Development and Psychopathology, **13** (2001), 629–652
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Maternal prenatal, postpartum, and concurrent stressors and temperament in 3-year-olds: A person and variable analysis

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Abstract
The study was based on the assumption that stressors in the lives of pregnant and parenting women are processes that affect prenatal, postpartum, and concurrent maternal hormones and emotions and that these processes affect child temperament. The hypotheses were tested in a group of 67 young mothers and their 3-year-old children. Mothers were clustered into groups based on longitudinal patterns of hormones and emotions at prenatal, postpartum, and 3-year follow-up assessments. The analyses focused on relating maternal patterns of hormones and emotions to the child's temperament at age 3 years. Temperament was assessed by questionnaire and observation of behavior during a challenging situation. Illustrative findings included the following. Verbal aggression and nonverbal aggression were significantly higher in children of mothers in the low *prenatal* hormone cluster than children of mothers in the high prenatal hormone cluster. Children of mothers in the *postpartum* low testosterone (T), estradiol (E_2), and androstenedione (Δ4-A) and medium cortisol (Cort) cluster (mainly low hormone cluster) exhibited significantly more physical aggression than children of mothers in the medium T and Δ4-A, high E_2 and low Cort cluster. Maternal patterns of hormones, emotions, and parenting attitudes and practices were related to multiple aspects of temperament when the children were age 3 years. The findings support the important role of maternal biological and psychological processes in the development of child temperament.

Contemporary theories about temperament suggest that it has biological roots but also is influenced by environmental processes. The evidence for biological influences on temperament is apparent in the known genetic contributions to temperament (DiLalla, Kagan, & Reznick, 1994; Goldsmith, Buss, & Lemery, 1997; Kagan, 1997; Zahn–Waxler, Schmitz, Fulker, Robinson, & Emde, 1996) and the relationship between prenatal neurobehavioral functioning and later temperament (DiPietro, Hodgson, Costigan, & Johnson, 1996). Although partially biologically rooted, temperament is not static but is adaptive to environmental demands (Rothbart & Ahadi, 1994) and influences (Goldsmith, Buss, & Lemery, 1997). Temperament herein was viewed as a dynamic process in that factors promoting maintenance and reorganization change with stress-related fluctuations in the maternal endocrine milieu and emotions during gestation, the transition to parenting, and parenting a 3-year-old.

Maternal hormonal and emotional consequences of stressors are proposed as mecha-

The research was supported by grants from the National Institute of Child Health and Human Development (HD RO1 HD26004) and the William T. Grant Foundation.

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https://doi.org/10.1017/S0954579401003121 Published online by Cambridge University Press

nisms affecting temperament. The degree of exposure to stressors is operationally defined herein as (a) variations in maternal hormones that are sensitive to environmental perturbations and (b) negative emotions reported by mothers. The aim of the present report was to identify developmental periods in which maternal hormones and emotions influence temperament in 3-year-old children. To this end, a truly longitudinal approach was employed that followed young women from the prenatal period to 3 years postpartum. A longitudinal approach contrasts with the long-standing tradition of considering only one period of assessment as a correlate or predictor of temperament. A better understanding of early influences on temperament is necessary for the implementation of early intervention programs designed to prevent the negative outcomes associated with the early onset of a difficult temperament (Bates, Pettit, Dodge, & Ridge, 1998; Block, Block, & Keyes, 1988; Caspi, Henry, McGee, Moffitt, & Silva, 1995, Guerin, Gottfried, & Thomas, 1997; Rutter, 1987; Thomas & Chess, 1985).

The theoretical framework consisted of a holistic, person-oriented approach to understanding development (Bergman & Magnusson, 1997; Cairns & Rodkin, 1998; Cairns, Elder, & Costello, 1976; Magnusson, 1988, 1998, 1999; Magnusson & Allen, 1983; Magnusson & Cairns, 1996). A person-oriented approach to development views individuals as functioning simultaneously as biological, psychological, and social being. These aspects of development are formed in the context of each other rather than in isolation (Cicchetti & Rogosch, 1996). Viewed from this perspective, hormones and emotions function as interactive regulatory processes in which the totality of the elements more validly reflects dynamic maternal qualities that affect the child's temperament than one specific hormone or emotion. In the taxonomy of species, no single variable defines a species (Magnusson, 1998) and no single hormone or emotion defines biological or psychological totalities.

The holistic perspective views individuals as self-organizing entities that both react to external influences as well as influence the environment in which they develop. Maternal and fetal, infant, and toddler characteristics likewise are interactive. Even during pregnancy, the fetal–placental–maternal unit is in constant interaction, thereby precluding that maternal influences are unidirectional. In the case of temperament, it arises in part from the self-organizing reactivity of underlying neural systems early in development. In the fetal period, individual differences in maternal hormones and emotions may have a significant impact on neural development (Derryberry & Rothbart, 1997). As the child develops, initially reactive forms of regulation and maternal influences are supplemented by an increasing capacity for voluntary or effortful forms of control (Rothbart, 1988). This change reflects a self-organizing and dynamic rather than a static and deterministic process. The self-organizing capacity of children's development may alter the consistency with which maternal patterns of hormones and emotions relate to temperament from the fetal to childhood periods. Thus, the longitudinal question addressed the degree to which links between maternal hormones and emotions and child temperament are established during gestation, shortly after birth in the postpartum period, and contemporaneously when the child is 3 years old.

The holistic perspective suggests that hormones, like testosterone (T), estradiol (E_2), androstenedione (Δ4-A), and cortisol (Cort), are jointly involved in the dynamic interaction between maternal stressors and child temperament. Hormones function in coordinated systems to regulate physiological functioning rather than acting individually. Consider, for instance, that T, E_2, Δ4-A, and Cort are derived from a common precursor, cholesterol (Griffin & Ojeda, 1996). Given this metabolic conversion pattern, it is not known which hormone is active in the brain or which hormone is influencing, or being responsive to, maternal stressors. In addition, an implication of the holistic theoretical perspective is that one hormone or emotion is not considered in isolation in relation to temperament. Accordingly, patterns of hormones or emotions within mothers are more likely to reflect the total functioning of the endocrine or emotional system than individual components. Patterns of maternal

https://doi.org/10.1017/S0954579401003121 Published online by Cambridge University Press

hormones and emotions during the prenatal, postpartum, and concurrent periods were viewed as components of organized biological and psychological holistic systems that operate together to influence development (Magnusson, 1999). Thus, groups of mothers were identified that share similar patterns of hormones or emotions—a person-oriented approach.

Prenatal Hormones and Emotions

The expected relationship between child temperament and prenatal stressors, indexed by patterns of maternal hormones and emotions, is based on considerable evidence showing the effect of the prenatal environment on neurobiological development (Lou, Hansen, Nordentoft, Pryd, Jensen, Nim, & Hemmingsen, 1994; Schore, 1994). Animal and human model studies show that alterations in prenatal hormones, maternal stressful life experiences, and emotions affect fetal development and later behavior (DaCosta, Dritsa, Larouche, & Brender, 2000). Fetal neurobehavioral antecedents of temperament already are established in human infants. Active fetuses were more difficult, unpredictable, unadaptable, and active infants than less active fetuses (DiPietro et al., 1996). The specific mechanisms whereby the maternal environment affects temperament are unknown.

The rationale for assessing patterns of maternal hormone concentrations in relation to temperament is based on the regulatory nature of the endocrine system. The endocrine component of the stress system is involved in regulating the secretion of corticotropin releasing hormone (CRH), the locus coeruleus (LC) sympathetic nervous system, and the immune response to internal and external stressors (Chrousos & Gold, 1992; Chrousos, Torpy & Gold, 1998), thereby providing an adaptive or protective function in the development of the fetus. The CRH–LC sympathetic system also interacts with hypothalamic–pituitary–gonadal (HPG) axis hormones, specifically T and E_2. Thus, stressors during pregnancy are expected to alter the levels of multiple hormones and thereby may affect fetal development via the maternal–placental–fetal unit. Alterations in hormones of the hypothalamic–pituitary–adrenal (HPA) stress axis (CRH, adrenocorticotropin hormone, and Cort) are speculated to affect birth weight and neurodevelopment in subhuman primates (Schneider, 1992; Schneider, Coe, & Lubach, 1992). In humans, the adverse effects include reduction in gestational age, lowered birth weight, precipitation of labor and delivery, and increase in neonatal morbidity and mortality (Peters, 1990; Sandman, Wadhwa, Chicz–DeMet, Dunkel–Schetter, & Porto, 1999). The regulatory function of alterations in HPG axis hormones, principally T and estrogens, include both structural and functional, sexually dimorphic differences in brain development and subsequent behaviors (see Gorski, 1997). In humans, individuals exposed to high or low concentrations of sex steroids during gestation show alterations in behavior (see review by Collaer & Hines, 1995). For instance, exposure to excessive androgens during fetal development, as in fetal congenital hyperplasia, predicted more masculinization of toy preference and aggressive behavior (Berenbaum, Duck, & Bryk, 2000) and poor spatial cognition (Berenbaum & Hines, 1992), suggesting that disturbances in the prenatal milieu have long-term implications for diverse behaviors. The aim of the current study was to examine the effects of more subtle individual variations in T and E_2 on child temperament.

