Maternal Stress and Affect Influence Fetal Neurobehavioral Development

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The authors investigated the association between maternal psychological and fetal neurobehavioral functioning. Data were provided by 52 maternal–fetal pairs at 24, 30, and 36 weeks gestation. The relations between maternal measures and fetal heart rate, variability, and motor activity were statistically modeled. Fetuses of women who were more affectively intense, appraised their lives as more stressful, and reported more frequent pregnancy-specific hassles were more active across gestation. Fetuses of women who perceived their pregnancy to be more intensely and frequently uplifting and had positive emotional valence toward pregnancy were less active. Associations with fetal heart-rate measures were detected at 36 weeks gestation. These data provide evidence for proximal effects of maternal psychological functioning on fetal neurobehavior.

We have frequently heard the statement made by expectant mothers that any sudden feeling of fear or of anger produces an almost immediate and marked increase in the number and violence of the fetal movements. (Sontag & Wallace, 1934, p. 1053)

The Fels longitudinal study of the 1930s was the first systematic investigation of the factors that affect development before birth, but allusions to an association between maternal stress and emotions date back to antiquity. During the past decade, an accumulating body of evidence has implicated maternal psychological distress as a factor in poor pregnancy outcomes (for reviews, see Austin & Leader, 2000; Istvan, 1986; Paarlberg, Vingerhoets, & Moore, 2000; Weinstock, 2001; Welberg & Seckl, 2001). Examination of the influence of antenatal stress and affect on infant development in humans has been far less systematic. Most reports include a constellation of negative psychological attributes, especially anxiety, which is considered to be one of several emotional responses to stress. Observations detailed in earlier work include associations between maternal anxiety distress and infant irritability (Ottinger & Simmons, 1964) and slower development (Davids, Holden, & Gray, 1963). Several recent studies used large, pre-existing data sets to address this issue. In one such study based on Finnish pregnancies from the mid-1970s, maternal distress during pregnancy was robustly associated with negative emotionality and nonadaptive behavior at 5 years of age for boys and girls and with a host of other temperament characteristics, including behavioral inhibition, for boys (Martin, Noyes, Wisenbaker, & Huttunen, 2000). In a population-based study in England, maternal anxiety was positively associated with emotional problems in both sexes, conduct disorder in girls, and hyperactivity in boys at 4 years of age (O’Connor, Heron, Golding, Beveridge, & Glover, 2002). Negative psychological situations during pregnancy have also been reported to be associated with maternal ratings of negative infant temperament at 6 months (Niederhofer & Reiter, 2000). These recent studies share a significant methodological and interpretative limitation: All base independent (maternal distress) and dependent (child outcome) measures on maternal report, making it impossible to rule out the possibility that women who report greater distress during pregnancy are also more likely to experience their children as temperamentally or behaviorally more difficult. However, a recent study based on teacher and observer ratings of child behavior at 8 years found that prenatal anxiety was...
significantly associated with behavioral regulation problems, including impulsivity and attentional difficulties (Van den Bergh, 2001).

Aspects of maternal psychological state during pregnancy have been examined in relation to objective ascertainment of neonatal performance on standard neurobehavioral exams. Investigators have reported associations between prenatal pregnancy-specific anxiety and reduced motor maturity (Standley, Soule, & Copans, 1979) and prenatal stressful life events and anxiety with poorer neonatal habituation (Oyemade et al., 1994). Increased infant irritability during examination has been associated with both prenatal anxiety (Van den Bergh, 1990) and a component of maternal Type A behavior (Parker & Barrett, 1992). In a small sample of adolescents, prenatal anxiety was negatively associated with neonatal cardiac vagal tone (Ponirakis, Susman, & Stifter, 1998). In contrast, prenatal affective distress was not found to be related to infant activity level as measured by mechanical actometers or infant irritability based on diary data (Miller, Barr, & Eaton, 1993).

One of the few studies to explicitly examine stressful life events during pregnancy found them to be associated with lower neonatal neurological scores (Lou et al., 1994). The most comprehensive study to date on the role of prenatal stress on child development includes multidimensional prospective data of 170 pregnant women with controls for postnatal maternal stress. Daily hassles and pregnancy-specific anxiety were negatively associated with infant mental development at 8 months but other measures of stress and affect, including life events, were not (Huizink, de Medina, Mulder, Visser, & Buitelaar, 2001). Biological support was provided by the significant association between daily hassles and salivary cortisol levels, which were independently associated with lower mental and psychomotor development.

