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PSYCHIATRY AND PRECLINICAL PSYCHIATRIC STUDIES - ORIGINAL ARTICLE

Sex-specific differences in adrenocortical attunement in mothers with a history of childhood abuse and their 5-month-old boys and girls

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Abstract Recent evidence points to the existence of a neurobiological attunement between mother and child, e.g., associations between maternal and child hypothalamic–pituitary–adrenal (HPA) axis functioning. As maternal history of abuse (HoA) has been shown to negatively affect mother–child interaction and HPA-axis functioning, we theorized those experiences to exert an influence on cortisol attunement, and we examined the role of infant gender in this context. Shortly after birth of their first child, a community sample of women was screened using the Childhood Trauma Questionnaire. Mothers reporting moderate or severe sexual and/or physical abuse were included in the maltreatment group ($n = 41$; MG) and compared with a non-maltreated comparison group ($n = 47$; CG). At the child's age of 5 months, mother and infant baseline salivary cortisol was collected on two consecutive days between 11 and 1 o'clock. Correlation analyses confirmed an association between maternal and infant salivary cortisol levels for the complete sample. However, hierarchical regression models revealed a moderating role of maternal HoA and infant gender: in the CG, cortisol attunement was only significant in mother–daughter dyads, whereas in the MG, we found cortisol levels to be associated only in mother–son dyads. Consequently, alterations of neurobiological attunement between mother and child might compose a mechanism for the transgenerational transmission of adverse childhood experiences.

Keywords Child maltreatment · Attunement · HPA-axis · Cortisol · Mother–child interaction · Gender

Introduction

Examining the relationship between mothers and their children has been a core area of developmental research for decades (Bornstein 2013; Brazelton et al. 1974). In addition, research trying to illuminate mechanisms of transgenerational transmission of child abuse builds on the study of mother–child interaction across generations (Dixon et al. 2005; Egeland et al. 1988). Multiple terms, such as co-regulation, reciprocity or bidirectionality, have been used to describe the temporal and dynamic process of behavioral and emotional transactions between mother and child. Between an infant's age of 3–6 months, mother–child interaction becomes more and more mutually regulated, forming a couple-specific "dance" (Feldman 2012; Tronick 1989). This process, which is here labeled as "attunement" (Bornstein 2013), is considered to be adaptive, and to exert a positive impact on offspring's developmental outcomes (Feldman 2012; Sroufe 2000). Behavioral mother–child attunement, for example, has been associated with increased self-regulation capabilities, attachment security and lower levels of behavior problems (Beebe et al. 2010; Criss et al. 2003; Wolff and Ijzendoorn 1997; Kochanska and Kim 2014; Suveg et al. 2016). In case of a maternal history of childhood abuse (HoA), however, results suggest this attunement to be disturbed, which appears to heighten the risk for transgenerational

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transmission of adverse childhood experiences (Dixon et al. 2005; Fuchs et al. 2015).

Only recently, theorists have started to include biology into the construct of harmonious mother–child relationships, aiming at a more integrated, holistic framework (Feldman 2007; Ruttle et al. 2011). In light of this, mother–offspring "interactional attunement" refers not only to the matching of behavior and affective states during social contact, but to the matching of physiological processes as well (Feldman 2007, 2012). A system appearing to be part of this physiological attunement between mother and offspring is the hypothalamic–pituitary–adrenal (HPA) axis. The HPA axis releases the stress hormone cortisol, (CT), a glucocorticoid helping to restore homeostasis in case of environmental demands. Cortisol has been shown to be under strong social regulation in infancy (Hostinar and Gunnar 2013; Tarullo and Gunnar 2006). Over the last 15 years, several independent research groups have reported significant associations between maternal and child cortisol levels in diverse samples and study designs. Gitau and colleagues (1998, 2004) were able to identify concordance between paired maternal and fetal plasma cortisol as well as corticotrophin releasing hormone (CRH) levels even before birth (Gitau et al. 1998, 2004). Continuing in infancy, four studies reported salivary cortisol attunement in mother–child pairs, two of them examining samples of preterm infants before and after holding (Castral et al. 2015; Neu et al. 2008), one study investigating dyads participating in an infant sleep training program (Middlemiss et al. 2012), and one study examining 6-month-old infants from a low-risk community sample before and after the still face procedure (Feldman et al. 2010). However, sample sizes were small ranging between $n = 20$ and $n = 53$. Studies reporting attunement in toddlerhood mainly focused on salivary cortisol levels before and after stress paradigms (Atkinson et al. 2013; Feldman et al. 2013; Hibel et al. 2015), thereby using diverse samples such as children exposed to continuous war (Feldman et al. 2013) or a low income, non-urban sample (Hibel et al. 2015). Additionally, attunement in salivary cortisol levels between mother and child has been shown in middle childhood (Bright et al. 2012; Granger 1998; LeMoult et al. 2015; Williams et al. 2013) and even in adolescence (Papp et al. 2009; Saxbe et al. 2014) for both basal cortisol levels as well as pre/post-challenge designs. In summary, there is valid evidence for the existence of an "endocrine fit" (Feldman et al. 2013) in mothers and their children.