The rationale for assessing maternal patterns of emotions in relation to temperament is based on the importance of reproductive transitions in affective development. Dorn and Chrousos (1997) suggest that the reproductive transition of pregnancy, especially when it occurs early in the childbearing years, is accompanied by emotional reorganization that has the potential for modifying the endocrine milieu. Early in gestation, maternal hormones are rising rapidly (Yen, 1994) and fetal organ systems are undergoing rapid development. Emotion-related alterations in the prenatal environment have the potential to affect neurobiological development as discussed above. Negative emotions during pregnancy predict pregnancy and infant outcomes such as early labor and delivery, maternal anxiety, and lower infant gestational age (Wadhwa,

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Sandman, Porto, Dunkel–Schetter, & Garite, 1993). Given that negative emotions and alterations in hormone concentrations during gestation have the potential to adversely affect fetal development, patterns of high or low maternal hormones or emotions were hypothesized to predict difficult temperament.

Postpartum Hormones and Emotions

Temperamental systems are functional at birth but become more complex and more organized with advancing development (Derryberry & Rothbart, 1997; Rothbart & Bates, 1998) and are responsive to environmental stimulation and demands. The postpartum environment possibly acts as a regulator of infant brain development and temperament, although considerable research remains to be done regarding this issue (Thompson & Nelson, 2001). Animal model studies show that early life experiences permanently alter hormonal response to stressors (Anisman, Zaharia, Meaney, Nerali, & Merali, 1998). In humans, the infant–maternal system of interactive caregiving is an external regulator of the infant's self-organization. This same infant–maternal unit likely regulates the neurochemistry of the infant's maturing brain as in other species (Polan & Hofer, 1999). Maternal hormone concentrations and emotions are proposed to contribute to temperament as mediated by the quality, quantity, and regularity of maternal interactions. These patterns of interactions are expected to modulate the infant's tendencies of arousal, attention, and reactivity to environmental stimulation.

Postpartum maternal emotions are characterized by dysphoria or other depression symptoms in some women. Although the majority of women experience some type of dysphoria, symptoms tend to be of less severity than those of postpartum depression (Najman, Williams, Nikles, Spence, Bor, O'Callaghan, Le Brocque, & Andersen, 2000). The rapid decrease in gonadal and adrenal hormone concentrations in the postpartum likely contribute to postpartum dysphoria (Magiakou, Mastorakos, Rabin, Dubbert, Gold, & Chrousos, 1996). Consequences of maternal emotions on children appear in the literature on maternal depression. Children of affectively ill mothers had earlier and significantly more depressive and disruptive behavior problems than children of nonaffectively ill parents (Radke–Yarrow, Nottelmann, Mortinez, Fox, & Belmont, 1992). Less severe symptoms of depression and negative emotions (anxiety and anger) also are expected to be related to temperament, as these emotions will affect the quality of maternal–child interactions. As was hypothesized for the prenatal period, children of mothers with relatively lower or higher concentrations of hormones or negative emotions in the postpartum period were expected to have children with more difficult temperament.

Concurrent Hormones, Emotions, and Parenting

Maternal hormone levels and emotions when the children were age three (concurrent assessment) similarly were expected to relate to differences in child temperament. High levels of T are related to dominance and aggressive behavior in females (Dabbs & Hargrove, 1997; Dougherty, Bjork, Moeller, & Swann, 1997; Mazur & Booth, 1998). The expectation was that mothers with high T would be dominant, harsh, and aggressive parents. Lower maternal Cort was expected to be related to difficult temperament, as low Cort is associated with externalizing behavior and conduct disorder symptoms (McBurnett, Lahey, Frick, Risch, Loeber, Hart, Christ, & Hanson, 1991; Moss, Vanyukov, & Martin, 1995; Pajer, Gardner, Rubin, Perel, & Neal, in press; Susman, Dorn, Inoff–Germain, Nottelmann, & Chrousos, 1997), oppositional defiant behavior (van Goozen, Matthys, Cohen–Kettenis, Gispen de Wied, Wiegant, & van Engeland, 1998) in children and adolescents, and habitual violence in males (Virkkunen, 1985). Thus, mothers with low Cort and high T were expected to be high on dominance and aggression, thereby creating a harsh child-rearing environment that contributes to difficult temperament.

Harsh child-rearing practices and attitudes about child rearing were expected to interact

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with contemporaneous (concurrent) hormone concentrations and emotions. Consideration of these interactions is consistent with the holistic interaction model that emphasizes the interactive nature of the psychological, biological, and contextual aspects of socialization (Magnusson, 1999). Parenting attitudes and the child's temperament develop as part of a person–environment system. Maternal states of mind (Kobak & Cole, 1999) and parenting practices may affect the child's temperament in a number of ways. Negative emotions and harsh and dismissing attitudes may reduce a mother's capacity to monitor the child's distress and to provide guidance and discipline conducive to regulating social behavior. Parental maladjustment was positively associated with temperamental reactivity–low manageability (Kyrios & Prior, 1990). In contrast, positive parenting may interact with hormone levels to affirmatively influence temperament. For instance, mothers with patterns of hormones characterized by high concentrations of T, but with positive parenting attitudes, are expected to produce children with less difficult temperament.

In summary, temperament was considered to be partially biologically based (Goldsmith, Buss, Plomin, Rothbart, Thomas, Chess, Hinde, & McCall, 1987), influenced by maternal processes characterized by individual differences in reactivity and self-regulation (Rothbart, 1988, 1989). Reactivity, within this definition, is the excitability or arousability of behavioral, endocrine, autonomic, and central nervous system responses, as assessed through response parameters of intensity, latency, and threshold. Self-regulation consists of the process that serves to enhance or inhibit reactivity, such as attention, approach, and avoidance (Derryberry & Rothbart, 1997). These components of temperament were assessed using a questionnaire and systematic observation as questionnaire and laboratory assessments of temperament do not necessarily concur (Rothbart, 1988). The observational coding system was designed to provide an independent measure of temperament reflecting the child's behavior reactivity and regulation (attention, approach, aggressive behavior, and avoidance) while engaging in a challenging task.

Methods and Procedures

Sample

This report is based on a longitudinal study that assessed 67 primiparous adolescent and young adult mothers at less than or equal to 16 weeks gestation ("prenatal"), the 3rd trimester (i.e., 32–34 weeks gestation; "late pregnancy"), 3–4 weeks postpartum ("postpartum"), and when the children were 3 years of age ("concurrent"; Ponirakis, Susman, & Stifter, 1998; Schmeelk, Susman, Granger, & Chrousos, 1999; Susman, Schmeelk, Granger, Ponirakis, & Chrousos, 1999). Adolescent and young mothers constituted the sample, given the relationship between early-life parenting and behavior problems and the links between early difficult temperament and developmental psychopathology. The concurrent, follow-up sample consisted of 60 primarily Caucasian (98% Caucasian, 2% African American), rural and semirural young adult mothers and their 3-year-old children (M = 3.1 years, SD = .18). The mothers ranged in age from 17.3 to 23.0 years (M = 21.0 years, SD = 1.4) when the children were age 3 years. Attrition of seven participants from the postpartum to the concurrent period was because of infant mortality (n = 2), unwillingness to participate (n = 1), and inability to schedule within the time frame of the study (n = 4). At entry into the study, the mean family socioeconomic status (SES; Hollingshead, 1975) was mainly working class and unemployed (e.g., machine operators, semiskilled workers; M = 22.28, SD = 5.82, range 8–66). At the concurrent assessment, family SES was similar to the prenatal period (M = 24.3, SD = 7.23, range 11–55). Criteria for study entry included English fluency, absence of chronic illness or severe mental health problems, plans to keep the baby, less than age 20 years at expected date of delivery, and 16 or fewer weeks gestation.

