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ORIGINAL PAPER

The Role of Supportive Parenting and Stress Reactivity in the Development of Self-Regulation in Early Childhood

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Abstract

Maternal sensitivity and supportive discipline are important determinants of child self-regulation. Some evidence suggests that specific genetic or temperamental markers determine children's susceptibility to the impact of maternal parenting on child self-regulation. Cortisol reactivity as a susceptibility marker moderating the relation between maternal parenting and child self-regulation has not yet been studied. In this longitudinal population-based study ($N = 258$), the moderating role of infant cortisol stress response to the Strange Situation Procedure at age 1 was examined in the association between parenting (sensitivity and supportive discipline) at age 3 and child self-regulation at age 3 and 4. Maternal sensitivity and supportive discipline were related to child immediate and prolonged delay of gratification at age 3, and maternal sensitivity was related to working memory skills at age 4. No evidence of differential susceptibility to maternal parenting was found, based on differences in infant cortisol stress response.

Keywords Self-regulation · Infant stress reactivity · Maternal sensitivity · Maternal supportive discipline · Differential susceptibility theory

Highlights

- Maternal sensitivity and supportive discipline relate to child immediate and prolonged delay of gratification at age 3.
- Maternal sensitivity is related to child working memory skills at age 4.
- No evidence was found for differential susceptibility to maternal parenting based on child stress reactivity.
- Our findings emphasize the importance of parental socialization for the development of self-regulatory functions in children.

The capacity of children to flexibly regulate cognition, emotions, and behavior (*self-regulation*) is crucial for a myriad of positive developmental outcomes (Bridgett et al., 2015; Moffitt et al., 2011), including academic success and cognitive development (Blair and Diamond, 2008; Monette et al., 2011), social functioning (Eisenberg and Sulik, 2012), and physical health (Moffitt et al., 2011). Theoretical and empirical studies provide a solid base for the promoting role of sensitive caregiving and discipline in the development of child self-regulation (for an overview see Bridgett et al., 2015). However, the influence of parenting on self-regulation may vary as a function of child characteristics

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(Bakermans-Kranenburg and Van IJzendoorn, 2011; Belsky et al., 2007; Belsky and Pluess, 2016; Boyce and Ellis, 2005). Previous studies have found evidence for child differential susceptibility to parenting in self-regulation development, based on differences in temperament (Kim and Kochanska, 2012; Poehlmann et al. 2011) and genetic make-up (Kochanska et al., 2009; Kok et al., 2013b; Sheese et al., 2007), but not yet for physiological markers of susceptibility. Recent studies on stress reactivity as a susceptibility marker for environmental adversities illustrate increased susceptibility of highly reactive children to poverty and early adversity in executive function development (e.g., Obradovic et al., 2016; Skowron et al., 2014). However, it remains unknown whether highly reactive children are also more susceptible to parental sensitivity or discipline practices that are in the normal range of a non-clinical, not at-risk population-based cohort. To test the validity of differential susceptibility for worse *and for better*, in the current study, the moderating role of infant cortisol stress reactivity in the association between observed parenting and experimentally assessed self-regulation in early childhood was studied in a population-based sample. Moreover, domain-specificity of differential susceptibility was explored by assessing the moderating role of cortisol stress reactivity in the association between two indices of parenting and four different aspects of self-regulation in early childhood.

Parental Socialization and Child Self-regulation

Self-regulation is considered at least partially temperament-based, and related to neurobiological factors, such as stress reactivity. Previous studies have indicated that chronically high levels of cortisol in preschoolers are linked to reduced self-regulation, whereas adaptive patterns of cortisol reactivity were related to enhanced self-regulation ability (for a review, see Bridgett et al., 2015). In addition, parental socialization practices are known to contribute to individual variation in child self-regulatory ability (Fay-Stammbach et al. 2014; Karreman et al., 2006). Socialization practices related to self-regulation can be divided into three broad categories: parental control and discipline, parental responsiveness and sensitivity, and parental scaffolding or cognitive stimulation. Most research to date on the link between parenting and self-regulation has addressed variation in parental control or discipline, and parental responsiveness and sensitivity (Karreman et al., 2006). Two meta-analyses about the relation between parental socialization and child self-regulation in early childhood describe a similar pattern (Karreman et al., 2006; Valcan et al., 2017). Parental discipline or control relates to lower levels of self-regulation when control is exerted in a negative way, characterized by power-assertiveness, negativity, and hostility, but relates to higher levels of self-regulation when control is exerted in a positive way, characterized by guidance, limit setting, and directiveness. Although Karreman et al. (2006) did not find a relation between parental responsiveness and sensitivity and child self-regulation (i.e., compliance, inhibition and emotion regulation), Valcan et al. (2017) demonstrated a small but consistent association of a composite of parental warmth, responsiveness and sensitivity with child inhibition, shifting, and working memory. The modest nature of the average effect sizes and heterogeneity within and between study samples in these meta-analyses could suggest that the strength of the association between parental socialization and child self-regulation varies as a function of child characteristics.

