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Youths' processing of emotion information: Responses to chronic and video-based laboratory stress

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ABSTRACT

Integrating multiple sources of information about others' emotional states is critical to making accurate emotional inferences. There is evidence that both acute and chronic stress influence how individuals perceive emotional information. However, there is little research examining how acute and chronic stress interact to impact these processes. The current study examined whether acute and chronic stress interact to influence how children make emotional inferences. Eighty-nine youths (aged 11–15 years) underwent a novel video-based social stressor. Children completed an emotion recognition task prior to and after the stressor in which they saw integrated displays of facial expressions and contexts depicting congruent or incongruent emotional information. Eye tracking assessed changes in attention to the stimuli. Children became more likely to use and attended more to facial information than contextual information when labeling emotions following exposure to acute stress. Moreover, the effect of acute stress on use of facial information to label emotions was stronger for children who experienced higher levels of chronic stress. These data suggest that acute stress shifts attention towards facial information while suppressing processing of other sources of emotional information, and that youths with a history of chronic stress are more susceptible to these effects.

1. Introduction

Individuals integrate and use a multitude of cues to make inferences about others' emotion states. Effectively integrating these cues is critical to successfully operating within a social group (Barrett et al., 2019; Powers et al., 2013). This may be especially true under circumstances of stress, when one perceives themselves as under threat. When assessed separately, both acute laboratory stress and chronic lifetime stress have been associated with alterations in memory for and attention to emotional information, as well as perception of emotion in others (Pollak, 2008; Wolf, 2009). However, there is little literature exploring how acute and chronic stress interact to influence these processes. Acute, short term stress is associated with physiological, psychological, and behavioral changes aimed at addressing a perceived immediate potential threat. In contrast, exposure to chronic and/or extreme lifetime stress is linked to dysregulation of stress response systems and negative mental and physical consequences for the individual (McEwen, 2012). But, of course, individuals facing an immediate stressor may, at the same time, also be subject to chronic stress or perceive immediate challenges as more stressful. This study investigated how different types of stress affect the processes through which individuals make inferences about others' emotions.

1.1. Effects of acute stress

In adults and children, acute laboratory stress is associated with changes in how individuals attend to and remember emotional information (Putman and Roelofs, 2011; Wolf, 2009). In the short term, this is thought to facilitate adaptive responses by increasing processing of negative information and allowing individuals to quickly respond to potential threats (Henckens et al., 2009; Weymar et al., 2012). Specifically, acute laboratory stress appears to enhance memory consolidation and recall of negative emotional information (Quas et al., 2014; Schwabe et al., 2010) and shift attention towards negative emotional information (Schultebraucks et al., 2016; Ursache and Blair, 2015). These shifts in both memory for, and attention towards, negative emotional information suggest that stress will have consequences for how individuals attend to and interpret others' behavior.

There have only been a few studies examining how acute stress changes perceptions of emotions in others (Chen et al., 2014;

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Daudelin-Peltier et al., 2017; Deckers et al., 2015; Domes and Zimmer, 2019). In adults, there is evidence for enhanced recognition and sensitivity to facial cues across emotion categories after exposure to laboratory stress (Deckers et al., 2015; Domes and Zimmer, 2019) and for changes in sensitivity specific to certain emotion categories (Daudelin-Peltier et al., 2017). Additionally, in children, acute stress results in shifts towards categorizing morphed facial configurations on an anger-fear continuum as fearful as compared to angry (Chen et al., 2014). While this body of research suggests that acute stress shifts how both children and adults perceive emotions in others, the mechanisms underlying this effect are not clear. One potentially contributing factor is that, to date, this research has assessed a limited aspect of emotion processing by only considering facial configurations. A growing literature demonstrates that individuals use multiple sources of information, including voices, body posture, faces, and, especially, context, to make assessments about others' emotional states (Aviezer and Dudarev, 2011; Barrett et al., 2019). For example, when facial configurations are paired with incongruent but highly perceptually similar bodily expressions of emotion (i.e., anger and disgust), individuals become less likely to identify the emotion as that of the facial configuration (Aviezer et al., 2008; Foul and Aviezer, 2018), and this appears to be especially true in early childhood (Leitzke and Pollak, 2016). Examining the effects of stress on emotion perception when multiple sources of information are available can provide insight into how and whether stress shifts the manner by which individuals integrate various environmental cues.

1.2. Effects of chronic stress

Chronic stress, especially in early childhood, is associated with altered processing and perception of emotional facial expressions. Children who have experienced severe adversity, such as child maltreatment, have heightened perceptual sensitivity to prototypes of threatening facial configurations (Pollak and Sinha, 2002; Shackman and Pollak, 2014). Additionally, stress-exposed children are less accurate at identifying facial emotions (da Silva Ferreira et al., 2014d; Koizumi and Takagishi, 2014). These effects appear to continue into adulthood (Young and Widom, 2014) and vary based on the intensity and chronicity of the stress exposure (Birn et al., 2017; Lupien et al., 2009). Together this research suggests that exposure to chronic stress may bias children towards attending to and identifying cues of threat in others.

1.3. Effects of both acute and chronic stress

Both acute and chronic stress have been associated with alterations in emotion processing, but it is less clear how they interact to influence emotion perception. Chronic lifetime stress is associated with alterations in neural stress response and emotion processing systems which have been linked to differences in emotion perception (Bruce et al., 2013; Danese and McEwen, 2012). Cumulative stress and severe childhood adversity have been associated with heightened amygdala reactivity to emotional images (Evans et al., 2016; Tottenham et al., 2011). This heightened reactivity appears to be at least partially a result of altered amygdala-prefrontal cortex (PFC) connectivity (Fan et al., 2014), leading to increased sensitivity to emotionally salient cues (Garrett et al., 2012; Wolf and Herringa, 2016). The intensity of stress exposure appears to moderate these effects (Hanson et al., 2015; van Harmelen et al., 2014). Additionally, chronic, early life stress has been linked to both hyperactivation and hypoactivation of the hypothalamic-pituitary-adrenal (HPA) axis, as measured by cortisol output, depending on the age of the child (Hostinar and Gunnar, 2013; Lupien et al., 2009). Together this suggests that exposure to acute stress may have differential effects on how individuals recognize emotions in others and may be dependent on an individual's prior exposure to stress.

1.4. Current study

Here, we examined the effects of acute laboratory stress and chronic lifetime stress on how youths (ages 11–15 years) perceive and attend to multiple sources of emotion information. To do so, we developed a modified social stress paradigm for children to induce acute laboratory stress. Below, we first describe and present validation of the modified stress paradigm and then use this new paradigm to test the effects of acute and chronic stress on youths' emotion perception.