The demographic characteristics of the mothers at the prenatal assessment include the

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following. The majority of the mothers at early pregnancy were in school (65.3%), with the remainder having either graduated (or obtained a GED; 20.0%) or dropped out (14.7%). The majority received some form of public assistance (e.g., welfare; 94.7%). The mothers received prenatal care at either a family practice resident's clinic, a family practice prenatal clinic, or a community obstetrician's office. At the 3-year concurrent period, the mothers were employed full time (14%), employed part time (15%), or unemployed (e.g., homemaker) or in school (71%).

Procedures

The maternal measures reported here were collected during three times of measurement: ≤16 weeks gestation (prenatal; Visits A and B), 3–4 weeks postpartum (postpartum, Visits A and B), and when the children were age 3 years (concurrent). During Visit A, questionnaires were completed and five saliva samples were obtained for saliva Cort determinations. During Visit B, interviews were completed and blood was obtained for T, E_2, and Δ4-A determinations and saliva for Cort determinations. The follow-up visit (concurrent; Visits A and B), when the children were age 3 years, consisted of obtaining measures of maternal emotions, demographic information, and parenting attitudes and practices. Saliva was collected from the mothers for Cort and T assays. The children were videotaped while completing the McCarthy Scales of Children's Ability (MSCA).

The project was approved by the institutional review boards of a research university and the collaborating community hospital. In the prenatal period, adolescents over age 18 years, and a parent or legal guardian of those under age 18 years, gave written consent to participate in the study. At the follow-up, the mothers provided written consent for themselves and their child to participate.

Measures

Maternal biological measures. The collection of blood and saliva samples began at 8:30 a.m. to control for diurnal variations in hormone concentrations.

Serum assays: Prenatal and postpartum. Serum for E_2, T, and Δ4-A was obtained at the prenatal and postpartum visits. In addition to T and E_2, Δ4-A an adrenal androgen, was obtained, as it is secreted under stressful conditions, has androgenic effects, and is related to extremes in aggressive behavior (Yalcinkaya, Siiteri, Vigne, Licht, Pavgi, Frank, & Glickman, 1993). Mothers were asked to refrain from eating, drinking, and smoking for 1 hr before coming to the laboratory. The venipuncture procedure for blood collection used a 21- or 23-gauge scalp vein needle that was inserted into a vein in the antecubital space, and samples were drawn at 0, 20, and 40 min. Patency was maintained between samples using Heparin lock flush solution (100 USP/ml). Whole blood was drawn, placed in ethylenediaminetetraacetic acid (EDTA) tubes on ice, and then was centrifuged for 20 min at 3000 RPM. Serum was removed, placed in cryostorage vials and frozen at –80°C until assayed. The mean of the three serum samples was used in the statistical models.

Total T and E_2 levels were determined by radioimmunoassay (RIA) using reagents from Diagnostic Products Corporation (DPC; Los Angeles, CA). The sensitivity of the method was 10 ng/dl for T and 10 pg/ml for E_2. The average intra-assay coefficients of variation were 8 and 9% for T and E_2, respectively. Δ4-A levels were determined by RIA using reagents obtained from Diagnostic Systems Laboratory (DSL; Webster, TX). The sensitivity of this assay is 0.1 ng/ml. The average intra-assay coefficient of variation was 11%.

Saliva assays: Prenatal and postpartum. Cort concentrations normatively are high during pregnancy but the majority of Cort is bound to (versus free of) its carrier protein, Cort binding globulin (CBG), thereby limiting its biological activity. Cortisol found in saliva is free, as CBG does not permeate the oral mucous membrane. Therefore, saliva versus serum Cort was used in all analysis at the prenatal, postpartum, and concurrent times of measurement. Salivary flow was stimulated by sugarless gum (Trident), which does not interfere with Cort assay determination (Schwartz, Granger, Susman, Gunnar, &

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Laird, 1998). To maintain consistency across samples, participants rinsed their mouths with water prior to beginning salivary sampling to remove particles from the oral cavity. After 5 min, the participants spat a 5-ml sample of saliva into a collection tube. Five samples of saliva for assay were obtained at 20-min intervals beginning upon arrival at the laboratory (time 0, 20, 40, 60, and 80 min). Samples were initially placed in a freezer following each visit to the laboratory and then transported on ice and frozen at −80°C for later analysis (within 6 months) at an endocrine laboratory. The mean of the five cortisol assays was used in the analysis.

Cort concentrations were determined by double antibody RIA (Pantex, Santa Monica, CA). The sensitivity of the method was 1.0 μg/dl. All samples were tested in duplicate according to the manufacturers protocol. Average intra- and interassay coefficients of variation were 4.9 and 4.4%, respectively. Duplicates that varied by more than 5% were repeated.

Saliva assays: Concurrent. At the 3-year follow up (concurrent), Cort and T only were assayed in saliva. The procedure for collecting saliva was identical to that described above. After the mothers signed the informed consent forms, five saliva samples were obtained at 0, 20, 40, 60, and 80 min. Cort levels were determined using the DPC (Los Angeles, CA) Cort RIA kit. The sensitivity of the method was 0.2 μg/dl. The mean intra- and interassay coefficients of variations for saliva Cort were 8.6 and 4.4%, respectively. All samples were tested in duplicate, with the average of duplicates used in the analyses. The mean of the five cortisol assays was used in the analysis.

Saliva T levels were determined by RIA using modifications of a kit from DSL. The sensitivity of this assay was 0.8 pg/ml. The average intra- and interassay coefficients of variation were 6.3 and 6.8%. The T mean of time 0 and time 20 min samples was used in the statistical models.

Maternal emotion measures.

Depression. Depression was assessed by the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) and the depression subscale of the Neuroticism, Extraversion, Openness Personality Inventory (NEO; Costa & McCrae, 1985). The BDI is a self-report measure consisting of 21 items reflecting symptoms and attitudes of depression. The items are scored from 0 to 3, with 3 indicating the greatest degree of depression symptoms. The NEO is a measure consisting of 40 items that fall into five subscales. The subscales for depression, anxiety, and hostility were used in the current analyses. The internal consistency indices for the depression measures in this sample (Cronbach's alpha) were Beck depression, .78; NEO depression, .83.

Anxiety. Anxiety was assessed with the State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). The STAI is a well-standardized 40-item, self-report instrument designed to measure both state and trait anxiety. Percentile scores were used in the analysis. A second measure of anxiety was obtained from the anxiety subscale of the NEO. The internal consistency indices (Cronbach's alpha) were trait anxiety, .57; state anxiety, .67; and NEO anxiety, .72.

Anger. Anger was assessed using the State–Trait Anger Scale (STAS; Spielberger, Jacobs, Russell, & Crane, 1983). The STAS is a well-standardized 30-item, self-report instrument designed to measure both state and trait anger. Sum T scores were used in the analysis, as standardized percentile scores are not available for the ages included. A second measure of hostility was the hostility subscale of the NEO. The internal consistency indices (Cronbach's alpha) in this sample were trait anger, .87; state anger, .95; and NEO hostility, .75.

Factor structure of emotions. To reduce the number of emotion variables, confirmatory factor analysis was done to create emotion factors at each time of measurement. Two factors were expected to emerge: a state emotion score and a trait emotion score. The following scores were used to create the factors: BDI sum score, state anxiety (percentile score), trait anxiety (percentile score), trait anger (sum score), state anger (sum score), NEO anxiety, NEO hostility, and NEO de-

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Table 1. *Factor loadings for state and trait emotions at the prenatal, postpartum, and 3-year follow-up (concurrent) periods*

Emotions	Prenatal State	Prenatal Trait	Postpartum State	Postpartum Trait	Concurrent State	Concurrent Trait
State anxiety	0.84	0.13	0.75	0.38	0.62	0.50
State anger	0.74	–0.15	0.90	–0.07	0.91	–0.10
Beck Depression Inventory	0.69	0.31	–0.02	0.71	0.26	0.76
Trait anxiety	0.65	0.59	0.41	0.79	0.38	0.78
Trait anger	0.07	0.71	0.07	0.76	–0.10	0.82
NEO anxiety	0.32	0.62	0.27	0.57	0.16	0.80
NEO hostility	0.05	0.82	0.32	0.65	0.06	0.76
NEO depression	0.13	0.80	0.02	0.88	0.06	0.84

pression. In interpreting the rotated factor pattern, an item was said to load on a given component if the factor score was .55 or greater for that component and was less than .55 on the other component. Two primary factors were identified at each time of measurement, which were labeled *state* emotion (sum of state anxiety percentile score, state anger sum score, BDI), and *trait* emotion (trait anxiety [percentile score], trait anger [sum score], NEO anxiety, NEO hostility, and NEO depression). The factor loadings appear in Table 1. The mean for each factor was used in the analyses.

