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The relation between emotion regulation strategies and physiological stress responses in middle childhood

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Middle childhood;
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Summary The current study sought to examine whether children's spontaneous use of the emotion regulation strategies suppression and reappraisal during a psychosocial stress task was related to their cortisol and alpha-amylase responses to that task.

Salivary cortisol and alpha-amylase responses to a psychosocial stress task were assessed in 158 10-year-old children (83 girls). The children completed a self-report questionnaire measuring use of reappraisal and suppression during the task. Results showed overall increases in cortisol and alpha-amylase in response to the stressor, with higher cortisol reactivity in girls than in boys. With regard to emotion regulation, more use of suppression was related to lower cortisol reactivity in girls, and lower alpha-amylase reactivity and quicker alpha-amylase recovery in all children. The use of reappraisal was not related to the children's cortisol or alpha-amylase responses.

The current study is the first to investigate the relation between the spontaneous use of reappraisal and suppression, and physiological stress responses to a psychosocial stressor in children. Our results indicate that reappraisal and suppression are used and can be measured even in 10-year-olds. At this age reappraisal appears ineffective at down-regulating physiological responses, while suppression was related to lower physiological responses. For cortisol reactivity there was a sex difference in the relation with suppression, indicating the importance of including sex as a moderator variable in research studying stress reactivity and its correlates in this age group.

1. Introduction

In face of a stressor, humans respond with changes in emotions and physiology. Two systems are central to human peripheral physiological stress responses: the autonomic nervous system (ANS), and the hypothalamic-pituitary-adrenocorticol (HPA) axis. The sympathetic branch of the ANS, the sympathetic nervous system (SNS), is a fast responding system involved in initiating the fight/flight response through the release of epinephrine and norepinephrine (Gunnar and Quevedo, 2007). The HPA-axis works through the release of glucocorticoids, a type of steroid hormones, the production of which takes some time. As a result, the HPA-axis responds slower to stressors and takes longer to return to baseline (Gunnar and Quevedo, 2007).

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There are individual differences in the regulation of physiological stress responses (Kudielka et al., 2009; Rohleder and Nater, 2009). Adequate regulation of physiological responses to stress is important, as previous research has indicated that repeated and long-lasting activation of the stress-system is related to adverse effects on the immune system (e.g. Sapolsky, 1998), and to the development of physical and psychological problems (McEwen, 1998; Charmandari et al., 2005). As such, it is important to determine the origins of the differences in physiological stress regulation. Therefore, the current study investigated whether the extent to which people try to regulate their appraisals and emotions in the face of a stressor, for instance by using emotion regulation strategies, might also affect the strength of their physiological responses to stress.

According to classical theories on stress, differences in physiological responding may follow from differences in cognitive appraisals of the stressful situation, and emotional responses associated with those appraisals (Lazarus and Folkman, 1984; Frijda, 1986). A recent paper investigated this notion for the HPA-axis, with a meta-analysis of 54 studies that experimentally manipulated social stress or induced emotions (Denson et al., 2009). Nine judges rated the likelihood that participants experienced certain appraisals and emotions. Results showed that higher appraisal ratings for challenge, threat, novelty, and intensity predicted larger effect sizes in terms of cortisol responses. For the experienced emotions, only surprise showed a positive relation with cortisol responses. The results of this meta-analysis show how appraisals and emotions are related to cortisol reactivity.

Activation of the SNS also appears to be related to experienced emotions. Salivary alpha-amylase (sAA) is considered a non-invasive biomarker of this system (Nater and Rohleder, 2009; but see also Bosch et al., 2011). A recent study showed that levels of sAA were related to participants' self-reported emotional state following the completion of a 'Fear Challenge Course' museum exhibit. Specifically, participants that indicated they were 'negatively aroused' showed significantly elevated levels of sAA, whereas participants that reported to be 'positively aroused' or 'positively calm' showed a significant reduction in sAA levels (Buchanan et al., 2010).

Research relating children's use of specific emotion regulation strategies to their physiological stress responses is limited. Investigating this is nonetheless important, as reactions to stressors in childhood at least partly determine how individuals respond to stressors later in life (Heim and Nemeroff, 2002). Also, both emotion regulation and physiological response systems are developing during childhood. For example, previous research found that children's HPA-axis reactivity to a psychosocial stress task changed from a significant response at age nine, to blunted reactivity at age 11, back to a significant response at age 13 (only in girls) and at age 15 (Gunnar et al., 2009). As a result, findings regarding the relation between emotion regulation strategies and physiological responding for older age groups might not generalize to children. In the current study, we investigated whether individual differences in the way 10-year-old children regulate their emotions is related to their physiological responses to a psychosocial stressor.

There is ongoing debate as to how the concept of emotion regulation should be defined (see e.g. Eisenberg and Spinrad, 2004; Thompson et al., 2008). Gross (1998a) defines it as the processes that influence which emotions a person has, when that person has these emotions, and how these emotions are experienced and expressed. Across the early years of life, children gradually learn how to regulate their emotions. Infants and toddlers greatly rely on the help of adults in regulating their emotion experience and expression. During the preschool years, the understanding emerges that expressed emotions do not need to reflect current emotion experience (Zeman et al., 2006). Between six and ten years of age, children's repertoire of emotion regulation strategies expands rapidly, and shifts from an external, behaviourally oriented approach (e.g. gaze aversion, hiding emotions), towards the use of more cognitively based strategies (e.g. mental distraction, reappraisal; Meerum Terwogt and Stegge, 1995). This availability of both behavioural and cognitive strategies of emotion regulation makes middle childhood a good age at which to study the use of two strategies that have recently gained a lot of attention in the adult literature: *reappraisal* and *suppression* (Gross, 1998b).

