Psychoneuroendocrinology (2014) 40, 91—95

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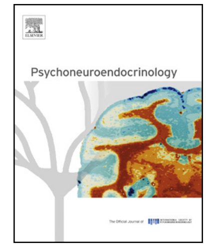

Effects of acute social stress on emotion processing in children

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Received 9 July 2013; received in revised form 3 November 2013; accepted 6 November 2013

KEYWORDS
Early experience;
Social stress;
Emotional expressions;
Face processing;
Attention bias

Summary The current study investigates the effect of a single episode of acute social stress on healthy children's processing of facial expressions of emotion. Healthy nine- and ten-year-old boys ($N = 39$) underwent either a standardized psychosocial laboratory stressor (the Trier Social Stress Test for Children) or a control condition without exposure to socio-evaluative stress. Immediately thereafter, they classified pictures of faces displaying ambiguous facial expressions. Boys who had undergone the stress procedure were more likely to categorize ambiguously angry-fearful faces as fearful (and simultaneously less likely to categorize them as angry) relative to boys who had undergone the control condition. We suggest (i) that decreased sensitivity to anger cues following a stressful experience may represent an adaptive coping mechanism in healthy children, and/or (ii) that a heightened sensitivity to fearful cues may indicate the influence of children's own emotional states on their interpretations of others' emotional states.

Individuals differ in their attention to, and interpretations of, others' emotions. For example, individuals with high trait anxiety show attentional biases toward angry faces (Bradley et al., 2000), and individuals with depression show heightened attention toward sad faces (Gotlib et al., 2004). Transitory affective states also seem to influence emotion processing, with bipolar patients showing heightened sensitivity to negative emotions when exhibiting depressed symptoms but not when exhibiting manic symptoms (Gray et al., 2006).

Exposure to adverse environments can bias children's responses to emotional expressions. Abused and neglected children are quicker to detect angry faces and more likely to interpret ambiguous emotional expressions as angry than

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0306-4530/$ — see front matter
http://dx.doi.org/10.1016/j.psyneuen.2013.11.003

children with no history of maltreatment (Pollak and Sinha, 2002; Pollak and Kistler, 2002). In an fMRI study, children raised in an environment of chronic family stress exhibited atypical neural responses to fearful and angry faces (Taylor et al., 2006).

One mechanism through which adverse environments might influence emotion processing is through the repeated activation of acute stress responses. Healthy adults show enhanced processing (larger N170 amplitudes) for angry faces during anticipation of social stress (Wieser et al., 2009). To our knowledge, however, direct effects of acute social stress on children's emotion processing have not yet been studied. To address this gap, we conducted a study to investigate effects of a single episode of acute social stress on healthy children's interpretations of ambiguous emotional expressions. We predicted that social stress would influence sensitivity to emotional cues associated with social threat (in particular, angry faces).

1. Methods

1.1. Participants

Healthy nine- and ten-year-old boys (20 stress condition, 19 control condition) were recruited via newspaper advertisements and local schools to participate in a study investigating "children's perceptions of faces." A prescreening telephone interview was conducted with parents to ensure that the children were not suffering from physical illnesses, had not been diagnosed with a mental disorder, were not using prescription medications, and had normal academic performance. Due to the potential confounding influence of female sex hormones on cortisol responses starting in puberty (Kirschbaum et al., 1992), only boys were included. The study was approved by the local Institutional Review Board.

1.2. Procedure

Each 2-h session was scheduled for the mid-afternoon to control for diurnal variations in cortisol secretion. Parents were asked to ensure that their child refrained from eating 1 h prior to the session. Upon arrival at the laboratory, written consent was obtained from the parent. The child was introduced to the experimenter through a brief play session and completed validated German versions of the Social Anxiety Scale for Children (SASC-R-D, Melfsen and Florin, 1997) and the Child Depression Inventory (DIKJ, Stiensmeier-Pelster et al., 2000). Parents completed the Child Behavior Checklist (CBCL, Arbeitsgruppe Deutsche Child Behavior Checklist, 1998).