Parenting attitudes. Parenting attitudes were assessed using the Adult–Adolescent Parenting Inventory (AAPI; Bavolek, 1975). The AAPI is a standardized 32-item, self-report instrument designed to measure constructs of parenting: empathy toward the child, views toward the use of corporal punishment, inappropriate expectations of the child, and role expectations of the child. High scores on the subscales reflect positive parenting practices, whereas low scores reflect negative parenting practices. The internal consistency indices (Cronbach's alpha) in the current sample were empathy toward the child, .86; views toward the use of corporal punishment, .90; inappropriate expectations of the child, .84; and role expectations of the child, .91.

Child measures.

Temperament. The Children's Behavior Questionnaire (CBQ; Rothbart, 2001; see also Goldsmith & Rothbart, 1991) was completed by the mother. The CBQ is a standardized 195-item questionnaire used to identify 15 subscales of child temperament: activity level (.81), anger/frustration (.76), approach (.76), attentional focusing (.74), discomfort (.74), falling reactivity and soothability (.80), fear (.69), high intensity pleasure (.79), impulsivity (.78), inhibitory control (.74), low intensity pleasure (low pleasure) (.70), perceptual sensitivity (.77), sadness (.67), shyness (.94), and smiling and laughter (.79). Internal consistency indices for the subscales (Cronbach's alpha), based on the current sample, appear in parentheses.

Reactivity and regulation. Behavior of the child was videotaped during administration of the MSCA (McCarthy, 1972) and later coded for dimensions of behavior reactivity and regulation. Purposeful overlap existed between the categories of the CBQ and the behavior reactivity and regulation observational categories. The overlap was intended to yield independent sources of information about temperament based on questionnaires and laboratory assessments. The categories were designed to assess behavior regulation based on Rothbart's (1989) notion of arousal to stimulation (reactivity) and modulation of that arousal (self-regulate). The categories were adapted from the Infant Behavior Record (Bayley Scales of Infant Development; Bayley, 1969), the Inhibition Index (Scarpa, Raine, Venables, & Mednick, 1997), and behaviors hypothesized to be related to the activational effects of hormone concentrations (e.g., aggressive behavior; Inoff–Germain, Arnold, Nottelmann, Susman, Cutler, & Chrousos,

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1988; Mazur & Booth, 1998). The videotapes were coded every 30 s for nonverbal aggression (1, no occurrence of nonverbal activity; 2, shows nonverbal activity to avoid the task [e.g., shakes head "No"]), physical aggression (1, no physical aggression; 2, any physical aggression [e.g., pushes, kicks mother or tester]), verbal aggression (1, no verbal refusal; 2, verbal refusal or verbal aggression [e.g., "I hate you"]), ability to return to task (1, returns easily to task or does not stray from task; 2, does not return to task without guidance), passive noncompliance (1, does not engage in nontask behavior; 2, engaged in a behavior not related to the task), feedback requests (1, does not request feedback; 2, requests feedback either verbally or through gestures [e.g., Can you help me?]), self-assertion (1, no communication regarding interest in the task; 2, communicates verbally or with gestures indicating interest in the task), and self-evaluation (1, does not verbalize self evaluation comments; 2, verbalizes that he or she is not good at the task). Behavior also was rated every 30 s using a 1–5 system for the following categories: physical activity (1, highly inactive [0 s of movement]; 5, highly active [23–30 s of movement]), redirection of activity (1, does not require redirection; 5, needs redirection five or more times during the 30-s period), avoidance (1, 0 s of avoiding behaviors; 5, covers eyes or tries to leave the room for 23–30 s), distractibility (1, 0 s of no interest; 5, no interest in the task for 23–30 s), happiness (1, appears very happy; 5, appears very unhappy), reaction to testing (1, 0 s of crying; 5, cries uncontrollably for 23–30 s), approach (1, always approaching tester; 5, pulls away from tester, turns head away, no eye contract), and verbalizations (1, speaks spontaneously throughout the 30-s interval, 5, does not speak in 30-s interval). Three undergraduate students were trained to code the videotapes. Every fourth or fifth tape was double-coded by an undergraduate and a senior graduate student (13% of the tapes). The mean interrater agreement for the behaviors was 96%, with no category having less than a 93% agreement. The possibility of chance agreement is acknowledged but the overall percent agreement is high.

Data analysis plan. The overall goal was to identify differences in child temperament in the 3-year-old children for groups of mothers who shared similarities in patterns of prenatal, postpartum, and concurrent hormones and emotions. At the concurrent period, groups of mothers based on patterns of attitudes toward parenting also were included in tests of hypotheses as possible moderators of hormones and emotions and child temperament. Consistent with the holistic, person-oriented approach, cluster analysis was done to identify mothers with similar patterns of hormones and emotions (Bergman, 1998). Cluster analysis will result in some structure even when applied to a random data set, as is true for other multivariate analyses (Wångby, Bergman, & Magnusson, 1999). To clarify the identity of the clusters, a one-way analysis of variance was done to ascertain the validity of the cluster solutions retained for further analysis for the hormones, emotions, and parenting attitudes (see Raine, O'Brien, Smiley, Scerbo, & Chan, 1990, for similar strategy). Bergman (1998) proposed that the number of clusters to be retained should be determined by examining the ratio of within clusters sum of squares to the total variance in the sample. The goal is to minimize this ratio, which can result in retaining too few clusters. To avoid retaining too few clusters while at the same time considering the number of participants per cluster, we used two criteria for retaining the clusters: (a) there must be significant differences between clusters on at least one of the measures used to construct the cluster and (b) there must be three or fewer clusters. The maternal hormones and emotions were considered in separate cluster analyses because of the complexity of interactions between hormones and emotions. Tests of hypotheses followed the cluster-difference analysis using multivariate analysis of covariance (MANCOVA).

Results

Pattern-oriented approach: Cluster analysis

The SPSS program (George & Mallery, 1999) was used to establish maternal hormone and emotion clusters at the prenatal, postpartum,

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and concurrent times of measurement. Scores for the various measures that formed the clusters first were converted to *Z* scores by the SPSS program. The squared Euclidian distance is used for measuring distance between each case or cluster, clusters are combined using Ward's method, and agglomerative hierarchical clustering is used to produce the clusters. The SPSS default option of an unlimited number of clusters initially was adopted. No more than three clusters were identified for the hormones or emotions across the three times of measurement, with one exception: five clusters of hormones were identified at the postpartum assessment. The hormones were reclustered restraining the number of clusters to three because of the relatively small sample size.

The hormone concentrations were controlled for weeks gestation in the cluster analyses, as the hormones included rise across weeks gestation. The means and standard deviations for the clusters appear in Figure 1.

Prenatal.

Hormone clusters. The maternal hormone clusters at the prenatal period were constructed using the mean values for serum T, E_2, and Δ4-A, and for saliva Cort. Two clusters of mothers were identified, one with *low* mean hormone levels and one with *high* mean hormone levels. There were significant differences between the high and low hormone cluster for all hormones: T, E_2, Δ4-A, and Cort ($p < .05$).

Emotion clusters. Emotion clusters were formed, at the prenatal, postpartum, and concurrent times of measurement, using the factor scores described earlier for *state* and *trait* emotions. At the prenatal period, three clusters were identified: (a) low state and trait emotions, (b) medium state and trait emotions, and (c) high state and trait emotions. There were significant mean differences between the clusters for state and trait emotions ($p < .01$).

Postpartum.

Hormone clusters. The three clusters were (a) low mean T, E_2, and Δ4-A, and medium Cort (primarily low levels); (b) medium T and Δ4-A, high E_2, and low Cort (varied levels, high estrogenized); (c) high T and Δ4-A, medium E_2, and high Cort (varied levels, high androgenized). The means were significantly different from each other ($p < .05$).

