) or an anxiety disorder. The average age of children in our sample was 9.76 years (*SD* = 1.33, range = 7.04–11.99), and 55.6% were male. In terms of children's race, 79.2% were Caucasian, 10.4% were African American, 7.6% were multiracial, and 2.8% were from other racial groups. In terms of ethnicity, 11.1% of children were Hispanic. Of the parents, 89.6% were women and the average age of parents in our sample was 37.68 years (*SD* = 6.52). In terms of parents' race, 85.4% were Caucasian, 11.8% were African American, and 2.8% were from other racial groups. In terms of ethnicity, 4.2% of parents were Hispanic. The median annual family income based on parent report was $40,000–$45,000.

Measures

Dot-probe task

A modified dot-probe task (cf. MacLeod et al., 1986) was used as the conditioning paradigm (i.e., acquisition phase). Stimuli for the dot-probe task consisted of pairs of facial expressions that contained one emotional (fearful, happy, or sad) photograph and one neutral photograph from the same actor taken from a standardized stimulus set (Tottenham et al., 2009). Photographs from each adult actor (10 male and 10 female) were used to create fear–neutral, happy–neutral, and sad–neutral stimulus pairs (60 pairs total). Children sat a distance of 65 cm away from the computer monitor, and each of the two facial stimuli was 15.5 cm tall × 12.75 cm wide. Each stimulus pair was presented in random order in each of the two blocks, with a rest in between blocks (120 trials total). Each trial began with the presentation of a central fixation cross, and participants were required to make a central fixation before stimuli were presented. Facial stimuli (one emotional and one neutral from the same actor) were presented for 1000 ms, followed by a probe (the letter "E" or "F") appearing in the nose region of one of the faces. The faces and probe remained on the screen until a manual response using a game pad was made, indicating whether the probe consisted of an E or F. The probe was presented with equal frequency in the location of the emotional and neutral faces. The intertrial interval varied randomly between 500 and 750 ms. As described earlier, children were randomly assigned to one of three conditions—active training (AT; $n = 44$), active control (AC; $n = 42$), or no sound (NS; $n = 58$)—and all children wore headphones (Sennheiser PMX 680) during the task. As shown in Fig. 1, children in the AT condition heard an 85-dB white noise burst after the appearance of any fearful face during the experiment (60 times). Children in the AC condition also heard the white noise burst 60 times, but it occurred with equal frequency with fearful, happy, and sad faces (20 times each). On noise trials for children in the AT or AC condition, the white noise burst started 200 ms after the appearance of the face and lasted 800 ms. Finally, children in the NS condition completed the dot-probe task without any noise trials.

Morphed faces task

Participants then completed a morphed faces task (cf. Burkhouse et al., 2014) in which they viewed grayscale faces from a standardized stimulus set of child actors (Egger et al., 2011) displaying a variety of emotions (fear, happy, sad, or neutral). Each face was 26.5 cm tall (16° visual angle) × 16.5 cm wide (10° visual angle). The stimuli consisted of emotional and neutral photographs from each actor morphed to form a continuum of 10% increments between the two photographs. Each emotion was represented by 4 continua (2 male and 2 female actors) for a total of 12 continua. A total of 11 morphed images were used from each continuum, representing 10% increments of the two emotions ranging from 100% neutral to 100% target emotion (e.g., 100% neutral; 0% fear, 90% neutral, 10% fear; 80% neutral, 20% fear). The pictures were presented one at a time in the middle of the screen for 3 s, after which they disappeared and participants were asked to indicate which emotion was being presented using the following four response options for each image: fear, happy, sad, or calm/relaxed. The intertrial interval varied randomly between 500 and 750 ms. The stimuli were presented in semirandom order with the condition that no two images from the same actor were presented consecutively. Each of the 132 images was presented twice for a total of 264 trials, with a rest after every 55 trials. As a behavioral measure of sensitivity to each type of emotional expression, we calculated the proportion of times children correctly identified the target emotion (fear, happy, or sad) per level of morph. Consistent with previous research (Burkhouse et al., 2014, 2016; Jenness, Hankin, Young, & Gibb, 2015), and to provide an adequate number of trials within each morph level, images were binned into three separate morph conditions for analyses: low (10%, 20%, and 30%), medium (40%, 50%, 60%, and 70%), and high (80%, 90%, and 100%).

During the morphed faces task, continuous electroencephalography (EEG) was recorded using a custom cap and the BioSemi ActiveTwoBio system (Amsterdam, Netherlands). The EEG was digitized at 24-bit resolution with a sampling rate of 512 Hz. Recordings were taken from 34 scalp electrodes based on the 10/20 system. The electrooculogram was recorded from four facial electrodes. Offline analysis was performed using the MATLAB extension EEGLAB (Delorme & Makeig, 2004) and the

	Fearful	Happy	Sad
Active Training (AT) ($n = 44$)	100%	0%	0%
Active Control (AC) ($n = 42$)	33%	33%	33%
No Sound (NS) ($n = 58$)	0%	0%	0%

Fig. 1. Overview of the conditioning task.

EEGLAB plug-in ERPLAB (Lopez-Calderon & Luck, 2014). All data were re-referenced to the average of the left and right mastoid electrodes and bandpass-filtered with cutoffs of 0.1 and 30 Hz. EEG data were processed using both artifact rejection and correction. Large and stereotypical ocular components were identified and removed using independent component analysis (ICA) scalp maps (Jung et al., 2001). Artifact detection and rejection was then conducted on epoched uncorrected data to identify and remove trials containing blinks and large eye movements at the time of stimulus presentation. Epochs with large artifacts (>100 μV) were excluded from analysis. The interval from −200 to 0 ms served as the baseline for ERPs. Participants' trial rejection did not exceed 50%, and the average number of trials rejected was 56 (*SD* = 36.51; 21.47%). The three conditioning groups (AT, AC, and NS) did not differ in the number of rejected trials ($p = .51$). Consistent with previous studies measuring LPP responses in children (Dennis & Hajcak, 2009; Kujawa, Klein, & Hajcak, 2012), and based on visual inspection of the current data, the LPP was calculated as the mean activity 400 to 1000 ms following face onset averaged across occipital (O1, O2, and Oz) and parietal (P3, P4, PO3, PO4, and Pz) electrode sites separately for each emotion and morph level (see Fig. 2).