2. General method

2.1. Participants

Participants were eighty-nine youths (42 female) ages 11–15 years old (M_{age} = 12.9 years, SD = 1.23 years; Race: 73.0 % White, 7.9 % Black/African-American, 6.7 % Hispanic-White, 2.2 % Asian or Asian-American, 3.4 % Multi-racial, and 6.7 % other). We chose this age range based on our previous research demonstrating this as a period of developmental shift in children's ability to integrate multiple cues of emotion (Leitzke and Pollak, 2016). Socioeconomic status (SES) was assessed using the Hollingshead Two Factor Index (Hollingshead, 2011; M = 50.06, SD = 12.46). All participants provided written assent and parents provided written informed consent. Parents received $20 for participation and child participants received $20 and a prize. This study was approved by the University of Wisconsin-Madison's Institutional Review Board.

3. Procedure

Participants completed one laboratory session lasting approximately two hours. First, participants completed a 15-minute emotion perception task, in which facial configurations associated with either anger or disgust were paired with congruent, incongruent, or neutral contexts. After the emotion perception task, participants underwent a novel modified social stressor. Post stressor, participants again completed the emotion perception task, after which they completed the Youth Life Stress Interview (YSLI; Rudolph et al., 2000). Eye tracking was measured throughout the emotion perception task to assess where and how long participants were looking. On completion of the study, all participants were debriefed regarding the stressor. While participants completed the study tasks, parents completed the parent interview portion of the YSLI.

4. Part I: validation of a video-based social stress test for youths

We aimed to assess whether a modified version of the Trier Social Stress Test for Children (TSST-C, Buske-Kirschbaum et al., 1997), utilizing a pre-recorded video panel of child judges, effectively induces stress in youths. We collected measures of physiological (cortisol and heart rate) and self-reported mood changes while participants underwent the stressor. If the modified stressor was effective, participants should show increases in cortisol and heart rate, indicative of HPA axis and autonomic nervous system (ANS) reactivity, and increases in negative mood, similar to those observed during exposure to existing stress paradigms for children and adolescents (Buske-Kirschbaum et al., 1997; Gunnar et al., 2009a, b).

5. Method

5.1. Stressor

Our video-based social stress task was a modification of the TSST-C (Buske-Kirschbaum et al., 1997). The task consisted of a 10-minute speech followed by a five-minute math task. Ordinarily, participants complete these tasks in front of live judges, who neutrally observe their behavior. We modified the task such that human judges were presented via video. Participants were told they would be giving a speech to four other children watching in different rooms via laptops who would be judging the speech. Participants were then given the speech prompt, which, as with the TSST-C, consisted of a story prompt for which participants were instructed to come up with an ending (Supplemental Materials). Participants had three minutes to prepare their speech during which the experimenter left the room. After the three-minute period, participants were introduced to their peer judges via computer in a video format. Through staged interactions, participants introduced themselves to each pre-recorded judge and watched the experimenter interact with each judge in real time. These scripted and timed interactions led participants to believe judges were real and interacting with them live. In fact, the child judges were actors who had been previously filmed within our laboratory. All participants saw the same staged video interactions between experimenter and child judges. The child judge videos consisted of a set of four videos (Fig. 1A).

After the introductions, participants were told that the experimenter was going to transfer the judges' video connection to a main computer so they could watch the participant's speech. Participants saw videos of the four judges who maintained neutral facial expressions with no visual or verbal feedback throughout the speech. The introductions and speech preparation took approximately three minutes. Participants then were told they had five minutes to give their speech to the judges. Prior to the speech portion, participants were given the opportunity to not complete the speech if they felt too uncomfortable. Four youths chose to skip the speech and were excluded from analysis. After the five-minute speech, participants completed the math portion of the stressor in which participants 11-years-old were asked to count backwards by seven from 758 as quickly and accurately as possible and 12 – 15-year-olds were asked to count backwards by 13 from 1023. During the math portion, the videos of the judges remained on the screen.

5.2. Indices of stress

We collected measures of physiological and mood responses throughout the stressor to ensure it elicited comparable psychological and physiological changes to the traditional TSST-C. All measures were collected at -15, 0, +15, +30, and +60 min during the social stress task (with 0 being the beginning of the speech). As a manipulation check a subset of 26 participants returned to the laboratory a year later and completed the same protocol without the social stress component. As expected, the subset of participants that returned did not show evidence of any physiological or mood responses during the laboratory visit; these results are reported in the Supplemental Materials.

5.2.1. Cortisol

Salivary cortisol samples were collected using passive drool technique (Fairchild et al., 2008; Roney et al., 2007). This involved participants pooling saliva in their mouth and then drooling passively through a straw into a 2 mL Cryovial (Wheaton© www.wheaton.com). Samples were frozen immediately in a −20 °C freezer. After completion of data collection, saliva samples were shipped to the Biochemisches Labor at the University of Trier where they were thawed and hormonal assays for cortisol were performed using a solid phase time-resolved fluorescence immunoassay with flouromeric end point detection (DELFIA) (Dressendörfer et al., 1992). Inter-assay CV value for cortisol was 9.4 % and intra-assay CVs for cortisol were 9.6 % which are within published range for similar populations (Gunnar et al., 2009a, b). Cortisol data was log