Emotion clusters. The clusters were (a) medium state and low trait emotions, (b) low state and medium trait emotions, and (c) high state and high trait emotions. The cluster means for state and trait emotions were significantly different from each other ($p < .05$).

Concurrent.

Hormones clusters. Salivary assays were done for T and Cort only because existing literature does not lend itself to the formulation of hypotheses regarding other maternal hormones and child temperament. Three hormone clusters were identified: (a) low T and low Cort, (b) medium T and high Cort, and (c) high T and medium Cort. The means for the clusters were significantly different from each other ($p < .05$).

Emotion clusters. The three emotion clusters were identical to the prenatal clusters: (a) low state and trait emotions, (b) medium state and trait emotions, and (c) high state and trait emotions. State and trait emotions were significantly different from each other in all three clusters ($p < .01$).

Parenting clusters. Parenting clusters were formed using the four subscales of the AAPI: empathy toward the child, views toward the use of corporal punishment, inappropriate expectations of the child, and role expectations of the child. High scores denote positive parenting. Two clusters were identified: (a) high scores on all subscales (positive) and (b) low scores on all the subscales (negative). The means for the four parenting scales were significantly different from each other ($p < .05$) and appear in Figure 1.

Maternal hormone and emotion patterns and child temperament

The analyses addressed the hypothesis that patterns (clusters) of maternal hormones predict individual differences in temperament in the 3-year-olds. The child outcome measures were the CBQ and behavior reactivity and

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regulation observational categories (hereafter referred to as behavior regulation). A person-oriented approach was used to define maternal patterns of hormones and emotions. A variable-oriented approach then was used to relate maternal hormones and emotions to the CBQ and behavior regulation categories. The relationship between mothers' current family SES (either nuclear or parent SES) and maternal chronological age and child temperament were examined to rule out the possible confounding influence of either SES or age. All CBQ subscales were entered simultaneously into a MANCOVA with maternal age and SES as covariates (George & Mallery, 1999) followed by a second multivariate analysis with the behavior regulation categories. None of the covariates were significant, so they were dropped from subsequent models. There were no main effects for sex. The means and standard deviations and *F, df,* and *p* appear in Table 2.

Prenatal.

Hormones. The model for the prenatal period consisted of a 2 (hormone clusters) × 3 (emotion clusters) × 2 (sex of child) multivariate analysis of variance (MANOVA). There were no main effects or interactions for the hormone clusters on the CBQ categories. For behavior regulation, there was a significant effect of hormone clusters for verbal and nonverbal aggression in the 3-year-old children. The results for nonverbal aggression emerged after removal of an outlier (>4 *SD*s above the mean). Verbal aggression and nonverbal aggression were significantly higher in children of mothers in the low hormone cluster than children of mothers in the high hormone cluster.

Emotions. There was a main effect for the CBQ categories for inhibitory control and low pleasure. Post hoc Tukey analyses ($p < .05$) showed that inhibitory control was higher in children of mothers with low state and trait emotions than in children of mothers in the high state and trait emotion clusters. Low pleasure was higher in the children of mothers in the low state and trait emotion cluster than in children of mothers in the medium state and trait cluster ($p = .057$), indicating that these children were rated by mothers as not enjoying low stimulus activities. For the behavior regulation categories, children of mothers with high state and trait emotions were lower on redirection of activity than children of mothers with medium state and trait mothers, indicating that children of high state and trait emotion mothers tended to stay on task. There was a significant interaction of Sex of Child × Emotion clusters for physical aggression. The *F, df* and *p* for the significant interactions appear in Table 2, but the pattern of means will not be interpreted for these and subsequent interactions because of the small number of children in some of the cells.

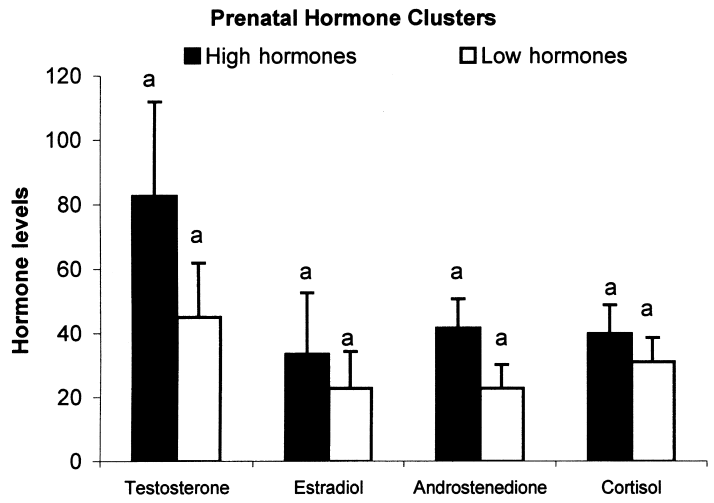
Postpartum.

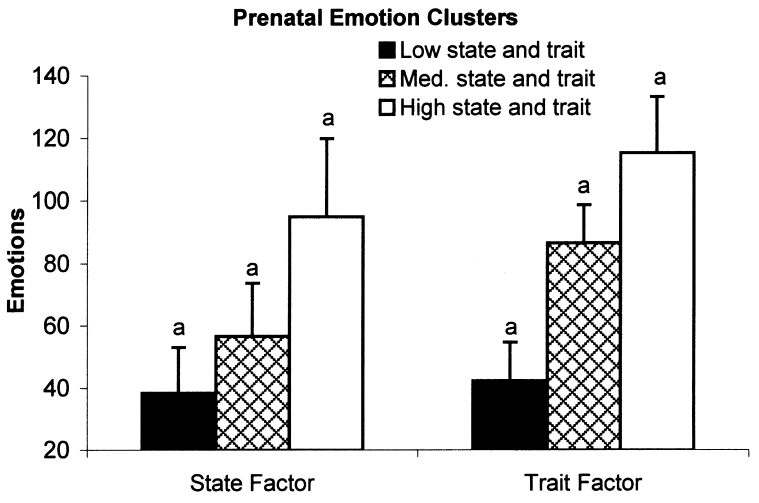
Hormones. The MANOVA consisted of a 3 (hormone clusters) × 3 (emotion clusters) × 2 (sex of child). For the CBQ, there were no main effects for the hormone clusters. There was a significant interaction of Sex × Hormone cluster for the CBQ categories for attentional focusing and for smiling and laughter. The behavior regulation categories revealed a significant main effect of the hormone clusters for physical aggression and for self-evaluation. Children of mothers in the low T, E_2, and Δ4-A and medium Cort cluster (mainly low hormone cluster) exhibited significantly more physical aggression than children of mothers in the medium T and Δ4-A, high E_2, and low Cort cluster (varied, high-estrogenized cluster). Children of mothers in the low T, E_2, and Δ4-A and medium Cort and children in the high T and Δ4-A, medium E_2, and high Cort group (varied, high-androgenized cluster) were significantly higher on negative self-evaluations than children of mothers in

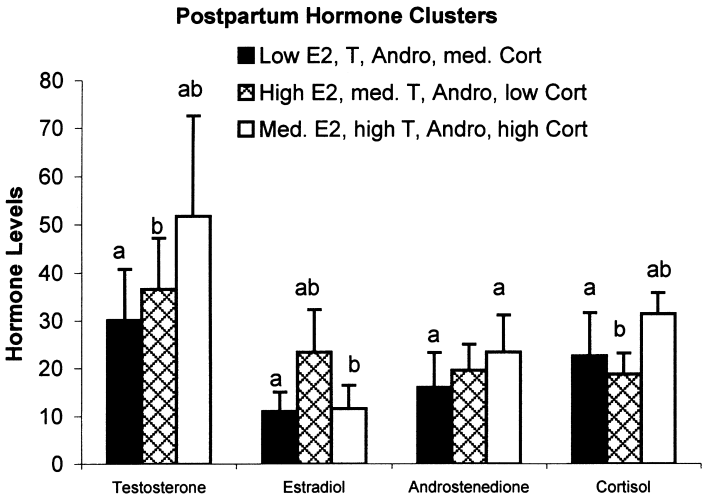
Figure 1. Means for hormone, emotion, and parenting cluster at the prenatal, postpartum, and 3-year follow-up (concurrent) periods. Values were standardized to be equivalent across hormones and emotions. Means with the same letters (*a* or *b*) are significantly different from each other based on Tukey post hoc tests.