Current mood ratings

Two visual analog scales (VASs) were used to measure state anxiety and sadness before and after the dot-probe paradigm. Specifically, participants indicated their current mood by making a mark on lines measuring 100 mm with anchors of *very calm* and *very anxious* on one line and *very happy* and *very sad* on the other. Higher scores reflect greater levels of state anxiety and sadness. In prior studies, the VAS has demonstrated excellent reliability and validity (Killgore, 1999).

Symptoms of anxiety and depression

Children's symptoms of anxiety and depression were assessed using the Multidimensional Anxiety Scale for Children (MASC; March, Parker, Sullivan, Stallings, & Conners, 1997) and the Children's Depression Inventory (CDI; Kovacs, 1985), respectively. Parents' symptoms of anxiety and depression were measured via the Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988) and the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996), respectively. The BAI, BDI, CDI, and MASC all have demonstrated excellent reliability and validity in previous research (e.g., Dozois, Dobson, & Ahnberg, 1998; Fydrich, Dowdall, & Chambless, 1992; Kovacs, 1981, 1985; March et al., 1997; Smucker, Craighead, Craighead, & Green, 1986). In the current study, internal consistencies ranged from good to excellent (CDI $\alpha = .81$; MASC $\alpha = .86$; BDI $\alpha = .90$; BAI $\alpha = .91$).

Psychiatric diagnoses

The Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I; First, Spitzer, Gibbon, & Williams, 1995) and the Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version (K-SADS-PL; Kaufman et al., 1997) were used to assess for past and current DSM-IV Axis I disorders in parents and children, respectively. As noted above, the K-SADS-PL was used to ensure that children in the study did not have a lifetime diagnosis of any anxiety disorder or MDD. Of the 144 parents in the study, 42 had a lifetime history of an anxiety disorder (25 current) and 58 had a lifetime history of MDD (8 current). Of those with anxiety disorders, 22 had a lifetime history of posttraumatic stress disorder (7 current), 16 had lifetime social phobia (11 current), 11 had lifetime panic disorder (5 current), 7 had lifetime obsessive-compulsive disorder (6 current), 6 had lifetime generalized anxiety disorder (6 current), and 5 had lifetime agoraphobia (5 current). A subset of 20 SCID-I and 20 K-SADS-PL interviews from this project were coded by a second interviewer, and kappa coefficients for depressive diagnoses were excellent ($\kappa s = 1.00$).

Procedure

Potential participants were recruited from the community through a variety of means (e.g., television, newspaper and bus ads, flyers). Parents responding to the recruitment advertisements were initially screened over the phone to determine potential eligibility. On arrival at the laboratory, parents were asked to provide informed consent and children were asked to provide assent to be in the study. Next, children completed the conditioning (i.e., acquisition) dot-probe paradigm, followed by the

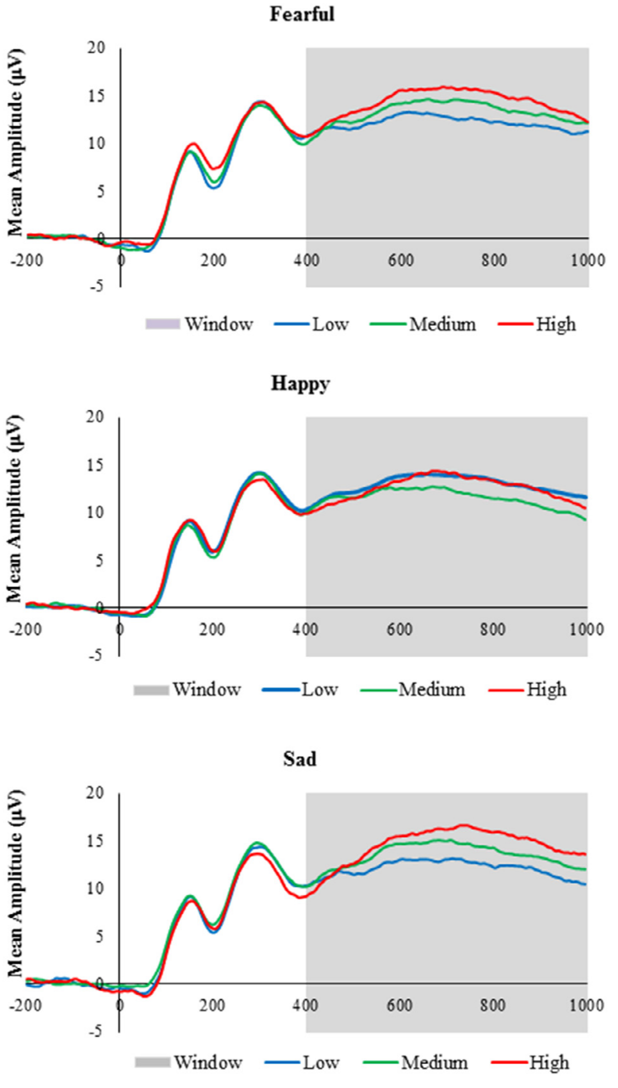

Fig. 2. Response-locked late positive potential waveforms for each emotion across separate morph conditions for the entire sample ($N = 144$).

morphed faces generalization paradigm. During this time, parents completed the K-SADS-PL with a trainer interviewer. Following this, the same interviewer administered the K-SADS-PL to children. Parents were then administered the SCID-I by a separate interviewer. The institutional review board approved all procedures.

Results

Preliminary analyses were conducted to test for potential demographic (age, sex, race/ethnicity, and family income) or clinical (child symptoms of depression or anxiety) differences among the three conditioning groups (Table 1). None of these analyses was significant (lowest $p = .12$), suggesting that

Table 1
Study characteristics separated by conditioning group.

