THE JOURNAL OF
CHILD PSYCHOLOGY AND PSYCHIATRY

Journal of Child Psychology and Psychiatry 50:4 (2009), pp 482–490 doi:10.1111/j.1469-7610.2008.01982.x

Physiological regulation of stress in referred adolescents: the role of the parent–adolescent relationship

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Background: Psychopathology in youth appears to be linked to deficits in regulating affective responses to stressful situations. In children, high-quality parental support facilitates affect regulation. However, in adolescence, the role of parent–child interaction in the regulation of affect is unclear. This study examined physiological reactivity to and recovery from stress in adolescents at risk for psychopathology, and their associations with internalising and externalising problems and parent–adolescent interactions. **Methods:** A total of 99 adolescents (M = 13.57 years, SD = 1.83) with a history of mental health problems underwent the Alarm Stress Task and were reunited with their primary caregiver after the stressor, while the physiological responses of the parasympathetic (respiratory sinus arrhythmia) and sympathetic (pre-ejection period) systems were measured. The quality of parent–adolescent interaction was determined from observations of secure-base seeking and providing during the task. Affect regulation was measured as physiological reactivity and recovery after the stressor. **Results:** Adolescents with high levels of externalising problems and low levels of secure-base support showed weaker parasympathetic reactivity and recovery. Higher level of adolescent secure-base seeking was associated with stronger sympathetic reactivity and recovery. **Conclusions:** Secure-base interactions between parents and adolescents facilitate physiological regulation of stress, especially for adolescents with externalising symptomatology. **Keywords:** Parent–child interaction, emotion regulation, internalising, externalising, physiological arousal. **Abbreviations:** AST: Alarm Stress Task; PEP: pre-ejection period; RSA: respiratory sinus arrhythmia.

Deficiencies in affect regulation constitute an important explanation for the development of psychopathology in children and adolescents (Southam-Gerow & Kendall, 2002). Dysregulated affective reactions to stressful situations tend to prolong heightened arousal, increasing the likelihood of maladaptive behaviour and the development of emotional and behavioural problems (Bradley, 2000). Emotionally warm, mutually sensitive, and well-synchronised interactions are suggested to facilitate affect regulation in children (Cassidy, 1994). In young children, the quality of the attachment relationship appears to be related to physiological indicators of affect regulation (Oosterman & Schuengel, 2007). However, little systematic research has investigated the role of the parent–child relationship with respect to physiological indicators of affect regulation during adolescence. Furthermore, research has mainly focused on nonclinical populations, but support from parents may be especially important for adolescents who have already exhibited vulnerability to developing emotional and behavioural problems. The present study examined the effect of parent–adolescent interactions on the regulation of arousal during a stressful situation in children and adolescents (given here as 'adolescents') with a history of referral for mental health problems.

Conflict of interest statement: No conflicts declared.

During situations appraised as stressful, the autonomic nervous system (ANS) is involved with initiating and maintaining physiological arousal (Kemeny, 2003). Regulation of arousal during a stressful period may be gauged from two parameters: (1) reactivity, a quantification of the increase in physiological arousal in reaction to a stressor; and (2) recovery, a quantification of the decrease in physiological arousal after a stressor (Linden, Earle, Gerin, & Christenfeld, 1997). Recovery from stress might be important in particular for children with psychopathology because it may indicate resilience against prolonged heightened arousal, which has been associated with the onset and continuation of psychological problems (Bradley, 2000). Both the sympathetic and the parasympathetic branches of the ANS may be involved in stress-related arousal. The sympathetic nervous system is involved with energy expenditure and the mobilisation of 'fight-or-flight' responses, and the parasympathetic branch (in particular the myelinated vagus) functions as an active vagal brake, regulating the activity of the sympathetic branch (Porges, 2003). Parasympathetic withdrawal may therefore facilitate mobilisation of fight-or-flight responses. However, under low levels of stress, parasympathetic increases are needed to inhibit mobilisation responses and facilitate calm behavioural states (Porges, 2007).

Parasympathetic withdrawal during stress (reactivity) and parasympathetic increases after stress