However, since this is a relatively new area of research, there are only a few studies so far who have been trying to identify influencing factors and trajectories of cortisol attunement. Recent evidence suggests a strong susceptibility to environmental factors: stress or noise have been shown to exert a detrimental effect on cortisol attunement (Hibel et al. 2015; Neu et al. 2008). In contrast, mild challenge, maternal sensitivity or time spent together have been found to have a supporting effect on cortisol attunement (Atkinson et al. 2013; Papp et al. 2009; Ruttle et al. 2011; Sethre-Hofstad et al. 2002). These studies seem to indicate that maternal factors and characteristics of the mother–child relationship may be meaningful in the development of adrenocortical attunement, but there are no studies examining the impact of a maternal history of abuse (HoA) on cortisol attunement.

Associations between this apparent physiological attunement system and maternal history of childhood abuse would be in line with a vast body of literature describing a detrimental impact of HoA on behavioral and affective attunement (Bert et al. 2009; Dixon et al. 2005; Fuchs et al. 2015; Lyons-Ruth and Block 1996; Smith et al. 2014). Furthermore, HoA has been shown to provoke dysregulation of the HPA axis, especially in victims of chronic maltreatment, placement into foster care or institutional deprivation (Bernard et al. 2010, 2015; Tarullo and Gunnar 2006; Feldman et al. 2013). Females, who have experienced childhood sexual abuse, seem to exhibit different developmental trajectories in basal cortisol production compared to nonabused females (Trickett et al. 2010). However, consequences of potentially altered HPA axis functioning for mother–child-attunement in HoA victims is vastly understudied and therefore a subject of speculation.

An important factor, which has been ignored in most studies examining cortisol attunement, is child gender—supposedly due to small sample sizes or different foci of the studies. Three research groups included and reported gender analysis in their studies (Ruttle et al. 2011; Saxbe et al. 2014; Williams et al. 2013), but none of them examined infants. Saxbe and Colleagues (2014) measured parent and child cortisol level in a community sample before, during and after a conflict discussion task. They found attunement between parents and adolescents to be higher in same-gender dyads (Saxbe et al. 2014). Ruttle and colleagues (2011) examined preschool children and their mothers with mostly low socioeconomic backgrounds and found cortisol attunement to be more common in high sensitivity mother–daughter dyads than in high sensitivity mother–son dyads (Ruttle et al., 2011). The third study, Williams and colleagues (2013), reported the interesting find of a stronger attunement in mothers and sons in a sample characterized by a high prevalence of anxiety disorders in mothers. Mothers and sons exhibited flattened diurnal cortisol more frequently than mothers and girls (Williams et al. 2013). Tronick and Reck (2009) concluded from their studies that, due to their lower self-regulatory skills, infant boys tend to be affectively more reactive towards their mothers (Tronick and Cohn 1989; Tronick and Reck 2009; Weinberg et al. 1999). As they are less

capable to self-regulate, infant boys put more focus on their mothers, and display more signals expressing distress and demands for contact than girls do. Girls, on the other hand, seem to have a more object driven focus, show greater constancy in emotion and better self-regulation of emotional states (Feldman 2003; Gartstein and Rothbart 2003; Tronick and Reck 2009; Weinberg et al. 1999). In light of this, it could be hypothesized that infant boys are more vulnerable to maternal behavioral, affective or physiological dysregulation.