	NS (n = 58)	AC (n = 42)	AT (n = 44)	Statistic (F value or χ^2)
Age [M (SD)]	9.49 (1.37)	9.86 (1.25)	11.98 (10.01)	F = 2.16
CDI [M (SD)]	5.81 (5.90)	6.70 (7.89)	5.47 (3.96)	F = 0.06
MASC [M (SD)]	46.71 (17.14)	45.26 (18.37)	44.31 (15.34)	F = 0.21
Family income (Mdn)	35,001–40,000	40,001–45,000	45,001–50,000	F = 0.60
Female [n (%)]	28 (48.2)	16 (38.1)	20 (45.4)	X^2 = 1.05
Caucasian [n (%)]	46 (79.3)	33 (78.6)	34 (77.3)	X^2 = 0.06
Hispanic/Latino [n (%)]	9 (10.0)	4 (9.5)	3 (6.8)	X^2 = 2.07

Note. NS, no sound; AC, active control; AT, active training; CDI, Children's Depression Inventory; MASC, Multidimensional Anxiety Scale for Children. There were no significant demographic or clinical differences among the groups.

our randomization was successful in creating equivalent groups. We then examined the potential impact of the conditioning task on changes in children's self-reported anxiety and sadness during the conditioning (dot-probe) task. Specifically, we conducted two separate 3 (Group: NS, AC, or AT) × 2 (Time: pre or post dot probe) repeated-measures analyses of variance (ANOVAs), with children's self-reported ratings of anxiety and sadness serving as the dependent variables. The main effects of group and time, as well as the Group × Time interaction, all were nonsignificant in both analyses (lowest $p = .11$). Therefore, any group differences in attention could not be attributed to group differences in affect.

Next, we examined the impact of the conditioning task on children's behavioral and neural sensitivity to facial displays of emotion in the morphed faces task. Focusing first on behavioral sensitivity, we conducted a general linear model examining the main and interactive effects of group (AT, AC, or NS), child age, target emotion (fearful, happy, or sad), and morph level (low, medium, or high) on children's accuracy in labeling each target emotion. Results indicated a significant main effect of morph level, $F(2, 276) = 23.72$, $p < .001$, $\eta_p^2 = .15$, which was qualified by significant interactions of Emotion × Morph, $F(4, 552) = 14.78$, $p < .001$, $\eta_p^2 = .10$, and Age × Emotion × Morph, $F(4, 552) = 4.60$, $p = .001$, $\eta_p^2 = .03$. The significant main effect of morph level reflected the fact that children's accuracy in correctly labeling all the emotions increased from low ($M = .28$) to medium ($M = .90$) to high ($M = .97$) morph faces (all ps < .001). The Emotion × Morph reflected significant main effects of emotion at the medium morph level, $F(2, 280) = 3.85$, $p = .02$, $\eta_p^2 = .03$, but not at the low morph level, $F(2, 280) = 0.26$, $p = .77$, $\eta_p^2 = .00$, or the high morph level, $F(2, 280) = 0.91$, $p = .40$, $\eta_p^2 = .01$. At the medium morph level, there were significant differences in accuracy between each emotion group (all ps < .001), with children displaying the highest accuracy in identifying fearful faces ($M = .96$), followed by happy faces ($M = .91$) and then sad faces ($M = .83$). To determine the form of the Age × Emotion × Morph interaction, we examined the Age × Morph interaction separately for each emotion. The Age × Morph interaction was significant for children's accuracy in labeling fearful faces, $F(2, 280) = 5.46$, $p = .005$, $\eta_p^2 = .04$, happy faces, $F(2, 280) = 5.37$, $p = .005$, $\eta_p^2 = .04$, and sad faces, $F(2, 280) = 3.75$, $p = .02$, $\eta_p^2 = .03$. Examining this further, we found that older children, compared with younger children, were significantly more accurate in labeling the high-morph fearful faces ($r = .19$, $p = .02$), happy faces ($r = .28$, $p = .001$), and sad faces ($r = .17$, $p = .047$). They were also more accurate in labeling the medium-morph fearful faces ($r = .16$, $p = .049$). None of the other correlations between children's age and accuracy was significant. Importantly, in these analyses, neither the main effect of conditioning group nor any of the interactions was significant (lowest $p = .37$), suggesting that fear conditioning did not influence children's interpretation abilities and any differences in attention are not due to the impact of conditioning group on children's ability to accurately recognize the facial expressions of emotion.

Focusing next on children's attention to faces using the LPP, we conducted another general linear model examining the main and interactive effects of group (AT, AC, or NS), child age, target emotion (fearful, happy, or sad), and morph level (low, medium, or high) on children's LPP amplitude. Results revealed a number of significant effects, including significant interactions of Group × Morph, $F(4, 276) = 2.78$, $p = .03$, $\eta_p^2 = .04$, Emotion × Morph, $F(4, 552) = 4.91$, $p < .001$, $\eta_p^2 = .03$, Group × Age × Morph, F

(4, 276) = 2.43, p = .048, η_p^2 = .03, Group × Emotion × Morph, F(8, 552) = 3.03, p = .002, η_p^2 = .04, Age × Emotion × Morph, F(4, 552) = 4.36, p = .002, η_p^2 = .03, and Group × Age × Emotion × Morph, F(4, 552) = 2.98, p = .003, η_p^2 = .04. To determine the form of the Group × Age × Emotion × Morph interaction, we examined the Group × Age × Morph interaction within each emotion type separately. We found that this interaction was significant for fearful faces, F(4, 276) = 5.40, p < .001, η_p^2 = .07, but not for happy faces, F(4, 276) = 1.74, p = .14, η_p^2 = .02, or sad faces, F(4, 276) = 0.70, p = .59, η_p^2 = .01. Exploring this further, we found that the Group × Age interaction was not significant for low-morph fearful faces, F(2, 138) = 1.01, p = .37, η_p^2 = .01, was a nonsignificant trend for medium-morph fearful faces, F(2, 138) = 2.54, p = .08, η_p^2 = .04, and was significant for high-morph fearful faces, F(2, 138) = 7.67, p < .001, η_p^2 = .10.