Evidence for Differential Susceptibility in Self-regulation Development

Differential susceptibility theory proposes that the influence of parenting on child development varies as a function of temperamental, physiological, or genetic characteristics of the child (Bakermans-Kranenburg and Van IJzendoorn, 2011; Belsky et al., 2007; Belsky and Pluess, 2016; Boyce and Ellis, 2005). Children are differentially susceptible to environmental influences, such as parenting, for better and for worse (for a recent meta-analysis, see Slagt et al., 2016). Previous studies have investigated the relevance of the differential susceptibility hypothesis for the development of child self-regulation. One line of research has focused on temperamental markers of child susceptibility to the environment, mostly described as infant negative emotionality or difficult temperament. Studies show mixed results, partially depending on the type of self-regulation that was assessed and depending on the nature of the sample. In low-risk families, children high in negative emotionality were more susceptible to the quality of parenting in the development of effortful control, impulse control and self-regulated compliance, for better and for worse (Feldman et al., 1999; Kim and Kochanska, 2012; Rochette and Bernier, 2016), but no evidence for differential susceptibility for parenting was found for set shifting and working memory (Rochette and Bernier, 2016). Studies in high-risk populations characterized by low socio-economic status or preterm birth mostly found support for the diathesis-stress model. For example, children high in negative emotionality showed worse self-regulation skills when they experienced negative (or lower levels of positive) parenting (Kochanska and Kim, 2013; Poehlmann et al., 2011), but did not show better self-regulation skills when they experienced positive parenting. The diverse nature of the samples could account for this pattern in results. Perhaps pervasive levels of stress due to socio-economic hardship or perinatal medical complications limit the potential beneficial effects of positive parenting (Kochanska and Kim, 2013).

Genetic characteristics as susceptibility markers in the relation between parenting and child self-regulation has been studied mostly in candidate gene studies, focused on polymorphisms involved in the dopamine or serotonin systems. Children with the 7-repeat variant of the DRD4 allele were more susceptible to parenting in the development of self-regulation in some studies (Cho et al., 2016), but not in others (Kok et al., 2013b; Sheese et al., 2007). Similar inconsistencies are found for genetic polymorphisms in the serotonin transporter gene. One study found evidence that SLC6A4 haplotypes explain variation in susceptibility to parenting in the development of compliance behavior, for better and for worse (Sulik et al., 2012), whereas another study only found a heightened vulnerability for poor regulatory capacity in children with long variants in 5-HTTLPR, indicative of a diathesis-stress model (Kochanska et al., 2009). The moderating role of COMT rs4680 in the association between parental discipline and child compliance awaits replication (Kok et al., 2013b). A study in adolescents, in which a composite of several susceptibility markers was used as a cumulative index of genetic plasticity, showed that adolescent males were more susceptible to maternal parenting when carrying more plasticity alleles (Belsky and Beaver, 2011).

Physiological Markers of Differential Susceptibility

The role of physiological markers in determining differential susceptibility of children to the caregiving environment in the development of self-regulation has not yet been empirically tested. However, previous studies have shown that individual differences in stress reactivity can determine children's susceptibility to their caregiving environment for other developmental outcomes (Ellis et al., 2011; Saxbe et al., 2012). These studies indicated that children and adolescents with higher levels of stress reactivity (as indicated by a greater increase in cortisol level) were more strongly affected by a supportive or aggressive family environment in the development of puberty, and psychological and behavioral problems. These findings illustrate that stress reactivity can potentially determine children's susceptibility to parenting, but do not address child self-regulation.