Indeed, a higher susceptibility in boys in the context of transgenerational transmission of stress has already been shown in animal models (Bock et al. 2014). In case of maternal HoA, which has been associated with dysregulated HPA-axis functioning, girls would be able to protect themselves by "tuning out" physiologically, whereas boys would be especially "tuned in", as shown in the study of Williams and colleagues (2013). Furthermore, as boys seem to be more reactive and demanding in early interaction, this might lead to them being the center of maternal attention more frequently, making it easier for mothers to know their needs and react on them, even physiologically. This could be especially effective in case of lower maternal emotional availability, as it has been shown in mothers with HoA (Fuchs et al. 2015).

In conclusion, there seems to be valid evidence for the existence of an adrenocortical attunement between mothers and their infant boys and girls. However, studies on influencing factors and trajectories of cortisol attunement are lacking. Some results indicate that maternal childhood experiences could exert an influence on the association, and maternal history of abuse is suggested as a likely candidate. A second factor possibly influencing cortisol attunement between mother and infant is infant gender. We therefore investigated the following hypotheses:

Hypotheses

1. First, we expected to find an association between maternal baseline salivary cortisol and infant baseline salivary cortisol as an indicator of mother–child adrenocortical attunement.
2. Secondly, we hypothesized that maternal experiences of HoA would have a detrimental effect on mother–child adrenocortical attunement.
3. Third, we expected gender of the infant to exert an influence on the association between cortisol attunement and impact of HoA. For the comparison group (CG), we expected significant correlations for both genders. For the maltreatment group (MG), we expected higher attunement in mother–son dyads than in mother–daughter dyads.

Method

Participant recruitment and study design

The study was approved by the Institutional Review Board of the Faculty of Medicine, University of Heidelberg, Germany. For an 18-month period, all women giving birth to a child in the cities of Heidelberg and Mannheim, were contacted by mail ($N = 2001$). They were presented with an information sheet about the study and a respective consent form, a sociodemographic questionnaire, and the Childhood Trauma Questionnaire (CTQ; Bernstein and Fink 1999). Written informed consent was obtained from all participating women before study inclusion. Women whose children were born as singleton, term babies (>37th week) with APGAR scores >7 were eligible to participate in the study. Twins and infants <2500 g were excluded.

Out of 2001 mothers who were contacted by mail, 748 completed the CTQ (37.4 %), and 73 (9.8 %) of those scored above the cut-off for moderate-to-severe abuse on the physical (score >9) and/or sexual abuse scale (score >7). Out of these, six had infants who did not meet eligibility criteria (APGAR, birth weight, and date), four had children with repeated infections or acute illnesses preventing them from participating, and six declined for lack of time. Thus, 58 mother–infant pairs were included to form the maltreatment group (MG). From the remaining 675 mothers who scored below the cut-off for moderate to severe physical or sexual abuse, 417 mothers were excluded from the comparison group (CG) because their scores fell in the intermediate group of minor to moderate abuse. Out of the remaining 258 mothers with a score of 0 for sexual or physical abuse, matching was performed according to the following criteria, ordered in priorities: child gender, maternal marital status and education, and number of siblings, resulting in a CG of 61 mothers. The original sample consisted of 58 mothers with a history of abuse (MG) and 61 comparison mothers (CG). Detailed results of the study have been described elsewhere (Fuchs et al. 2015; Moehler et al. 2007).

As the study of cortisol was not implemented in the original study proposal but added as a supplement, we were not able to assess the first 12 of the originally examined 119 mother–infant dyads. In addition, 19 mother–infant pairs had to be excluded due to participant refusal or insufficient sample quality. Out of the original sample, complete cortisol data were available from 88 mother–infant dyads. There were no differences between the excluded dyads and the remaining 88 mother-infant pairs in terms of level of psychopathology [$t(116) = 0.11$; $p = 0.914$], maternal age [$t(117) = -0.50$; $p = 0.616$], maternal smoking habits χ^2 (4, 119) = 4.38, $p = 0.36$),

child gender [χ^2 (1, 119) = 0.03, $p = 0.86$] or maternal education [χ^2 (2, 119) = 1.19, $p = 0.553$]. Additionally, the proportion of women assigned to the CG compared to women assigned to the MG was stable ($z = 1.46$, $p = 0.144$).