To determine the form of the significant Group × Age interaction for high-morph fearful faces, we conducted a series of regions of significance analyses using the PROCESS macro in SPSS (Hayes, 2018). This allowed us to retain child age as a continuous variable and avoid creating artificial age groups (e.g., median split; cf. MacCallum, Zhang, Preacher, & Rucker, 2002). Focusing first on comparing the AT and AC groups, the Group × Age interaction was significant, t(82) = 3.68, p < .001, $r_{\text{effect size}}$ = .38, and the regions of significance tests showed that, among younger children (<9.55 years), the AT group exhibited smaller LPP magnitudes to high-morph fearful faces; however, this pattern was reversed among older children (>11.26 years). Similar results were observed when we compared the AT and NS groups. Again, the Group × Age interaction was significant, t(98) = 2.71, p = .008, $r_{\text{effect size}}$ = .26, and the regions of significance tests showed that, among younger children (<8.35 years), the AT group exhibited smaller LPP magnitudes to high-morph fearful faces; however, this pattern was reversed among older children (>11.28 years). In contrast, the Group × Age interaction was not significant when comparing the AC and NS groups, t(96) = −1.61, p = .11, $r_{\text{effect size}}$ = −.16. Given this latter result, we combined our two control groups (AC and NS) and compared them with the AT group. This yielded a significant Group × Age interaction, t(140) = 3.45, p < .001, $r_{\text{effect size}}$ = .28. These results are depicted in Fig. 3, which shows that, among younger children in our sample (<9.16 years), those in

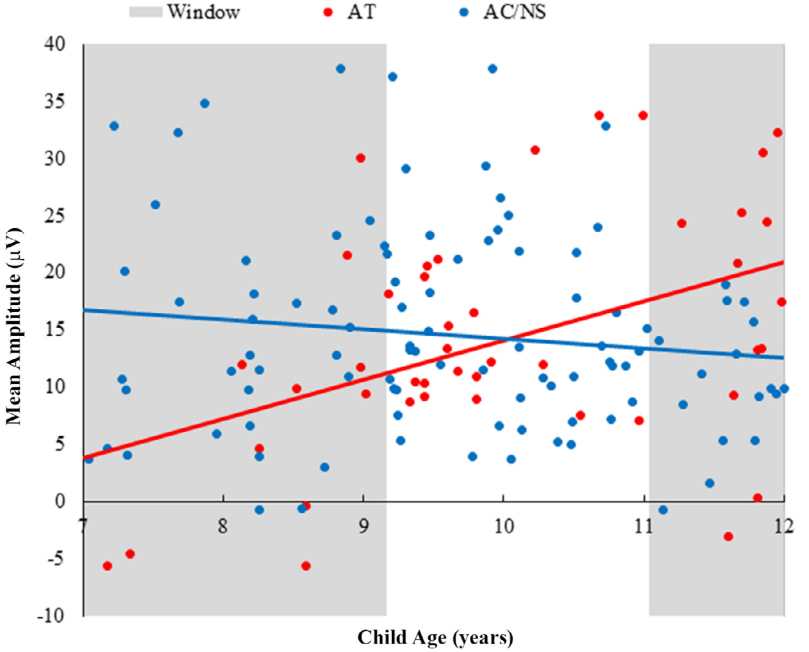

Fig. 3. Scatterplot depicting the impact of the conditioning task on children's late positive potential amplitude to high-morph fearful faces. AT, active training group; AC/NS, active control/no-sound groups. Highlighted areas reflect regions of significance.

the AT group exhibited significantly smaller LPP amplitudes in response to high-morph fearful faces than children in the AC and NS groups. However, among older children in our sample (>11.03 years), the group difference was reversed, with children in the AT group exhibiting significantly larger LPP amplitudes in response to high-morph fearful faces. These findings were maintained even after statistically controlling for the influence of children's state anxiety and sadness before or after the conditioning task, children's symptoms of anxiety and depression, parents' symptoms of anxiety and depression, and parents' history of anxiety disorders and MDD, suggesting that the results were not driven by the presence of psychopathology in children or their parents.

Finally, we conducted a series of exploratory analyses to determine whether any of the conditioning effects were moderated by children's sex. None of these analyses reached significance.

Discussion

The current study examined the extent to which pairing the presentation of fearful faces with aversive stimuli (i.e., white noise burst) affected children's processing of novel facial displays of emotion in a separate task. Contrary to our hypothesis, children assigned to the active conditioning group did not differ from children in the control conditions (i.e., children receiving no sound or noise bursts at random) in their sensitivity in detecting facial displays of emotion. However, we did find conditioning effects on children's attention that were moderated by children's age. These effects were specific to fearful faces and were strongest for high-intensity fearful faces. Specifically, among younger children in our sample, those randomized to the active training group exhibited significantly smaller LPP amplitudes in response to high-intensity fearful faces relative to children in the two control groups. In contrast, among older children in our sample, the group difference was reversed, with children in the active training group exhibiting significantly larger LPP amplitudes in response to high-intensity fearful faces than children assigned to the two control groups. These effects were observed in the absence of any conditioning effects on children's affect and were maintained when statistically controlling for the potential influence of children's and parents' internalizing psychopathology, suggesting that group differences were due to the conditioning effects themselves rather than secondary to changes in affect or internalizing psychopathology among children and their parents.