Two studies on physiological markers of differential susceptibility to environmental adversities in development of self-regulation further substantiate our hypothesis. These studies have focused on distal indices of the quality of the caregiving environment (i.e., parental income) or on environmental extremes (i.e., exposure to child maltreatment), and on cortisol stress reactivity as well as respiratory sinus arrhythmia, as a sign of parasympathetic control. Both studies provide evidence for physiologically based susceptibility in self-regulation development. Children with high cortisol response to laboratory challenges showed better executive functions in families with a high income but worse executive functions in families with a low income (Obradovic et al., 2016). Children with low levels of respiratory sinus arrhythmia during a joint task with their parent, showed worse inhibitory control when they experienced child maltreatment, but better inhibitory control when they did not experience child maltreatment (Skowron et al., 2014). These studies provide evidence for physiological markers of differential susceptibility in self-regulation in adverse circumstances, but do not address susceptibility to normal variation in caregiving, as observed in population samples.

The Current Study

In sum, support for the differential susceptibility hypothesis is extant but sometimes inconsistent (Belsky and Pluess, 2016; Rabinowitz and Drabick, 2017). The question remains whether children differ in susceptibility to parenting as a result of physiological differences and whether these interactive processes influence child self-regulation development. To advance our knowledge on differential susceptibility, studies are needed with careful measures of both the environment and outcome (Belsky and Pluess, 2016; Ellis et al., 2011), preferably in samples with normal variation in environmental exposures (Belsky and Pluess, 2016; Cicchetti and Valentino, 2006). In the current longitudinal population-based study, we therefore investigate whether infant stress reactivity in the Strange Situation Procedure moderates the association between observed maternal sensitivity and supportive discipline and experimentally measured child self-regulation. We hypothesize that children with high stress reactivity in infancy will show better self-regulation skills at age 3 and 4 when they experience sensitive and supportive parenting at age 3, but worse self-regulation skills when they experience less sensitive and supportive parenting. We hypothesize that children with low stress reactivity in infancy are less susceptible to sensitive and supportive parenting. Because divergence in previous findings could be explained by variation in the nature of the environmental exposure and variation in the operationalization of child self-regulation, we address two indices of parenting (maternal sensitivity and supportive discipline) and we explore associations with four different aspects of self-regulation (immediate and prolonged delay of gratification and impulse control, working memory, and attention skills), and the moderation of these associations by infant cortisol reactivity as measured during the Strange Situation Procedure.

Method

Procedure

The current investigation is embedded within the Generation R Study, a prospective cohort investigating growth, development, and health from fetal life onwards in Rotterdam, the Netherlands (Jaddoe et al., 2008, 2010). Detailed measurements were obtained in a subgroup of children of Dutch national origin, meaning that the children, their parents, and their grandparents were all born in the Netherlands to reduce confounding and effect modification (e.g., Luijk et al., 2010; Tharner et al., 2011). Children with a delivery date between February 2003 and August 2005 were enrolled. All measures were approved by the Medical Ethics Committee of the Erasmus Medical Center, Rotterdam. Written informed consent was obtained from all adult participants.

Infant cortisol stress response was collected from saliva samples before and after the Strange Situation Procedure at 14 months of age. The Strange Situation Procedure was successfully conducted in 717 mother-infant dyads. Sufficient saliva samples to calculate stress response were available for 375 children. Reasons for nonresponse were lack of time and failure to obtain saliva samples. A high rate of refusal to chew on cotton swabs is not uncommon in this age group and has been reported before (Goldberg et al., 2003). This is typically found in infants who are not familiar with pacifiers. Self-regulation was assessed concurrently with maternal parenting, at age 3, and one year later, at age 4, in age-appropriate self-regulation tasks.

Study Population

Due to attrition, sample size at age 4 was smaller than at age 3. Moreover, one child was excluded because a mother participated in the study cohort twice, with two siblings. The sample for the analyses on self-regulation at age 3, consisted of 258 children, who completed two self-regulation tasks and two mother-child interaction tasks at age 3. Due to attrition or because the child visited the lab with their father, the sample for the analyses on self-regulation at age 4 consisted of 206 children who completed two mother-child interaction tasks at age 3 and two self-regulation tasks at age 4. Nonresponse analyses comparing the included samples with the initial sample of 717 children indicated that in the included 258 children boys were slightly overrepresented, $\chi^2(1, N = 717) = 4.57$, $p = 0.03$, Cramer's V $= 0.08$. Moreover, mothers of children included in the analyses showed less supportive discipline than mothers of children who were excluded, $t(602) = 2.64$, $p = 0.008$, $d = 0.22$. Nonresponse analyses on the 206 children in the sample showed that the socio-economic context of children excluded from the analyses was somewhat lower than for children included in the analyses, $t(615.4) = -4.06$, $p < 0.001$, $d = 0.31$.