The child was first familiarized with the emotion classification task (described below) and then randomly assigned to take part in either the Trier Social Stress Test for Children (TSST-C; Buske-Kirschbaum et al., 1997) or a specifically-designed control condition. The TSST-C is a standardized psychosocial laboratory stressor in which a child is prompted to complete a story and perform a mental arithmetic task in front of a video camera and a two-person committee (Buske-Kirschbaum et al., 1997). Like the adult version (Trier Social Stress Test, TSST; Kirschbaum et al., 1993), it combines elements of socio-evaluative stress and uncontrollability. It induces reliable psychological and physiological stress responses in children (Buske-Kirschbaum et al., 1997; Schmitz et al., 2011). In the control condition, children read a simple text aloud and counted backwards (i.e., 100, 99, 98, etc.) while standing alone in a room. Thus, the control condition contained all factors of the TSST-C (e.g., orthostasis, speech task, cognitive load, timing of events) except for the psychosocially stressful components.

Immediately following the stress/control condition, the child completed an emotion classification task modeled on Pollak and Kistler (2002). Black-and-white facial images of one woman and man were taken from the NimStim set (Tottenham et al., 2009). Following Pollak and Kistler (2002), four pairs of prototype (100%) emotions (happy-sad, happy-fearful, angry-fearful, and angry-sad) were digitally morphed with each other using Winmorph 3.01 (http://debugmode.com/winmorph) in increments of 10%. This procedure yielded sets of nine ambiguous emotional expressions along four continua. Faces depicting the original prototype emotional expressions (100% happy, sad, fearful, and angry) were used only during the familiarization phase. The child viewed the ambiguous emotion images for the first time in the test phase. Each image (visual angle $9^\circ \times 12^\circ$) appeared in the center of a 56 cm computer screen (resolution 1680×1050 pixels) at a viewing distance of 60 cm. Each face was accompanied by two emotion labels and remained on the screen until the child indicated via button press which of the two emotions the face's expression more closely resembled. Faces were shown in four blocks (order randomized) corresponding to the four emotion continua.

After the procedure, the parent and child were debriefed and thanked. Children received a 15 Euro gift certificate to a children's store, and parents received 10 Euro to reimburse travel costs.

1.3. Stress response measures

Saliva samples were collected at six time points (at −1, +10, +20, +30, +40 and +55 min relative to the onset of the stress/control procedure) using a commercially-available sampling device (Salivette; Sarstedt, Nuembrecht-Rommelsdorf, Germany) and were stored at −20 °C. For biochemical analyses of free cortisol concentration, saliva samples were thawed and spun at 3000 rpm for 10 min to obtain 0.5—1.0 ml clear saliva with low viscosity. Salivary cortisol concentrations were determined by a commercially available chemiluminescence immunoassay (CLIA; IBL Hamburg, Germany). Inter- and intrassay coefficients of variation were both under 8%.

Subjective stress ratings were collected at seven time points (at −15, −1, +5, +10, +20, +30, and +40 min relative to the onset of the stress/control procedure) and assessed how fearful and nervous the child felt using two 10-point scales ranging from "not at all" to "very much" (Schmitz et al., 2011).

1.4. Statistics

To test the effects of the stress manipulation, we conducted two-way analysis of variance (ANOVA) with repeated measures for cortisol and subjective stress (group [2 groups: stress versus control] by time [repeated factor: 6 for cortisol,

Table 1 Characteristics of Study Groups.

	Stress	Control	Group comparison
N	20	19	
Age (years)	9.7 (±0.1)	10.0 (±0.1)	$t(37) = 1.8$, *ns*
Trait Social Anxiety (SASC-R)	38.7 (±1.9)	38.7 (±1.6)	$t(36) = 0.0$, *ns*
Depressive Symptoms (CDI)	6.6 (±1.0)	8.6 (±1.2)	$t(36) = 1.2$, *ns*
Child Behavior Checklist Total	48.7(±2.9)	52.2(±1.8)	$t(37) = 1.0$, *ns*
Internalizing behaviors	52.3(±2.6)	51.7(±1.9)	$t(37) = 0.2$, *ns*
Externalizing behaviors	51.5(±2.4)	51.3(±2.0)	$t(37) = 0.0$, *ns*

Individual cells depict means ± one standard error.