Reappraisal is a strategy where the meaning of a situation is reinterpreted in such a way that the emotional impact of the situation is changed. As this strategy is used prior to the activation of emotional response tendencies, it is considered antecedent-focused. Suppression, on the other hand, is a tactic that involves inhibiting the expression of emotions that are already being experienced, and as such it is a response-focused strategy (Gross, 1998b). In adults, reappraisal has been related to the experience and expression of more positive emotions and less negative emotions, better interpersonal functioning, and greater well-being (Gross and John, 2003). Suppression has been associated with less experience and expression of positive emotions, more experience of negative emotions, worse interpersonal functioning, and lower well-being in adults (Gross and John, 2003). In relation to the larger repertoire of emotion regulation strategies that are available in middle childhood, reappraisal is considered a cognitive strategy, whereas suppression is considered a behavioural strategy (Meerum Terwogt and Stegge, 1995). As such, reappraisal could be considered a more mature strategy, and suppression a more immature strategy.

The use of reappraisal and suppression in middle childhood and early adolescence has been researched by Gullone et al. (2010). They found that use of reappraisal seems to be relatively stable across middle childhood and early adolescence, while the use of suppression gradually decreases. In relation to adaptive functioning it has been found that children and adolescents reporting high levels of depressive symptoms used less reappraisal and more suppression than matched controls with low levels of depressive symptoms (Hughes et al., 2011). Also, a school refusal sample of children and adolescents with a primary diagnosis of an anxiety disorder reported fewer use of reappraisal, and more use of suppression than matched controls (Hughes et al., 2010).

Previous research on adults that investigated the relation between the use of these emotion regulation strategies and physiological responses consisted primarily of experimental studies that related the use of reappraisal and/or suppression to SNS activation (e.g. Steptoe and Vögele, 1986; Gross and

Levenson, 1993). For example, in a study by Gross (1998b) physiological responses to watching a disgust inducing film clip were comparable for participants in a reappraisal and control condition. However, participants in a suppression condition showed heightened SNS activity.

Although experimental studies provide a good impression on what the use of a certain type of emotion regulation *can* do, they do not provide information on how day-to-day spontaneous use of these strategies influences physiological responses. An individual differences approach could shed more light on these types of questions. To accommodate this type of research, Gross and John (2003) devised a trait measure of suppression and reappraisal. In adults, this measure has been used to investigate the relation between the tendency to use reappraisal or suppression, and cortisol reactivity to a speech task (Lam et al., 2009). Results showed that higher trait use of both suppression and reappraisal was related to higher cortisol reactivity to the speech task.

Although the use of a trait measure provides information about more naturally occurring use of emotion regulation strategies, it is limited to participants' overall indication of strategy use. The pattern of results from a study assessing both trait use of suppression and reappraisal, and state use in five different scenarios indicated that state strategy use arises from both dispositional and situational factors (Egloff et al., 2006, Study 1). As such, the use of a state measure for emotion regulation might be an even more adequate measure to explain variance in individual differences in acute physiological responses to stress.

Egloff et al. (2006, Study 3) investigated how state use of reappraisal and suppression during an evaluative speech task was related to physiological responses to the same task. Suppression was positively related to SNS activation. No relations were found for reappraisal or with heart rate.

In sum, research into the relation between the use of reappraisal and suppression, and physiological responding has focused on adult populations. Also, use of state measures to assess emotion regulation strategies is scarce, thereby limiting our knowledge on how the spontaneous use of emotion regulation strategies is related to acute physiological stress reactions. In the current study, we used a state measure to assess the extent to which 10-year-old children had used the emotion regulation strategies reappraisal and suppression during their performance on a psychosocial stress task, and related these scores to their cortisol and sAA responses to the task. As the emotion regulation strategies may differentially relate to initial physiological reactivity versus subsequent recovery, we included both physiological reactivity and recovery as measures in our study. As reappraisal is an antecedent-focused emotion regulation strategy, and has been associated with greater experience of positive emotions, we expected to find that more use of reappraisal would be related to less physiological reactivity to our stress task. And also given the antecedent-focused nature of reappraisal, we expected it to relate to reactivity only, and not to subsequent recovery. For suppression, as a response-focused strategy, we expected that more use would be related to higher physiological reactivity, based on findings indicating greater experience of negative emotions and heightened physiological arousal. With regard to the relation between suppression and recovery, we had different expectations for cortisol recovery and sAA recovery. For sAA, which responds and recovers relatively fast as compared to cortisol, we expected that more use of suppression would be related to slower sAA recovery. Given the slowly responding nature of the HPA-axis, we did not expect suppression to be related to cortisol recovery.

Because the age of our sample is close to the onset of puberty, and at least one study found a marginally significant positive correlation between puberty and cortisol reactivity (Gunnar et al., 2009), we took pubertal stage into account as a possible confounder. Also, as onset of puberty is slightly different for boys and girls, we incorporated sex as a moderator variable in all analyses.

