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Prenatal Predictors of Infant Temperament

ABSTRACT: Emerging data suggest that prenatal factors influence children's temperament. In 50 dyads, we examined fetal heart rate (FHR) activity and women's antenatal psychiatric illness as predictors of infant temperament at 4 months (response to novelty and the Infant Behavior Checklist). FHR change during maternal challenge was positively associated with observed infant motor reactivity to novelty ($p = .02$). The odds of being classified as high versus low motor among fetuses who had an increase in FHR during maternal stress was 11 times those who had a decrease in FHR ($p = .0006$). Antenatal psychiatric diagnosis was associated with an almost fourfold greater odds of having a high cry reactivity classification ($p = .03$). There also were modest associations between baseline FHR and maternal reports of infant temperament and between observed temperament and that based on mothers' reports. All of the infant results were found independent of the influence of women's postnatal anxiety. These data indicate that physiological markers of individual differences in infant temperament are identifiable in the fetal period, and possibly shaped by the prenatal environment. © 2007 Wiley Periodicals, Inc. *Dev Psychobiol* 49: 474–484, 2007.

Keywords: antenatal psychiatric illness; fetal heart rate; infant temperament

INTRODUCTION

Although still without a precise and universally accepted definition (Goldsmith et al., 1987), the commonly used term “temperament” generally refers to variation in behavioral predispositions which are rooted in distinct neurophysiological substrates, and termed constitutionally based (Boyce, Barr, & Zeltzer, 1992; Fox, 2004; Marshall, Fox, & Henderson, 2000; Rettew & McKee, 2005; Rothbart & Ahadi, 1994; Whittle, Allen, Lubman, & Yucel, 2005). Temperament characteristics are thought to emerge early in life and to show moderate stability across the lifespan (Kagan, 1994; Rothbart and Ahadi) (Whittle et al.). Because certain temperament traits, such as behavioral inhibition and negative emotionality, are

risk factors for psychopathology in later childhood (Biederman et al., 2001; Perkins et al., 1995) (Fendrich, Mackesy-Amity, Johnson, Hubbell, & Wislar, 2005) their developmental determinates are of great interest. Temperament often is thought to be under genetic control (De Luca et al., 2001; De Luca et al., 2003; Dragan & Oniszczenko, 2005; Goldsmith & Lemery, 2000; Oniszczenko & Dragan, 2005) and therefore independent of environmental influences (Marshall et al.). In partial support of this view, recent research has identified various genetic polymorphisms related to specific temperament traits (De Luca et al., 2000, 2001, 2003; Dragan and Oniszczenko, 2005; Goldsmith and Lemery, 2000; Oniszczenko and Dragan, 2005).

In contrast, other researchers (Marshall et al., 2000; Rothbart & Ahadi, 1994; Whittle et al., 2005) emphasize an integrative model that also considers the role of the environment in shaping temperament and associated developmental outcomes. In this view, experience-based change in the expression of temperamental predispositions can occur. For example, children with more challenging temperament characteristics may elicit parenting that inadvertently consolidates their behavioral styles.

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The potential role of the environment in shaping temperament is supported by research suggesting that mood dysregulation during pregnancy is associated with alterations in the in utero environment (Culhane et al., 2001; Federenko & Wadhwa, 2004; Feldman, Dunkel-Schetter, Sandman, & Wadhwa, 2000; Gitau, Cameron, Fisk, & Glover, 1998; Glover, Teixeira, Gitau, & Fisk, 1999; Sandman et al., 1994; Sandman et al., 1999; Sandman et al., 2003; Sandman et al., 2006; Teixeira, Fisk, & Glover, 1999; Wadhwa, Porto, Garite, Chiez-DeMet, & Sandman, 1998; Wadhwa, Garite, & Sandman, 2001), which, in turn, may influence fetal and child neurobehavioral development (de Weerth, van Hees, & Buitelaar, 2003; Gutteling et al., 2005; Huizink, Robles de Medina, Mulder, Visser, & Buitelaar, 2002; Monk et al., 2000; Monk, Myers, Sloan, Ellman, & Fifer, 2003; Monk et al., 2004; O'Connor, Heron, & Glover, 2002; O'Connor, Heron, Golding, & Glover, 2003; O'Connor et al., 2005; Van den Bergh, Mulder, Mennes, & Glover, 2005). In this context, other results from perinatal research, such as findings indicating continuity in fetal and infant neurophysiological substrates (e.g., in movement (Groome et al., 1999) and heart rate (HR) patterns (DiPietro, Costigan, Pressman, & Doussard-Roosevelt, 2000; DiPietro, Costigan, & Pressman, 2002b)) could be viewed as influenced by the antenatal environment as well as genetics. Thus, what has been termed "constitutional" about temperament is emerging as identifiable in the prenatal period and may be, in part, the consequence of environmental influences before birth.