7 for subjective stress]). The effect of stress on emotion classification was tested for each of the four emotion continua using two-way analysis of variance (ANOVA) with repeated measures (group [2 groups: stress versus control] by morph level [repeated factor: 9 increments]). We accounted for multiple testing with a Bonferroni correction (corrected significance level: 0.05/4 = 0.012). Where appropriate, Greenhouse—Geisser corrected values are reported. All analyses were conducted using SPSS18 (SPSS, Inc). All psychometric measures had satisfactory internal consistency (α values between .60 and .92).

2. Results

2.1. General characteristics

Groups did not differ in mean age, trait social anxiety, depression symptoms, internalizing or externalizing behaviors. Group characteristics are summarized in Table 1.

2.2. Manipulation checks

As expected, only the stress condition induced an increase in salivary free cortisol levels (main effect of time, $F(1.37, 50.79) = 3.95$, $p < .05$, $\eta^2 = .10$; time by group interaction, $F(1.37, 50.79) = 6.10$, $p < .05$, $\eta^2 = .14$) (Fig. 1, Panel A). Only the stress condition induced an increase in fearfulness and nervousness; for both scales, there was a significant main effect of time (fearfulness $F(2.93, 105.52) = 9.63$, $p < .001$, $\eta^2 = .21$; nervousness $F(3.41, 122.60) = 12.24$, $p < .001$, $\eta^2 = .25$) and a significant time by group interaction (fearfulness $F(2.93, 105.52) = 3.81$, $p < .05$, $\eta^2 = .10$; nervousness $F(3.41, 122.60) = 3.00$, $p < .05$, $\eta^2 = .08$) (Fig. 1, Panels B and C). No significant differences in baseline cortisol levels, fearfulness or nervousness were observed between the two groups (all $p > .05$).

2.3. Emotion classification after stress

Children in the stress and control groups did not differ in their baseline classification of prototype emotions, as evidenced by the number of errors made during the familiarization task ($t(37) = .31$, *ns*). However, a significant main effect of group was found for post-manipulation emotion classification along the angry-fearful continuum ($F(1, 37) = 9.36$, $p = .004$, $\eta^2 = .20$).[1] Children in the stress group were more likely to classify faces as fearful than children in the control group (Table 2). No significant differences between the two groups were found in classification of emotional faces along the angry-sad, happy-fearful, and happy-sad continua (all $p > .29$).

As expected, a significant main effect of morph level increment was found for all four continua (angry-fearful, $F(5.28, 195.65) = 104.49$, $p < .001$, $\eta^2 = .74$; angry-sad, $F(5.65, 209.16) = 59.99$, $p < .001$, $\eta^2 = .62$; happy-fearful, $F(4.99, 184.57) = 148.47$, $p < .001$, $\eta^2 = .80$, happy-sad, $F(4.16, 153.92) = 137.08$, $p < .001$, $\eta^2 = .79$), reflecting the general tendency of children to classify emotional faces based on the relative intensity of emotional cues displayed. However, no significant interactions between group and morph level were found (all $p > .32$). The inclusion of age, trait social anxiety (SASC score) and depression symptoms (CDI score) as covariates did not change any of the emotion classification results.

3. Discussion

This study represents, to our knowledge, the first systematic investigation of the effects of acute social stress on healthy children's classification of emotional expressions. Healthy boys who had experienced social stress were subsequently more likely to classify ambiguous faces as fearful rather than angry (relative to healthy boys who had not experienced stress).

Interestingly, these results contrast with the heightened sensitivity to angry cues documented in maltreated children and in adults with high trait anxiety. Acute social stress appears to have a qualitatively distinct effect on healthy children's emotion processing compared to the effects of chronic social stress that presumably accompanies maltreatment or high-stress family environments.

The tendency of healthy children to interpret some ambiguous emotional expressions as less angry after acute social stress may represent an adaptive coping mechanism. For instance, reduced sensitivity to angry expressions after

[1] There is no significant effect of facial image sex on classification in the angry-fearful continuum (paired-sample t-test of overall classification response across morph levels, $t = 1.29$; $p > 0.20$).