If maternal stress, anxiety, and emotionality do indeed generate effects on pregnancy and developmental outcomes, effects should also be evident during gestation, when the mechanisms moderating subsequent associations are operative. Observations that fetal movement increases in response to acute maternal stress have been made for many years (Ianniruberto & Tajani, 1981; Sontag, 1941). Anecdotal and single subject reports persist in the contemporary literature (Hepper & Shahidullah, 1990; Yoles, Hod, Kaplan, & Ovadia, 1993), testament to the rudimentary nature of this field of knowledge. Because of the relative inaccessibility of the fetus, only a handful of studies have examined the contemporaneous relations between maternal psychological and fetal neurobehavioral functioning. Data from two projects suggest that maternal stress impairs fetal neurobehavioral development. Greater maternal stress appraisal was associated with reduced fetal heart-rate variability (DiPietro, Hodgson, Costigan, Hilton, & Johnson, 1996b) and synchronization between fetal heart rate and fetal movement (DiPietro, Hodgson, Costigan, Hilton, & Johnson, 1996a) beginning at 20 weeks gestation and continuing through term. In the other project, fetuses of women with evidence of hypothalamic-pituitary-adrenal (HPA) axis activation, measured by elevated levels of neuropeptides, displayed reduced habituation to repeated stimuli (Sandman, Wadhwa, Chicz-DeMet, Porto, & Garite, 1999). Maternal anxiety during pregnancy has been associated with altered fetal state and motor behavior at term in two studies. In the first, higher anxiety was associated with greater fetal motor activity across states (Van den Bergh et al., 1989), but in the second it was associated with more time spent in quiet sleep and reduced motor activity during active sleep (Groome, Swiber, Bentz, Holland, & Atterbury, 1995). This discrepancy cannot be reconciled by the window of observation, because both relied on at least 2 hr of fetal data collection, but may be a result of small samples (ns = 10 and 18, respectively).

An alternate approach to investigating the role of maternal stress and affect on fetal behavior is to experimentally manipulate maternal state. Stress induction has been associated with increased fetal heart rate in women with high, but not low, anxiety in one study (Monk et al., 2000) but with no discernible effects in another (Van den Bergh et al., 1989). Interventions designed to reduce maternal anxiety have been similarly inconsistent, resulting in a decrease (Field, Sandberg, Quetel, Garcia, & Rosario, 1985) and an increase (Zimmer, Peretz, Eyal, & Fuchs, 1988) in fetal motor activity. Thus knowledge regarding the proximal effects conferred on the developing fetus by the maternal psychosocial environment is both limited and inconclusive.

Stress is conceptually elusive and difficult to operationalize. A range of psychological characteristics moderate both the appraisal and affective response to stressors (Krohne, 1990), prompting a leading stress theorist to argue that emotional quality and intensity should be measured in lieu of or in addition to stress (Lazarus, 1990). The unique psychosocial features of pregnancy complicate measurement because pregnancy itself is a significant life stressor (Carlson & LaBarba, 1979; Zajicek & Wolkind, 1978) and is included as an item in the scale most commonly used to measure stressful life events (Holmes & Rahe, 1967). Failure to ascertain pregnancy-specific stress may result in underestimation of maternal stress, thereby obscuring potential relations between pregnancy stress and outcomes. Pregnancy-specific stressors have not been widely applied in studies of the relation between stress and birth outcomes, but efforts to develop pregnancy-specific scales note the variety and intensity of concerns among pregnant women (Arizmendi & Affonso, 1987; DaCosta, Brendler, & Larouche, 1998; Kumar, Robson, & Smith, 1984; Yali & Lobel, 1999).

A common approach to quantifying stress has been to focus on frequently occurring, aggravating occurrences as opposed to major, but infrequent, life events. Such daily hassles correlate strongly with other psychological factors, including negative affect, mood, and general distress (Chamberlain & Zika, 1990; DeLongis, Folkman, & Lazarus, 1988). Measurement of hassles that are not pregnancy-specific has been recently applied to studies of pregnancy (Curry, Campbell, & Christian, 1994; DaCosta et al., 1998; Huizink et al., 2001; Mackey, Williams, & Tiller, 2000; Thompson, Murphy, O’Hara, & Wallymahmed, 1997) and the postpartum (Ayers, 2001). However, existing hassles scales have been described as simultaneously overrepresentative in that they contain hassles rarely experienced by pregnant women, and underrepresentative in their lack of pregnancy concerns (Ruiz & Fullerton, 1999).