2. Method

2.1. Participants

Parents and children were invited through 31 primary schools in Nijmegen and surrounding areas (The Netherlands) to participate in a study on different aspects of responses to stress and their consequences for cognitive functioning. Schools handed out information packages to the children in grades 4 and 5 (age 9—11). Each package contained information about the research project and an application form. Parents of children willing to participate sent in the application form. Inclusion criteria were: birth date between 1 February 1998 and 1 September 2000, and proficiency in the Dutch language. Exclusion criteria were: stuttering, a diagnosis of a developmental disorder, and the use of centrally acting corticosteroid medication. A total number of 183 applications were received from 27 schools. Of this group, seven children did not participate because they did not meet the inclusion criteria. An additional eleven children did not participate due to scheduling problems ($n = 4$), and personal reasons ($n = 7$). This resulted in a sample of 165 participants.

For the current study, five additional children were excluded because they did not complete the entire data collection protocol, and two children were excluded because during data collection it was discovered they met one of the exclusion criteria. Thus, the sample for the current study consisted of 158 children (83 girls; $M_{\text{age}} = 10.61$ years, SD = .52). The majority of the participants was Caucasian (94%), and had at least one parent with a college or university degree (79%).

The study was approved by the ethics committee of the Faculty of Social Sciences of the Radboud University Nijmegen. All parents provided written informed consent prior to their child's participation.

2.2. Procedure

As part of the larger study, all children were first visited at home with a mobile lab, where they completed questionnaires and memory tasks. As this visit was not relevant for the current study, it will not be discussed further.

Testing took place after school in the laboratory of the Behavioural Science Institute of the Radboud University Nijmegen (for an overview of the procedure, see Fig. 1). Upon arrival, children were taken to a separate room, where the experimenter told them that they would be asked to do some tasks and fill out several questionnaires. After this

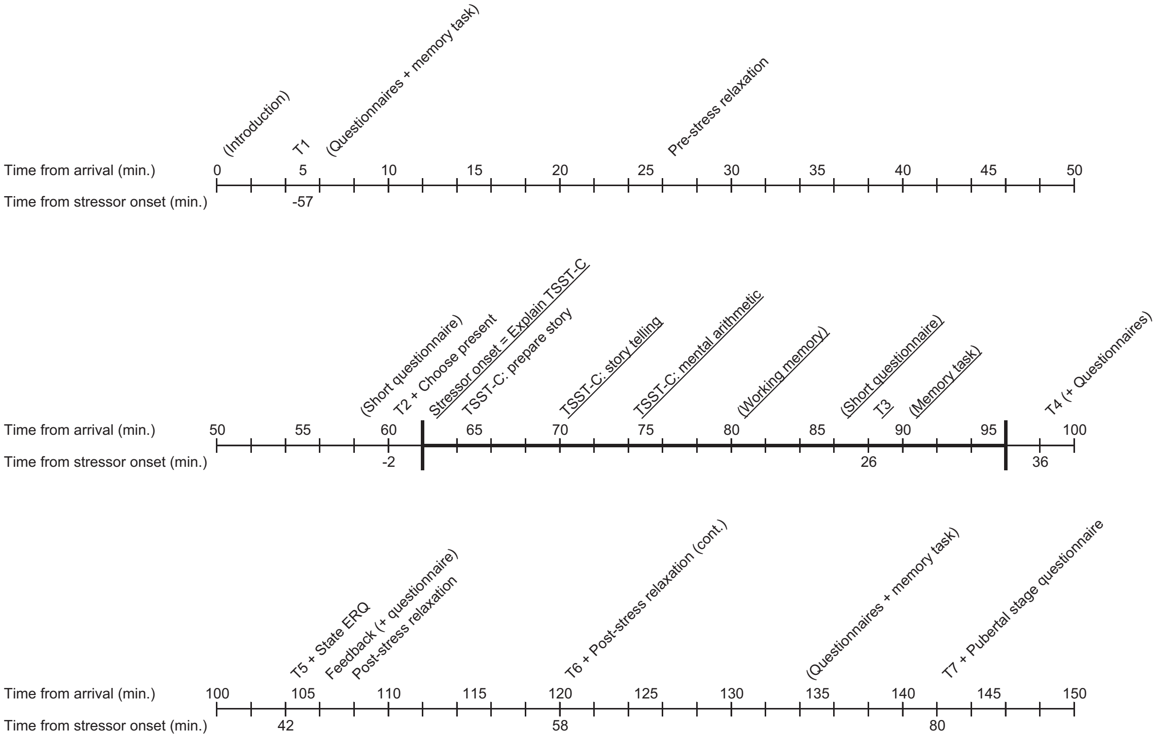

Figure 1 Overview of the procedure expressed in minutes from arrival and minutes before/after stressor onset (indicated by the first thick black vertical bar). Underlined tasks were done in the presence of the TSST-C jury. The thick black horizontal bar indicates the stress task. Tasks in parentheses are not relevant to the current study.

introduction, children provided a saliva sample (T1; within 5 min after arrival), filled out several questionnaires, and performed a memory task. This was followed by a 30 min relaxation period during which children could read a magazine or make puzzles, and listened to relaxing music. Right after relaxation they filled in a short questionnaire, provided a second saliva sample (T2), and chose a favourite and least preferred present out of six small items. After this, children were led to an adjacent room where a stress task took place (adapted and extended TSST-C; see Section 2.3). During this procedure, a third saliva sample was taken (T3). Afterwards, the children were escorted back to the first room, where they provided another saliva sample (T4), and completed two questionnaires. This was followed by a fifth saliva sample (T5), and the completion of a state emotion regulation questionnaire (see Section 2.3). Upon completion of this questionnaire the children received positive feedback on their performance during the stress task, followed by a short questionnaire. Then, a 25 min post-stress relaxation period was initiated. 10 min into this relaxation period, a saliva sample was obtained (T6). After relaxation, children completed several questionnaires, performed a memory task, provided a last saliva sample (T7), and completed a pubertal stage measure (see Section 2.3). The entire procedure took approximately 2.5 h.