Table 2 Emotion Classification after Stress.

Emotion 1—Emotion 2	% Classified as Emotion 1, stress condition	% Classified as Emotion 1, control condition	Group comparison
Angry—fearful	45% (±1%)	54% (±2%)	$t(37) = 3.06$, $p < .01$
Angry—sad	44% (±3%)	46% (±2%)	$t(37) = 0.44$, *ns*
Happy—fearful	53% (±2%)	56% (±3%)	$t(37) = 1.07$, *ns*
Happy—sad	54% (±3%)	51% (±2%)	$t(37) = 0.85$, *ns*

Individual cells depict means ± one standard error.

social stress may serve to encourage social approach behavior, which within a healthy environment could result in social support and stress-buffering effects. Alternatively, stress may induce a heightened tendency to categorize ambiguous expressions as fearful due to a more general bias of children to interpret the emotions of others in terms of their own current emotional state. The possible existence of a more general mood-congruency effect could be tested in further research designed to induce other mood states in children.

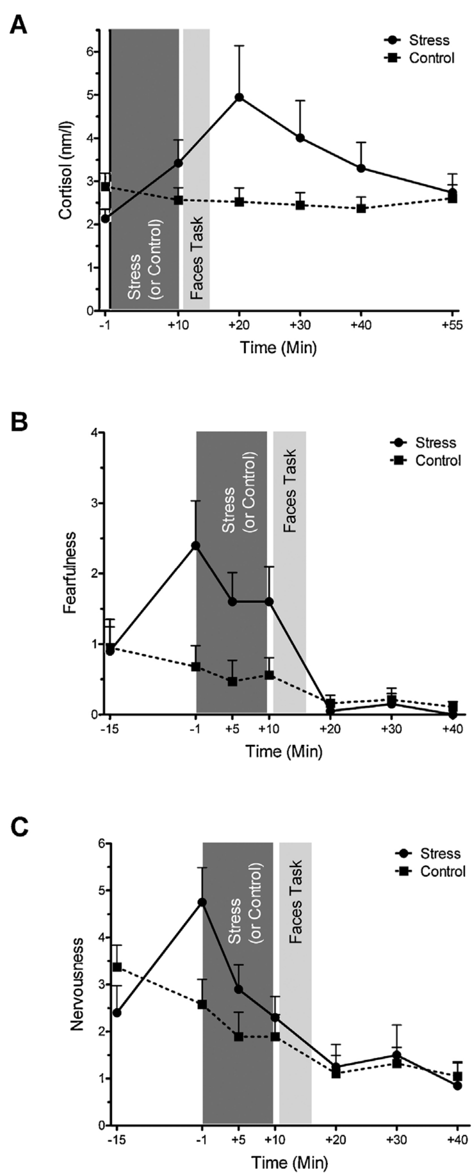

Figure 1 Mean (A) salivary cortisol levels, (B) fearfulness, and (C) nervousness before, during (shaded area), and after acute social stress/control. Error bars represent standard errors of the mean (SEM).

In the current study, stress did not induce a significant angry bias when angry and sad faces were paired, nor a fear bias when fearful and happy faces were paired. It is possible that emotion processing biases may be more evident when children are given classification choices involving context-relevant emotions (with expressions of anger and fear likely being more relevant in the context of social stress than happiness and sadness). To directly investigate the degree of specificity of the reported effect, future studies might pair other combinations of emotions. The persistence of the observed effect, the generalizability of the results to girls, responses to other types of faces (e.g., other children's faces) and other types of stress (e.g. physical stress), also remain to be determined. Furthermore, directly comparing the responses of children from low- and high-stress family environments to an acute social stressor would be an important next step in this line of research.

Understanding children's psychological responses to stress has broad health implications. Continued research in both healthy and clinical samples on children's psychological responses to stress and their development of stress-coping mechanisms may in the long term shed light on stress resilience as well as improve strategies for the treatment and prevention of stress-related disorders.