Measures

Self-regulation

Child self-regulation was measured with age-appropriate tasks, in the laboratory at age 3 ($M = 37.2$ months, $SD = 1.3$) and during a home visit at age 4 ($M = 51.2$ months, $SD = 1.2$). Two tasks at age 3 assessed immediate delay of gratification and impulse control (snack delay; max. 20 s. delay) and prolonged delay of gratification and impulse control (gift delay; 3 m. delay) and two tasks at age 4 assessed inhibition and sustained attention, and working memory.

Delay of Gratification/Impulse Control

In the snack delay task, the experimenter put a snack under a transparent cup placed on a placemat in front of the child and the child was instructed to wait until the experimenter rang a bell before retrieving the snack (Kochanska et al., 2000). After two practice trials, four experimental trials were conducted with delays of 5 s, 10 s, 15 s, and 20 s. Coding reflected the delay performance of children over all six trials (0 = "never waits until the bell is rung"; 6 = "waits for the snack until the experimenter lifts the bell every trial"). Kappa reliability among four independent coders was 0.98 on average (range 0.87–1.00). Because the snack delay scores were severely skewed, a dichotomous score was created: 69.8% of children waited all trials and were able to wait for 20 seconds; 30.2% did not. The snack delay score reflects the child's ability for immediate impulse control and delay of gratification.

In the gift delay task, the experimenter brought a paper bag containing a wrapped gift and placed the bag on the table in front of the child (Kochanska et al., 2000). Then the experimenter asked the child to wait until she brought a sticker, which was part of the gift, and to not touch the gift and stay seated while waiting for her return. The experimenter left the child for 3 m. Coding reflected the behavior with regard to the gift (e.g., 1 = opens the gift, 3 = touches the gift, 6 = does not touch the bag or the gift), and the time in seat (e.g., 1 = less than 15 s, 3 = 30–59 s, 6 = remains seated until experimenter returns). Gift behavior scores and in seat scores were modestly correlated ($r(256) = 0.34$, $p < 0.001$). Kappa reliability among four independent coders was 0.94 on average (range 0.84–1.00) for gift behavior, and 0.95 on average (range 0.93–1.00) for time in seat. Because the gift delay scores were severely skewed, a dichotomous score was created: 56.2% of children waited in their seat for the full 3 m without touching the bag or gift; 43.8% of children did not. The gift delay score reflects the child's ability for prolonged impulse control and delay of gratification.

Inhibition and Sustained Attention

Inhibition and sustained attention were assessed with the Auditory Continuous Performance Test for Preschoolers (ACPT-P, Mahone et al., 2001). Trials consisted of distractors (church bell) and targets (dog bark). Incorrect responses were used as an indicator of child impulsivity ("commission error": an incorrect response to a distractor stimulus) and inattention ("omission error": failure to respond to a target stimulus). The scoring was adapted by including children who failed both demonstration trials instead of discarding them from the analyses. The appropriateness of including this group as a separate category in both commission and omission error scores has been demonstrated before (see Mileva-Seitz et al., 2015). The commission error variable was categorized based on the number of commission errors (maximum 15): 4 = did not start test trials, 3 = four or more errors, 2 = two to three errors, 1 = one error, and 0 = no errors. The omission error variable was similarly categorized into: 3 = did not start test trials, 2 = three or more errors, 1 = one or two errors, and 0 = no errors. Commission errors and omission errors were positively correlated, $r(204) = 0.71$, $p < 0.001$. A composite for inhibitory control and sustained attention was created by standardizing and averaging the reversed scores for commission errors and omission errors. This composite will be referred to as "attention skills".

Working Memory

Children's ability to remember colors in order of presentation or in backward order was evaluated using a computerized color memory span task (Mileva-Seitz et al., 2015). The test consisted of two sections: a forward short-term memory test and a backward working memory test. The test trials consisted of four memory trial sections of increasing difficulty, including two to five circles of different colors in each trial. Children were asked to identify the colors they saw in order from first to last, either verbally or nonverbally. The test was stopped if the child failed a trial twice. The total error score could vary between 0 (if the child succeeded on all trials either with or without extra trials) and 8 (if the child failed the test trial of two colors twice). In the backward memory test, the children were asked to name the colors in order from last to first. Forward and backward memory scores were positively correlated, $r(204) = 0.40$, $p < 0.001$. An overall working memory composite was created by standardizing and averaging the scores on forward and backward memory span.