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(recovery) are suggested to facilitate regulation of stress (Porges, 2007), and the parasympathetic system thus is also called the 'emotion regulation system' (Beauchaine, 2001). Conversely, sympathetic increases during stress and weak sympathetic decreases after stress support the activation of fight-or-flight responses that evoke strong emotions of anger and avoidance (Beauchaine, Gatzke-Kopp, & Mead, 2007). Therefore, weak parasympathetic and strong sympathetic reactivity to stress, and weak parasympathetic and sympathetic recovery, might be associated with emotional and behavioural problems. Indeed, parasympathetic decreases in reaction to stress have been found to protect children from the influence of negative environments such as marital conflict (El Sheikh & Whitson, 2006) and parental drinking problems (El Sheikh, 2001). Moreover, poor parasympathetic recovery was found in the children of depressed parents as compared to controls (Forbes, Fox, Cohn, Galles, & Kovacs, 2006). However, studies with clinical samples have provided conflicting results for the association between parasympathetic reactivity and emotional and behavioural problems (Beauchaine et al., 2007; Calkins, Graziano, & Keane, 2007; Crowell et al., 2005). Similarly, the hypothesised association between psychopathology and heightened sympathetic reactivity has received scant empirical support and appears different for children with internalising compared to externalising problems (Beauchaine, 2001; Boyce et al., 2001; Crowell et al., 2005). These equivocal findings suggest that other factors may interact with psychological problems affecting the association with physiological reactivity and recovery.

A review of the literature shows that social support has beneficial effects on buffering physiological reactions to acute psychological stress, especially when it is provided by family members (Uchino, Cacioppo, & Kiecolt Glaser, 1996). More specifically, the parent–child attachment relationship is suggested to improve physiological regulation (Cassidy, 1994). Adolescents with a self-reported insecure attachment style showed increased blood pressure during daily social situations (Gallo & Matthews, 2006). Adults with a secure attachment style had weaker sympathetic reactivity during discussion with their marital partner (Roisman, 2007). However, it is unclear whether the quality of social support *during* a stressful situation also facilitates the physiological regulation of arousal. Moreover, it is unclear whether the effect is adolescent or parent driven. Supportive interactions during a stressful situation may especially be related to physiological recovery from stress because supportive interactions may function in soothing and limiting rumination-induced physiological responses (Christenfeld & Gerin, 2000). Therefore, we expect that secure-base interactions during a stressful situation, when adolescents openly display their distress to a positively involved parent, facilitate physiological recovery from stress in adolescents. An important question that remains is to what extent this is also the case when psychopathology comes into play.

Adolescents with high levels of psychopathology as well as an unsupportive parent–adolescent relationship might be most vulnerable to stress, compared to adolescents with or without psychopathology in a supportive relationship. Is it also the case, then, that the quality of parent–adolescent interaction is associated with sympathetic and parasympathetic recovery after stress, particularly for adolescents with high as compared to low levels of emotional and behavioural problems?

The current study examined sympathetic and parasympathetic reactivity and recovery during a mildly stressful situation in adolescents at risk for emotional and behavioural problems. The Alarm Stress Task (AST) was used, in which participants were required to perform a simple task that presumably all adolescents can do successfully (lying quietly on a bed), but which they all were led to believe that they failed at, by predetermined alarm messages. After the suggested failure, adolescents were briefly reunited with their parent. During this reunion episode, observations were made of the way adolescents approached the parent for support and the way in which the parent provided support to the adolescent. Dickerson and Kemeny (2004) have shown that tasks containing uncontrollable and social-evaluative elements, in which task performance could be negatively judged by others, were associated with the largest stress reactions and the longest times to recover. The Alarm Stress Task was developed to facilitate simultaneous recording of physiological responses, interactive behaviour, and reactions to separations and reunions will minimising possible interference from locomotion and speaking (such as in public speaking tasks). In a preliminary study with 40 adolescents with and without psychological problems, the task was shown to elicit significant increases in arousal, to allow reliable ratings of parent–adolescent secure-base interaction, and to yield meaningful differences between clinical and nonclinical adolescents (Willemen, Goossens, Koot, & Schuengel, 2008).

First, the effects of internalising and externalising problems on physiological reactivity and recovery were examined. Adolescents with higher levels of internalising and externalising problems were expected to show stronger sympathetic reactivity, weaker parasympathetic reactivity, and weaker sympathetic and parasympathetic recovery than adolescents with lower problem levels. Second, we examined the association between secure-base behaviour and physiological responses. Secure-base behaviour of parents as well as adolescents was expected to be related to stronger sympathetic and parasympathetic recovery. We expected higher levels of secure-base behaviour to be related to stronger sympathetic and parasympathetic recovery. Third, the moderating effect of secure-base behaviour was examined. We expected that adolescents with high levels of internalising or externalising problems would especially benefit from high quality secure-base interactions, as indicated by stronger sympathetic and parasympathetic recovery compared to adolescents with high problem levels and a low quality of secure-base interactions.