Role of the funding source

Funding for this study was provided by the Swiss National Science Foundation (SNSF PP001-114788) to M.H. F.S.C. was supported by a research fellowship from the Alexander von Humboldt Foundation.

Conflict of interest statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Acknowledgements

The authors thank Eleonore Brudasca, Juliane Kant, Angela Karutz, Kathleen Krol, Johanna Schäfer, and Imke Witschen for help during data collection, Fynn D. Heinrichs and Valentin König for helping to pilot the study, and the parents and children who participated in the study.

References

Arbeitsgruppe Deutsche Child Behavior Checklist, 1998. Elternfragebogen über das Verhalten von Kindern und Jugendlichen; deutsche Bearbeitung der Child Behavior Checklist (CBCL/4-18). In: Döpfner, M., Plück, J., Bölte, S., Lenz, K., Melchers, P., Heim, K. (Eds.), Einführung und Anleitung zur Handauswertung. 2. Auflage mit deutschen Normen. Arbeitsgruppe Kinder-, Jugend- und Familiendiagnostik (KJFD), Köln.

Bradley, B.P., Mogg, K., Millar, N.H., 2000. Covert and overt orienting of attention to emotional faces in anxiety. Cognit. Emotion 14, 789—808.

Buske-Kirschbaum, A., Jobst, S., Wustmans, A., Kirschbaum, C., Rauh, W., Hellhammer, D., 1997. Attenuated free cortisol response to psychosocial stress in children with atopic dermatitis. Psychosom. Med. 59, 419—426.

Gotlib, I.H., Krasnoperova, E., Yue, D.N., Joormann, J., 2004. Attentional biases for negative interpersonal stimuli in clinical depression. J. Abnorm. Psychol. 113, 127—135.

Gray, J., Venn, H., Montagne, B., Murray, L., Burt, M., Frigerio, E., Perrett, D., Young, A.H., 2006. Bipolar patients show mood-congruent biases in sensitivity to facial expressions of emotion when exhibiting depressed symptoms, but not when exhibiting manic symptoms. Cognit. Neuropsychiatry 11 (6) 505—520.

Kirschbaum, C., Pirke, K.M., Hellhammer, D.H., 1993. The 'Trier Social Stress Test' — a tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology 28, 76—81.

Kirschbaum, C., Wust, S., Hellhammer, D., 1992. Consistent sex differences in cortisol responses to psychological stress. Psychosom. Med. 54, 648—657.

Melfsen, S., Florin, I., 1997. Ein Fragebogen zur Erfassung sozialer Angst bei Kindern (SASC-R-D). Kindheit und Entwicklung 6, 224—229.

Pollak, S.D., Kistler, D.J., 2002. Early experience is associated with the development of categorical representations for facial expressions of emotion. Proc. Natl. Acad. Sci. U.S.A. 99, 9072—9076.

Pollak, S.D., Sinha, P., 2002. Effects of early experience on children's recognition of facial displays of emotion. Dev. Psychol. 38, 784—791.

Schmitz, J., Krämer, M., Tuschen-Caffier, B., Heinrichs, N., Blechert, J., 2011. Restricted autonomic flexibility in children with social phobia. J. Child Psychol. Psychiatry 52, 1203—1211.

Stiensmeier-Pelster, J., Schürmann, M., Duda, K., 2000. Depressions-Inventar für Kinder und Jugendliche, 2nd ed. Hogrefe, Göttingen.

Taylor, S.E., Eisenberger, N.I., Saxbe, D., Lehman, B.J., Lieberman, M.D., 2006. Neural responses to emotional stimuli are associated with childhood family stress. Biol. Psychiatry 60, 296—301.

Tottenham, N., Tanaka, J., Leon, A.C., McCarry, T., Nurse, M., Hare, T.A., Marcus, D.J., Westerlund, A., Casey, B.J., Nelson, C., 2009. The NimStim set of facial expressions: judgments from untrained research participants. Psychiatry Res. 168, 242—249.

Wieser, M.J., Pauli, P., Reicherts, P., Mühlberger, A., 2009. Don't look at me in anger! Enhanced processing of angry faces in anticipation of public speaking Psychophysiology 47, 271—280.