2.3. Instruments and measures

2.3.1. Stress task

To induce psychosocial stress, an adapted and extended version of the Trier Social Stress Test for Children (TSST-C; Buske-Kirschbaum et al., 1997) was administered. This task consists of a public speaking task in which children provide the ending to a story, and a mental arithmetic task in which children count backwards from 758 to zero by repeatedly subtracting seven from the most recently acquired number. Both tasks are performed in front of a jury of two confederates in white lab coats. To increase motivation, children were asked to pick a favourite and least preferred present out of six small items (Jones et al., 2006), and told that a favourable judgement by the jury would earn them their favourite present, whereas in case of an unfavourable judgement they would get the least preferred present. After the TSST-C, children were seated in front of the TSST-C jury. There they performed a working memory task, supplied a saliva sample (T3), filled out a short questionnaire, and performed an additional memory task. This entire procedure took approximately 34 min (see Fig. 1).

2.3.2. State emotion regulation strategies

Children's use of emotion regulation strategies during the stress task was assessed with an adapted version of the Emotion Regulation Questionnaire (ERQ; Gross and John, 2003). The ERQ is a 10-item questionnaire assessing the use of both suppression and reappraisal. The four-item suppression scale includes items such as "I keep my emotions to myself". The reappraisal scale contains six items such as "I control my emotions by changing the way I think about the situation I am in". Responses are indicated on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree).

For use in the current study, the Dutch translation of the ERQ (Koole, 2004) was adapted for the use in 10-year-old children by simplifying the formulation of the items, and extending the instructions. To reflect emotion regulation strategy use during the stress task, the questionnaire was adapted to a state measure. For example, the original item "I control my emotions by not expressing them" was changed into "I controlled my emotions by not showing them". The instructions explained that emotions describe how you feel, and that in this case we wanted to know how the child had dealt with his or her emotions during the time spent in front of the jury. To make referrals to positive and negative emotions in the questions less abstract, instructions were supplemented with a box containing exemplars of positive emotions (e.g. happy, proud), and a box with exemplars of negative emotions (e.g. angry, sad). Mean item scores for each scale were computed as indices for state use of reappraisal and suppression.

Principal components analysis revealed a two-factor solution, corresponding to the original factor structure reported by Gross and John (2003). Reliability in the current sample was sufficient for both scales (Cronbach's alpha .67 for suppression, and .84 for reappraisal).

2.3.3. Pubertal stage

To assess pubertal stage, children reported their physical development using Tanner criteria (breast development and pubic hair for girls, genital development and pubic hair for boys; Marshall and Tanner, 1969, 1970). For both physical attributes, each child indicated which one out of five pictures (Lee, 2001) best corresponded to how his/her body currently looked. Mean item scores were then computed as an index of pubertal stage.

2.3.4. Cortisol and sAA

To obtain reliable cortisol measures, participants were asked to only drink water in the 2 h before arrival in the lab, to limit physical exercise in the hour prior to arrival, and to abstain from meals at least 45 min before arrival.

Seven saliva samples were obtained throughout the course of the procedure, at −57, −2, 26, 36, 42, 58, and 80 min from the onset of the stressor. Participants swallowed all saliva in order to empty their mouths, and collected all subsequently secreted saliva in their mouths for 2 min, after which they used a short straw to spit the saliva into a small tube. This procedure was repeated until at least 0.25 ml of saliva was collected, with a maximum total collection time of 5 min. Samples were kept frozen at −20 °C until their shipment to the analysis lab.

Cortisol concentrations were determined at the Endocrinology Laboratory of the University Medical Center Utrecht, using an in house competitive radio-immunoassay employing a polyclonal anticortisol-antibody (K7348). [1,2-3H(N)]-hydrocortisone (Amersham TRK407) was used as a tracer. The lower limit of detection was 1 nmol/L and inter-assay and intra-assay variations were below 10%.

sAA concentrations were determined from the same saliva samples as were used to determine cortisol concentrations. Analysis was performed at the Endocrinology Laboratory of the University Medical Center Utrecht. Alpha amylase was measured on the DxI analyzer (Beckman Coulter Inc., Fullerton, CA, USA). Saliva samples were diluted 500× with 0.2% BSA in 0.01 M Phosphate buffer pH 7.0. Interassay variation was <2.2%.

All physiological data were screened for outliers, which were defined within each assessment point as values greater than 3 SD above the mean. See Table 1 for the number of outliers per sample for each measure. All outliers were winsorized[1] by replacing their values with the value of 3 SD above the mean (Tukey, 1977).

Table 1 Overview of number of outliers, number of participants with lowest pre-stress value (baseline), and number of participants with highest post-stress value (peak) at each sample for cortisol and sAA. A dash indicates that this sample was not considered in determining baseline and/or peak.