Method

Participants

The sample was recruited from a longitudinal follow-up study of adolescents and their parents who had been referred four years earlier to a general or a university child psychiatric outpatient clinic in Rotterdam, The Netherlands (Bastiaansen, Koot, Ferdinand, & Verhulst, 2004). A sample of 125 families was selected for participation based on four criteria: IQ above 70, age between 10 and 17 years, living at home with one or two parents, and without any diagnosis in the autistic spectrum. Twenty-three families (18%) refused to participate for a variety of reasons (such as lack of time, severity of child's problems, or lack of interest). Of the 102 parent–adolescent dyads participating in this study, three were excluded from analyses because of missing data due to technical problems during the AST. Finally, 99 dyads (10 fathers; 63 boys) participated in the study. Adolescents with a mean age of 13.57 years (*SD* = 1.83, range 10.24–17.15) and a broad range of problems were included (i.e., attention deficit and disruptive behaviour disorders, anxiety and mood disorders).

Procedure

Permission for this research was granted by the Central Committee on Research Involving Human Subjects and the university hospital medical ethical committee. All qualified families were informed by letter and contacted by phone to request their participation. Informed consent was obtained for all families. None of the participants reported cardiovascular problems. All participants were asked to refrain from using medications or products with caffeine or nicotine for at least four hours prior to participation. At the end of the home visit, the researcher debriefed parent and adolescent and answered all of their questions. They were told that they were deceived to elicit a mildly stressful reaction. They were explicitly told that if they had known that the alarm was programmed, they would not have shown a stressful reaction, and would not have discussed the alarm with their parent. The physiological data were shown graphically on the laptop, so they could see that the task was successfully completed. Adolescents were praised for their successful performance and received €10 for their participation.

Instruments

Alarm Stress Task (AST). The AST (Willemen et al., 2008) is a controlled paradigm in which the adolescents have to lie quietly on their beds in their own bedroom for 21 minutes, while their physiological activity is measured by an ambulatory monitoring system (see below). The experimenter suggests that any movement will set off an alarm signal and could spoil the measurement. However, independent of movement, this alarm signal is given twice. Following each alarm, there is a three-minute reunion with the parent. The AST has been shown to induce significant changes in sympathetic and parasympathetic reactivity in adolescents with and without psychopathology and to elicit variation in secure-base behaviour (Willemen et al., 2008). Information about the duration of the episodes is given in Figure 1.

Distracting objects in the adolescent's bedroom were removed or turned off (e.g., cuddly toys on the bed, television, computer, mobile phone, and watch). A video camera was placed with the adolescent in the room to record their behaviour and that of their parents. Electrodes were placed on the body, connected to an ambulatory monitoring device (see below), which was visibly connected to a laptop near the bed. First, the child's physiological activity, such as heart rate frequency and breathing cycles, was shown to the child on the laptop. Second, the researcher explained the episodes of the task to parent and adolescent, accompanied by PowerPoint slides on the laptop, including 1) a blue slide with an overview of the episodes of the task, 2) a white slide with the text 'Alarm. Try to lie quietly!' in red letters, and a slide with a circle diagram suggesting that 75% of the respondents succeeded in having no alarm. Finally, the researcher started a programmed PowerPoint slide show with the first blue slide and left the adolescent alone. Researcher and parent waited in another room. After three minutes the parent visited the adolescent for one minute. An alarm clock with vibration alert reminded the parent to leave the bedroom. At 6.5 and 14.5 minutes after the start of the task, the white slide with red letters was automatically presented on the laptop. After 30 seconds, the blue slide was

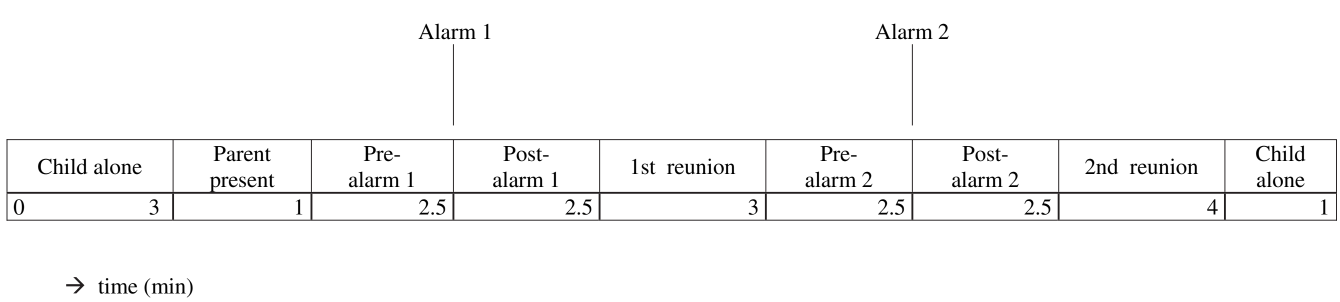

Figure 1 Procedure of the Alarm Stress Task

shown again. A soft acoustic alarm signal accompanied this slide. At 2.5 minutes after each alarm, the parent was instructed to visit the adolescent for three minutes. One minute after the third parental visit, the researcher came in, evaluated the task with the adolescent, and removed the electrodes.