Salivary Cortisol: Stress Reactivity

Salivary cortisol was collected during a lab visit around 14 months of age ($M = 14.5$, $SD = 0.8$), around the Strange Situation Procedure (SSP; Ainsworth et al., 1978), including two brief separations of the parent to evoke mild stress in the infant. Details are described in Luijk et al. (2010). Three saliva samples were taken using Salivette sampling devices (Sarstedt, Rommelsdorf, Germany); the first prior to the SSP, the second directly after the SSP (which was on average 10 min after the first separation of the SSP) and the third about 15 min after the SSP ($M = 16.7$, $SD = 9.2$). None of the children used systemic corticosteroid medication, but 12 children used other corticosteroid-containing medication. Excluding these children did not change the results, so they were included in further analyses. Salivary cortisol concentrations were measured using a commercial immunoassay with chemiluminescence detection (CLIA; IBL Hamburg, Germany). Intra- and interassay coefficients of variation were below 7% and 9%, respectively. For each time point, cortisol values that were above the 99th percentile (>200 nmol/L) were excluded ($n = 12$) from the analysis to reduce the impact of outliers.

A difference score (delta) was calculated between the last sample (cortisol level post SSP) and the first sample (cortisol level pre SSP) (Luijk et al., 2010). The second assessment, just after the SSP, was not used, as it was too close in time to the onset of stress. Analyses were adjusted for cortisol level of the first sample, based on the Law of Initial Values (Wilder, 1968). For sensitivity analyses, we also calculated area under the curve with respect to ground (AUCg; see Pruessner et al., 2003, for the formula). We used all three cortisol assessments to calculate AUCg as a cumulative index of total cortisol output in response to the SSP. One outlier was winsorized to reduce the impact of this outlier. We calculated AUCg to include variability in initial cortisol levels and correct for individual differences. In order to remove variation in cortisol levels due to diurnal rhythm, log-10-transformed AUCg scores were regressed on the time of the first sample collection and standardized residual factor scores were used for analyses. For both delta and AUCg, higher scores indicate higher cortisol excretion, which is indicative of stronger activation of the body's stress system.

Table 1 Sample characteristics

Child characteristics	%	*M*(*SD*)	Range	*N*
Gender, % female	42.2			
Socio economic context		−0.02 (0.72)	−2.99–1.06	258
Age				
14 months		14.5 (0.8)	11.98–17.75	258
3 years		37.2 (1.3)	34.84–43.19	258
4 years		51.3 (1.2)	48.99–56.09	206
Cortisol reactivity (delta)		0.95 (6.2)	−25.49–42.33	258
Delay of gratification/impulse control at age 3				
Immed. Delay of grat., % optimal score	69.8			258
Prolong. Delay of grat., % optimal score	56.2			258
Self-regulation at age 4				
Working memory[a]		0.02 (0.8)		206
Attention[a]		0.00 (0.9)		206
Maternal characteristics				
Maternal sensitivity		0.00 (0.70)	−1.66–1.83	258
Maternal supportive discipline		−0.15 (0.97)	−2.81–2.20	258

Parenting

Sensitivity At 3 years maternal sensitivity was observed when mother and child performed two 3-min tasks that were too difficult for the child: building a tower and an etch-a-sketch task. Mothers were instructed to help their child as usual. Maternal sensitivity was coded with rating scales for Supportive presence and Intrusiveness (Egeland et al., 1990). Correlations between Supportive Presence and Intrusiveness within and across tasks ranged from −0.19 to −0.41. An overall sensitivity score was created by reversing the Intrusiveness scales, standardizing all scores, and creating an average over both scales and both tasks. The two tasks were independently coded by 13 trained coders. Coders were unaware of other data concerning the mother-child dyad. Reliability of the coders was assessed directly after the training and at the end of the coding process to detect any rater drift. ICCs between independent coders for the subscales were 0.75 on average for the tower task (range 0.73–0.77, $n = 53$) and 0.79 on average for the etch-a-sketch task (range 0.65–0.93, $n = 55$; Kok et al., 2013a).

Supportive Discipline Maternal supportive discipline was observed at 3 years. In a task of 2 min the parent prohibited the child to touch or play with a set of attractive toys that were displayed before the child. Coding procedures were based on Kuczynski et al. (1987) and Van der Mark et al. (2002). Maternal verbal discipline strategies were observed and coded for level of support (all maternal remarks that helped the child to comply, such as distracting the child from the toys and making conversation with the child); and for Supportive presence with the 7-point rating scale of the revised Erickson scales (Egeland et al., 1990), which refers to the amount of positive regard and emotional support the mother shows toward the child. Support and Supportive presence represent maternal supportive discipline practices. Maternal behavior was coded by five trained coders, unaware of other data concerning the mother-child dyad. Reliability was assessed directly after the training and at the end of the coding process to detect any rater drift. Intercoder reliability was adequate (ICC for Support 0.85, and for Supportive presence 0.79, $n = 57$; Kok et al. 2013b). An overall maternal supportive discipline score was created by standardizing and summing the scores.