	T1	T2	T3	T4	T5	T6	T7
Cortisol							
Outliers	3	3	5	3	3	3	3
Baseline	17	141	–	–	–	–	–
Peak	–	–	35	60	54	9	–
sAA							
Outliers	4	4	4	3	3	3	3
Baseline	28	129	–	–	–	–	–
Peak	–	–	49	74	34	–	–

To compute the strength of children's physiological responses to the stressor, we first determined a baseline value for cortisol and sAA by selecting the lowest pre-stress value for each participant. Then, we determined peak reactivity for each measure. To capture inter-individual differences in timing of the peak cortisol reactivity, this was done by selecting the highest post-stress cortisol concentration from samples T3 through T6. For sAA, being a faster-responding measure, peak reactivity was defined as the maximum concentration from samples T3, T4, and T5.[2] See Table 1 for the number of children that had their baseline and peak at each sample. Peak reactivity and baseline variables were lg 10 (cortisol) or sqrt (sAA) transformed to normalize their distributions.

A recovery measure for cortisol was computed by subtracting the baseline value for cortisol from cortisol concentrations at T7. For sAA, recovery was computed by subtracting the baseline sAA value from sAA at T6. Lower recovery scores thus indicate quicker recovery.

2.4. Statistical analyses

Square root (sqrt) and logarithm (lg 10) transformations were applied where necessary to correct skewed data. To assess whether there was a significant increase in cortisol and sAA to the stressor, we used repeated measures ANOVA with Time as a within subject factor. In case of a violation of the sphericity assumption, multivariate statistics are reported.

To test whether reappraisal and suppression were associated with cortisol and sAA reactivity and recovery, two hierarchical regression analyses were performed for all dependent variables. In the first model, all possible confounders and predictors were entered in separate steps. These

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[1] We also analyzed the data without participants whose cortisol or sAA values had been winsorized. For both cortisol and sAA, and both reactivity and recovery, this yielded significant results that were comparable to the ones presented below.

[2] The fact that children show the peak of their physiological responses at different times does not influence the results; for both cortisol and sAA controlling for time from baseline to peak yielded results that are comparable to the ones presented below.

Table 2 Descriptives and correlations for the study variables.

	Descriptives		Correlations								
	N	*M* (SD)	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Cortisol reactivity	158	0.00 (1.00)	–								
2. Cortisol recovery	158	0.89 (0.18)	.84***	–							
3. sAA reactivity	157	0.00 (1.00)	.28***	.24**	–						
4. sAA recovery	157	41.17 (5.17)	.15	.14	.55***	–					
5. Suppression	158	4.35 (1.16)	−.16	−.13	−.16*	−.22**	–				
6. Reappraisal	158	3.91 (1.26)	−.02	−.12	.02	.06	.33***	–			
7. Pubertal stage	158	1.98 (0.64)	−.09	−.11	−.08	−.08	.07	.10	–		
8. Age	158	10.61 (0.52)	−.06	−.06	.02	.07	.05	.01	.27***	–	
9. Parental education	158	6.30 (1.63)	.00	.02	−.03	.00	.11	.17*	.09	.10	–
10. Sex	83 girls 75 boys										

* $p < .05$.
** $p < .01$.
*** $p \leq .001$.

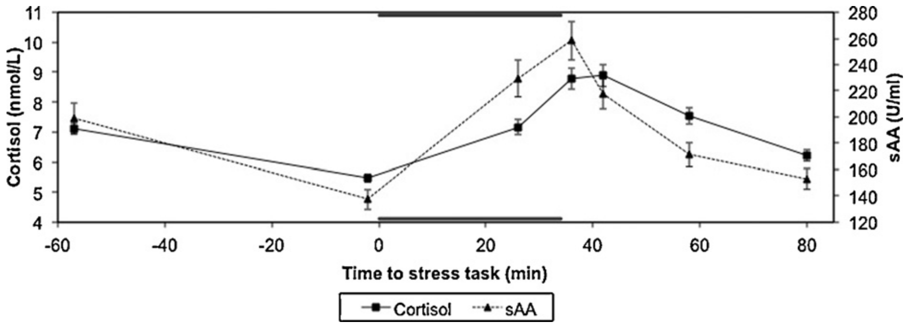

Figure 2 Cortisol and sAA responses to the stress task. Duration of the stressor is indicated with the dark grey bars.

first models are presented in a footnote to the tables with the final models (see Section 3). The second and final model contained only variables that individually explained at least 1% of the variance in the first model (calculated as (part correlation)$^2 \times 100$), thus eliminating irrelevant confounders and predictors, and increasing power.

3. Results

3.1. Preliminary analyses

Descriptives and correlations of the study variables for the whole sample are presented in Table 2. Cortisol reactivity was significantly higher for girls than for boys ($M_{\text{girls}} = .17$, $M_{\text{boys}} = -.19$, $t(156) = 2.31$, $p < .05$, *Cohen's* $d = .37$), and cortisol recovery was significantly less for girls than for boys ($M_{\text{girls}} = 1.27$, $M_{\text{boys}} = .48$, $t(156) = 2.37$, $p < .05$, *Cohen's* $d = .38$). There were no sex differences for the other variables. When correlations were computed separately for girls and boys, girls showed some significant correlations that were not significant for boys. This was the case for the correlations between sAA reactivity and cortisol recovery ($r = .26$, $p < .05$), suppression and cortisol reactivity ($r = -.30$, $p < .01$), suppression and cortisol recovery ($r = -.24$, $p < .05$), reappraisal and suppression ($r = .44$, $p < .01$), and age and pubertal stage ($r = .48$, $p < .01$). The correlation between suppression and sAA recovery was significant only in boys ($r = -.26$, $p < .05$).