Final sample

The final sample consisted of $N = 88$ mothers and their 5-month-old infants. Percentage of male infants did not significantly differ in MG ($n = 23$; 56.1 %) and CG ($n = 24$; 51.1 %). Most mothers were highly educated, with $n = 38$ (44.2 %) of the 88 mothers reporting to have finished grammar school, and $n = 27$ (31.4 %) of them reporting to have achieved a university degree. Moreover, $n = 85$ (96.6 %) lived in a stable relationship with the child's father (see Table 1 for further information and group comparisons).

Measures

Maternal and infant cortisol

During their lab visit, mothers were given detailed instruction for at home cortisol collection. Basal salivary cortisol levels were collected on two consecutive days using salivette collection devices (Sarstedt, Germany). Mother–child dyads had to chew on cotton rolls at the same time for 3 min between 11 o'clock a.m. and 1 o'clock p.m. Mothers were asked, with reference to both themselves and their infants, to refrain from brushing their teeth, eating, and drinking 60 min before procedures to avoid contamination. All samples were assayed in duplicate (on two consecutive days) and the average of the duplicates was used in all analyses. Subjects were instructed to collect saliva out of their oral cavity in a quiet and non-stressed situation, store the salivettes in the fridge and send them back in a covered envelope. The salivettes were centrifuged at 300 rpm for 5 min. Salivary-free cortisol concentrations were measured at the Steroid Laboratory of the Department of Pharmacology, University of Heidelberg, by a specific in-house radioimmunoassay (RIA) using tritiated steroid (Amersham Biosciences, Freiburg, Germany) and antibodies, raised and characterized in the steroid laboratory, as described elsewhere (Vecsei 1979). Cortisol was extracted from 500-µL saliva aliqots using dichloromethane prior to RIA. The intra-assay coefficient of variation (CV) was 5.95 % and inter-assay CV was <10 %.

Maternal history of abuse

A history of childhood physical or sexual abuse was assessed by the German version (Driessen et al. 2000) of the Childhood Trauma Questionnaire (CTQ; Bernstein and Fink 1999). The CTQ is a self-administered questionnaire with 28 items that quantifies the frequency of abusive experiences on a 5-point sale, ranging from 0, never, to 5, very often. Different types of childhood trauma are

Table 1 Sample characteristics for maltreatment and comparison group

Demographics	Maltreatment group ($n = 41$)		Comparison group ($n = 47$)		*df*	Pearson-Chi-square	*p* value
	n	%	*n*	%			
Child gender (male)[a]	23	56.1	24	51.1	1	0.22	0.637
Mother's relationship status[a]							
Mother in a relationship	38	92.7	47	100	1	3.56	0.059
Mother married	32	78.0	41	87.2	1	1.31	0.253
Mother's educational status[a]							
Intermediate school (or less)	10	25.6	11	23.4			
Grammar school	17	43.6	21	44.7			
University	12	30.8	15	31.9	2	0.58	0.971
	M	SD	*M*	SD	*df*	*t* value	*p* value
Age mother[b]	32.07	5.69	32.49	5.06	86	−0.36	0.717
Birth weight child[b]	3.93	1.15	3.87	1.05	86	0.23	0.817
Salivary cortisol mother (ng/mL)	2.09	1.27	2.08	1.33	86	0.04	0.965
Salivary cortisol child (ng/mL)	2.67	1.78	3.00	1.41	86	−0.92	0.353
SCL-90 global severity index[b]	0.47	0.31	0.22	0.20	86	4.53	<0.001

[a] Pearson Chi-square

[b] Student's *t*-test (two-tailed, alpha of 0.05)

operationalized on five subscales (emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect). Subjects are asked to rate the frequency of abusive experiences during their childhood and adolescence. Cut-off scores have been determined to define the severity of the abusive experiences: none or minimal, minor, moderate, and severe (Bernstein and Fink 1999). The CTQ has demonstrated strong psychometric properties in community (Scher et al. 2001), clinical (Bernstein et al. 2003), and mixed samples (Spinhoven et al. 2014) and has been evaluated to be the leading retrospective measure of childhood maltreatment currently in use (Tonmyr et al. 2011). The subscales of the German CTQ version have shown high internal consistencies ($\alpha \geq 0.80$) with the exception of the "physical neglect" subscale, and construct validity was supported (Klinitzke et al. 2012). Likewise, in our sample of $N = 119$ mothers, Cronbach's α for each subscale was high (physical abuse: $\alpha = 0.88$; sexual abuse $\alpha = 0.80$; emotional abuse: $\alpha = 0.88$, and emotional neglect: $\alpha = 0.93$) except for the "physical neglect" subscale, which showed only moderate internal consistency ($\alpha = 0.68$).