Prior work identifying fetal origins of infant temperament has used characteristics of fetal movement and HR to predict aspects of infant temperamental reactivity. One study showed that increased levels of fetal activity, assessed over a 50-min resting period, was associated with mother-ratings of less infant adaptability to new situations and/or people at 3 and 6 months (DiPietro, Hodgson, Costigan, & Johnson, 1996). In another report from the same laboratory (DiPietro et al., 2002b), more fetal movement (also assessed during a 50-min resting period) predicted less distress to limitations at 1 year, and more exploratory behavior in response to novelty at 2 years of age (DiPietro et al., 2002a). Finally, using Kagan's laboratory-based test of temperament (Kagan & Snidman, 1991), Snidman, Kagan, Riordan, and Shannon (1995) compared 15-min assessments of resting fetal cardiac activity to 4-month-old infant crying and movement reactivity to novel stimuli. Lower resting fetal heart rate (FHR) predicted lower levels of crying and motoric responses (Snidman et al.).

Other studies of prenatal predictors of infant temperament have shown associations between women's antenatal mood and infant behavior. Van den Bergh (1990) found a significant positive relationship between elevations in

women's state and trait anxiety in the 3rd trimester and difficult temperament at 10 weeks and 7 months. In another report (Buitelaar, Huizink, Mulder, de Medina, & Visser, 2003), pregnancy-specific fears (e.g., of giving birth to a handicapped child) predicted poorer attention regulation at 8 months while increased perceived stress during pregnancy was related to problems in adaptation to novelty at 3 months. In contrast, a study based on Kagan's novelty paradigm (Mohler, Parzer, Brunner, Wiebel, & Resch, 2006), found that greater antenatal stress (assessed retrospectively at 2-weeks postpartum) was associated with less infant crying at 4 months. Finally, a recent report showed that pregnant women exposed to the 9/11 World Trade Center collapse who went on to develop Post Traumatic Stress Disorder (PTSD), versus those who did not, rated their infants as showing greater distress to novelty at 9 months (Brand, Engel, Canfield, & Yehuda, 2006). The women with PTSD also had lower morning and evening cortisol levels that were inversely related to their ratings of their child's distress to novelty.

As is evident from the preceding discussion, there are several approaches to studying infant temperament (Goldsmith & Campos, 1986; Kagan & Snidman, 1991; Kagan, 1997; Rothbart, 1981; Rothbart & Ahadi, 1994; Thomas & Chess, 1977). Both parent-report and laboratory systems of rating temperament have strengths and weaknesses (Rettew & McKee, 2005). Self-report measures reflect informant's access to the child's "usual" temperament across time (Rettew and McKee). However, evidence suggests that parental reports are influenced by the observer's own psychological functioning, and often are not associated with ratings from trained observers (Belsky, Hsieh, & Crnic, 1998). Observation-based systems reduce bias by relying on standardized procedures and using trained observers who are not influenced by a relationship with the child. However, data collection is most often constrained to one testing period and a narrow repertoire of activities (Rettew and McKee). Given these limitations, use of both approaches has been advised (Rettew and McKee).

To date, no studies have examined continuities between fetal characteristics and infant temperament while also considering the potential influence of women's antenatal mood on the child's perinatal neurobehavioral development. In this current study, we aimed to build on prior research by: (1) examining the temperament concept of reactivity to stimulation during both the infant *and fetal* periods, (2) assessing infant temperament based on observations as well as maternal reports, and (3), considering women's antenatal mood as a potential influence on infant neurobehavior. Based on our prior work (Monk et al., 2000; Monk et al., 2004), we used a standard laboratory stressor, the Stroop task, delivered to the pregnant woman, as the means for assessing FHR

reactivity (Monk et al., 2000; Monk et al., 2004). Our specific hypotheses were as follows: (1) greater increases in FHR during women's exposure to a laboratory stressor will be associated with more infant reactivity in motor and cry behavior in response to novel stimuli at 4 months of age; (2) infants, who as fetuses displayed HR increases, more likely will be rated by their mothers as high on negative reactivity; (3) women's diagnosed antenatal depression and anxiety will predict greater infant cry and motor reactivity to novel stimuli as well as maternally-reported negative reactivity. Finally, we predicted that results pertaining to each of these hypotheses will be independent of women's postnatal mood.