Physiological measures for reactivity and recovery. During the 21 minutes of the task, physiological activity was recorded by the Vrije Universiteit-Ambulatory Monitoring System (VU-AMS) (De Geus & Van Doornen, 1996). Indices of sympathetic and parasympathetic activity were derived by analysis of electrocardiogram and thoracic impedance signals, averaged across 15-second periods. Pre-ejection period (PEP), defined as the interval between the onset of ventricular depolarisation (Q-wave onset in ECG) and the onset of ventricular ejection (B-point in ICG), is regarded as a reliable marker of sympathetic activity. PEP shortens when the sympathetic system is activated. Respiratory sinus arrhythmia (RSA) is an accurate, non-invasive indicator of parasympathetic activity, referring to the variability in heart rate that occurs with the frequency of breathing. RSA decreases as a result of parasympathetic withdrawal. RSA was computed using the peak-to-trough method (Grossman, Van Beek, & Wientjes, 1990); it is defined by the difference score between the shortest inter-beat interval during heart rate acceleration in the inspiration phase, and the longest inter-beat interval during deceleration in the expiration phase. Numerous studies have demonstrated the reliability and validity of the VU-AMS device (De Geus & Van Doornen, 1996; Willemsen, De Geus, Klaver, Van Doornen, & Carroll, 1996). The computation of PEP is automated by computer software (AMSIMP, http://www.psy.vu.nl/vu-ams), but PEP complexes were also individually inspected and adapted when morphologies were inconsistent (Riese et al., 2003). The subtraction of RSA from the respiration and electrocardiogram recordings was automated by the program AMSRES. Respiration data were prepared by checking for unrealistic breathings, and spikes in inter-beat intervals were removed by hand. Because RSA was skewed at all episodes of the AST, its natural logarithm (lnRSA) was used in the analyses.

Time-stamped information from the videotapes was combined with the physiological data to indicate the exact time of the alarm and the start and end times of the episodes. PEP and lnRSA data were averaged across each episode. *Reactivity* was computed by subtracting the average value for the pre-alarm episode from the average value for the post-alarm episode. *Recovery* was defined as the decrease in arousal from the post-alarm episode until the episode after reunion. High scores indicate more reactivity and recovery.

To verify that both alarms in the AST induced heightened arousal, repeated measures ANOVAs were performed on PEP and lnRSA in pre- and post-alarm episodes. As expected, PEP and lnRSA decreased significantly in reaction to the first (PEP: $F(1,98) = 10.48$, $p < .01$, $\eta = .32$; lnRSA: $F(1,98) = 17.00$, $p < .01$, $\eta = .39$) and second alarm (PEP: $F(1,97) = 17.48$, $p < .001$, $\eta = .39$; lnRSA: $F(1,98) = 10.50$, $p < .01$, $\eta = .32$). After the first post-alarm episode, PEP and RSA significantly increased (PEP: $F(1,97) = 13.50$, $p < .001$, $\eta = .35$, lnRSA: $F(1,98) = 11.36$, $p < .01$, $\eta = .32$). Increases were not significant after the second post-alarm episode (PEP: $F(1,93) = 2.05$, $p = .16$, $\eta = .14$, lnRSA: $F(1,97) = .37$, $p = .54$, $\eta = 0$). Significant correlations appeared between the first and second alarms for reactivity (PEP $r = .40$, lnRSA $r = .26$, $p < .01$) and recovery (PEP $r = .53$, lnRSA $r = .36$, $p < .01$).

Parent–adolescent interaction. The Secure Base Scoring System (SBSS; Crowell et al., 1998) is an observation-based scoring manual to measure secure-base interaction. Although originally developed to study interaction between adult romantic partners, the scales of the SBSS tap behavioural dimensions of attachment relationships, which also apply to parent–adolescent relationships. There were five rating scales for observing parent behaviour. *Interest in distress* is the willingness and ability of the parent to be a good listener and a catalyst in encouraging the adolescent to express his feelings and thoughts. *Recognition* represents the immediate awareness of the distress as soon as the adolescent expresses his concern. *Interpretation* is the correctness in understanding the adolescent's concern. *Responsiveness* represents the readiness, flexibility, and effectiveness in supporting the adolescent. The *Summary scale* is the observer's overall impression of the secure-base support of the parent. Also, five rating scales described the secure-base behaviour of the adolescent. *Strength and clarity* of the distress signal refers to the intensity and clarity of the request to the parent that something is bothering him. *Maintenance* of distress is the activity and persistency in maintaining a clear distress signal. *Approach* to the attachment figure refers to a clear and direct expression in behaviour, words, and affect of the desire and need for the support and help of the parent. The *Ability to be comforted* refers to markedly diminished behavioural distress in the adolescent in reaction to comforting behaviour of the parent. The *Summary scale* is the observer's overall impression of the secure-base use of the adolescent.