Because there was a significant correlation between the baseline and peak values for both measures ($r = .32$, $n = 158$, $p < .001$ for cortisol, and $r = .76$, $n = 157$, $p < .001$ for sAA), reactivity was recalculated for both measures by saving the standardized residuals from a regression of the peak reactivity variable on the baseline values (Schuetze et al., 2008). This resulted in two peak residualized reactivity variables, one for cortisol and one for sAA, that were used as the dependent variables in the subsequent regression analyses.[3]

3.2. Cortisol stress response

Data for each assessment point were first lg 10 transformed to normalize the distribution. A repeated measures ANOVA with Time as a within subject factor showed a significant effect of time, Wilks' Lambda = .19, F (6, 152) = 105.02, $p < .001$, multivariate partial eta squared = .81. As shown in Fig. 2, the significant effect of Time was due to an increase in cortisol in response to the stressor.

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[3] For both cortisol and sAA regression analyses using an autoregressive model predicting peak reactivity while controlling for baseline in Step 1 yielded results that are comparable to the ones presented below.

Table 3 Final regression model for the prediction of cortisol reactivity.

	B	SE *B*	β	Part^2	R^2_{model}	F_{change}	R^2_{change}
Cortisol reactivity[a,b]							
Step 1					.02	3.46^{+}	
Time of day	.20	.13	.12	.01			
Step 2					.07	2.39^{+}	.04
Suppression	−.10	.03	$-.38^{**}$	.06			
Reappraisal	.05	.03	$.21^{+}$	.02			
Sex (girls)[c]	−.10	.05	$-.15^{*}$	.02			
Step 3					.12	4.61^{*}	.05
Suppression × sex	.13	.04	$.31^{**}$	.05			
Reappraisal × sex	−.08	.04	$-.20^{+}$	.02			

[a] Initial model for cortisol reactivity (sqrt): step 1 — age, parental education level (lg 10), puberty (sqrt), time of day (lg 10); step 2 — suppression, reappraisal, sex; step 3 — suppression × reappraisal, suppression × sex, reappraisal × sex; step 4 — suppression × reappraisal × sex.

[b] We also tested a model with cortisol recovery (sqrt) as a dependent variable. This initial model was the same as that for cortisol reactivity, except that in step 1 peak cortisol value (lg 10) was also entered in the model. As none of the variables of interest individually explained at least 1% of the variance in the first model, there was no final model for cortisol recovery.

[c] Sex was coded as 0 (girl) or 1 (boy).

* $p < .05$.

** $p < .01$.

$^{+}$ $p < .10$.

3.3. sAA stress response

Data for each assessment point were first sqrt transformed to normalize the distribution. A repeated measures ANOVA with Time as a within subject factor showed a significant effect of time, Wilks' Lambda = .41, F (6, 148) = 36.24, $p < .001$, multivariate partial eta squared = .60. The significant effect of Time was due to an increase in sAA in response to the stressor (see Fig. 2).

3.4. Associations between cortisol reactivity and emotion regulation strategies

The final regression model for the prediction of cortisol reactivity from emotion regulation strategies was significant, and is summarized in Table 3. There was a significant main effect of sex, indicating that girls showed a stronger cortisol response than boys. In addition, there was a significant Suppression × Sex interaction. For girls, more use of suppression was associated with lower cortisol reactivity, whereas there was no relation between suppression and cortisol reactivity in boys (see Fig. 3).

3.5. Associations between cortisol recovery and emotion regulation strategies

As none of the variables of interest individually explained at least 1% of the variance in the first model, there was no final model for cortisol reactivity. Hence, there was no relation between use of reappraisal and suppression, and cortisol recovery.

3.6. Associations between sAA reactivity and emotion regulation strategies

The final regression model for the prediction of sAA reactivity from emotion regulation strategies was marginally significant, and is summarized in Table 4. There was a significant effect of suppression, such that more suppression was related to lower sAA reactivity.

3.7. Associations between sAA recovery and emotion regulation strategies

The final regression model for the prediction of sAA recovery from emotion regulation strategies was significant and is

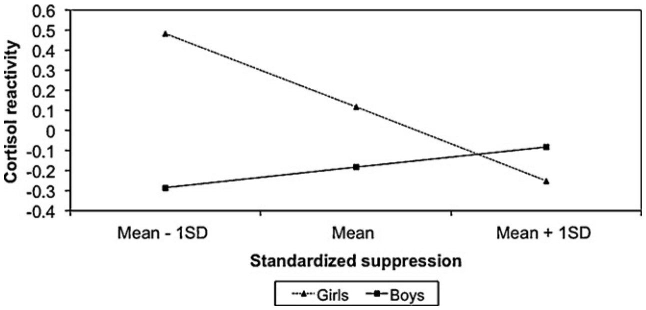

Figure 3 The relation between suppression use and cortisol reactivity separately for girls and boys.

Table 4 Final regression models for the prediction of sAA reactivity and recovery.