As previously highlighted, the LPP is thought to reflect facilitated attention toward motivationally relevant emotional stimuli (Hajcak & Olvet, 2008). Accordingly, findings from the current study suggest that active conditioning resulted in increased facilitated attention to fearful faces among older children but potential attentional avoidance of fearful stimuli among younger children. This is the first study to show that children's age may influence the direction of the LPP response to fearful stimuli following active conditioning. Indeed, prior studies highlight the importance of considering age when examining conditioning effects (for a review, see Shechner, Hong, Britton, Pine, & Fox, 2014), and there is evidence that older children, relative to younger children, exhibit greater conditioning effects across behavioral and physiological (i.e., startle) responses (Glenn, Klein, et al., 2012; Kim & Richardson, 2010; Michalska et al., 2016). However, the majority of studies exploring developmental differences in conditioning patterns have focused on adult versus adolescent populations (e.g., Pattwell et al., 2012; Shechner et al., 2014). Findings from these studies suggest that differences in LPP responses observed across age groups may be a function of changes in the brain networks subserving aversive conditioning (Lau et al., 2011; Shechner et al., 2014). For example, the amygdala, a region implicated in the LPP response (Bradley et al., 2003), and the hippocampus have been proposed to play a large role in associative learning and aversive conditioning in adolescents, whereas prefrontal regions are more strongly implicated during differential learning among adult populations (Lau et al., 2011).

Although no studies to date have directly explored differences in brain circuits following aversive conditioning between younger and older youths, there is evidence that task-based functional connectivity between the amygdala and medial prefrontal cortex when viewing fearful faces switches from positive to negative during late childhood (at around 10 years; Gee et al., 2013). This is a key neural circuit thought to influence information-processing biases (Disner, Beevers, Haigh, & Beck, 2011). Intriguingly, this is the same age at which we see the transition from increased to decreased attention to fearful faces in our active training group in the current study. Relatedly, a separate study demonstrated that children, when compared with adolescents and young adults, exhibit less functional connectivity between neural regions implicated in top-down control of attention while completing an affective Stroop paradigm (Hwang, White, Nolan, Sinclair, & Blair, 2014). Age-related increases (i.e., from 7 to 29 years) in connectivity between a cognitive control network and regions involved in higher-level cognitive processing have also been observed (Burkhouse et al., 2019). Notably, models of attention bias highlight higher-order cognitive processes as potential mechanisms responsible for detecting and orienting attention toward threat-relevant stimuli such as threat detection, allocation of cognitive resources, and strategic processing of threat (i.e., threat perceived as major/minor or aligned with goals/beliefs) (for a review, see Cisler & Koster, 2010). Greater conditioned responses, reflected by increased facilitated attention (i.e., LPP response) toward threat-relevant stimuli, observed among adolescents may be explained by more fully developed bottom-up and top-down pathways in neural networks supporting higher-level cognitive processes, which have also been observed to play a critical role in successful aversive conditioning (Sehlmeyer et al., 2009). Future research is needed to understand the precise neural processes underlying the observed attentional responses among younger and older children as well as how these patterns may increase risk for psychopathology in the future.

As noted above, there were no conditioning effects on children's sensitivity in detecting facial displays of emotion. This said, we did find that all children, regardless of conditioning group, were more accurate in labeling each of the emotions as the emotional intensity of the face increased from low to medium to high. In addition, consistent with previous studies (Lawrence et al., 2015), older children were more accurate in labeling the emotions than younger children. It appears, therefore, that although the active training condition was strong enough to affect neural indices of facilitated attention, it was not potent enough to affect behavioral responses at a conscious level. Therefore, stronger or more sustained environmental influences, like those observed in the context of physical abuse (Pollak & Kistler, 2002; Pollak & Tolley-Schell, 2003; Pollak, 2003) may be required to affect children's sensitivity in detecting facial displays of emotion.

These findings contribute to the field in several important ways. As previously discussed, attentional biases in children are linked to several forms of psychopathology (for reviews, see Bar-Haim et al., 2007; Gotlib & Joormann, 2010; Peckham et al., 2010). However, little is known about how these biases may develop. Previous studies have provided retrospective evidence for attentional plasticity by showing that children exposed to physical abuse and high levels of parental criticism exhibit attentional biases specifically for angry faces (Gibb et al., 2011; Pine et al., 2005; Pollak & Tolley-Schell, 2003; Pollak, 2003). However, because parental behavior represents a combination of environmental and genetic influences, these investigations cannot differentiate environmental and genetic influences on attentional biases. Seeking to address this, the current findings provide promising evidence from a laboratory-based conditioning task for an experience-specific model of attentional bias in children where the specific form of attentional bias exhibited is based on children's prior learning history and developmental stage. Future research is needed to better understand the process by which environmental influences on children's attentional biases may change across development as well as the potential proximal and distal impacts of these biases on children's risk for psychopathology.

The current study demonstrated several strengths, including the use of a novel conditioning task, the examination of age effects on conditioning responses, and the focus on a neural index of facilitated attention (LPP). This said, there were limitations as well that provide important avenues for future research. First, the current study was not designed to examine other fear-learning processes that have been implicated in internalizing disorders such as extinction and memory. Therefore, future studies would benefit from examining the degree and speed at which these learning effects extinguish. These studies should also consider the role of children's age given evidence that older children, compared with younger children, display better discrimination and memory during extinction recall (Michalska et al., 2016). Second, the study examined conditioning effects only for fearful facial expressions. We chose to focus specifically on threat-relevant stimuli for the conditioning task given prior evidence for conditioning effects using these types of paradigms (e.g., Lau et al., 2008; Pischek-Simpson et al., 2009). However, theory would suggest that experience-specific biases should be likely to develop in the context of exposure to other forms of affectively salient stimuli (e.g., sad facial expressions). Indeed, there is evidence that children of depressed mothers exhibit attentional biases specifically to facial displays of sadness (Burkhouse, Siegle, Woody, Kudinova, & Gibb, 2015; Gibb et al., 2009, 2016; Joormann et al., 2007; Kujawa et al., 2011). Future research should use laboratory-based tasks to determine whether the acquisition of these biases is similar to that observed for biases to fearful faces in the current study. Similarly, adult facial expressions were used to induce conditioning responses among youths, whereas child facial expressions were used for the subsequent morphed faces task to determine whether conditioning effects from the dot-probe task would generalize to a separate set of facial stimuli. We view this as a very conservative test of the conditioning effects because the generalization task included not only novel facial displays of emotion but also a different age group of actors (children vs. adults). This said, however, there may be important differences in how children interpret fear expressions displayed by adults versus similarly aged peers, which could have affected the generalizability of the conditioning effects. Thus, it will be important for future studies to determine whether the effects are replicated using a separate set of adult facial expressions or other types of threat-relevant stimuli. Finally, underlying individual differences and mechanisms not assessed in the current study may privilege learning from threat cues. Specifically, previous studies highlight important neurological differences (Hartley, Fischl, & Phelps, 2011) and genetic differences (Garpenstrand, Annas, Ekblom, Oreland, & Fredrikson, 2001) in aversive conditioning. Therefore, future studies would benefit from examining how these individual differences may affect the current pattern of findings.