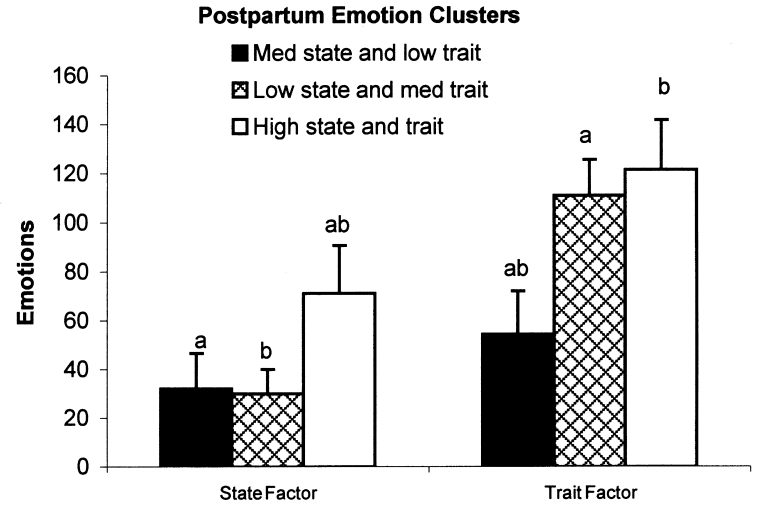
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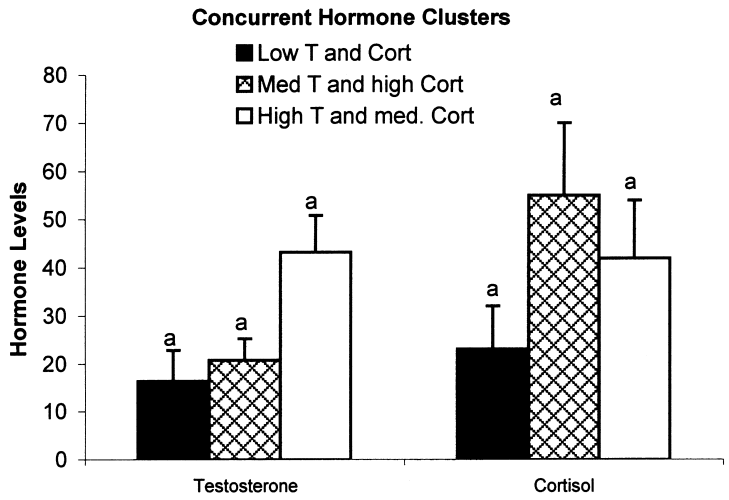


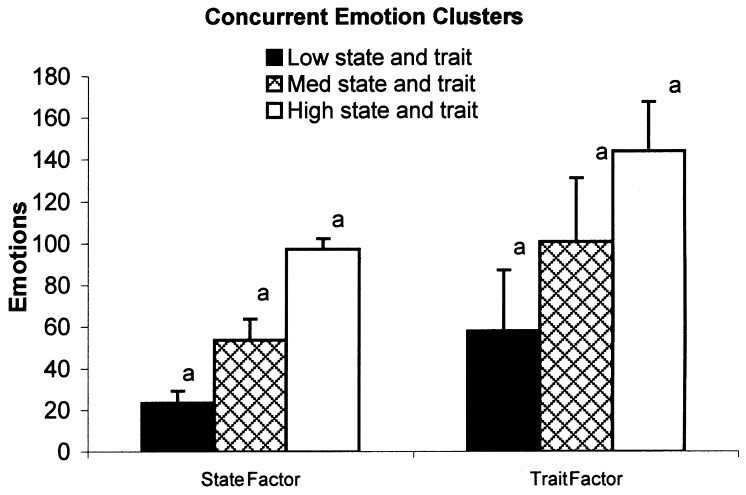


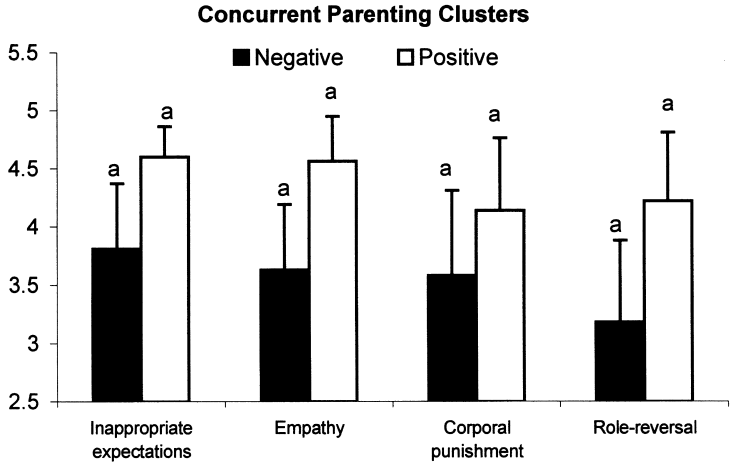




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Table 2. *Means (and standard deviations) and multivariate analysis for prenatal, postpartum, and 3-year follow-up (concurrent) periods for temperament by hormone, emotion clusters, and parenting clusters and sex of child*

	Clusters			*F* (*df*)	*p*
	Prenatal				
Hormone clusters	Low hormones	High hormones			
Behavior regulation					
Verbal aggression	1.91 (0.09)	1.85 (0.14)		5.052 (1, 49)	.03
Nonverbal aggression	1.93 (0.08)	1.86 (0.17)		7.032 (1, 49)	.01
Emotion clusters	High state and trait	Medium state and trait	Low state and trait		
CBQ					
Inhibitory control	3.77 (0.87)[a]	4.10 (0.60)	4.46 (0.81)[a]	3.372 (2, 53)	.04
Low intensity pleasure	5.39 (0.84)	4.97 (0.49)[a]	5.63 (0.42)[a]	3.076 (2, 53)	.06
Behavior regulation					
Redirection of activity	4.23 (0.68)[a]	3.59 (0.92)[a]	4.03 (0.64)	4.185 (2, 49)	.02
Sex by emotion					
Behavior regulation					
Physical aggression				3.382 (2, 49)	.04
	Postpartum				
Hormone clusters	Low T, E_2, Δ4-A, medium Cort	Medium T and Δ4-A, high E_2, low Cort	High T and Δ4-A, medium E_2, high Cort		
Behavior regulation					
Physical aggression	1.95 (0.09)[a]	1.86 (0.06)[a]	1.94 (0.08)	3.569 (2, 48)	.04
Self-evaluation	1.93 (0.06)[a]	1.84 (0.12)[a,b]	1.92 (0.04)[b]	10.585 (2, 48)	.000
Emotion clusters	Medium state and low state	Low state and medium trait	High state and high trait		
Behavior regulation					
Self-evaluation	1.92 (0.05)	1.88 (0.12)	1.93 (0.07)	5.323 (2, 48)	.01
Sex by hormone					
CBQ					
Attentional focusing				3.130 (2, 53)	.05
Smiling and laughter				4.776 (2, 53)	.01
Sex by emotion					
CBQ					
Approach				3.554 (2, 53)	.04
Perceptual sensitivity				3.368 (2, 53)	.04