Socio-Economic Context

Educational level of mothers and fathers, and household income at intake were used as indicators of the child's socio-economic context. Mothers and fathers reported on their highest educational level attained in 6 categories: 0 = *no education*; 1 = *only primary education*; 2 = *lower vocational education*; 3 = *intermediate vocational education*; 4 = *higher vocational education*; 5 = *university*. Only few parents reported finishing only primary education (0.8% mothers, 2.2% fathers) or lower vocational education (7.1% mothers, 10.3% fathers). Most parents finished intermediate vocational education (30.7% mothers, 26% fathers), higher vocational education (31.1% mothers, 23.8% fathers), or university (30.3% mothers, 37.7% fathers). Parents reported on the net household income in ten categories, ranging from 450–600 Euros per month to 2200 or more Euros per month. 79% of the families had a monthly income of 2200 Euros or more. An aggregate for family socio-economic context was created based on the standardized indicators of maternal and paternal educational level, and net household income. Due to the nature of the sample socio-economic context was negatively skewed.

Analysis Plan

Analyses were conducted for child self-regulation at age 3 ($N = 258$) and at age 4 ($N = 206$) separately. First, the bivariate associations among covariates, infant cortisol stress response, child self-regulation at age 3 and 4, and maternal parenting were determined by *t*-tests and Pearson correlations. Binary logistic regression analyses were conducted to test the interaction effects of maternal parenting (sensitivity and supportive discipline) and child cortisol stress response on snack delay and gift delay performance, and multiple regression analyses were conducted for attention and working memory skills as outcomes. In all

Table 2 Bivariate correlations between main variables ($N = 258$)

	1	2	3	4	5	6	7
1. Socio-economic context	–						
2. Cort reactivity (delta) 14 m	0.01	–					
3. Maternal sensitivity 3 years	0.23**	0.03	–				
4. Maternal pos. disc 3 years	0.15*	−0.06	0.17**	–			
5. Immed. Delay of grat. 3 years	−0.04	0.00	0.14*	0.17**	–		
6.Prolong. Delay of grat. 3 years	0.07	−0.02	0.13*	0.25**	0.12	–	
7. Working memory 4 years[a]	0.02	0.07	0.18**	0.11	0.04	0.04	–
8. Attention 4 years[a]	0.11	−0.09	0.12	0.12	0.00	0.14	0.21**

[a] $N = 206$

*$p < 0.05$, **$p < 0.01$

regression equations, we included child gender and child's socio-economic context as covariates. Interaction terms were computed after centering of the constituent variables. Moderation was tested with cortisol delta and AUCg as possible moderators. If interaction effects were significant, regions of significance were estimated (Hayes and Matthes, 2009) and the Widaman procedure (Widaman et al., 2012) was followed to test whether interactions had an ordinal or a disordinal form. The exploration of regions of significance and the Widaman procedure are recommended procedures to test whether data follows a pattern of diathesis-stress or of differential susceptibility (Belsky and Pluess, 2016).

Results

Sample characteristics are presented in Table 1. Maternal sensitivity and supportive discipline at age 3 were related to better immediate and prolonged delay of gratification/impulse control at age 3. Maternal sensitivity was also positively related to working memory at age 4 (see Table 2). Immediate and prolonged delay of gratification/impulse control at age 3 were not significantly correlated, but attention and working memory performance at age 4 were correlated. Self-regulation indices at age 3 were not related to self-regulation indices at age 4. No significant effect of gender was found for maternal sensitivity, but mothers showed more supportive discipline towards girls than towards boys, $t(256) = -2.69$, $p = 0.008$, d = 0.35. Girls showed better attention skills at age 4 than boys, $t(204) = -3.91$, $p < 0.001$, d = 0.55, and better working memory skills, $t(204) = -2.03$, $p = 0.04$, $d = 0.28$. No significant gender differences were found for the other self-regulation skills.