In summary, the current findings provide promising insight regarding how attentional biases may develop in children and how this may change across middle to late childhood. Specifically, we found that, for children in the active training condition where the presentation of a fearful face was paired with a white noise burst, younger children exhibited *less* facilitated attention (smaller LPP) to fearful faces in a separate task, whereas older children exhibited *greater* attention to these fearful faces compared with children in the two control conditions. These findings provide additional support for an experience-specific model of the development of attentional biases in youth and, crucially, suggest that the impact of environmental influences on children's attentional biases may change across development.

Acknowledgments

This work was supported by a National Institute of Mental Health grant (MH098060-02) awarded to B. E. Gibb. K. L. Burkhouse is supported by a National Institute of Mental Health grant (MH113793). We thank Mary Woody, Devra Alper, Cope Feurer, Erik Funk, Anastacia Kudinova, Sydney Meadows, Aliona Tsypes, Effua Sosoo, Michael Van Wie, and Andrea Hanley for their help in conducting assessments for this project.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2019.104676.

References

Baas, J. M. P., Kenemans, J. L., Böcker, K. B. E., & Verbaten, M. N. (2002). Threat-induced cortical processing and startle potentiation. *NeuroReport, 13*, 133–137.
Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M., & van IJzendoorn, M. H. (2007). Threat-related attentional biases in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*, 1–24.
Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology, 56*, 893–897.
Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the beck depression inventory-II*. San Antonio, TX: Psychological Corporation.
Beevers, C. G., & Carver, C. S. (2003). Attentional bias and mood persistence as prospective predictors of dysphoria. *Cognitive Therapy and Research, 27*, 619–637.
Beevers, C. G., Lee, H. J., Wells, T. T., Ellis, A. J., & Telch, M. J. (2011). Association of predeployment gaze bias for emotion stimuli with later symptoms of PTSD and depression in soldiers deployed in Iraq. *American Journal of Psychiatry, 168*, 735–741.
Böcker, K. B., Baas, J. M., Kenemans, J. L., & Verbaten, M. N. (2004). Differences in startle modulation during instructed threat and selective attention. *Biological Psychology, 67*, 343–358.