Two trained observers independently scored adolescent and parent secure-base behaviour during the first and second reunions of the AST on a seven-point scale. The observers were blind to all other information. Higher scores indicated a higher quality of secure-base behaviour. Because of adequate interrater reliability (ICC = .81, range .72–.94), the scores of the two observers were averaged. To arrive at a reliable measure for the quality of the parent–adolescent relationship, secure-base behaviour in the first and second reunion were averaged across both reunions into a mean secure-base score for parent and adolescent ($r_{\text{parent}} = .54$, $p < .01$; $r_{\text{child}} = .77$, $p < .01$). The scores on the five parent secure-base scales (mean alpha = .87) were strongly intercorrelated (mean $r = .53$, $p < .01$), and principal component analyses (PCAs) pointed to one underlying factor (factor loadings .60–.98). Therefore, the scores on the scales were averaged to indicate the secure-base support of the parent. The scores on the adolescent scales (mean alpha = .69), however, were less strongly correlated (mean $r = .36$, $p < .01$), and the PCAs resulted in two factors (factor loadings .22 to .93), with deviating loadings for the comfort scale. Therefore, the comfort scale was excluded, and an average adolescent secure-base behaviour score was computed on the remaining four scales (mean alpha = .83, mean $r = .58$, $p < .01$; factor loading ranging from .67 to .91, one factor).

Psychopathology. The Child Behaviour Checklist/4–18 (CBCL, parent report; Achenbach, 1991a) and the Youth Self-Report (YSR, adolescent report; Achenbach, 1991b) were used to obtain standardised parent and adolescent reports of the adolescent's emotional and behavioural problems over the preceding six months. The questionnaires consist of 120 (CBCL) and 119 (YSR) problem items rated on a 3-point Likert scale (0 = not true, 1 = somewhat true, 2 = very true or often true). In this study, the Internalising (including withdrawn, anxious/depressed behaviours, and somatic complaints) and Externalising (including aggressive and delinquent behaviours) scales were used. Good psychometric qualities of the Dutch versions of both CBCL and YSR have been demonstrated (Verhulst, Van der Ende, & Koot, 1996; Verhulst, Van der Ende, & Koot, 1997). When both parents had filled in the CBCL ($n = 65$), an average score was computed (Bartels et al., 2003). Parent and adolescent reports were moderately to strongly intercorrelated ($r_{\text{internalising}} = .44$, $r_{\text{externalising}} = .55$, $p < .001$) and were averaged to a mean score. Thirty-one percent of the adolescents had current CBCL internalising scores in the clinical range, and 40% had externalising problems in the clinical range, i.e., above the cut-off point $T \geq 63$ ($\geq$ 90th percentile) (Achenbach, 1991a).

Data analyses

The repeated measures design of this study produced a multilevel or nested data structure. Physiological reactivity and recovery scores obtained for two alarm episodes (level 1) were nested within individual participants (level 2). Multilevel analyses (Linear Mixed Models, SPSS 14.0) were performed to identify main and interaction effects of psychopathology and secure-base behaviour on physiological reactivity and recovery. In the Linear Mixed Models procedure, data are permitted to exhibit correlated and non-constant variability, and therefore provides the flexibility of modelling not only the means of the data but their variances and covariances as well. A high proportion of variance was explained on the level of the participant (RSA reactivity 75%, RSA recovery 71%, PEP reactivity 60%, and PEP recovery 47%), indicating that the multilevel model is appropriate (Snijders & Bosker, 1999).

Parasympathetic and sympathetic reactivity and recovery were separately regressed on the independent variables in three steps: internalising and externalising problems in the first step, secure-base behaviour of adolescent and of parent separately included in the second step, and the interactions between secure-base behaviour and internalising and externalising problems in the third step. To test whether predictors contribute to the explanation of change, one predictor at a time is added and change of the fit of the total model is calculated as a deviance statistic (−2loglikelihood). The deviance statistic has a large-sample chi-square distribution with degrees of freedom equal to the difference in the number of parameters estimated. Analyses were controlled for age when appropriate. To avoid the problem of multicollinearity, predictor variables and moderators were centred. Significant interactions were interpreted by generating two regression lines for adolescents with high and low (median split) secure-base behaviour and psychological problems. Internalising and externalising scores below the median ($Mdn_{\text{int}} = 10.00$, $Mdn_{\text{ext}} = 10.00$) fell in the non- or sub-clinical range (Internalising: $M = 5.55$, $SD = 2.79$, range 0–10, Externalising $M = 6.11$, $SD = 2.13$, range .50–10).