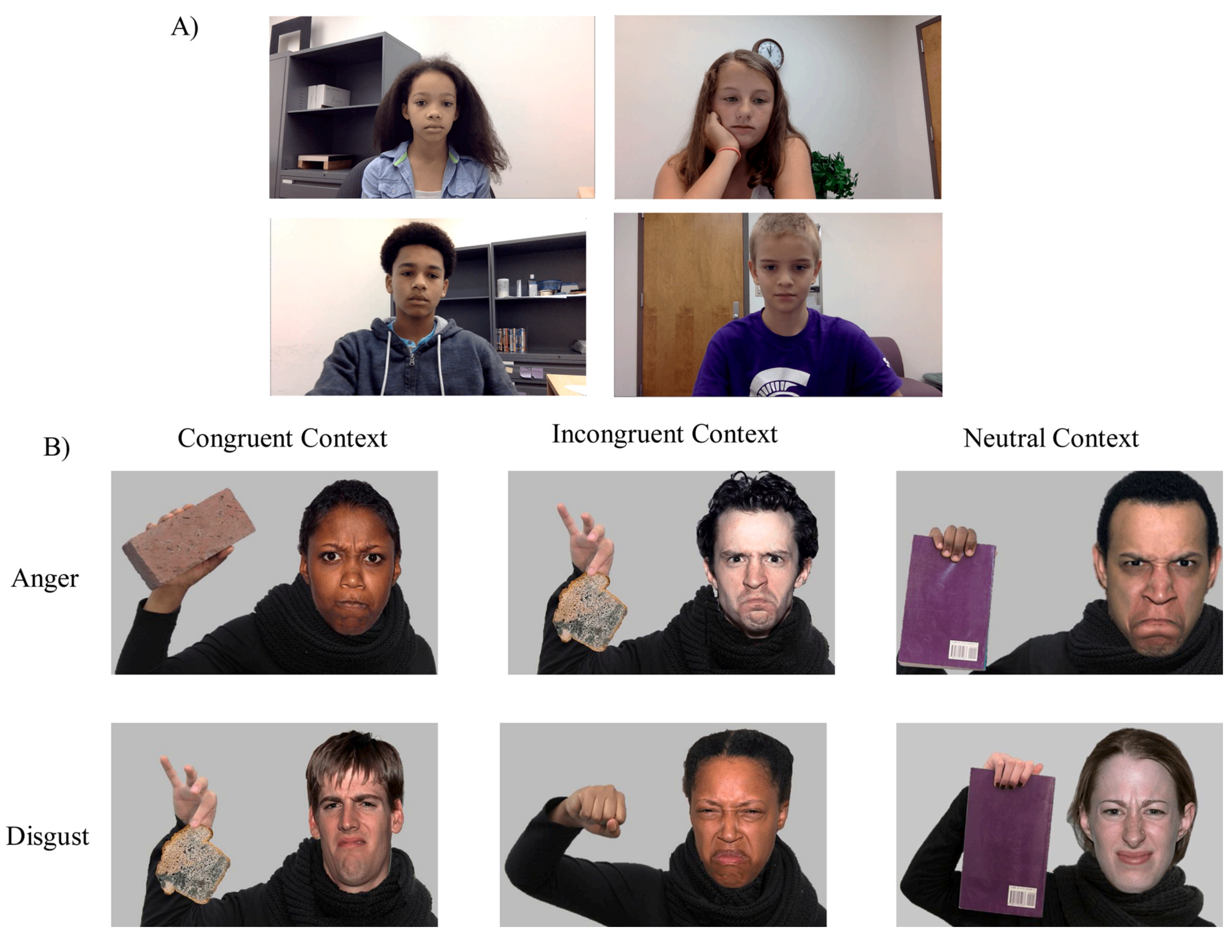

Fig. 1. A) Video stimuli for neutral judge videos. Judges consisted of four child actors, two male (one Black, one White) and two female (one Black, one White), who had been previously filmed in the laboratory. B) Examples of congruent and incongruent anger and disgust stimuli in emotion perception task.

transformed prior to analyses. Five participants (one due to refusal to do some of the samples and four due to inability to produce sufficient saliva) were missing cortisol data from at least one of the five time-points during the stressor, leaving a total of 80 participants with complete data.

5.2.2. Heart rate

Participants wore a Polar chest-strap heart rate monitor for the duration of the study. An electrode gel was applied to the strap to enhance conductivity. Throughout the task, key transitions in the experiment (e.g., onset of speech, end of speech) were marked with a Polar M400 watch to synchronize heart rate data with key events in the experiment. Heart rate was averaged in five bins corresponding to self-reported mood ratings and cortisol levels at -15, 0, +15, +30, and +60 min from the onset of the stressor. Ten participants refused to wear the monitor and did not have heart rate data available (citing discomfort with how the chest-strap felt), and 17 participants were missing heart rate data in at least one of the bins (14 due to equipment malfunctions and 3 due to experimenter error), leaving a total of 58 participants with complete data.

5.2.3. Mood

Participants completed self-reported mood ratings using a Visual Analogue Scale (VAS). Participants were asked to rate how hungry, tired, sad, pleased, happy, social, calm, anxious, and irritated they felt from not at all to extremely. We collapsed across positive (pleased, happy, calm) and negative (sad, anxious, irritated) items separately for each rating and subtracted participants' negative score from their positive score to create an overall mood score. Thirteen participants had missing data for at least one of the five mood ratings, leaving a total of 72 participants who were included in analyses.

5.2.4. Statistical analyses

To confirm the video-based stressor was associated with standard physiological and mood responses, we ran three repeated measures analyses of variance (ANOVAs) incorporating time during stressor with each physiological and mood variable (cortisol, heart rate, and overall mood) as outcome variables in R v 3.6.0 (2019) using the afex package (Singmann et al., 2019). All post-hoc tests were conducted using the emmeans package (Lenth, 2019). Mauchly's Test of Sphericity was used to determine if analyses violated ANOVA assumptions of sphericity. When significant, p-values were adjusted using the Greenhouse-Geisser correction for violations of sphericity.

6. Results

6.1. Cortisol

There was a significant effect of time during the stressor on cortisol, such that cortisol increased after the onset of the stressor and returned to baseline by the end of the study ($F(2,158) = 12.45$, $p < .001$; see Fig. 2). Post-hoc Bonferroni corrected pairwise comparisons indicated there was a significant increase in cortisol from immediately prior to the stressor (Time 2) to 15 min after the onset of the stressor (Time 3; $t(316) = -5.13$, $p < .001$), as well as a significant decrease in cortisol from 30 min after the onset of the stressor (Time 4) to 60 min after the onset of the stressor (Time 5; $t(316) = 3.88$, $p = 0.001$). Additionally, there was a significant difference between 15 min prior to onset of stressor (Time 1) and Time 3 ($t(316) = -3.31$, $p = 0.011$) and Time 3 and Time 5 ($t(316) = 6.54$, $p < .001$) such that cortisol levels were higher 15 min after the onset of the stressor relative to 15 min prior or 60 min after stressor onset. There were no significant differences between Times 2 and 1, 4 and 1, 2 and 4, or 3 and 4(all $ps > .05$). There was a significant difference between Time 1 and 5 ($t(316) = 3.23$, $p = 0.014$), such that cortisol levels were lower by the end of the study than at the beginning. Controlling for age and