Maternal psychopathology

To control for potential differences in psychopathology, mothers were asked to fill out the German Version of the Symptom Checklist 90-Revised (SCL-90-R; Franke and Derogatis 2002), a 90-item self-report inventory measuring psychological distress in nine dimensions and three global scales. The global severity index (GSI), obtained by averaging the scores over the 90 items, is considered to be the best indicator of the current degree of psychological distress (Franke and Derogatis 2002) and its use has been reinforced by recent validation studies (Urbán et al. 2014). The SCL-90-R has been shown to have satisfactory psychometric properties and has been used widely in research (Derogatis and Unger 2010; Urbán et al. 2014).

Statistical analyses

To test mother–child cortisol synchrony, we examined correlations using the spearman rho correlation coefficient. In addition, we conducted hierarchical multiple regression analyses (Aiken et al. 1991) to control for potential confounds and subsequently add variables of interest to the regression model. Child cortisol level was the dependent variable in the regression model. For all hypotheses, we included the following control variables in block one: maternal age, birth weight child and maternal psychopathology, as these factors have been found to influence behavioral attunement (Easterbrooks and Biringen 2005; Belsky and Jaffee 2006; Bornstein 2013). To test the first hypothesis of a mother–child cortisol attunement, maternal cortisol was entered in block 2 (see Table 2). For the second hypothesis, the factor group was added in block 3, and the group × maternal cortisol interaction was added to the model in block 4. Finally, the two-way interactions between gender, group and maternal cortisol were added in block 5, and their three-way interaction in block 6. In addition, we applied the PROCESS macro written by Andres Hayes (2012). PROCESS probes the interaction term using an alternative method for making inferences about indirect effects that does not rely on the normality assumption by applying bias corrected bootstrapping intervals (Preacher and Hayes 2008). The number of bootstrap samples used to determine 95 % bias-corrected bootstrap confidence intervals was 5000. For dichotomous moderators, PROCESS produces the conditional effects of the independent variable ("simple slopes") at each of the two values of the moderator, along with a standard error, *t*-, and *p* value. Variable *W* moderates the relationship between the independent and the dependent variable for values of *W* where the confidence bands do not contain zero (Preacher et al. 2007).

Table 2 Maternal history of childhood abuse, maternal cortisol and child gender as predictors for child cortisol levels

Model	Predictor	β	t	β_{sig}
(1) $R^2 = 0.033$	Gender	0.01	0.08	0.938
	Birth weight	0.03	0.27	0.786
	Maternal age	−0.04	−0.39	0.697
	SCL 90 GSI	−0.18	−1.68	0.097
(2) $R^2 = 0.106$	$Cort^m$	0.27	2.57	0.012
(3) $R^2 = 0.107$	Group	0.04	0.34	0.734
(4) $R^2 = 0.131$	$Cort^m$ × group	−0.57	−1.37	0.174
(5) $R^2 = 0.136$	$Cort^m$ × gender	0.23	0.64	0.523
	Group × gender	0.07	0.14	0.886
(6) $R^2 = 0.217$	$Cort^m$ × group × gender	3.67	2.83	<0.01

Hierarchical regression analysis

GSI Global severity index (SCL 90-R), *Cort*^{m} maternal salivary baseline cortisol, *Group* MG/CG; dependent variable: infant salivary baseline cortisol ($Cort^c$); $\alpha = 0.05$