Bradley, M. M., Sabatinelli, D., Lang, P. J., Fitzsimmons, J. R., King, W., & Desai, P. (2003). Activation of the visual cortex in motivated attention. *Behavioral Neuroscience, 117*, 369–380.
Bublatzky, F., & Schupp, H. T. (2011). Pictures cueing threat: Brain dynamics in viewing explicitly instructed danger cues. *Social Cognitive and Affective Neuroscience, 7*, 611–622.
Burkhouse, K. L., Siegle, G. J., & Gibb, B. E. (2014). Pupillary reactivity to emotional stimuli in children of depressed and anxious mothers. *Journal of Child Psychology and Psychiatry, 55*, 1009–1016.
Burkhouse, K. L., Siegle, G. J., Woody, M. L., Kudinova, A. Y., & Gibb, B. E. (2015). Pupillary reactivity to sad stimuli as a biomarker of depression risk: Evidence from a prospective study of children. *Journal of Abnormal Psychology, 124*, 498–506.
Burkhouse, K. L., Stange, J. P., Jacobs, R. H., Bhaumik, R., Bessette, K. L., Peters, A. T., ... Welsh, R. C. (2019). Developmental changes in resting-state functional networks among individuals with and without internalizing psychopathologies. *Depression and Anxiety, 36*, 141–152.
Burkhouse, K. L., Woody, M. L., Owens, M., McGeary, J. E., Knopik, V. S., & Gibb, B. E. (2016). Sensitivity in detecting facial displays of emotion: Impact of maternal depression and oxytocin receptor genotype. *Cognition & Emotion, 30*, 275–287.
Chorpita, B. F., & Barlow, D. H. (1998). The development of anxiety: The role of control in the early environment. *Psychological Bulletin, 124*, 3–21.
Cisler, J. M., & Koster, E. H. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review, 30*, 203–216.
Clark, D. A., & Beck, A. T. (2010). Cognitive theory and therapy of anxiety and depression: Convergence with neurobiological findings. *Trends in Cognitive Sciences, 14*, 418–424.
Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods, 134*, 9–21.
Dennis, T. A., & Hajcak, G. (2009). The late positive potential: A neurophysiological marker for emotion regulation in children. *Journal of Child Psychology and Psychiatry, 50*, 1373–1383.
Disner, S. G., Beevers, C. G., Haigh, E. A. P., & Beck, A. T. (2011). Neural mechanisms of the cognitive model of depression. *Nature Reviews Neuroscience, 12*, 467–477.
Dozois, D. J., Dobson, K. S., & Ahnberg, J. L. (1998). A psychometric evaluation of the Beck Depression Inventory-II. *Psychological Assessment, 10*, 83–89.
Egger, H. L., Pine, D. S., Nelson, E., Leibenluft, E., Ernst, M., Towbin, K. E., & Angold, A. (2011). The NIMH Child Emotional Faces Picture Set (NIMH–ChEFS): A new set of children's facial emotion stimuli. *International Journal of Methods in Psychiatric Research, 20*, 145–156.
Field, A. P., & Lester, K. J. (2010). Is there room for "development" in developmental models of information processing biases to threat in children and adolescents? *Clinical Child and Family Psychology Review, 13*, 315–332.
First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (1995). *Structured Clinical Interview for Axis I DSM Disorders-Patient Edition (SCID-I/P)*. New York: Biometrics Research Department, New York State Psychiatric Institute.
Fydrich, T., Dowdall, D., & Chambless, D. L. (1992). Reliability and validity of the Beck Anxiety Inventory. *Journal of Anxiety Disorders, 6*, 55–61.
Garpenstrand, H., Annas, P., Ekblom, J., Oreland, L., & Fredrikson, M. (2001). Human fear conditioning is related to dopaminergic and serotonergic biological markers. *Behavioral Neuroscience, 115*, 358–364.
Gee, D. G., Humphreys, K. L., Flannery, J., Goff, B., Telzer, E. H., Shapiro, M., ... Tottenham, N. (2013). A developmental shift from positive to negative connectivity in human amygdala–prefrontal circuitry. *Journal of Neuroscience, 33*, 4584–4593.
Gibb, B. E., Beevers, C. G., & McGeary, J. E. (2013). Toward an integration of cognitive and genetic models of risk for depression. *Cognition & Emotion, 27*, 193–216.
Gibb, B. E., Benas, J. S., Grassia, M., & McGeary, J. (2009). Children's attentional biases and 5-HTTLPR genotype: Potential mechanisms linking mother and child depression. *Journal of Clinical Child & Adolescent Psychology, 38*, 415–426.
Gibb, B. E., Johnson, A. L., Benas, J. S., Uhrlass, D. J., Knopik, V. S., & McGeary, J. E. (2011). Children's 5-HTTLPR genotype moderates the link between maternal criticism and attentional biases specifically for facial displays of anger. *Cognition & Emotion, 25*, 1104–1120.
Gibb, B. E., Pollak, S. D., Hajcak, G., & Owens, M. (2016). Attentional biases in children of depressed mothers: An event-related potential (ERP) study. *Journal of Abnormal Psychology, 125*, 1166–1178.
Glenn, C. R., Klein, D. N., Lissek, S., Britton, J. C., Pine, D. S., & Hajcak, G. (2012). The development of fear learning and generalization in 8 to 13 year-olds. *Developmental Psychobiology, 54*, 675–684.
Glenn, C. R., Lieberman, L., & Hajcak, G. (2012). Comparing electric shock and a fearful screaming face as unconditioned stimuli for fear learning. *International Journal of Psychophysiology, 86*, 214–219.
Gotlib, I. H., & Joormann, J. (2010). Cognition and depression: Current status and future directions. *Annual Review of Clinical Psychology, 6*, 285–312.
Hajcak, G., & Olvet, D. M. (2008). The persistence of attention to emotion: Brain potentials during and after picture presentation. *Emotion, 8*, 250–255.
Hartley, C. A., Fischl, B., & Phelps, E. (2011). Brain structure correlates of individual differences in the acquisition and inhibition of conditioned fear. *Cerebral Cortex, 21*, 1954–1962.
Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). New York: Guilford.
Hwang, S., White, S. F., Nolan, Z. T., Sinclair, S., & Blair, R. J. R. (2014). Neurodevelopmental changes in the responsiveness of systems involved in top down attention and emotional responding. *Neuropsychologia, 62*, 277–285.
Jenness, J. L., Hankin, B. L., Young, J. F., & Gibb, B. E. (2015). Misclassification and identification of emotional facial expressions in depressed youth: A preliminary study. *Journal of Clinical Child & Adolescent Psychology, 44*, 559–565.
Joormann, J., Talbot, L., & Gotlib, I. H. (2007). Biased processing of emotional information in girls at risk for depression. *Journal of Abnormal Psychology, 116*, 135–143.
Jovanovic, T., Nylocks, K. M., Gamwell, K. L., Smith, A., Davis, T. A., Norrholm, S. D., & Bradley, B. (2014). Development of fear acquisition and extinction in children: Effects of age and anxiety. *Neurobiology of Learning and Memory, 113*, 135–142.