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Behavior regulation					
Reaction to testing				6.895 (2, 48)	.003
Hormone by emotion					
Behavior regulation					
Self-evaluation				3.614 (4, 48)	.01
		Concurrent			
Hormone clusters	High T, medium Cort	Med T, High Cort	Low T and Cort		
CBQ					
Activity level	5.64 (0.87)[a]	5.28 (0.72)[b]	4.66 (0.55)[a,b]	5.447 (2, 59)	.04
Approach	5.35 (0.80)	5.29 (0.63)[b]	5.01 (0.43)[b]	6.816 (2, 59)	.00
Attentional focusing	4.19 (1.34)	4.44 (0.71)	4.73 (0.58)	3.436 (2, 59)	.04
High intensity pleasure	5.46 (0.87)	5.37 (0.76)	4.94 (0.94)	7.094 (2, 59)	.003
Impulsivity	5.82 (1.00)[a,b]	4.93 (0.73)[a]	4.93 (0.75)[b]	5.818 (2, 59)	.01
Low intensity pleasure	4.78 (1.14)[a]	5.21 (0.71)	5.49 (0.64)[a]	3.817 (2, 59)	.03
Shyness	2.86 (1.50)	3.73 (1.24)	3.73 (1.13)	3.833 (2, 59)	.03
Behavior regulation					
Physical activity	3.06 (0.82)	3.58 (0.71)	3.52 (0.76)	4.569 (2, 54)	.02
Distractability	3.39 (0.99)	3.67 (0.87)	3.71 (0.69)	3.898 (2, 54)	.03
Passive noncompliance	1.48 (0.28)	1.55 (0.28)	1.54 (0.22)	3.565 (2, 54)	.04
Emotion clusters	Low state and trait	Medium state and trait	High state and trait		
CBQ					
Approach	5.23 (0.54)[a]	5.21 (0.58)[b]	4.60 (0.60)[a,b]	3.775 (2, 59)	.03
	Positive parenting	Negative parenting			
Approach	5.34 (0.52)	5.03 (0.60)		15.44 (1, 59)	.000
High intensity pleasure	5.38 (0.90)	5.01 (0.82)		9.93 (1, 59)	.003
Low intensity pleasure	5.62 (0.68)	4.99 (0.71)		4.08 (1, 59)	.05
Sex by hormone					
CBQ					
Approach				7.735 (2, 59)	.002
Shyness				4.225 (2, 59)	.02
Sex by emotion					
CBQ					
Falling reactivity and soothability				6.080 (1, 59)	.02

(*continued*)

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Table 2. *Continued*

	Clusters			$F(df)$	p
Hormone by emotion					
CBQ					
Approach				2.61 (4, 59)	.05
High intensity pleasure				2.74 (4, 59)	.04
Behavior regulation					
Nonverbal aggression				3.66 (4, 54)	.01
Distractability				2.66 (2, 59)	.05
Hormone by parenting	High T and Cort	Medium T and Cort	Low T and Cort		
CBQ					
Falling reactivity and soothability				3.29 (2, 59)	.05
Negative parenting	4.17 (0.75)	4.54 (0.56)	4.71 (0.59)		
Positive parenting	4.39 (1.57)	4.72 (0.52)	4.41 (0.56)		
Emotion by parenting	High state and trait	Medium state and trait	Low state and trait		
CBQ					
Fear				4.00 (2, 59)	.05
Negative parenting	4.65 (1.60)	4.24 (0.74)[a]	3.63 (0.91)		
Positive parenting	4.56 (0.15)	3.79 (0.98)[a]	4.38 (0.82)		
Behavior regulation					
Nonverbal aggression				4.23 (1, 54)	.005
Negative parenting	1.77 (0.28)	1.90 (0.11)	1.95 (0.09)		
Positive parenting	2.00 (0.00)	1.95 (0.43)	1.91 (0.12)		
Self-evaluation				9.27	.005
Negative parenting	1.95 (0.00)	1.86 (0.10)[a,b]	1.96 (0.04)[b]		
Positive parenting	1.95 (0.00)	1.93 (0.04)[a]	1.92 (0.06)		

Note: CBQ, Child Behavior Questionnaire. Means with the same letters are significantly different from each other based on Tukey post hoc tests.

the medium T and Δ4-A, high E_2, and low Cort cluster.

Emotions. There were no main effects for the emotion clusters on the CBQ, but there was a significant interaction of Sex × Emotion for approach and for perceptual sensitivity. For the behavior regulation categories, there was a significant effect for self-evaluation. The post hoc tests were not significant. There was a significant interaction for Sex × Emotion for *reaction to testing*. Finally, there was a significant interaction of Hormone × Emotion clusters for self-evaluation.

Concurrent.

Hormones. The model consisted of a 3 (hormone clusters) × 3 (emotion clusters) × 2 (sex of child) × 2 (AAPI clusters). There was a significant main effect of the hormone clusters on the CBQ subscales activity level, approach, attentional focus, high pleasure, impulsivity, low pleasure, and shyness. As shown in Table 2, the strongest findings were for activity level, impulsivity, and low pleasure based on the significance of post hoc Tukey tests. Children of mothers with high T and medium Cort or medium T and high Cort had significantly higher activity level than children of mothers with low T and low Cort. Similarly, children of mothers with high T and medium Cort were higher on impulsivity than children of mothers with medium T and high Cort and low T and low Cort. The main effect for low pleasure was that children of mothers with low T and low Cort had lower low pleasure scores than children of mothers in the high T and medium Cort cluster. The post hoc tests were not significant for the remaining significant categories.

Emotions. There was a significant main effect for the CBQ category of approach. Children of mothers in the low state and trait and medium state and trait clusters were significantly higher on approach than children of mothers in the high state and trait cluster. No main effects emerged for the behavior regulation categories.

Parenting. The main effects for AAPI parenting clusters emerged for three CBQ categories. Children of mothers who were in the negative parenting cluster were significantly lower on approach, high pleasure, and low pleasure.

Hormones, emotions and parenting interactions

A hypothesis was that in the concurrent period, hormones, emotions, and parental attitudes and practices would interact to influence temperament. There was a significant interaction between concurrent hormone clusters and AAPI for the CBQ subscale of falling reactivity and soothability and an interaction between emotions and AAPI for the CBQ subscale of *fear* and the behavior regulation categories of nonverbal aggression and self-evaluation. The pattern of means and post hoc Tukey tests showed that there were no significant differences between the means for falling reactivity and soothability or for nonverbal aggression. For fear, children of mothers in the medium state and trait clusters and negative parenting cluster were significantly higher on fear than children of mothers in the positive parenting cluster. The interaction for self-evaluation cannot be meaningfully interpreted because two of the cells contain only one participant.

Interactions also were identified for Hormone × Emotion clusters for the CBQ categories of approach and high pleasure and for the behavior regulation categories of nonverbal aggression and distractability, Sex × Hormone for approach and shyness and Sex × Emotion for falling reactivity and soothability.

Discussion

The results of the study cannot be compared with previous reports as this report is the first to link maternal prenatal, postnatal, and concurrent hormones and emotions and temperament in young children. The clearly identified hormone patterns varied across the prenatal, postpartum, and concurrent times of assessment, whereas the emotion patterns were similar at the prenatal and concurrent assessments. Of note is that the person-oriented theoretical approach that focused on holistic processes within mothers was more effective in linking maternal hormones and emotions to

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child temperament than a linear relationship or variable-oriented model (Susman, 1998). The maternal hormone and emotion patterns that were identified related to child temperament in theoretically meaningful ways.

Prenatal hormones and emotions

The normal physiology of pregnancy undoubtedly limited the number of hormone patterns that were possible in the prenatal period. The adrenal (Cort) and gonadal (T and estrogens) hormones that are included show a rise (albeit physiologically adaptive; Yen, 1994) beginning in the 1st trimester. These normative pregnancy-related increases in hormones are essential to the maintenance of the maternal–fetal unit; thus, wide variations in patterns of hormone levels are not adaptive and may compromise the survival of the fetus. In spite of the normative constraints on hormone levels, there remain significant mean hormone level differences between the high and low clusters, suggesting that nonpregnancy-related processes contribute to these patterns. Variations in hormone levels are a function of genetic and metabolic differences, but experiences, like stressors, can contribute to differences in hormone concentrations as well. Maternal stress is related to elevated Cort in pregnant women which can affect the developing fetal nervous system (Sandman et al., 1997) and is hypothesized to be related to poor neonatal outcomes.

The pattern of emotions at the prenatal and concurrent periods was identical. In the postpartum, the emotion patterns were characterized by slight variations in state anxiety, whereas trait emotions were characterized by low, medium, and high trait emotions at all three times of measurement. The variation in the postpartum state emotions is attributable to the dramatic psychological and role-requirement changes that co-occur with the transition into motherhood. New mothers are required to assume the responsibility for a helpless infant often without adequate preparation. These challenging roles and responsibilities occurred in a family context without adequate social or economic support for some of the young women in our sample. The consistent patterns of trait emotions across pregnancy, the postpartum, and 3-year follow-up indicate that trait emotional patterns are enduring even in the face of major biological and social role transitions.