	B	SE B	β	Part^2	R^2_{model}	F_{change}	R^2_{change}
sAA reactivity[a]					.03	2.60^{+}	
Suppression	−.03	.01	$-.19^{*}$	.03			
Reappraisal	.01	.01	.09	.01			
sAA recovery[b]							
Step 1					.14	8.61^{***}	
Age	.64	.42	.12	.01			
Puberty	−1.36	.98	−.10	.01			
Peak sAA value	.19	.04	$.35^{***}$	.12			
Step 2					.21	6.16^{**}	.07
Suppression	−.66[c]	.19	$-.26^{***}$	.06			
Reappraisal	.33	.18	$.14^{+}$	.02			

[a] Initial model for sAA reactivity (lg 10): step 1 — age, parental education level (lg 10), puberty (sqrt), time of day (lg 10); step 2 — suppression, reappraisal, sex; step 3 — suppression × reappraisal, suppression × sex, reappraisal × sex; step 4 — suppression × reappraisal × sex.

[b] Initial model for sAA recovery (sqrt) was the same as that for sAA reactivity, except that in step 1 peak sAA value (sqrt) was also entered in the model.

[c] Note that lower values for sAA recovery represent quicker recovery.

* $p < .05$.

** $p < .01$.

*** $p \leq .001$.

$^{+}$ $p < .10$.

summarized in Table 4. There was a significant effect of suppression, such that more suppression was related to quicker sAA recovery.

4. Discussion

The current study sought to examine whether 10-year-old children's spontaneous use of the emotion regulation strategies suppression and reappraisal during a psychosocial stress task was related to their cortisol and sAA responses to that task. We found that the stress task led to an overall increase in both cortisol and sAA, indicating that it was effective in inducing stress in the current sample. For cortisol, reactivity was higher in girls than in boys. For the relation between physiological stress reactivity and emotion regulation strategies we found that more use of suppression was related to lower cortisol reactivity in girls, and to lower sAA reactivity in the whole sample. In addition, we found that more use of suppression was also related to quicker sAA recovery. There was no relation between reappraisal and physiological responses to the stress task.

The finding that girls showed higher cortisol reactivity than boys is contrary to results in adults, where men are often found to show higher reactivity to psychosocial stressors than women (see review by Kudielka et al., 2009). Sex differences in cortisol reactivity to a psychosocial stressor have not been consistently found in middle childhood (e.g. Gunnar et al., 2009). However, this may have to do with limited power to detect these differences, due to smaller sample sizes. A possible explanation for our findings might lie in psychological differences between boys and girls at this age, as research has shown that girls report more fear of failure and criticism than boys (Gullone, 2000). The socio-evaluative nature of the stress task may therefore have made the task more stressful for the girls than for the boys. Alternatively, as boys have been found to feel more competent at math than girls (e.g. Herbert and Stipek, 2005), it is possible that they perceived the mental arithmetic part of the stress task as less stressful than girls did, leading in turn to less cortisol reactivity in boys.

Contrary to our findings for cortisol, there was no sex difference in sAA reactivity to the stress task. This is consistent with earlier research in adults (see Rohleder and Nater, 2009), and children (Sumter et al., 2010). This is possibly due to the fast responding nature of the SNS, which may make this system less susceptible to individual differences in how the stress task is perceived and experienced. Consistent with the fast-responding nature of the SNS, in the current study sAA showed a faster increase in concentration in response to the stress task than cortisol, in addition to an earlier peak and faster recovery to the stress task.

The finding that the use of more suppression was related to lower physiological reactivity and quicker sAA recovery to the stress task is opposite to what we had hypothesized: we had expected to find that more use of suppression would be associated with higher physiological reactivity and slower sAA recovery. One possible explanation for this unexpected finding is that our current study used a state measure of emotion regulation, versus the trait measure used in most other studies. A state measure of emotion regulation is more likely to be influenced by interactions between participant dispositional factors and the situational demands (Egloff et al., 2006). As such, it is possible that for children who experienced the stress task as more demanding, this experience resulted in higher physiological reactivity, slower sAA recovery, and more difficulty in suppressing the outward signs of their distress.

Another possible explanation for the unexpected finding that the use of more suppression was related to lower physiological reactivity and quicker sAA recovery may lie in the difference in age of the current sample versus those in previous studies (e.g. Lam et al., 2009). In adults, suppression could be regarded as a less effective emotion regulation strategy, as it may increase physiological arousal (Gross, 1998b) and the experience of negative affect (Gross and John, 2003), as opposed to reducing it. For 10-year-olds, however, suppression could be the most adequate strategy that is currently available. Although around this age emotion regulation shifts from a behaviourally oriented approach to the use of more cognitive strategies (Meerum Terwogt and Stegge, 1995), it could be argued that the efficiency with which these emerging cognitive strategies are used is still limited. As a result, the well-practiced behaviourally oriented strategies like suppression may still work better to reduce physiological responses than the more cognitive strategies like reappraisal.

It should be noted that the negative association between suppression and physiological reactivity and sAA recovery can be interpreted in different ways. It may indicate, for example, that suppression is effective in decreasing physiological responding. But it is also possible that children who were more stressed by the task and experienced more persistent arousal, were less able to use suppression to regulate their emotions. Our current research is unable to differentiate between these two different explanations for the found effects. A next step would be to experimentally manipulate the use of reappraisal and suppression in order to investigate the causal direction of the current findings.