Results

Preliminary analyses

Table 1 shows the descriptives for the study variables. Pearson correlations were computed between all variables. As shown in Table 1, age was significantly and negatively associated with internalising and externalising problems, secure-base behaviour of the parent, and RSA reactivity. We found a significant positive association between being a girl and having internalising problems. LnRSA reactivity and recovery were significantly and positively interrelated. The same was true for PEP reactivity and recovery, but PEP and lnRSA measures were not significantly associated.

Table 1 Descriptives and Pearson correlations between variables

		Mean	*SD*	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	Age	13.57	1.83	−.10	−.21*	−.23*	−.12	−.23*	−.24*	.17	−.13	−.13
2.	Gender	1.36	.48	–	.35*	−.04	.09	−.10	.07	−.04	−.03	.09
3.	Internalising problems	10.82	6.91		–	.45*	−.11	.04	−.09	−.11	−.17	−.20*
4.	Externalising problems	12.29	7.77			–	.00	−.03	−.13	−.19	−.14	−.10
5.	Secure-base adolescent	4.12	.88				–	.21*	.03	.04	.15	.33*
6.	Secure-base parent	3.64	.70					–	.11	.01	.10	.17
7.	lnRSA reactivity (ms)	−.11	.27						–	.85**	.09	.11
8.	lnRSA recovery (ms)	.20	.45							–	.10	.12
9.	PEP reactivity (ms)	−.96	2.95								–	.83**
10.	PEP recovery (ms)	2.25	5.62									–

Note. Gender was coded as 1 (males) and 2 (females). lnRSA = respiratory sinus arrhythmia, PEP = pre-ejection period.
$^{**}p < .01$, $^{*}p < .05$.

Table 2 Summary of the multilevel model for parent and self-reported internalising and externalising problems

	lnRSA reactivity (ms)			lnRSA recovery (ms)			PEP reactivity (ms)			PEP recovery (ms)		
	B	*SE*	ΔDS	*B*	*SE*	ΔDS	*B*	*SE*	ΔDS	*B*	*SE*	ΔDS
Step 1			2			2			3			2
Age	.81	1.25										
Internalising (INT)	−.17	.36		−.70	.71		−6.32	3.90		−13.80	8.10	
Externalising (EXT)	−.25	.32		−.25	.63		−.17	3.48		2.17	7.15	
Step 2			17**			8**			16**			22**
Secure-base adolescent (SBa)	−2.28	2.48		.79	4.90		73.60**	26.79		183.59**	55.16	
Step 2			16**			8**			10**			14**
Secure-base parent (SBp)	−1.06	3.17		−2.54	6.17		39.76	34.41		112.23	70.39	
Step 3			3			3			0			0
INT × SBa	−.78	.43		−1.35	.86		−.43	4.76		.94	10.08	
EXT × SBa	.52	.36		1.05	.71		.84	3.93		−2.12	7.99	
Step 3			8**			8**			0			2
INT × SBp	−.93	.61		1.34	1.24		1.31	6.98		2.61	14.12	
EXT × SBp	−1.42*	.50		2.04*	.01		−.39	5.70		10.66	11.53	

lnRSA = respiratory sinus arrhythmia, PEP = pre-ejection period, *B* = parameter estimate in multilevel model, *SE* = Standard error, ΔDS = decrease in deviance statistic.
$^{**}p < .01$, $^{*}p < .05$.

Psychopathology, secure-base behaviour, and parasympathetic reactivity and recovery

As shown in Table 2, including internalising and externalising problems in the prediction of parasympathetic reactivity and recovery did not significantly improve the model fit (χ^2 (2) = 2, $p = .63$; χ^2 (2) = 2, p .63). Including secure-base use of adolescents strongly improved the model fit. The same was true for parent secure-base support. Individual parameters were not significant. The interaction effect between externalising problems and secure-base behaviour of the parent was significant, indicating that adolescents with high levels of externalising problems showed less parasympathetic reactivity and less recovery when secure-base support was low (Figure 2). Excluding the interaction term with internalising problems from the analyses, the interaction effect of externalising problems remained significant for RSA reactivity ($B = -.91$, $SE = .38$, $p = .02$) and was marginally significant for RSA recovery ($B = 1.30$, $SE = .76$, $p = .08$).