Results

No statistically significant group differences were found regarding any of the demographic variables examined (see Table 1 for sample characteristics for each group). Cortisol mean values were $M = 2.07$ ng/mL (SD 1.29 ng/mL) for mothers and $M = 2.83$ ng/mL (SD 1.59 ng/mL) for infants. Regarding hypothesis 1, our results show a significant association between maternal baseline salivary

cortisol and infant baseline salivary cortisol (Spearman's rho; $N = 88$, $r = 0.23$, $p = 0.034$). Regression analyses confirmed the predictive value of maternal cortisol in respect to child cortisol above and beyond potential confounding variables such as maternal psychopathology (see Table 2). As for hypotheses 2, hierarchical regression analysis did not confirm a moderating effect of maternal HoA, as the interaction term did not reach significance. In addition, neither did we find significant main effects of maternal HoA or gender on child cortisol level, nor did any of the two-way interaction terms reach significance (see Table 2). However, by testing hypothesis 3, we found a significant three-way interaction between maternal HoA, maternal cortisol level and child gender ($\beta = 1.58$; $p < 0.01$; see Table 2). Applying the PROCESS macro (Hayes 2012) results show significant attunement in the CG only in mother–daughter pairs, whereas in the MG, only mother's and son's cortisol level display significant associations (see Fig. 1a, b). In both groups, significant relations are positive, meaning higher maternal cortisol is associated with higher child cortisol (for an overview of the conditional effect see Table 3). Table 4 summarizes the conditional effect of the interaction between maternal cortisol level and maternal HoA on child cortisol level, depending on gender: In our sample, maternal HoA exerts its influence on adrenocortical attunement only in mother–son dyads.

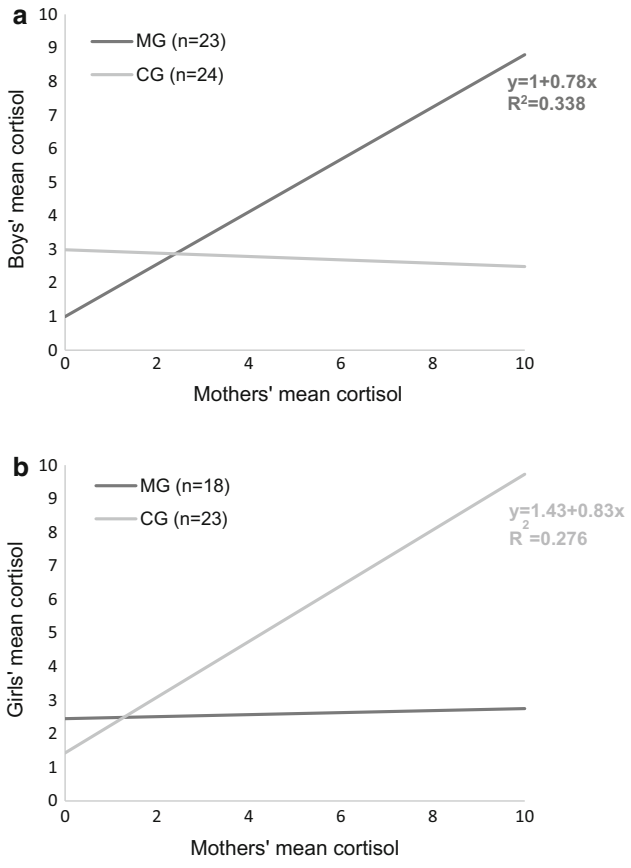

Fig. 1 **a** Mother–son-adrenocortical attunement. **b** Mother–daughter-adrenocortical attunement. *MG* Maltreatment group, *CG* comparison group

Table 3 Conditional effect of $Cort^M$ on $Cort^C$ at values of gender and group

Gender	Group	β (*SE*)	*t*	β_{sig}	LLCI	ULCI
Male	MG	0.80 (0.23)	3.53	<0.01	0.35	1.25
Male	CG	−0.05 (0.19)	−0.28	0.777	−0.14	0.32
Female	MG	0.03 (0.36)	0.08	0.935	−0.70	0.76
Female	CG	0.83 (0.33)	2.51	0.014	0.17	1.49

MG Maltreatment group, *CG* comparison group, $Cort^m$ maternal baseline cortisol, $Cort^c$ infant baseline cortisol, level of confidence for confidence intervals: 95 %

Table 4 Conditional effect of the $Cort^M$*group interaction on $Cort^C$ at values of gender

Gender	β (*SE*)	*t*	β_{sig}	LLCI	ULCI
Male	−0.85 (0.30)	−2.88	<0.01	−1.44	−0.26
Female	0.80 (0.49)	1.63	0.108	−0.18	1.79

$Cort^m$ Maternal baseline cortisol, $Cort^c$ infant baseline cortisol, level of confidence for confidence intervals: 95 %

Discussion

We examined adrenocortical attunement in mothers with a history of childhood abuse and their 5-month-old infants. In line with previous work (e.g., Castral et al. 2015; Feldman et al. 2010), we were able to confirm an association between maternal and infant salivary cortisol levels both in mother–daughter and mother–son dyads. In addition, we identified two important moderating factors influencing the link between maternal and child physiological systems: maternal history of childhood abuse and child gender.