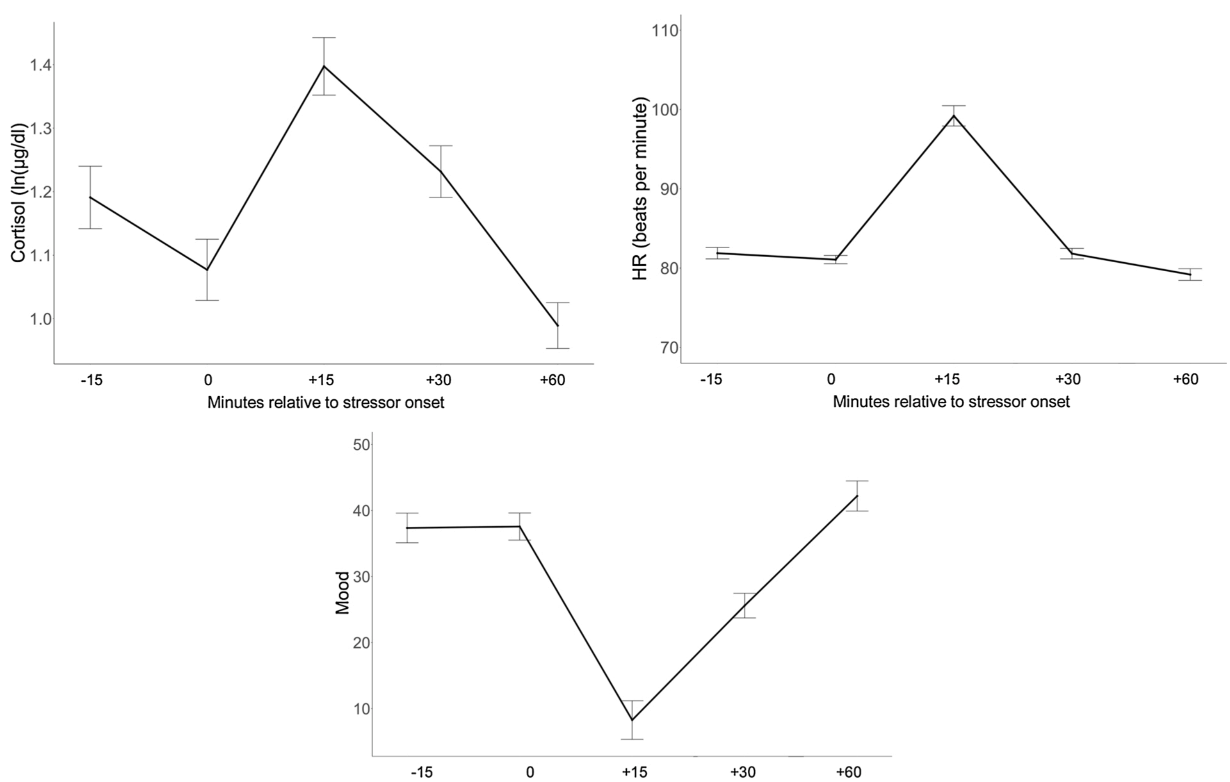

Fig. 2. Cortisol, heart rate, and mood changes during the modified TSST-C. There are significant increases in cortisol ($F(2,158) = 12.45$, $p < .001$) and heart rate ($F(2.20, 125.40) = 99.16$, $p < .001$) and decreases in mood ($F(2.80,198.80) = 35.45$, $p < .001$) during stress exposure. Error bars represent standard error.

gender did not change any of the results ($F(2,146) = 11.40$, $p < .001$)). Using classification criteria outlined in Miller et al. (2013), we classified anyone exhibiting an increase of 0.85 nm/l or over as a cortisol responder. 42 of the 80 subjects (52.5 %) with complete cortisol data were responders to the stressor which is comparable to previous research (Fiksdal et al., 2019; Van West et al., 2009)

6.2. Heart rate

A similar pattern to that of cortisol was observed for heart rate, such that heart rate increased during the stressor and quickly declined after the stressor ended (Fig. 2; $F(2.20, 125.40) = 99.16$, $p < .001$). Post-hoc Bonferroni corrected comparisons indicated there was a significant increase in heart rate from immediately prior to the stressor (Time 2) to 15 min after stressor onset (Time 3) ($t(228) = -15.54$, $p < .001$) and a significant decrease from Time 3 to Time 4 (+30 min) ($t(228) = 14.89$, $p < .001$). There were significant differences in heart rate 15 min prior to stressor onset (Time 1) and Time 3 ($t(228) = -14.84$, $p < .001$) and Time 3 and 5 (+60 min) ($t(228) = 17.15$, $p < .001$) with participants having elevated heart rate at Time 3 as compared to Times 1 and 5. There were no other significant differences between any other time points ($ps > .10$). Including age and gender did not change the results ($F(2.16,110.16) = 89.43$, $p < .001$).

6.3. Mood ratings

There was a significant effect of time on participants' reported mood ($F(2.80,198.80) = 35.45$, $p < .001$; Fig. 2). Post hoc Bonferroni corrected comparisons indicated that there was a significant decrease in participants' reported mood from immediately prior to the onset of the stressor (Time 2) to +15 min after stressor onset (Time 3) ($t(284) = 9.00$, $p < .001$) and a significant increase from Time 3 to +30 min after stressor onset (Time 4; $t(284) = -5.32$, $p < .001$) and Time 4 to + 60 min after the stressor onset (Time 5; $t(284) = -5.10$, $p < .001$). Additionally, there were significant differences between Times 1 and 3 ($t(284) = 8.94$, $p < .001$), Times 1 and 4 ($t(284) = 3.61$, $p = .004$), Times 2 and 4 ($t(284) = 2.68$, $p = 0.003$), and Times 3 and 5 ($t(284) = -10.42$, $p < .001$). Together this suggests that the stressor induced a negative mood state in participants. Results were not affected by participant age or gender ($F(2.80, 187.60 = 34.20$, $p < .001$).

7. Conclusion

These results provide validation for the use of a video-based social stressor that included pre-recorded peer-aged judges with children and adolescents. The modified social stressor induced the expected increases in cortisol and heart rate, indicative of HPA and ANS reactivity, as well as increases in negative mood and a return to baseline of all measures within one hour of the stressor. Thus, this procedure is a valid alternative method for inducing stress in the laboratory. This video-based method confers several advantages. It eliminates the need for a panel of trained in-person judges, dramatically reducing personnel costs and time associated with running the paradigm. The video-taped interactions reduce effects of variability between and within judges in their facial and body movements, and feedback, during the participants' speeches. Additionally, it represents a paradigm in which participants are judged by their peers rather than adults, increasing its comparability to standard paradigms utilized with adults. The current paradigm represents a low cost option for studying stress in children and adolescents in a field with limited proven protocols available (Gunnar et al., 2009a, b).