The differences in children's temperament and behavior regulation in mothers with high and low hormone concentrations during pregnancy were not as apparent as anticipated, based on the animal-model literature on alterations in hormone concentrations and later offspring behavior. Nonetheless, the two significant differences that emerged, that mothers in the low hormone group had children who exhibited more aggressive behavior, appropriately could be attributed to chance given the number of group–difference analyses. Nonetheless, the pattern of low maternal hormone concentrations and aggressive behavior in children is consistent with an emerging body of literature showing that low hormone concentrations, especially products of the HPA axis, like Cort and CRH, are related to antisocial behavior (Pajer et al., in press; see Susman & Finkelstein, 2001, for review of findings). Specifically, low levels of CRH, the hormone responsible for precipitating the cascade of hormones following a stressor, were related to greater numbers of self-reported symptoms of conduct disorder in the mothers in the current study (Susman et al., 1999). Low hormone levels may reflect low physiological arousal that is implicated in antisocial behavior. Low arousal reflected in resting heart rate predicted later aggressive behavior (Raine, Venables, & Mednick, 1997). Low hormone levels and related arousal, then, may be a contributing process to the intergenerational transmission of antisocial behavior (Farrington, Lambert, & West, 1998) that is reported in national and cross-national studies.

Lower concentrations of HPG axis hormones, like estrogen, have the potential for affecting brain development and temperament through a number of possible mechanisms. Adequate concentrations of HPG axis hormones are necessary for optimal fetal development as these hormones may promote cell survival and prevent apoptosis (cell death; Gorski, 1997). Although there are a number of mechanisms that may be involved in the

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relationship between low levels of hormones and aggressive behavior, each explanation remains speculative but important to systematically examine in future research.

Not surprisingly, children of mothers with low state and trait emotions tended to report less difficult temperament based on the CBQ categories of inhibitory control and low pleasure. In parallel fashion, children of mothers with a pattern of high state and trait emotions needed continuous redirection of activity to stay on task during the challenging cognitive task. Difficulties in the ability to self-regulate in challenging situations are related to the development of various types of psychopathologies (Derryberry & Rothbart, 1997). The pattern of relationships between maternal emotions and temperament supports the longstanding hypothesis of positive affect and a good outcome of pregnancy—in this case, positive temperamental qualities. The mechanisms whereby positive or negative emotions and the neurobiology of fetal development are linked are yet to be explained.

Postpartum hormones and emotions

The pattern of three hormone clusters that emerged in the postpartum period undoubtedly reflects the expanded variability in hormone concentrations of the nonpregnant state. HPG axis hormones, but not cortisol, will have returned to the basal nonpregnant state 3–4 weeks postpartum. As was the case in the prenatal period, differences between the maternal hormone patterns were prominent in the behavior regulation categories reflecting aggressive behavior (viz., physical aggression). Noteworthy also is that physical aggression was more prominent in children of mothers with low hormone levels, although negative self-evaluations were significantly higher in children of mothers in both the low and high T and Δ4-A clusters. The pattern of low hormone concentrations—principally, low T, E_2 and Δ4-A—may indicate a low arousal and a related nonengaged pattern of maternal childrearing. Testosterone, E_2, and Δ4-A are considered to be associated with arousal as a component of the neuroendocrine preparedness mechanism. In the presence of low hormone concentrations, mothers may be less aroused and, therefore, less engaged and active in setting limits and otherwise fostering the child's regulatory behavior. In contrast, when maternal T and Δ4-A were high, child self-evaluations were more negative, suggesting less positive interaction between mothers and children.

The absence of findings between patterns of maternal emotions in the postpartum and temperament were unanticipated given the findings relating postpartum depression to later child characteristics. The exception was a significant but small difference between the emotion patterns and self-evaluations. The lack of clinically significant self-reports of anxiety and depression in the young women likely reduced the overall relationship between patterns of emotions and child temperament.

Concurrent hormones and emotions

Developmental transformations were apparent in the relationship between hormones and temperament. The observed pattern of maternal high T and low Cort and high activity and impulsivity in the children reflects the expected relationship. Mothers with higher T were expected to be harsh or aggressive in their approach to child rearing, given the relationship between T and aggressive and dominant behavior (Mazur & Booth, 1998). In animal model studies, high T and low Cort is reflective of high status and dominance (Sapolsky, 1991). Dominance may lead to parenting that is accompanied by excessive and harsh discipline that is not conducive to self-regulation. The relationship between T and impulsivity also has been identified in adolescents (Olweus, Mattsson, Schalling, & Low, 1988). The mechanism involved in an active and impulsive temperamental style in children of high T and low cortisol mothers is that the child may mimic the mother's impulsive style of dealing with challenges and thereby fail to develop self-regulation. The relationship between low cortisol and high activity and impulsivity is consistent with the literature cited above documenting the relationship between low cortisol and antisocial behavior. Finally,

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as was true for the relationship between maternal emotions and temperament in the prenatal period, children of mothers in the low state and trait cluster had more positive temperamental qualities, as reflected in significantly higher approach behaviors than children of mothers in the high state and trait cluster.

The holistic interactionistic theoretical notion that parenting attitudes and practices, hormones, emotions, and temperament form a dynamic system was supported by the interaction between hormone clusters and the CBQ category of falling reactivity and soothability and the interaction of the emotion by CBQ category of fear and the behavior regulation categories of nonverbal aggression and self-evaluation. Unfortunately, the sample size in the various cells was too small to meaningfully interpret the findings. Nonetheless, these interactions support the theoretical perspective regarding the importance of integrating biological, psychological, and contextual processes in development and developmental psychopathology.

Theoretical implications

Consistencies in the longitudinal relationships between maternal hormones and emotions and temperament were apparent on both the questionnaire and observational indices of temperament. Differences were also apparent across the times of measurement, but the inconsistencies across time support the holistic interaction principle of the dynamic and changing influences of biology, psychology, and context over time. The lack of consistency over time is consistent with Cairns's (1979) perspective that what appears to be the same activity at different stages of development may be similar only in superficial ways. In the prenatal period, multiple unmeasurable and indirect pathways undoubtedly mediate the effects of maternal hormones and emotions, fetal neurodevelopment, and later temperament. The normal and dynamic changes in hormones during pregnancy mask individual differences in hormones and related ties to fetal neurobiology and later temperament. In addition, hormones affect neurotransmitters, and in some cases hormones themselves are neurotransmitters negating the possibility of defining specific paths between hormones and temperament. In the case of postpartum and concurrent hormone periods, the child-rearing environment provides the context for affecting attentional and motivational processes. In turn, attentional and motivational processes interact with reactivity of underlying neuronal systems serving regulatory functions related to motivation and attention (Derryberry & Rothbart, 1997). These conjectures are proposed in lieu of specific information regarding the precise mechanisms linking prenatal, postpartum, and concurrent hormones and temperament and behavior regulation.

Consistency was noted in findings for boys and girls. The maternal hormones and emotions and the temperament and behavior regulation were virtually identical for boys and girls. The lack of sex differences reflects previous observations that boys and girls are more alike than different with respect to temperament (Chess & Thomas, 1984; Guerin & Gottfried, 1994). In contrast, the significant interactions between sex of child and hormones or emotions attest to the importance of assessing temperament in relation to biological and psychological issues.

Limitations and future directions

The number of findings linking maternal hormones and emotions with later temperament were somewhat scant given the number of analyses. Nonetheless the findings may reflect the reality that normal physiological changes of pregnancy undoubtedly masked associations between prenatal development and later temperament. Future research could eliminate the biases introduced by pregnancy-related hormonal changes by measuring hormones very early in the 1st trimester of pregnancy.

The links between parenting and child temperament are likely reciprocal, and these reciprocal interactions were not tested as mother–infant interactions were observed in only a subsample of the children (Ponirakis et al., 1998). Parents, like teachers (Graziano, Jensen–Campbell, & Sullivan–Logan, 1998), have expectations about the outcomes for

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children with different types of temperament. In turn, children's temperament differentially affects parental responses, further modulating the development of child temperament. The reciprocal effects of infant characteristics on postpartum maternal hormones and emotions were not examined. Methodological limitations are acknowledged as well: small sample size, multiple analyses, and the absence of an older adult–mother comparison group. Additionally, the prenatal, postpartum, and concurrent components of the longitudinal model were not tested simultaneously, because of the relatively small *N*. Finally, cluster analysis is a descriptive analysis, and the clusters were derived empirically rather than deductively. Nonetheless, the findings provide a framework for future replication and the development of testable hypotheses based on hypothesis-based pattern procedures, like latent transition analysis (Collins & Wugalter, 1992). The study is strengthened by including both temperament, based on maternal questionnaire, and behavior regulation, based on systematic observations in this first examination of a simultaneous assessment of maternal biological characteristics, emotions, and temperament in young children.

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