Jung, T. P., Makeig, S., McKeown, M. J., Bell, A. J., Lee, T. W., & Sejnowski, T. J. (2001). Imaging brain dynamics using independent component analysis. *Proceedings of the IEEE, 89*, 1107–1122.
Kaufman, J., Birmaher, B., Brent, D., Rao, U. M. A., Flynn, C., Moreci, P., ... Ryan, N. (1997). 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 & Adolescent Psychiatry, 36*, 980–988.
Killgore, W. D. S. (1999). The Visual Analogue Mood Scale: Can a single-item scale accurately classify depressive mood state? *Psychological Reports, 85*, 1238–1243.
Kim, J. H., & Richardson, R. (2010). New findings on extinction of conditioned fear early in development: Theoretical and clinical implications. *Biological Psychiatry, 67*, 297–303.
Koster, E., Crombez, G., Van Damme, S., Verschuere, B., & De Houwer, J. (2005). Signals for threat modulate attentional capture and holding: Fear-conditioning and extinction during the exogenous cueing task. *Cognition & Emotion, 19*, 771–780.
Kovacs, M. (1981). Rating scales to assess depression in school-aged children. *Acta Paedopsychiatrica: International Journal of Child and Adolescent Psychiatry, 46*, 305–315.
Kovacs, M. (1985). The children's depression inventory. *Psychopharmacology Bulletin, 21*, 995–998.
Kujawa, A., Klein, D. N., & Hajcak, G. (2012). Electrocortical reactivity to emotional images and faces in middle childhood to early adolescence. *Developmental Cognitive Neuroscience, 2*, 458–467.
Kujawa, A. J., Torpey, D., Kim, J., Hajcak, G., Rose, S., Gotlib, I. H., & Klein, D. N. (2011). Attentional biases for emotional faces in young children of mothers with chronic or recurrent depression. *Journal of Abnormal Child Psychology, 39*, 125–135.
Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons, & M. T. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 97–135). Mahwah, NJ: Lawrence Erlbaum.
Lau, J. Y., Britton, J. C., Nelson, E. E., Angold, A., Ernst, M., Goldwin, M., ... Shiffrin, N. (2011). Distinct neural signatures of threat learning in adolescents and adults. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 4500–4505.
Lau, J. Y., Lissek, S., Nelson, E. E., Lee, Y., Roberson-Nay, R., Poeth, K., ... Pine, D. S. (2008). Fear conditioning in adolescents with anxiety disorders: Results from a novel experimental paradigm. *Journal of the American Academy of Child & Adolescent Psychiatry, 47*, 94–102.
Lawrence, K., Campbell, R., & Skuse, D. (2015). Age, gender, and puberty influence the development of facial emotion recognition. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.00761.
Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: An open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience, 8*. https://doi.org/10.3389/fnhum.2014.00213.
MacCallum, R. C., Zhang, S., Preacher, K. J., & Rucker, D. D. (2002). On the practice of dichotomization of quantitative variables. *Psychological Methods, 7*, 19–40.
MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*, 15–20.
March, J. S., Parker, J. D. A., Sullivan, K., Stallings, P., & Conners, K. (1997). The Multidimensional Anxiety Scale for Children (MASC): Factor structure, reliability, and validity. *Journal of American Academy of Child & Adolescent Psychiatry, 36*, 554–565.
Michalska, K. J., Shechner, T., Hong, M., Britton, J. C., Leibenluft, E., Pine, D. S., & Fox, N. A. (2016). A developmental analysis of threat/safety learning and extinction recall during middle childhood. *Journal of Experimental Child Psychology, 146*, 95–105.
Nelson, B. D., Weinberg, A., Pawluk, J., Gawlowska, M., & Proudfit, G. H. (2015). An event-related potential investigation of fear generalization and intolerance of uncertainty. *Behavior Therapy, 46*, 661–670.
Osinsky, R., Lösch, A., Hennig, J., Alexander, N., & MacLeod, C. (2012). Attentional bias to negative information and 5-HTTLPR genotype interactively predict students' emotional reactivity to first university semester. *Emotion, 12*, 460–469.
Pattwell, S. S., Duhoux, S., Hartley, C. A., Johnson, D. C., Jing, D., Elliott, M. D., ... Soliman, F. (2012). Altered fear learning across development in both mouse and human. *Proceedings of the National Academy of Sciences of the United States of America, 109*, 16318–16323.
Peckham, A. D., McHugh, R. K., & Otto, M. W. (2010). A meta-analysis of the magnitude of biased attention in depression. *Depression and Anxiety, 27*, 1135–1142.
Pereira, A. I., Barros, L., Mendonça, D., & Muris, P. (2014). The relationships among parental anxiety, parenting, and children's anxiety: The mediating effects of children's cognitive vulnerabilities. *Journal of Child and Family Studies, 23*, 399–409.
Perez-Olivas, G., Stevenson, J., & Hadwin, J. A. (2008). Do anxiety-related attentional biases mediate the link between maternal over involvement and separation anxiety in children? *Cognition & Emotion, 22*, 509–521.
Pine, D. S., Mogg, K., Bradley, B. P., Montgomery, L., Monk, C. S., McClure, E., ... Kaufman, J. (2005). Attention bias to threat in maltreated children: Implications for vulnerability to stress-related psychopathology. *American Journal of Psychiatry, 162*, 291–296.
Pischek-Simpson, L. K., Boschen, M. J., Neumann, D. L., & Waters, A. M. (2009). The development of an attentional bias for angry faces following Pavlovian fear conditioning. *Behaviour Research and Therapy, 47*, 322–330.
Platt, B., Waters, A. M., Schulte-Koerne, G., Engelmann, L., & Salemink, E. (2017). A review of cognitive biases in youth depression: Attention, interpretation and memory. *Cognition & Emotion, 31*, 462–483.
Pollak, S. D. (2003). Experience-dependent affective learning and risk for psychopathology in children. *Annals of the New York Academy of Sciences, 1008*, 102–111.
Pollak, S. D., & Kistler, D. J. (2002). Early experience is associated with the development of categorical representations for facial expressions of emotion. *Proceedings of the National Academy of Sciences of the United States of America, 99*, 9072–9076.
Pollak, S. D., & Tolley-Schell, S. A. (2003). Selective attention to facial emotion in physically abused children. *Journal of Abnormal Psychology, 112*, 323–338.
Puliafico, A. C., & Kendall, P. C. (2006). Threat-related attentional bias in anxious youth: A review. *Clinical Child and Family Psychology Review, 9*, 162–180.
Sehlmeyer, C., Schöning, S., Zwitserlood, P., Pfleiderer, B., Kircher, T., Arolt, V., & Konrad, C. (2009). Human fear conditioning and extinction in neuroimaging: A systematic review. *PLoS One, 4*(6) e5865.
Shechner, T., Hong, M., Britton, J. C., Pine, D. S., & Fox, N. A. (2014). Fear conditioning and extinction across development: Evidence from human studies and animal models. *Biological Psychology, 100*, 1–12.

Smucker, M. R., Craighead, W. E., Craighead, L. W., & Green, B. J. (1986). Normative and reliability data for the Children's Depression Inventory. *Journal of Abnormal Child Psychology, 14*, 25–39.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., ... Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research, 168*, 242–249.

Van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin, 140*, 682–721.

Weinberg, A., Ferri, J., & Hajcak, G. (2013). Interactions between attention and emotion: Insights from the late positive potential. In M. Robinson, E. Watkins, & E. Harmon-Jones (Eds.), *Handbook of cognition and emotion* (pp. 35–54). New York: Guilford.

Williams, J. M., Watts, F. N., MacLeod, C., & Matthews, A. (1988). *Cognitive psychology and emotional disorders*. Oxford, UK: John Wiley.

Woody, M. L., Owens, M., Burkhouse, K. L., & Gibb, B. E. (2016). Selective attention toward angry faces and risk for major depressive disorder in women: Converging evidence from retrospective and prospective analyses. *Clinical Psychological Science, 4*, 206–215.