7.1. Part II: effects of stress on emotion processing

In the second part of this study, we posed three primary questions to address the effects of acute and chronic stress on youths' emotion perception. First, we assessed whether acute stress exposure in the form of our video-based social stressor has an effect on how youths use facial and contextual information to make emotion inferences. We hypothesized that when the face and context conveyed different emotions, acute stress exposure would increase youths' likelihood of labeling the emotion as matching the facial configuration and that looking times, as a measure of attention, would similarly be longer for the face than the contextual information following the stressor. Second, we hypothesized that high levels of lifetime chronic stress would be associated with an increased likelihood of labeling emotions as anger when anger cues were present either in the context or face. Additionally, we expected that higher lifetime stress would be associated with increased attention towards cues of anger, measured via looking times, in both the context and face. Third, we predicted acute and chronic stress would interact to influence how youths' use facial and contextual information to make emotional inferences. We expected that higher lifetime stress would be associated with increased labeling of emotions as anger when cues of anger were present in either the face and context as well as increased attention towards facial and contextual expressions associated with anger after exposure to acute stress.

8. Method

8.1. Emotion perception task

Participants viewed faces displaying prototype configurations commonly associated with disgust or anger. These emotion categories were chosen as previous research has found facial configurations associated with anger and disgust demonstrate high perceptual similarity (Aviezer and Dudarev, 2011; Susskind et al., 2007). Facial stimuli were selected from the NimStim database (Tottenham et al., 2009; Supplemental Materials) and included four black females, four black males, four white females, and four white males. The faces were paired with different contexts as done previously (Aviezer and Dudarev, 2011; Leitzke and Pollak, 2016; Fig. 1B). Participants were asked to identify what each person was feeling using seven response options: anger, disgust, fear, happiness, sadness, surprise, and pride. All facial configurations were paired with all contexts, resulting in six different face/-context pairings of anger/anger, anger/disgust, anger/neutral, disgust/disgust, disgust/anger, and disgust/neutral.

Participants viewed twelve trials of each of the six pairings, equally matched by race and gender. Each image consisted of a different contextual item and pose to represent anger (arm raising a pipe, arm raising a rock, hand in a fist), disgust (arm holding feces on a napkin, unknown substance on a hand, moldy bread), and neutrality (loose hand, cell phone, bottle of water). All models and contextual items/poses were randomly paired and presented an equal number of times. Stimuli were randomized and counterbalanced within and across participants to ensure participants were not seeing the same set of stimuli both prior to and after the stressor. Stimuli were preceded by a fixation cross which was replaced by stimuli only after 1000 ms of continuous gaze was directed towards the cross. Stimuli were presented for 3000 ms to provide for adequate eye tracking collection. All stimuli remained present on screen while participants responded. The computer task was administered using E-Prime Psychology Software 2.0 (Psychology Software Tools Inc, Pittsburgh, PA).

8.2. Eye tracking

Data were collected on a wide screen Tobii T60XL Eye Tracker using binocular pupil tracking and sampling at a rate of 60 Hz. Participants were seated at a viewing distance of approximately 70 cm and eye movements were calibrated using a 5-point calibration-accuracy test. We removed data from any face-context condition where a participant had missing eye tracking data for three consecutive trials within that condition. Two primary regions of interest (ROIs) were defined to examine how participants were allocating their attention towards the scene. An ellipse that spanned form the hairline down to the chin and from temple to temple defined the face. The context included stimuli (body and object) outside of the defined area. We calculated the proportion of the total time spent looking at each ROI. Eye tracking data were not available for 14 participants (due to calibration or equipment malfunctions). For the participants with eye tracking data, data was missing from at least one condition for three participants.

8.3. Chronic stress exposure

To assess participants' chronicity of lifetime stress exposure, all participants and their parents were administered the Youth Life Stress Interview (YLSI; Rudolph et al., 2000). The YLSI assesses the occurrence of specific stressors that participants may have experienced throughout their lives. Trained interviewers used semi-structured questions to assess the context of the event (e.g. timing, durations, and consequences). Data from these interviews were than evaluated by an independent team of three to seven raters who provided a consensual rating on a scale ranging from 1 to 10 reflecting chronicity of lifetime stress exposure. This rating system has demonstrated high reliability and validity (Rudolph et al., 2000; Rudolph and Flynn, 2007).

8.4. Statistical analyses

As all factors of interest were within participants, we ran repeated measures ANOVAs for all outcomes of interest. As above, Mauchly's Test of Sphericity was used to determine if analyses violated ANOVA assumptions of sphericity. When significant, p-values were adjusted using the Greenhouse-Geisser correction for violations of sphericity. For analyses examining the effects of chronic stress, YSLI score ($M = 2.81$; $SD = 1.83$; $Min = 1$; $Max = 8.5$) was mean centered and included as a continuous covariate. Repeated measures mixed effects ANOVAs were run as full factorials including the cross-products between YLSI score and the within participants factors. As initial analyses suggested there were no differences in how participants were using labels other than anger and disgust (Figure S1), we decided to group these labels together as an "other label" category for all analyses. All analyses were also run controlling for participants' age and gender, as these factors have previously been related to differences in emotion perception (De Sonneville et al., 2002; Parmley and Cunningham, 2014). For all analyses, reported effects did not change when controlling for age and gender (Supplemental Materials). Additionally, we analyzed changes in performance on the emotion perception task for the subset of individuals who returned to complete the follow-up study without the stressor and found no comparable effects, suggesting reported effects are due to stressor exposure and not repeated exposure to the task (Supplemental Materials). We also examined whether lifetime stress exposure was associated with physiological reactivity during the video-based TSST. We do not find strong evidence of an association, and these analyses are reported in the Supplemental Materials.

9. Results

9.1. Effects of acute stress on emotion perception

To assess whether acute stress changes how youths use context and facial cues to label emotions, we ran a repeated measures ANOVA including stress exposure (pre and post stressor), how participants labeled the scene (disgust, anger, or other label), and face-context pairing (anger-anger, disgust-disgust, anger-disgust, disgust-anger, anger-neutral, and disgust-neutral) with probability of labeling each emotion type as the outcome variable. We had hypothesized that acute stress would change how youths label emotions when provided with differing facial and contextual cues. In support of this, there was a significant interaction between stress exposure, emotion labeled, and face-context pairing (angry-angry, disgust-disgust, angry-disgust, disgust-angry, angry-neutral, disgust-neutral) ($F(4, 324) = 8.52$, $p < .001$; Fig. 3). This suggested that participants labeled face-context pairings differently post-stressor compared to pre-stressor. Bonferroni-corrected pairwise comparisons indicated that this was driven by participants being more likely to label the emotion as the facial emotion post-stressor and less likely to label the emotion as the context emotion for incongruent face context pairings (angry faces paired with disgust contexts and for disgust faces paired with angry contexts) ($ps < .001$; for other significant contrasts see Supplemental Materials and Table S1). This is indicative of participants shifting towards utilizing facial information as compared to context information after stress exposure. There was no significant interaction between stressor exposure and how emotions were labeled ($F(1.40, 113.40) = 1.63$, $p = 0.206$), but there was a significant interaction between emotion labeled and face context pairing ($F(3.10, 251.1) = 266.31$, $p < .001$) (see Supplemental Materials for further discussion).