METHODS

Subjects

Through posted announcements and signs in obstetricians' offices, 52 medication-free, nonsmoking pregnant women with singleton fetuses were recruited at the Columbia-University Medical Center (CUMC). Women were excluded from the study if there were any maternal or fetal complications including hypertension, diabetes mellitus, suspected fetal growth restriction, or a fetal structural anomaly on ultrasound. None of the subjects reported drinking more than two glasses of wine throughout the entire pregnancy. Forty-nine percent of the sample was Latina, 34% Caucasian, 15% African-American, and 2% Asian or other. For all subjects, English was the primary language. The mean maternal age was 28 years. Sixty-one percent of the sample had completed at least high school or 2–4 years of college and 6% had completed postgraduate work. At the time of the fetal testing session (during the 3rd trimester), 49% of the women were married and 25% were cohabitating; 57% were primiparous; 56% were working outside the home at least half-time. Because this sample was drawn from an urban hospital and included physicians, support staff, as well as patients, there was a large range for average annual family income: 21% of the sample reported annual income at \$0–15,000; 11% \$16,000–25,000; 19% \$26,000–50,000; 30% \$51,000–90,000; and 19% over \$100,000. All babies were born after 37 weeks (mean = 40 weeks, range 37–42 weeks). The average weight at birth was 3,274 grams (SD = 439) (range 1,990–4,335 g). At the 4-month session, the average infant age was 19 weeks (SD = 2). This study was approved by the New York State Psychiatric Institute Institutional Review Board. Informed consent was obtained from each subject.

Procedures

Sessions During Pregnancy. Pregnant women made two visits to the laboratory. For the first visit in the 24th–26th week, they completed demographic questionnaires and were interviewed by a licensed psychologist using the Axis I module of the Structured Clinical Interview for DSM-IV (SCID) (First, Spitzer, Gibbon,

& Williams, 1997). During the 3rd trimester, they returned to the laboratory for a psychophysiology session that began at about 11 a.m. and ended at 1 p.m. They completed a self-report demographic information form and were told that they would be asked to rest quietly and then to participate in a “challenging color-word matching computer task” (computerized version of the Stroop task). They were instructed by a member of the research staff to sit in a specialized chair reclined to a semi-recumbent position. Women were instrumented for ECG, respiration, and blood pressure collection, but these data are not used in this report. To respond to the task on the computer, a numeric keypad was secured in a comfortable position relative to the dominant hand. Subjects could not see the keypad but could identify the keys by feel. An ultrasound transducer was placed on the subject's abdomen to record fetal instantaneous HR. At the start of data collection, subjects were instructed to remain silent throughout the procedures. Subjects rested quietly for a 5-min baseline and then performed a 5-min Stroop color-word matching task followed by 5-min recovery period.

The Stroop Task. In this computerized version of the Stroop task, subjects were presented with color names (blue, green, yellow, and red) in colors that were either congruent or incongruent with the names. In addition, color names were “spoken” by the computer. The subjects' task was to press the key on the keypad that corresponded to the color of the letters. The task was paced by the computer and an incorrect response or failure to respond rapidly enough resulted in a message indicating “incorrect” on the screen.

Acquisition and Processing of Fetal Signals. FHR was recorded via an ultrasound transducer (Advanced Medical Systems, IM76) and digitized at 50 Hz.

Structure clinical interview for DSM-IV. Based on results from the SCID (First et al., 1997), a semi-structure clinical interview, pregnant women were given a diagnosis of major depressive disorder, dysthymia, or an anxiety disorder (e.g., social phobia, a simple phobia, generalized anxiety disorder, or agoraphobia without panic disorder). They were grouped as comorbid if they had both a depression and an anxiety disorder. If they did not reach criteria for any Axis I disorder, they were designated control subjects.

4-Month-Old Session. A common element in temperament assessment is the examination of individual differences in reactivity, that is the responsiveness of emotional and arousal systems to sensory stimuli (Kagan & Snidman, 1991; Kagan, 1997; Rothbart, 1981; Rothbart & Ahadi, 1994). As articulated by Rothbart (Rothbart; Rothbart and Ahadi) and operationalized in a parent report assessment, this approach considers the reactivity of specific responses, such as motor activity, as well as that of integrated emotions, for example, smiling, laughter, and fear. Infant self-regulation, such as, the use of attention and avoidance and other processes to modulate responses is also rated. In related work, Kagan's approach, utilizing laboratory observation, evaluates differences in infant motor and cry reactivity in response to a standardized series of novel stimuli

(Kagan and Snidman; Kagan). We used both strategies in our study.