Results of the regression models for child self-regulation at age 3 and age 4 are presented in Table 3. Logistic regression analyses were conducted to test the interaction of the two indices of maternal parenting (sensitivity and supportive discipline) and cortisol stress reactivity on the two dichotomous indicators of self-regulation at age 3 separately, immediate delay of gratification/impulse control (see first two columns of Table 3) and prolonged delay of gratification/impulse control (see second two columns of Table 3). Analyses were controlled for gender, child's socio-economic context, and baseline cortisol. Immediate delay of gratification/impulse control was related to maternal sensitivity ($B = 0.47$, $p = 0.03$) and to maternal supportive discipline ($B = 0.38$, $p = 0.01$). Prolonged delay of gratification/impulse control was not significantly related to maternal sensitivity ($B = 0.27$, $p = 0.17$) and significantly related to maternal supportive discipline ($B = 0.51$, $p < 0.001$). Interactions between maternal parenting indices and child cortisol stress reactivity on delay of gratification/impulse control were not significant. Sensitivity analyses with AUCg instead of delta as a moderator yielded similar (non-significant) results.

Linear regression analyses were conducted to test the interaction of the three indices of maternal parenting and cortisol stress reactivity on the two continuous domains of self-regulation at age 4 separately, attention skills (see third column of Table 3) and working memory skills (see fourth column of Table 3), controlling for gender, child's socio-economic context, and baseline cortisol. Working memory skills at age 4 were positively related to maternal sensitivity at age 3 (B = 0.21, $p = 0.02$). In both regression models, interactions between indices of maternal parenting and child cortisol delta were not significant. Sensitivity analyses with AUCg instead of delta as a moderator yielded similar (non-significant) results.

Discussion

In a population-based longitudinal cohort we tested whether infant cortisol stress reactivity moderated the association between different aspects of maternal parenting and various domains of child self-regulation at age 3 and age 4. Maternal parenting was cross-sectionally related to child

Table 3 Maternal supportive parenting, infant cortisol reactivity and child self-regulation

	Immed. Delay of gratification (3 years)[a]			Prolong. Delay of gratification (3 years)[a]			Attention skills (4 years)[b]			Working memory skills (4 years)[b]		
	B	*p*	R^2	*B*	*P*	R^2	*B*	*p*	R^2	*B*	*p*	R^2
			0.10			0.10			0.12			0.07
Child gender	−0.12	0.70		0.06	0.82		0.45	<0.001		0.22	0.06	
Cortisol first sample	−0.05	0.10		−0.02	0.43		0.03	0.06		−0.01	0.46	
Socio-economic context	−0.31	0.14		0.05	0.79		0.16	0.14		−0.04	0.71	
Maternal sensitivity (36 m)	0.47	0.03		0.27	0.17		0.13	0.17		0.21	0.02	
Maternal sup. disc. (36 m)	0.38	0.01		0.51	<0.001		0.05	0.48		0.04	0.49	
Cortisol delta (14 m)	0.00	0.95		−0.01	0.64		0.00	0.89		0.01	0.39	
Maternal sensitivity * delta	−0.04	0.38		0.01	0.74		−0.02	0.36		0.00	0.96	
Maternal sup. disc. * delta	−0.04	0.19		−0.01	0.73		0.00	0.84		−0.01	0.41	

[a]$N = 258$

[b]$N = 206$

delay of gratification and maternal sensitivity was related to better child attention skills one year later. However, no evidence was found for differential susceptibility to maternal parenting based on child stress reactivity.

This study was the first study to examine the specific moderating role of infant cortisol stress response in the association between normal variation in observed maternal parenting and child self-regulation in early childhood. Our results did not support our tentative hypothesis, based on previous studies illustrating that highly reactive children are more susceptible to distal indicators of caregiving or to rearing adversities in their self-regulation development (Obradovic et al., 2016; Skowron et al., 2014), and on evidence for physiological markers determining children's susceptibility to parenting for other child outcomes (Ellis et al., 2011; Saxbe et al., 2012). However, we need to be cautious in interpreting these null findings, because of limited power to detect interaction effects in non-experimental designs (McClelland and Judd, 1993), and because interactions effects can be small. The time lag between the measure of stress reactivity and the environmental exposure was 2 years. If either stress reactivity or quality of maternal parenting is fluctuating over time, a moderating effect might go undetected. Previous research has however demonstrated considerable stability in maternal sensitivity (Dallaire and Weinraub, 2005; Haltigan et al., 2013; Kok et al., 2013c, and discipline (O'Leary et al., 1999) in childhood. Moreover, it is not uncommon to test biological sensitivity to context as a moderator measured earlier than the environmental factor (e.g., Boyce et al., 1995; van der Kooy-Hofland et al., 2012; Windhorst et al., 2015). It has been suggested that the timing of susceptibility could vary across individuals or that susceptibility could be restrained to specific sensitive periods (Belsky and Pluess, 2016; Windhorst et al., 2015). Studies with repeated measures of child susceptibility and repeated measures of the environmental exposure could shed light on this possible explanation.