To examine whether stress exposure is also associated with changes in how youths attend to different cues of emotion, we ran a repeated measures ANOVA incorporating stress exposure (pre- and post-stressor), region of interest (ROI: face and context), and face-context pairing with proportion of total looking time as the outcome variable. In support of our hypothesis that acute stress exposure changes how youths attend to contextual and facial information, there was a significant interaction of acute stress exposure with region of interest on proportion of total time looking ($F(1,65) = 761.82$, $p < .001$; Fig. 4). Post-hoc Bonferroni corrected pairwise comparisons indicated that this was due to participants allocating a greater proportion of total looking time toward the face post-stressor as compared to pre-stressor ($t(65) = -14.14$, $p < .001$) and less looking time toward the context ($t(65) = 14.14$, $p < .001$).

Additionally, there was a significant interaction of exposure to the stressor, ROI, and face-context pairing ($F(5, 325) = 4.39$, $p < .001$), suggesting that participants shifted attention differently based on what type of information was being presented. Post-hoc Bonferroni corrected pairwise comparisons indicated that this was driven by there being a more pronounced difference in how participants attended to faces as compared to contexts for faces (for both anger and disgust facial configurations) paired with disgust contexts (see Table S2). There was also a significant main effect of ROI ($F(1,65) = 761.82$, $p < .001$) and a significant interaction effect between ROI and face-context pairing ($F(3.75,243.75) = 152.90$, $p < .001$; see Supplemental Materials). Together these results suggest that when youths are provided with multiple cues of information differing in emotional content, acute stress exposure results in a shift towards increased reliance on facial information as compared to contextual information.

9.2. Effects of chronic stress on emotion perception

To examine the effects of chronic stress exposure on emotion recognition and looking times, we ran a repeated measures mixed effects ANOVA for participants' performance on only the emotion recognition task completed prior to acute stress exposure We included how participants labeled the scene and face-context pairing as within participant factors and score from the YLSI as a continuous covariate. We had hypothesized that chronicity of lifetime stress would be associated with increased labeling of emotions as anger. However, there was no significant interaction effect between chronic stress and how participants labeled emotions ($F(1.38, 85.56) = 2.06$, $p = 0.139$) or between chronic stress, how participants labeled emotions, and face-context pairing ($F(3.4, 210.80) = 0.40$, $p = 0.780$). This suggests chronic lifetime stress was not related to differences in how youths label emotions or differences in how they label emotions when presented with multiple sources of emotional information prior to stress exposure.

To examine whether chronic stress was associated with differences in how youths attend to facial and contextual emotion information, a repeated measure mixed effects ANOVA was run with proportion of total

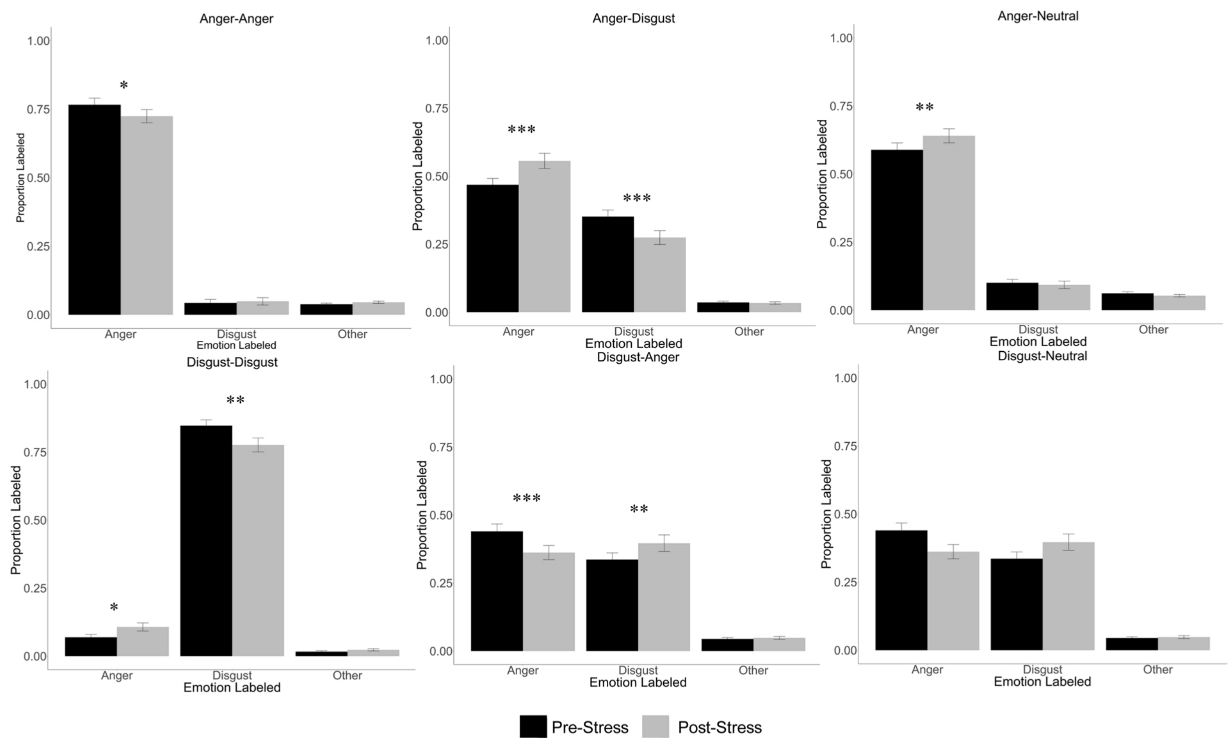

Fig. 3. Changes in how youths label emotions for different face-context emotion pairings pre- and post-stressor. Youths demonstrate increased probability of labeling the emotion as that associated with the facial configuration and decreased probability of labeling the emotion as that associated with the context post-stress for incongruent face-context pairings ($F(4.0, 324) = 8.52$, $p < .001$). Error bars represent standard error. *$p < .05$, **$p < .01$, ***$p < .001$.