To further understand the interaction effect, secure-base interactions of adolescents with internalising and externalising problems were compared. Therefore, adolescents with internalising scores in the (sub)clinical range ($n = 14$) were compared to adolescents with externalising scores in the (sub)clinical range ($n = 17$). Adolescents with clinical scores on both internalising and externalising scales were excluded. We found that externalising adolescents showed stronger secure-base-seeking behaviour than internalising adolescents ($M_{int} = 3.52$, $SD = .82$, $M_{ext} = 4.13$, $SD = .78$, F (4, 26) = 3.12, $p < .03$). In contrast, secure-base support of parents of children with internalising and externalising problems was not significantly different (F (5, 25) = .66, $p = .66$). The discordance between parents and

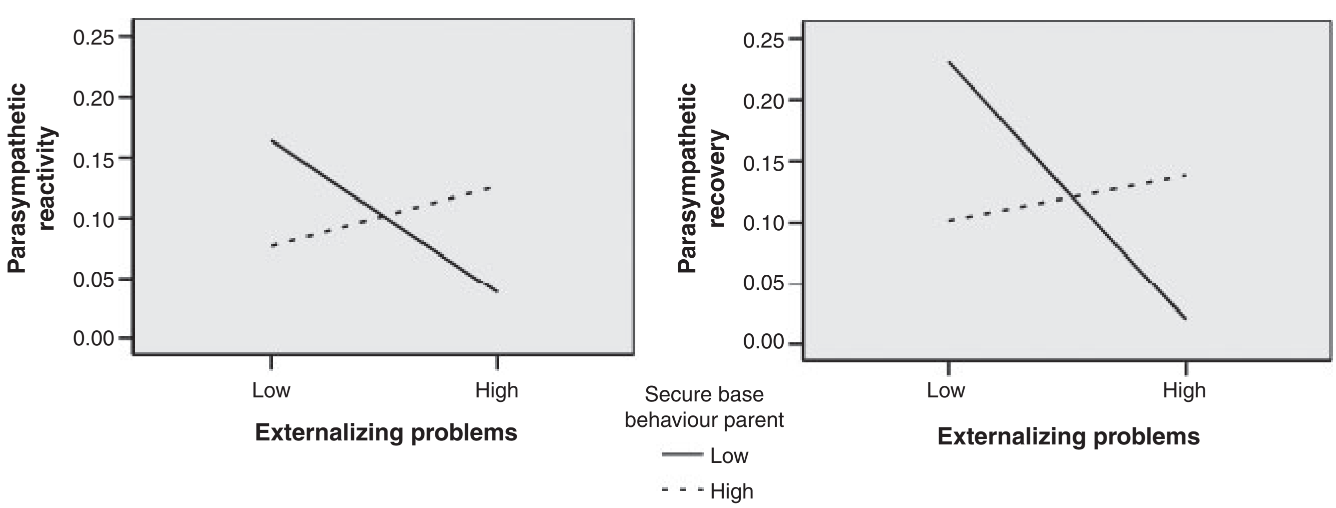

Figure 2 Interaction between externalising problems and secure-base support of the parent in predicting parasympathetic reactivity and recovery

children with internalising problems was underlined further by the correlation between secure-base behaviour of parents and adolescents, which was significantly stronger in the externalising group ($r = .57$, $p < .01$) than in the internalising group ($r = -.19$, $p = .58$) ($Z = -1.96$, $p < .05$).

Psychopathology, secure-base behaviour, and sympathetic reactivity and recovery

Multilevel analyses were repeated for sympathetic reactivity and recovery as dependent variables. As shown in Table 2, the model fit was not significantly improved after internalising and externalising problems were included. However, including secure-base behaviour of the adolescent significantly improved the model fit and predicted stronger PEP reactivity and recovery. The association between secure-base use and PEP recovery remained significant after controlling for PEP reactivity ($B = .75$, $SE = .30$, $p = .01$). The interaction effects were not significant.

Discussion

This study extends previous research on emotion regulation in adolescents by demonstrating that parent–adolescent interactions are involved in regulating physiological arousal in adolescents at risk for psychopathology. Suggested failure on a seemingly simple task induced significant physiological reactivity among referred adolescents, as indicated by parasympathetic withdrawal and sympathetic activation. Reunion with the parent after the stressor facilitated, on average, physiological recovery as shown by parasympathetic increases and sympathetic decreases. Among adolescents with externalising problems, secure-base support of the parent was associated with stronger parasympathetic reactivity and recovery as compared to high-externalising, low-supported adolescents. Additionally, high-quality secure-base seeking of the adolescent was related to stronger sympathetic reactivity and recovery in all adolescents. Internalising and externalising problems were not directly associated with the strength of physiological reactivity and recovery. The role of parent–adolescent interaction in parasympathetic reactivity and recovery appeared different for adolescents with externalising and internalising symptomatology.