When the infants were 4 months old, the mothers returned with them to our laboratory between 1:00 and 2:00 pm. They were placed in an infant seat on a child-friendly carpet on the laboratory floor. Infants were vocally and physically quiet prior to stimulus presentation in order to ensure that their reactions were caused by the stimuli. They were exposed to the following four episodes (Kagan & Snidman, 1991): (1) the first episode was the presentation of a tape recording of eight distinct utterances spoken by a female voice. These utterances were: (a) "Hello, pretty baby. How are you today?" (b) "It's time to give me a great, big smile." (c) "You have been a very good baby today." (d) "Please won't you give us a great, big laugh?" (e) "Are you ready for some nice, warm milk?" (f) "Okay, baby. Don't you fall to sleep on us now." (g) "Did you like playing these games today?" (h) "What a very big baby you are." (2) Next was the presentation of three mobiles containing one, three, or seven moving, three-dimensional plush animal toys on three successive occasions for a total of nine 20-s trials. (3) Third was the presentation of three different olfactory stimuli (distilled water, low-concentration butanol, and high-concentration butanol) on a cotton swab. The distilled water was presented first for 10 s. Then, the low-concentration butanol was presented for a duration of 10 s on three successive trials, followed by the high-concentration butanol for 10 s on three successive trials. The distilled water was then presented again for 10 s. (4) Finally, three mobiles containing one, three, or seven moving, three-dimensional plush abstract shapes were presented on three successive occasions for a total of nine 20-s trials. During the presentation of these stimuli the mother was seated behind a one-way mirror through which she could view her child. The infant's reaction to the stimuli was videotaped using a VHS camcorder, and all tapes were viewed for coding purposes on a 13" television attached to a VCR. Also, during this 4-month visit, mothers completed Rothbart's temperament questionnaire, the infant behavior questionnaire (IBQ) (Rothbart, 1981) as well as state and trait anxiety questionnaires (STAI) (Spielberger, 1983).

Coding infant observed temperament. Following Kagan et al. (Kagan & Snidman, 1991; Snidman et al., 1995), two extensively trained coders each rated half of the videotapes for motor and cry reactivity. Coders assigned each infant to one of two motor reactivity groups ("high motor" or "low motor") based on both the frequency and the vigor of: (a) limb movements (both flexing and extending movements that were greater than 45°); (b) arching of the back; (c) tongue protrusions; and (d) motor tension in the hands and limbs. Neither vocalization nor fretting was used in these classifications. The total motor score for each infant was calculated by adding the number of motor reactions. Infants who were much more likely to arch the back and extend the limbs in momentary spasticity during the stimulus presentations typified those characterized as "high motor". Coders then assigned each infant to one of two fret-cry groups based on the frequency and intensity of fretting or crying to the stimuli, as well as the ease with which the infant was soothed by the examiner or mother if the infant became upset. For example, infants who intensely cried for more than 10 s after

the presentation of a stimulus in at least two episodes and could not be soothed were likely coded as "high cry". After the infants were coded according to their motor and cry activity, they were classified into one of four temperament groups: high motor-high cry ("high reactive"), low motor-high cry, high motor-low cry, or low motor-low cry ("low reactive"). Inter-rater reliability (Cohen's Kappa coefficient) for this coding procedure has been reported to be 0.90 in previous studies (Snidman et al.). For our temperament ratings, there were three coders (one coder was replaced by a second). Based on comparisons of 38% of randomly selected tapes, the inter-rater reliability between the first two coders was Cohen's Kappa coefficient = 1.00). The second pair of coders had the same level of agreement.

Mother-reported infant temperament. The IBQ includes 94 items evaluated on a 7-point scale reflecting the relative frequency of specified infant reactions to certain situations in the last week (e.g., when put into the bath water how often did the baby wave his/her arm? Squirm or try to roll away, etc.). These are then tabulated under six subscales (activity level, distress to limitations, latency to approach novel situations (fear), duration of orienting, smiling and laughter, and soothability, which can range from 1 to 7. An item-weighted sum of fear and distress to limitations subscales form a "negative reactivity" cluster and smiling and activity form a "positive reactivity" cluster (Pesonen, Räikkönen, Strandberg, & Järvenpää, 2006). The reliability of the IBQ is good (Rothbart, 1986), ranging from .70 to .90 (e.g., Pesonen et al.).

Women's postnatal anxiety. The Spielberger STAI is a 40-item, self-report instrument that measures a predisposition to feel "generally" anxious (trait anxiety) or the current experience of it (state anxiety). Anxiety scores on the trait and state categories range from 20 to 80, with higher scores reflecting higher levels of anxiety. Reported average scores of state and trait for women from two samples ages 19–39 are 35.20 ± 10.61 and 36.17 ± 10.96 (state) and 35 ± 9 and 36 ± 10 (trait) (Spielberger & Sydeman, 1994).

Data Reduction and Analyses. FHR was computed as the mean values for each of the 5-min periods (baseline and the stressor periods).

Based on results from the SCID interview, women with major depressive disorder and/or dysthymia were classified as depressed. Women who had a social phobia, a simple phobia, generalized anxiety disorder, or agoraphobia without panic disorder were classified as having an anxiety disorder. Women with both depression and one of the above-listed anxiety disorders were grouped as comorbid. Results from SCID interviews yielded the following distribution: 5 depressed, 6 with anxiety disorders, 8 comorbid, and 31 without an Axis I psychiatric disorder.¹ Given the small cell sizes for the specific

¹Recent data have shown rates of antenatal depression to be between 10 and 20% (Evans, Heron, Francomb, Oke, & Golding, 2001; Josefsson, Berg, Nordin, & Sydsjö, 2001; Llewellyn, Stowe, & Nemeroff, 1997). However, in our sample, the rate of Axis I disorders is 60%. This likely reflects a self-selection bias in who responds to our recruitment flyers asking pregnant women to "help us learn about . . . effects of mood on the developing fetus and baby."

disorders, we grouped women as either controls ($n = 31$) or carrying a diagnosis (Dx) ($n = 19$).