The finding that suppression was related to lower cortisol reactivity in girls but not in boys could mean that girls and boys use suppression differentially, resulting in different effects on cortisol reactivity. Indeed, in middle childhood, girls tend to replace one emotional display with another, whereas boys tend to neutralize their emotional expressions (Zeman et al., 2006). Perhaps the way girls use suppression is more demanding, thereby providing distraction from the demands of the stress task, which could in turn lead to lower cortisol reactivity. For sAA, this distraction may not influence reactivity because it is a faster responding measure. This would be in line with our first possible explanation, namely that suppression is effective in decreasing physiological responding.

Although we did not find any sex differences in state use of suppression in the current sample, Gullone et al. (2010) found that trait use of suppression was higher in boys than in girls. As a result, boys may be more experienced in using this type of emotion regulation. This could mean boys were able to use suppression regardless of their level of distress, whereas girls may have had more difficulty using suppression as stress levels increased, resulting in lower self-reported suppression scores. This would be in line with our second possible explanation, namely that stressed children are less able to use suppression to regulate their emotions.

A third, and more general, possible explanation is that girls in the current study that were high in their use of suppression, also used other strategies to actively regulate their emotions. It may be that the use of one or a combination of these strategies led to the current results. Therefore, methodological research into the specificity of the ERQ scales when used in children would be interesting, as well as inclusion of other emotion regulation strategies in future studies. For example, the other antecedent focused strategies proposed by Gross (1998a): situation selection, situation modification, and attentional deployment, could be operationalized to investigate their relation to physiological stress responses.

Although we had expected that more use of reappraisal would be associated with lower physiological stress reactivity, we did not find a relation between reappraisal and physiological stress reactivity. For sAA, this is in line with the results of earlier studies investigating the relation between reappraisal and SNS activation (e.g. Gross, 1998b; Egloff et al., 2006). Perhaps reappraisal, being a very cognitively based emotion regulation strategy, is unable to influence the relatively fast and automatic response of the SNS.

More generally, the lack of an association between reappraisal and cortisol and sAA stress reactivity in the current study may be the result of the way the reappraisal items in our state measure of emotion regulation were formulated. We asked participants to indicate to which extent the items were true for them *during* the stress task, as opposed to *prior* to the stress task. Thus, the answers to the questions may indicate a more response-focused use of reappraisal, versus the antecedent-focused use indicated in the model by Gross (1998b). Perhaps the response-focused type of reappraisal is unable to influence physiological reactivity, as it is employed once physiological responses have already been initiated.

Another possible explanation for the lack of a relation between reappraisal and physiological stress responses is that the relation is curvilinear, as is for example the case for the relation between physiological responses and (mal)adaptive functioning (e.g. Charmandari et al., 2005). However, post hoc analyses showed no evidence of a curvilinear relation between reappraisal and the physiological stress responses.

There are several strengths and limitations to the current study that provide directions for future research. First, the study measures both HPA-axis reactivity and SNS reactivity, thus providing information on both of the major physiological stress systems. This is important, as alterations in both of these systems have been related to psychopathology (e.g. van Goozen et al., 2000; Boyce et al., 2001), and both have a different function and time frame within stress responses.

Second, state measures are rarely used to relate the use of emotion regulation strategies to physiological responding, despite evidence that situational demands, in addition to participant dispositional factors, are important in determining the use of emotion regulation strategies (Egloff et al., 2006). The current study shows that 10-year-old children are already able to reliably report on their strategy use during a stress task, and indicates that meaningful links between these reports and other important variables can be found. This opens the way for future research employing state measures of emotion regulation, for example more frequent sampling of state emotion regulation use during a stress task as a way to help determine causality of the current results.

Third, studying a large sample of children from a relatively small age range allowed us to reveal pronounced sex differences in the relation between use of suppression and cortisol reactivity. This stresses the importance of sample sizes large enough to allow for between-sex comparisons. However, this also limits the generalizability of our results to other age groups. Future studies are needed to explore the relation between emotion regulation and physiological responding across the lifespan, as it seems plausible that developmental changes influence the relation between emotion regulation and physiological reactivity.

Finally, it is important to note that the amount of variance in cortisol and sAA stress reactivity explained by the use of reappraisal and suppression is small. This indicates that, at least for 10-year-olds, the spontaneous use of these emotion regulation strategies is not very effective in regulating their physiological reactions to psychosocial stress. Future research could focus on whether the use of these strategies is more effective at other ages, and which other factors, for example self-esteem, personality, experienced emotions, and position in the peer group, contribute to physiological stress responses at this age.

In conclusion, the current study is the first to investigate the relation between the spontaneous use of the emotion regulation strategies suppression and reappraisal and physiological stress responses to a psychosocial stressor in children. Our results indicate that these emotion regulation strategies are used and can be successfully measured even in 10-year-olds. While the effect of suppression on physiological responses was opposite of what could be expected, reappraisal appeared altogether ineffective at down-regulating physiological responses to a psychosocial stressor in this age group. These results stress the importance of a developmental perspective on the relation between the use of specific emotion regulation strategies and physiological responses, as it shows that results from studies in adult populations are not necessarily generalizable to children. Interestingly, we found a sex difference in cortisol reactivity to the psychosocial stressor. We also found a sex difference in the relation between cortisol reactivity and the use of suppression, indicating that at this age sex may be an important moderator variable in research studying stress reactivity and its correlates.

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Conflict of interest

There were no conflicts of interest, financial or otherwise to declare.

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