In the CG, our data show adrenocortical attunement in girls and their mothers, but not in boys and their mothers. Correspondingly, stronger links of physiological attunement in mother–daughter pairs have been reported in two previous studies focusing on normative samples and older age groups (Ruttle et al. 2011; Saxbe et al. 2014). Thus, this is the first study to describe stronger attunement in mother–daughter pairs compared to mother–son pairs in an infant sample. Generally, growing evidence suggests sex-specific HPA-response patterns, especially in adult samples (Kirschbaum et al. 1999), whereas research on gender differences in HPA-axis-activity in children or even infants is more sparse (Hatzinger et al. 2007; Kudielka et al. 2004).

However, preliminary evidence indicates gender differences in baseline and stress-elicited HPA-system activity already in preschool age (Hatzinger et al. 2007; Rosmalen et al. 2005; Williams et al. 2013). According to Feldman (2003), who studied 100 first-time mothers and fathers interacting with their 5-month-old infants, attunement might build on the infant's biological rhythms. A gender-specific physiological system, in addition to gender-specific affective reactivity and interactional quality (Feldman 2007; Weinberg et al. 1999), might be more easily matched in same-sex dyads (Feldman 2003). That way, girls would be more "tuned in" than boys in normative samples of mother–child dyads.

Contrary to this, in the MG, we found significant adrenocortical attunement only in mothers and their sons. Examining a high-risk sample characterized by a high prevalence of anxiety disorders in mothers, Williams and colleagues (2013) reported a similar effect of gender in adrenocortical attunement: mothers showing flatter diurnal slopes tended to have children with a similar diurnal profile only if they had sons. Recent results indicate adrenocortical attunement to be dependent on sensitive behavior on part of the mother, linking higher sensitivity to higher attunement (Atkinson et al. 2013; Hibel et al. 2015; Ruttle et al. 2011; Sethre-Hofstad et al. 2002). Previous studies have also indicated a possible link between both maternal history of childhood abuse and maternal anxiety disorders and less optimal parenting behavior in infancy (Smith et al. 2014; Fuchs et al. 2015; Nicol-Harper et al. 2007; Feldman et al. 2009). One might hypothesize that, under risk conditions such as lowered maternal sensitivity, mothers are more strongly attuned to boys. Research findings suggest that infant boys, potentially due to lower self-regulatory capacities, put more focus on their mothers, demand for contact more than girls do and, in addition, display more signals expressing distress (Gartstein and Rothbart 2003; Tronick and Cohn 1989; Weinberg et al. 1999). This could be in line with results describing mothers of infant sons reporting higher levels of parenting stress than mothers of infant girls (Scher and Sharabany 2005). As a consequence, boys might provoke higher amount of attention from mothers, and, as they seem to be highly reactive, expressive and less withdrawn, mothers would have to invest less effort in understanding their needs and responding adequately. In case of lower maternal sensitivity, the reactive, demanding interactional style of infant boys might provoke and allow mothers to be "attuned". Infant girls, however, seem to have higher effortful control capabilities (Else-Quest et al. 2006), evidence greater emotional stability over time (Tronick and Cohn 1989) and display more withdrawal (Gartstein and Rothbart 2003). Consequently, attunement between mothers less likely to provide high sensitive care and their female infants might be impaired. In conclusion, in normative mother-infant-pairs with normative behavioral interactional quality, the underlying same-sex biological systems might lead to higher attunement in mother–daughter than mother–son dyads. However, in at-risk mother–infant pairs, whose behavioral attunement system might be disturbed, interactional qualities of the infant such as reactiveness and expressiveness might become a matter of high importance. This could potentially lead to infant boys showing higher physiological attunement to their mothers with a history of childhood abuse.