We determined that maternal state and trait ratings from the 4-month-old session differed by either having an antenatal diagnosis or not in the 2nd trimester (Dx versus control classification) ($t = 2.05, p = 0.05$; $t = 2.26, p = 0.03$); there was higher state and trait anxiety in women who had prenatal psychiatric diagnosis versus controls. Because of this association, we also examined the potential influence of *postnatal* mood on infant behavior while controlling for women's *antenatal* psychiatric diagnosis. For this, we conducted logistic regression analyses or linear regression analyses to examine the effect of postnatal STAI scores on temperament variables and IBQ reactivity ratings in diagnosed and control groups separately. Within groups (Dx and control), we found no significant associations (all $ps > .2$) between women's state and trait anxiety at 4 months postpartum and infant observed temperament based on Kagan's novelty paradigm ("high motor", "high cry", or one of the four temperament groups). We conducted similar tests on IBQ ratings of reactivity using linear regressions and, again, found no associations between women's postnatal anxiety and infant positive or negative reactivity (all $p > .4$). Based on these results, we did not include women's postnatal state and trait anxiety scores in the regression models.

We conducted logistic regression analyses of the baby's observed motor, cry, and temperament ratings using the following independent variables: baseline FHR, standard deviation of baseline FHR, FHR change from baseline to the Stroop stressor period, and women's antenatal psychiatric status (control or Dx). We conducted linear regression analyses to determine the effect of the prenatal predictors (previously listed) on IBQ-based negative and positive reactivity. Finally, we used t -tests to examine the association between observed motor, cry, and temperament ratings and maternal reports of IBQ negative and positive reactivity.

We used t -tests and Pearson-coefficients a priori to assess collinearity among our predictor variables. There was no association between women's antenatal diagnostic status (Dx versus control) and FHR at baseline ($t = -0.08, p = .94$) and the standard deviation of FHR ($t = 0.72, p = .47$). There also was no association between women's antenatal psychiatric status and FHR change during women's exposure to the laboratory challenge ($t = 0.60, p = .55$).²

RESULTS

Two significant outliers (Tukey, 1977) were detected for FHR change from the baseline to the stressor period (values = 45 and 31 bpm; next highest value = 20 bpm). Examination of the raw data indicated the possibility of measurement artifact for both fetuses (e.g., a value of

72 bpm during a 5 min period for one fetus and for the other, a reading of 202 bpm; no other fetuses had values above 165 bpm or below 107 bpm for any of the baseline, stressor, or recovery periods). Because outliers have a disproportionate influence on correlations and change in FHR is a primary predictive variable in this study, the fetal and maternal data for both of these subjects were excluded from analyses. Means and SDs for the data collected on the remaining 50 fetuses (31 female, 19 male) and for the observed and mother-reported temperament ratings are provided in Tables 1 and 2.

Infant Temperament Classifications

Infant observed (Kagan) and mother-reported (IBQ) temperament data are reported in Table 1. As can be seen, 28% of the infants were rated as high on motor reactivity and 38% were rated high on cry reactivity. Eighteen percent were classified as high on both motor and cry behavior ("high reactive") while 52% were rated low in both categories ("low reactive").

Prenatal Variables and Infant Observed Temperament

4-Month-Old Motor Reactivity. Logistic regression analyses were used to determine relationships between infant motor reactivity (dependent variable) and the four independent variables of fetal baseline HR, FHR change during maternal stress, the standard deviation of baseline FHR, and women's antenatal diagnostic classification. The only significant predictor of motor reactivity was the change in FHR ($p = 0.02$). The odds of being classified as

Table 1. Assessment of Infant Temperament

Infant Variable	Mean \pm SD or Count (%)
Kagan temperament scores	
Motor reactivity, high	14(28.0)
Cry reactivity, high	19(38.0)
Temperament, high reactive	9(18.0)
Temperament, low reactive	26(52.0)
Temperament high motor, low cry	5(10.0)
Temperament low motor, high cry	10 (20.0)
IBQ scores (range = 0–7)	
IBQ activity level	3.8 \pm 0.9
IBQ distress to limitations	3.3 \pm 0.8
IBQ distress/latency to approach	2.6 \pm 0.4
IBQ duration of orientation	4.6 \pm 0.9
IBQ smiling	4.9 \pm 1.0
IBQ soothability	5.3 \pm 0.9
Negative reactivity (latency + distress)/2	2.9 \pm 0.6
Positive reactivity (activity + smiling)/2	4.4 \pm 0.7

²A 2×2 table revealed a near-significant relationship as an equal number of fetuses of Dx versus control women had increased HR while 9 of 19 Dx women and 21 of 31 control women had decreased HR: odds ratio 2.33, $p = .15$. These data are in the same direction as our prior results showing differences in FHR change related to antenatal psychiatric status yet weaker likely due to issues of power (Monk et al., 2004).