The susceptibility marker in our study, infant cortisol stress response, was measured as a response to the Strange Situation Procedure, in which the child is separated from the mother to induce mild stress. Although this is a common procedure to evoke stress in infants, the susceptibility marker may be related to the quality of the caregiving environment and thus not independent of maternal parenting. Maternal parenting could be considered as a determinant of infant stress reactivity, as various studies in humans and mammals have previously shown (e.g., Blair et al. 2007; Meaney, 2001). In our sample, maternal parenting at age 3 was not related to infant stress reactivity. Our design resembles previous studies in which differential susceptibility to environmental adversities in child development was studied. Both Saxbe et al. (2012) and Skowron et al. (2014) measured cortisol reactivity and respiratory sinus arrhythmia during interactions with a caregiver, and found that these physiological markers affected susceptibility of children to family aggression and child maltreatment in predicting inhibitory control, psychological, and behavioral problems.

Maternal sensitivity and supportive discipline were concurrently related to immediate and prolonged delay of gratification/impulse control at age 3. Moreover, maternal sensitivity was related to better working memory at age 4, but not to better sustained attentions skills at age 4. In general, these results are in line with solid empirical support for the importance of parenting for self-regulation (e.g., Bernier et al., 2012; Kok et al., 2014; Lucassen et al., 2015). In general, the pattern of results shows that associations are more prominent between the concurrent measures of parenting and child self-regulation at age 3. The fact that the association between maternal parenting and child attention skills was not robust in the fully adjusted models, is in contradiction to other studies that do find this association even after stringently controlling for covariates (e.g., NICHD, 2003). In our sample, the gender differences in attention skills, indicating that girls outperform boys, were a stronger determinant than variation in maternal parenting. Infant cortisol stress reactivity was not related to child self-regulation, but infant baseline cortisol levels before the stressor did predict child attention skills at age 4. Some previous studies have linked higher basal cortisol levels with more impulsive personality in adolescents (Laceulle et al., 2015), and have demonstrated that administration of corticosteroids can directly undermine selective attention (Henckens et al., 2012). However, the longitudinal nature of the association in our study does not allow a direct comparison with these previous studies. Moreover, our single measure of baseline cortisol cannot be interpreted as an indicator of prolonged elevation of cortisol level.

The results of the separate predictive models for different elements of maternal parenting and self-regulation could indicate the relevance of a multi-dimensional approach in the assessment of self-regulation (Miyake et al., 2000; Zelazo and Carlson, 2012) and parenting (Rochette and Bernier, 2016), but the variability in results could also be due to measurement error in parenting observations or the experimental tasks on self-regulation. Our findings emphasize the importance of parental socialization strategies for the development of self-regulatory functions that allow children to control impulses to act according to social standards, and to reproduce information from memory.

Limitations

Our results should be considered in the light of a number of limitations. Despite the substantial sample size, the power of our study may have been limited by measurement error in cortisol sampling, and in the observations of child self-regulation and maternal parenting. The fact that only two samples were used to determine cortisol reactivity limits the reliability of our measure of cortisol stress response. However, results were similar when cortisol stress response was based on three samples (AUCg). Moreover, the observations of self-regulation at age 3 yielded ceiling effects which forced us to dichotomize the data and limits our power to detect smaller (interactive) effects. Although the experimental tasks have been successfully used previously in children of a similar age (Carlson 2005), the low-risk nature of our sample could explain why many children passed these tasks.

Conclusion

The current study is the first study to examine differential susceptibility to maternal parenting in the development of self-regulation by infant cortisol stress response. No evidence for an interaction between stress reactivity and parenting on child self-regulation was found, even though other studies have found evidence for the moderating potential of genetic and behavioral markers of susceptibility in the same association (Kim and Kochanska, 2012; Kochanska et al., 2009; Kok et al., 2013b; Poehlmann et al., 2011; Sheese et al., 2007), and yet other studies have found evidence that increased stress reactivity is a susceptibility marker in other environment-outcome associations (Ellis et al., 2011; Saxbe et al., 2012). Before drawing firm conclusions, the relevance of infant cortisol stress reactivity as a susceptibility factor should be studied in other samples and other developmental periods to test the developmental dimension of differential susceptibility effects of different aspects of parenting on children's self-regulation.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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