Interestingly, we did not find any direct effect of maternal psychopathological symptoms on adrenocortical mother–child-attunement in our sample. Since we assessed psychopathology using maternal self-report, we cannot rule out the possibility that response bias or a limited ability to self-reflect affected the results. In addition, we were not able to investigate the full history of mothers' psychopathology. However, we examined a community-based sample with high levels of social support reporting mostly low or average levels of psychological distress. The missing link between maternal psychopathological symptoms and adrenocortical attunement could be due to limited range or low average symptom severity. To elucidate the associations between physiological attunement and psychopathology, future studies should therefore include clinical samples.

Furthermore, contrary to earlier research (Bernard et al. 2015; Trickett et al. 2010), we did not find significant differences in mean values of salivary cortisol between MG and CG. However, as we assessed basal cortisol levels on two consecutive days, we did not examine awakening response or followed up on the diurnal rhythm of cortisol activity of those dyads. We therefore cannot completely rule out the possibility that there might still be a difference in HPA activity between both groups.

Strengths

This study was based on sampling from the general population and the only manifest difference between mothers was the history of childhood abuse and neglect, as psychosocial status was carefully matched. In addition, this is the first study to examine adrenocortical attunement in mothers with and without a history of childhood abuse, thereby contributing to the yet limited number of studies examining influential factors of physiological attunement. It is also the first study to focus on the effect of gender on attunement in infancy.

Limitations

In our study, we examined cross-sectional intercorrelation between salivary baseline cortisol, hypothesized to reflect concurrent attunement between mother and child. However, in current literature, cortisol assessment usually comprises of analyzing cortisol awakening response data and diurnal trajectories of cortisol, requiring multiple assessment points per day. It would be interesting to see associations between cortisol attunement, HoA and gender in time-lagged analysis. Both assessment methods represent distinct constructs and therefore different theoretical implications. Cross-sectional intercorrelation might reflect transmission of arousal from one person to another, whereas covariation around a trajectory could reflect similar reactivity to a shared context (Saxbe et al. 2015). A deeper understanding of both processes would be beneficial, as well as longitudinal data on attunement over the course of development. Additionally, there is evidence that an individual's diurnal cortisol rhythm may be influenced by genetic mechanisms (Van Hulle et al. 2012), which suggests further investigation of genetic factors. However, Schreiber et al. (2006) were able to show that family members had similar cortisol levels not only due to genetic influences, but also depending on the degree to which they shared environmental factors. Cortisol levels have also been shown to be affected by menstrual cycle, which we did not include in our analyses. Additionally, due to limited resources, we did not use clinical interviews to screen for current or history of maternal psychopathology. We did, however, control for current symptomatology using a valid and broadly utilized questionnaire. At last, in a recent study, Saxbe and Collegues (2014) were able to show not only adrenocortical attunement between adolescents and their mothers, but between youth and their fathers also. It would have been interesting to see if this recent finding might be replicable in an infant sample, where mothers usually are the main caretaker of the child.

Conclusion

This is the first study examining adrenocortical attunement in a sample of mothers with a history of abuse. Our findings indicate an important role of maternal childhood experiences, interacting with the child's gender, as there was significant attunement in the MG only in mother–son dyads, and in the CG only in mother–daughter dyads. Consequently, in addition to behavioral attunement and dependent on child gender, physiological attunement between mother and child might compose a mechanism for the transgenerational transmission of adverse childhood experiences.

There are many questions unanswered. It is suggested that higher level of physiological attunement is associated with positive developmental outcome as it is the case in behavioral attunement (Feldman 2012). However, empirical evidence to underline this assumption is lacking. Examining samples such as mothers with a history of abuse, who have been shown to display dysregulated HPA-functioning, question arises whether a strong coupling between mother and child is still beneficial. It may be possible that, in this case, strong adrenocortical attunement changes from being a protective to being a risk factor in development. Inferring from our results, boys might then be at greater risk than girls are, which has also been shown in animal studies (Bock et al. 2014). Furthermore, the exact mechanisms and trajectories of physiological attunement are vastly unknown. Prospective longitudinal studies are needed to shed light on functioning, influential factors, developmental pathways and, ultimately, consequences for the developing child.

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