Table 2. Fetal Heart Rate

Fetal Variable	Mean ± SD or Count (%)
Baseline FHR (bpm, $N = 50$)	140 ± 11
Baseline standard deviation (SD) of FHR (bpm, $N = 49$)	4.0 ± 1.7
Change in FHR (baseline-maternal stress, $N = 50$)	0.5 ± 5.1
Change in FHR (fetuses with decreases in HR, $N = 30$)	-2.6 ± 2.2
Change in FHR (fetuses with increases in HR, $N = 20$)	5.0 ± 4.8

high motor were increased by 23% for every beat per minute increase in FHR. See Table 3. A follow-up 2×2 table showed a significant relationship between FHR change (increase or decrease) versus motor reactivity (high versus low). Of the 14 infants in the high motor group, 11 had exhibited increases in FHR during maternal stress whereas only 3 had decreases in FHR. In contrast, of the 36 infants classified as low motor reactivity, 9 exhibited FHR increases and 27 had decreases during maternal stress. Thus, the odds of being classified as a high motor reactivity baby was 11 times greater for infants who, as fetuses, exhibited increases in HR during their mothers' exposure to the laboratory stress challenge ($p \leq .01$). Antenatal Dx was a near significant predictor of motor reactivity. In the high motor group, 8 of 14 (57%) had mothers with an antenatal Dx, whereas for low motor, 11 of 34 mothers (32%) were in the Dx group. The odds ratio of an infant being classified as high motor reactivity was increased 3.2-fold ($p = .11$) (controlling for FHR) if the mother had an antenatal diagnosis.

4-Month-Old Cry Reactivity. The same logistic regression analysis was used to predict infant high or low crying reactivity. Only women's antenatal Dx was a significant predictor ($p = .03$). Antenatal psychiatric diagnosis was associated with a fourfold greater odds risk for high cry reactivity. (See Tab. 4 and Fig. 1). Further analyses showed that 58% (11 of 19) of high cry babies had mothers with antenatal Dx while only 26% (8 of 31) of low cry infants had mothers with a psychiatric diagnosis. Thus, the odds of having a "high cry" baby among women with an antenatal psychiatric diagnosis is increased 3.9 times

above those born to women who were psychiatrically healthy ($p \leq 0.05$).

4-Month-Old "Low Reactive" Temperament. Following other studies (Snidman et al., 1995; Kagan & Snidman, 1991; Kagan, 1997), we combined motor and cry classifications to form four reactivity groups. One group, "low reactive" was formed from infants who had been classified as low motor and low cry ($N = 26$). All other infants were classified as either "high reactive" (high motor and high cry) or one of the other two combinations (see Tab. 1 for group distribution). Using logistic regression models, the odds of being low reactive versus the other motor-cry combinations among infants whose mothers did *not* have an antenatal DX was 8.4 times that of diagnosed mothers ($p \leq 0.01$). (see Tab. 5).

Prenatal Variables and Maternal Reports of Infant Temperament (IBQ)

Using the combined variables of negative and positive reactivity from mother reports on the IBQ scales, we conducted linear regression analysis to determine whether prenatal variables were related to these temperament dimensions.³ There was a trend for FHR change to be positively associated with infant negative reactivity ($p = .08$). Baseline FHR was positively associated with infant positive reactivity ($p \leq .05$); the score of positive reactivity was increased by 0.02 for every increase in FHR (See Tabs. 6 and 7, respectively).

Table 3. Logistic Regression: Prenatal Predictors of Infant Motor Reactivity

	Estimate ^b	Chisq (df = 1)	p-Value	Odds Ratio
Psych diagnosis ^a	0.59	2.54	0.11	3.24
FHR change	0.21	5.89	0.02	1.23
FHR baseline	0.06	2.12	0.15	1.06
SD FHR baseline	0.02	0.01	0.92	1.03

^aDx or control.^bEstimate unstandardized.

Associations Between Infant Observed and Mother-Reported Temperament

Using *t*-tests, we observed a near significant association between observed high motor reactivity and maternal reports of high negative reactivity ($t = 1.86$, $p = .07$). There was no relationship between observed cry reactivity and maternal reports of infant reactivity ($t = 1.42$, $p = .16$;

³We did not transform the negative and positive reactivity variables as the Shapiro-Wilk test for normality indicated that they were both normally distributed: $W = 0.97$, $p = 0.33$ and $W = 0.96$, $p = 0.10$, respectively.