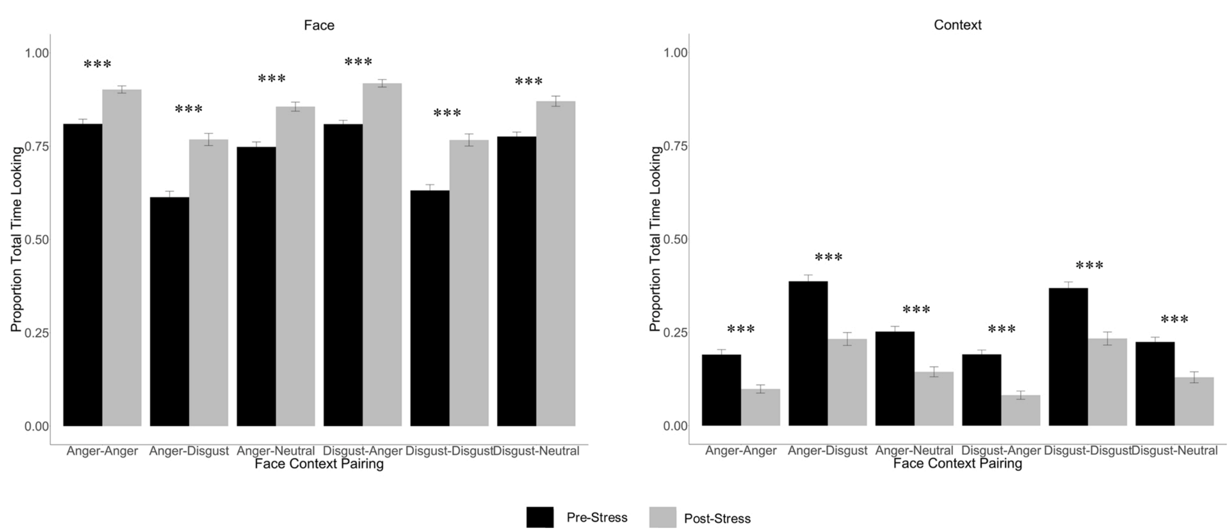

Fig. 4. Changes in looking times pre- and post-stressor by face and context regions of interest. While overall, youths spend more time looking at the face as compared to the context, post-stress youths increase the amount of time they spend looking and the face and decrease the amount of time spent looking at the context ($F(1,65) = 761.82$, $p < .001$). Error bars represent standard error. *$p < .05$, **$p < .01$, ***$p < .001$.

looking time as the outcome variable including region of interest and face-context pairing as within participants factors and score from the YSLI as a continuous covariate for only the post-stressor emotion perception task. We had hypothesized that participants with higher levels of chronic lifetime stress would demonstrate increased attention to cues of anger, and there was a significant interaction between lifetime stress exposure and ROI ($F(1,65) = 5.41$, $p = 0.023$) on proportion of time spent looking during the task at baseline. Despite this suggesting that participants varied in how they attended to different sources of emotional information based on chronicity of lifetime stress exposure, it was not in the hypothesized direction. Moderation analyses indicated that although all participants look more at the face as compared to context, proportion of total time spent looking at the context increased with increased exposure to life stress ($\beta = -0.03$, SE $= 0.01$, $p = 0.023$). There was not a significant interaction between lifetime stress exposure, face-context paring, and ROI ($F(5,325) = 0.27$, $p = 0.928$), suggesting there were no differences in how participants attended to facial and contextual information based on the types of information being presented.

9.3. Effects of both acute and chronic stress on emotion perception

To examine whether acute and chronic stress interacted to influence youths' emotion perception, we ran a repeated measures ANOVA as described above for the effects of acute stress on emotion perception including YSLI score as a continuous covariate. Including YLSI score did not change the previously reported effect of acute stress exposure on emotion judgments ($F(4,248) = 6.27$, $p < .001$). We had hypothesized lifetime stress exposure would interact with laboratory stress exposure to influence how youths label different face context pairings. As expected, there was a significant interaction of lifetime stress exposure with exposure to the laboratory stressor, emotion label, and face-context pairing ($F(4,248) = 4.35$, $p = 0.002$), suggesting that chronic and acute stress interact to influence how participants label emotions based on the context and facial information. Post-hoc analyses (Supplemental Materials) suggested this interaction was driven by participants with higher lifetime exposure to stress demonstrating greater shifts towards labeling the emotion as that associated with the facial expression and away from that associated with the context as compared to the contextual for faces paired with incongruent or neutral contexts, especially so for facial configurations associated with disgust (Fig. 5).

Including participants' lifetime stress exposure did not change the previously reported interaction between acute stress exposure, ROI, and face-context pairing ($F(4.45,275.90) = 4.11$, $p = .002$) or the interaction between chronic stress and ROI ($F(1,62) = 7.37$, $p = .009$). There were no interactions between acute stress exposure and chronic stress and ROI and/or face-context pairing on proportion of total looking time (*ps* > .10), indicating that lifetime stress exposure and acute stress exposure did not interact to shift how participants attended to different cues of emotional information.

10. Discussion

The current study aimed to assess ways in which different types of stress influence how youths infer emotion in others. We hypothesized that both acute laboratory stress and chronic lifetime stress exposure would influence how youths attend to and processes emotion information. Specifically, we expected that acute laboratory stress would increase youths' sensitivity to facial cues. Indeed, acute stress was associated with youths labeling emotions as that associated with facial configurations and increased looking times to the face relative the context. In contrast, we expected chronic stress exposure to be associated with increased attention toward threat, and, further, that these biases would be more pronounced after exposure to the laboratory stressor. However, in contrast to our hypotheses, we found little evidence that chronic stress exposure was associated with differences in how youths use context and facial information. Yet, chronic stress interacted with acute social stress to influence youths' emotion processing, with high levels of chronic stress being associated with a more pronounced shift towards labeling the scene based on the facial information to the exclusion of contextual information.

Our findings that youths become more likely to use facial, rather than contextual, cues are in line with previous reports of increased sensitivity to facial emotion cues in adults after acute stress exposure (Deckers et al., 2015; Domes and Zimmer, 2019). This study suggests these changes may result from increased attention to the face after acute stress exposure. If so, this finding has implications for understanding how stress affects the way youths perceive their social environments. Social stress may shift attention towards facial information, perhaps as a way to quickly discern the level of threat or safety in the environment. Yet, this shift may come at some cost, given that facial cues alone are