Externalising adolescents showed weaker parasympathetic reactivity and recovery when the support from their parents was low. Impaired parasympathetic regulation, in particular hyporesponsiveness, has been connected to aggression and delinquency (Eysenck, 1977; Raine, 1993; Porges, 2007). However, as expected, when secure-base interactions were high, parasympathetic functioning of high-externalising adolescents improved. This is consistent with earlier studies that found a protective effect of the parent–child relationship against further adjustment problems for externalising children and adolescents (Rothbaum & Weisz, 1994), and it might provide clues as to why externalising problems of some adolescents are highly persistent, while others may improve in the course of adolescence and young adulthood (Moffitt, 1993).

Contrary to expectations, no protective effect of secure-base interactions on parasympathetic functioning was found for adolescents with internalising problems. One explanation may be that internalising and externalising adolescents are differently affected by the stressor in the AST. Externalising adolescents may be inclined to experience feelings of frustration and irritability after the alarm, while feelings of incompetence and shame may prevail in internalising children. Frustration and irritability may be easier to recognise for parents and to adequately respond to than feelings of incompetence and shame, especially when these last feelings are less clearly expressed by internalising adolescents. Indeed, as shown by the post-hoc analyses, secure-base behaviour of externalising adolescents was more explicit and secure-base behaviour of their parents was better attuned to adolescents' support-seeking behaviour than in internalising adolescents. This might enable externalising adolescents to co-regulate their distress with their parents, as expressed by improved parasympathetic functioning, while internalising adolescents continue to deal with the distress by themselves.

Unexpectedly, we found that adolescents with high levels of secure-base behaviour showed stronger sympathetic reactivity to stress. This may imply that adolescents who experienced greater distress during the alarm mobilised more secure-base behaviour to regulate their arousal. Apparently, the level of stress plays an important role in mobilising adolescents to display their distress to their parent. While parasympathetic regulation has been shown to be involved with co-regulation within the parent–child relationship, sympathetic activation may be mobilised when co-regulation is insufficient. As expected, sympathetic recovery was increased in adolescents who approached their parents for support. Thus, adolescents approaching their parents for support experienced a shorter duration of the sympathetic mobilising responses associated with fight or flight. The effect of secure-base use on sympathetic recovery was not solely explained by sympathetic reactivity, stressing the importance of secure-base use for down-regulation of the fight–flight response. Stronger sympathetic recovery in adolescents with high-quality secure-base interactions corresponds with the hypothesis that the security of the parent–child relationship promotes adaptive emotion regulation in children and adolescents (Kobak, Cole, Ferenz-Gillies, Fleming, & Gamble, 1993).

Limitations

While physiological indices of arousal showed that the failure suggested within the AST induced stress in adolescents, future research should examine whether the physiological and behavioural responses to this, apparently real, stressor are related to such responses to stressors that occur naturally in the life of adolescents. The contrived nature of the situation, reuniting adolescents and parents right after failure on a task, and the instruction for adolescents to lie quietly, might limit the ecological validity of the secure-base interactions observed. This procedure allowed, however, examination of contemporaneous associations between interaction and psychophysiology, eliminating the bias in physiological measures due to movement. Furthermore, as the differences between adolescents with internalising and externalising problems demonstrated, the associations between arousal and parent–adolescent interaction are moderated by the kind and severity of psychological problems, so that the diversity of emotional and behavioural disorders included in our sample might have diluted the results. Although we controlled for age, the wide age range may have had a similar effect. Given the gender distribution (nearly 75% male) and the overrepresentation of mothers, there was little opportunity to control for different gender compositions of the dyads. Finally, an important avenue for further research would be to link physiological indicators of arousal to self-perceived stress.

Implications

While earlier studies suggested an association between parent–child relationship quality and affect regulation, this is the first study showing for referred adolescents the role of parent–adolescent interactions with regard to affect regulation. The findings are consistent with Porges' (2007) suggestion that social engagement in response to stress is intertwined with the parasympathetic part of the autonomic nervous system. Moreover, in our study sympathetic reactions to stress and recovery were associated with engagement by adolescents of their parents as well. It may be concluded that parent–child interaction continues to be important for adolescents and the regulation of stress. The quality of interaction appeared related to regulation of arousal, at least for adolescents with externalising problems, which may help explain differences in outcomes. The quality of the parent–adolescent relationship might not only be important in the aetiology, but also in the stability, and recovery from psychopathology. This suggests that one avenue for improving emotion regulation in adolescents with psychopathology might be to focus on the quality of secure-base interaction between parents and adolescents.

Acknowledgements

We thank Frank C. Verhulst, Robert F. Ferdinand, and Dennis Bastiaansen and the other staff of the Department of Child and Adolescent Psychiatry of the Erasmus Medical Center Rotterdam, Sophia Children's Hospital for their assistance and their courtesy of granting access to the current sample. We gratefully acknowledge the participation of the adolescents and families who volunteered to be part of our study.

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Manuscript accepted 3 June 2008