Table 4. Logistic Regression: Prenatal Predictors of Infant Cry Reactivity

	Estimate ^b	Chisq (df= 1)	p-Value	Odds Ratio
Psych diagnosis ^a	0.70	4.56	0.03	4.03
FHR change	-0.06	0.80	0.37	0.94
FHR baseline	0.00	0.01	0.93	1.00
SD FHR baseline	-0.08	0.16	0.69	0.92

^aDX or control.^bEstimate unstandardized.

$t = -0.55$, $p = 0.58$, negative, positive reactivity, respectively). Finally, there was a marginal positive association between having a *nonlow* motor/low cry temperament (that is, being in one of the three other groups such as high motor/high cry or high motor/low cry) and mothers' report of negative reactivity ($t = 1.73$, $p = .09$).

DISCUSSION

In this study, we found that fetal reactivity, as defined by change in FHR during women's exposure to a stressful laboratory task, predicted observed infant temperament characteristics at 4 months. Specifically, 3rd trimester fetuses who showed HR increases during exposure to maternal stress were 11 times more likely to exhibit high motor reactivity in response to novelty at 4 months. Having a mother who had had an antenatal Dx was a near significant predictor of greater motor reactivity. There were no significant associations between fetal baseline HR or the standard deviation of HR and infant observed motor reactivity. In addition, there was a fourfold increase

in the odds of being classified as high cry reactivity if the mother was depressed and/or had an anxiety disorder during pregnancy. In contrast, none of the FHR variables were associated with cry behavior. FHR reactivity also was moderately associated with maternal reports of infant temperament. The higher the increase in FHR during the mother's exposure to a cognitive stressor, the more likely the mother rated her child as high on negative reactivity. In addition, the higher the baseline FHR, the greater the infant's chance of being judged high on positive reactivity. Finally, there were marginal effects for associations between observed assessments of temperament and mothers' reports of greater negative reactivity. Observed high motor reactivity was modestly associated with maternal reports of greater negative reactivity. Infants classified in one of the three groups besides "low reactive" more likely were rated by their mothers as high on negative reactivity. To control for postnatal influences on infant temperament, we assessed women's anxiety and found that there were no significant relationships between women's postnatal anxiety and any of the infant measures.

It is possible that changes in FHR from the baseline to the stressor period in part reflect individual or group differences in mothers' physiological reactivity. Indeed, previously we had found weak associations between FHR responses and maternal blood pressure reactivity (Monk et al., 2000, 2004). However, we also suggest that differences in FHR responses may reveal variation in fetus' emerging regulatory style. That is, a HR increase versus decrease could indicate a more reactive phenotype and/or a lower threshold for responding to stimuli. From this perspective, we might *not* expect baseline FHR or the standard deviation of HR to be associated with infant temperament, only reactivity. This is consistent with our findings. On the other hand, in the study by Snidman et al. (1995), associations between baseline FHR and subsequent behavioral traits were found. Methodological differences may account for the contrasting results. In the Snidman study, baseline FHR was collected for 15 min as opposed to 5 min in our study (Snidman et al.). It may be that the longer assessment period allowed for a more reliable measure of baseline FHR with respect to individual differences and thus for greater predictive power.

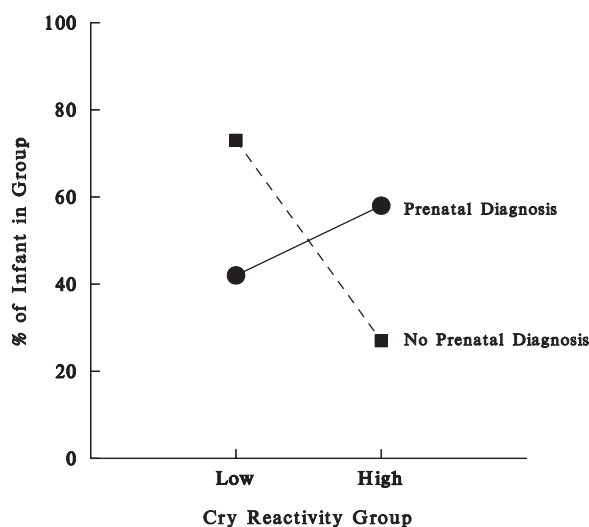


FIGURE 1 This figure shows the percent of infants who at 4 months of age were classified as being either high cry or low cry and whose mothers did or did not have an antenatal DX.

Table 5. Logistic Regression: Prenatal Predictors of Infant Observed 'Low Reactive' Temperament

	Estimate ^b	Chisq (df = 1)	p-Value	Odds Ratio
Psych diagnosis ^a	1.07	9.00	0.01	8.44
FHR change	0.11	1.62	0.20	1.10
FHR baseline	0.01	0.10	0.75	1.01
SD FHR baseline	0.05	0.07	0.80	1.05

^aDiagnosis versus control.^bEstimate unstandardized.