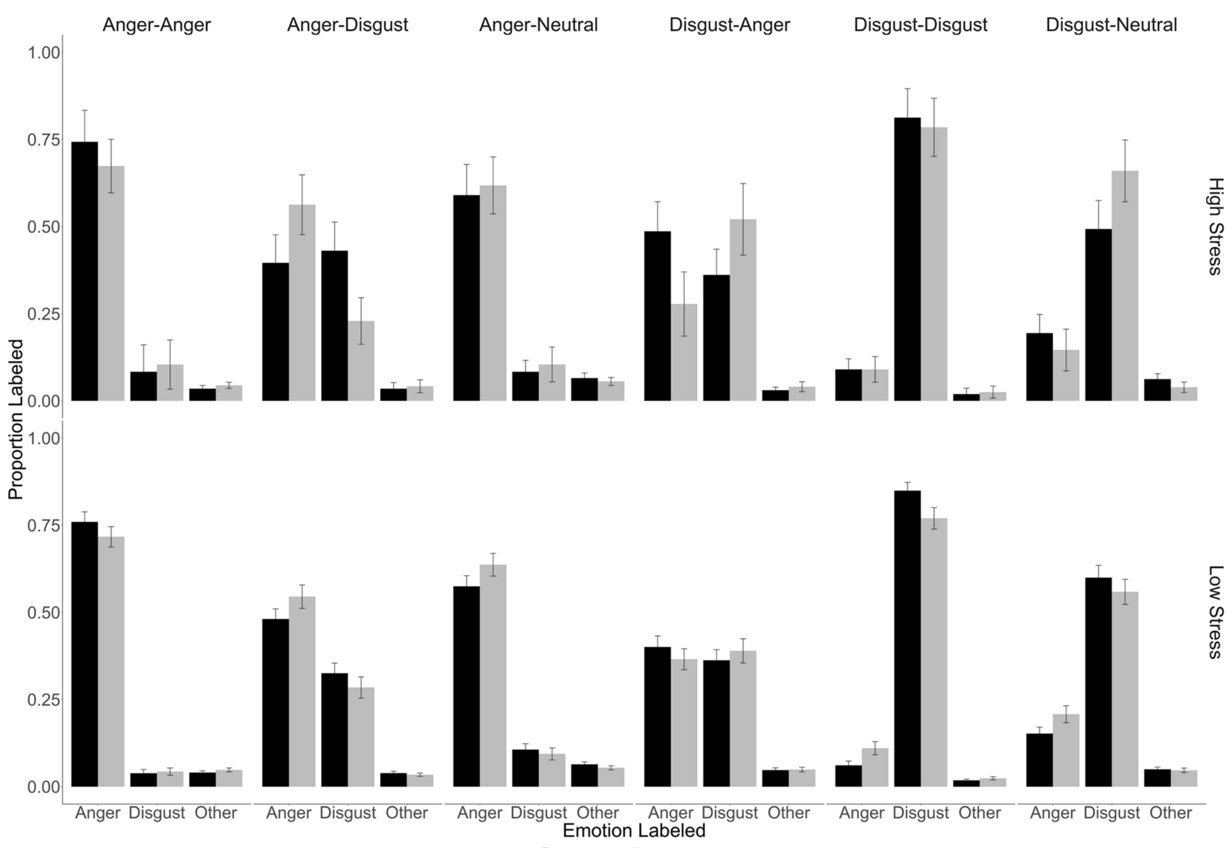

Fig. 5. Effects of chronic lifetime stress on how youths label emotions for different face-context emotion pairings. High and low stress are plotted at ½ a standard deviation above and below the mean YLSI score respectively. Youths with higher chronic stress demonstrate increased shifts towards using facial information in the incongruent conditions, particularly for facial configurations classically associated with disgust ($F(4,248) = 4.35$, $p = 0.002$). Error bars represent standard error.

non-specific and require contextual information to make more accurate inferences about others' emotions (Barrett et al., 2019). However, the current research examined only two sources of potential emotion information, both primarily person related (i.e., facial information and bodily information). Future work should explore these questions in the context of cues outside of the immediate person to better understand whether these attentional shifts are face-specific, and whether they still occur when there is more contextual information requiring integration. Additionally, it may be the case that since the TSST-C uses a lack of any positive or negative feedback from the judges as part of its stress induction, other forms of acute stress, less reliant on social feedback, such as cold pressor or shock stress, may have differential effects on how they shift attention.

Chronic exposure to stress moderated the effects of acute laboratory stress on emotion perception: Youths with higher lifetime stress exposure demonstrated especially pronounced shifts in their reliance on facial cues for labeling emotions after exposure to acute stress. Although somewhat contrary to our hypotheses, this is in line with previous research demonstrating that youths with higher stress exposure are faster and more accurate at discriminating threat cues in ambiguous faces as compared to youths with minimal stress exposure (da Silva Ferreira et al., 2014d; Pollak and Tolley-Schell, 2003). Additionally, it suggests when placed under stress youths with higher prior exposure to stress may more quickly shift towards facial cues to determine potential levels of threat and safety. We do find baseline differences in how youths attend to faces and context information, with higher lifetime stress being associated with increased time spent looking at the context. It is possible that the effects of lifetime stress on how youths label emotions post-stress exposure are driven by this baseline difference. However, we find no evidence that youths with higher levels of lifetime stress are labeling stimuli differently than those with lower levels at baseline. This suggests the baseline association of lifetime stress exposure with increased attention to contextual information is not related to how youths label emotions. Additionally, we find no evidence that lifetime exposure to stress is associated with more or less pronounced shifts in attention towards facial information, again suggesting that the observed differences in how these youths label emotions post-stressor exposure are not a result of baseline variation. It is somewhat surprising we do not find a parallel relationship between attention shifts after acute stress and lifetime stress exposure, and future research should explore the mechanisms underlying this effects of lifetime stress exposure on utilization of contextual and facial information to infer emotions.

There are several limitations to the current study. This research did not utilize only isolated posed facial expressions, but was still reliant on posed expressions of facial and bodily emotion information. These types of stimuli do not represent the range and subtlety of expressions and emotional cues individuals encounter in their daily life (Barrett et al., 2019). Additionally, youths were presented with forced response options to label the emotions, which limited labels to standard emotion categories, not allowing for other interpretations that youths may have of the scenes. However, the goal of the current study was to examine how stress changes youths' integration of and attention to different sources of emotional information and, as structured, the current paradigm allowed us to effectively address that question. Future work should explore how this changes when youths are presented with more than two sources of emotional information, and whether youths will naturally label these types of scenes as specific emotion categories when allowed the flexibility to label freely.

The current research represents the first step, to our knowledge, in understanding how acute social stress changes how individuals perceive emotion expressions when provided with multiple sources of emotional information. The data suggest that acute stress changes what youths attend to, shifting their attention towards facial cues and away from contextual cues that are useful for inferring emotion in others. Moreover, these effects are exacerbated by exposure to chronic stress. The current study did not assess youths' psychological and behavioral outcomes, but it is possible this represents one mechanism through which chronic stress early in life is linked to increased risk for psychopathologies such as depression and anxiety and behavioral problems. Better understanding how exposure to adversity affects how children and adolescents perceive and interpret socio-emotional information in their environments holds tremendous promise for the development of intervention efforts to help support healthy social development.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.psyneuen.2020.104873.

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