The data here show some parallels to those of St. James-Roberts (St. James-Roberts & Menon-Johansson, 1999). In that study, weak fetal body movements, versus full, strong body movements, were positively associated with the amount of crying at 1, 6, and 12 weeks of age (St. James-Roberts and Menon-Johansson). In their study, as in ours, an early marker of arousal assessed in one modality (movement or HR) predicted later arousal in another modality in early infancy (crying or motor and crying behavior). St. James-Roberts & Menon-Johansson hypothesize that characteristics that underlie this fetal-to-infant continuity in reactivity are an inability to inhibit responsiveness once a response or arousal is initiated (St. James-Roberts and Menon-Johansson). This is convergent with our hypothesis that a FHR increase during women's exposure to a laboratory stressor, and in turn, high motor reactivity at 4 months, represents some underlying continuity in the regulation of autonomic response during early development and regulation of behavioral responses at a later age. Both may be related to underlying differences in arousal threshold and/or the ability to regulate arousal once it is initiated.

Our findings may appear to contrast with Dipietro et al. (2002a), in which greater fetal motor activity was associated with observed characteristics of more easy going temperament at 1 and 2 years old, whereas in our study, FHR reactivity predicted more reactive observed temperament. However, the DiPietro et al. study assessed spontaneous movement (including full, strong body movements not included in the St. James-Roberts' results) over a period of 50 min, likely an index of overall endogenous activity, whereas we measured a 5-min acute

change in FHR during stimulation. In our study, we did not measure fetal movement and thus do not know whether it was coincident with the HR change. Overall activity level versus general arousal and magnitude of acute HR reactivity might reflect distinct characteristics that are evident in the fetal period and which may predict to different aspects of temperament later in life.

Having a psychiatric diagnosis during pregnancy was associated with greater cry reactivity to novelty at 4 months of age. This result suggests three working hypotheses: (1) infant crying behavior and women's emotion dysregulation are manifestations of the same heritable emotional disposition, perhaps one characterized by greater and prolonged reactivity; (2) the early developmental determinates of crying (versus movement) reactivity can be influenced by mood-based differences in women's physiology; (3) women who had an antenatal psychiatric illness maintained this mood dysregulation postpartum, which, in turn, had a negative impact on their emotional availability and parenting and, consequently, their child's early self-regulation skills.⁴

The results of this study add to those from Mohler (Mohler et al., 2006), who also used the Kagan paradigm to characterize 4-month-old infant reactivity in relation to women's antenatal mood. In this report, antenatal stress (assessed retrospectively at 2-weeks postpartum) was inversely related to crying reactivity and not associated with motor reactivity. It may be that the biological correlates of life stress versus depression and anxiety differ such that fetuses in the two studies are the products of different epigenetic environments and consequently vary in temperaments. It also should be noted that the course of mood dysregulation in the two studies, and, theoretically, timing effects of fetal exposure, differed. In the Mohler study, women reported on their antenatal mood throughout the course of pregnancy while our work is based on a psychiatric interview during the 2nd

Table 6. Linear Regression: Prenatal Predictors of Infant IBQ Negative Reactivity

	Estimate ^b	t (df = 1)	p-Value
Psych diagnosis ^a	0.23	1.24	0.22
FHR change	0.04	1.80	0.08
FHR baseline	-0.01	-1.46	0.15
SD of FHR baseline	-0.01	-0.22	0.82

^aDiagnosis versus control.^bEstimate unstandardized.

⁴We did not administer psychiatric assessments during the postpartum period so we do not have the data to evaluate the third proposition. On the other hand, this hypothesis is supported by the finding that women who had had an antenatal Dx had greater trait and state anxiety in the postpartum period.

Table 7. Linear Regression: Prenatal Predictors of Infant IBQ Positive Reactivity

	Estimate ^b	t(df=1)	p-Value
Psych diagnosis ^a	0.32	1.43	0.16
FHR change	0.03	1.24	0.23
FHR baseline	0.02	2.31	0.03
SD of FHR baseline	0.02	0.24	0.80

^aDiagnosis versus control.^bEstimate unstandardized.

trimester and thus, the mood dysregulation could have occurred over a briefer time period.

We found only moderate associations between infant observed temperament and mothers' reports. This is consistent with the literature in that parental reports are influenced by the observer's own psychological functioning, and often are not associated with ratings from observers (Belsky et al., 1998; DiPietro et al., 1996; Zeanah, Keener, & Anders, 1986).

There are several limitations of our study. We collected fetal data only at one time point during gestation. As DiPietro has shown, using multiple assessments throughout pregnancy (DiPietro, 2005), patterns in the associations between fetal behaviors at different ages and infant temperament can change. A single assessment such as ours may have lead to spurious results. We also do not have fetal movement data, or psychiatric assessments of women postpartum. Both sets of variables would help to clarify several issues raised in our paper.

Current research is uncovering the epigenetic and developmental contributions to the 'constitutional' aspect of temperament. These data add to the emerging body of work indicating that long-term temperament characteristics can be identified before birth, and may be, in part, the consequence of in utero environmental influences.

NOTES

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