Pregnancy has been treated as a stressful, anxiety-provoking circumstance in most of the existing literature despite the cultural perception of pregnancy as a joyful event. The construct of eustress, arousal with positive valence (Selye, 1974), has not been well integrated into the stress literature but may be particularly relevant to the experience of pregnancy. Although “ uplifts” as well as hassles have been traditionally measured (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982), uplift data have not been widely published. A single report provides data regarding the
of 54 self-referred, volunteer women began the study; 2 were excluded, 1 after developing gestational diabetes and another after delivering prior to term. Gestational age ascertainment was based on a pregnancy test within a month of first missed menstrual period, a first trimester obstetric or ultrasound examination, or both. Gestational age was established by the best clinical estimate based on available dating information (DiPietro & Allen, 1991) provided during the first trimester. The mean age of a positive pregnancy test was 5.3 weeks after the last menstrual period. All infants were healthy, with 5-min Apgar scores of 7 or greater, and all were discharged according to routine hospital schedules. Thirty-one (60%) were boys; this was the first birth for 33 (63%) of the women. Maternal and infant characteristics are presented in Table 1.

**Psychosocial Assessments**

**Affect Intensity Measure.** The Affect Intensity Measure (AIM; Larsen, Diener, & Emmons, 1986) is a 40-item self-report measure that quantifies the intensity with which an individual experiences emotions, irrespective of hedonic tone, on a 6-point scale (e.g., “When I am nervous I get shaky all over,” “When something good happens, I am usually much more jubilant than others”). The items were empirically derived from a larger set based on construct validity and have been validated against daily ratings of reactions to specific events. Stability in scores over 2 years has been demonstrated (Larsen & Diener, 1987), indicating that the scale indexes a core trait underlying emotionality. The AIM is scored by averaging the responses across all items after reverse coding of some. Higher values indicate higher affective intensity. Two participants did not complete the AIM at 30 weeks, and 1 did not complete the AIM at 36 weeks.

**Daily Stress Inventory.** The Daily Stress Inventory (DSI; Brantley, Waggoner, Jones, & Rappaport, 1987) was administered to assess recent, non-pregnancy-specific stressors. The DSI lists 58 events (e.g., “Hurried to meet a deadline,” “Had car trouble”) that are scored on a 7-point scale of stressfulness. The scale has good psychometric properties (Brantley et al., 1987) and has been validated against measures of autonomic responsiveness and somaticism (Waters, Rubman, & Hurry, 1993). Scoring involves summing the values of the endorsed items and dividing them by the number of items endorsed; higher scores indicate greater perceived stress.

**Pregnancy Experience Scale.** We developed the Pregnancy Experience Scale (PES) for this study to measure maternal appraisal of exposures to maternal stress in mediating fetal development; data regarding the developmental trends for the fetal neurobehavioral measures have been previously reported (DiPietro, Costigan, Shupe, Pressman, & Johnson, 1998).

**Table 1**

**Maternal and Infant Characteristics (N = 52)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age</td>
<td>29.9</td>
<td>3.5</td>
<td>21–39</td>
</tr>
<tr>
<td>Maternal education (in years)</td>
<td>16.3</td>
<td>2.6</td>
<td>12–20</td>
</tr>
<tr>
<td>Gestational age at delivery</td>
<td>39.6</td>
<td>1.1</td>
<td>37–41</td>
</tr>
<tr>
<td>Infant birth weight (in grams)</td>
<td>3,502</td>
<td>470</td>
<td>2,612–4,394</td>
</tr>
<tr>
<td>5 min Apgar score</td>
<td>8.9</td>
<td>0.5</td>
<td>7–10</td>
</tr>
</tbody>
</table>
daily, ongoing hassles and uplifts that are specific to pregnancy (e.g., “Thinking about labor and delivery,” “Physical symptoms,” “Making nursery arrangements”). The PES was modeled on the existing, non-pregnancy-specific, Hassles and Uplifts Scale (DeLongis et al., 1982). A total of 41 items were generated by nondirective interviews of 31 pregnant women of similar socioeconomic background who participated in a previous study in which the only stress measure was not specific to pregnancy. Women indicated the degree to which each item was appraised as hassling or uplifting since the previous visit, using a 4-point Likert scale that ranged from 0 (not at all) to 3 (a great deal). The internal consistency of these items is high: α = .94, .95, .91 for hassles; α = .90, .88, and .85 for uplifts. Consistent with DeLongis et al. (1982), scoring of the PES included computation of both frequency of hassles and uplifts (number of endorsed items) and intensity (summed values divided by number of endorsed items). Both intensity and frequency were included as variables because of their conceptual and empirical independence (Diener, Larsen, Levine, & Emmons, 1985). In addition, a ratio score relating intensity of hassles to uplifts (i.e., hassles ÷ uplifts) was computed to provide a measure of the emotional valence of the pregnancy experience. Values greater than 1 indicate greater perceived intensity of hassles; scores below one indicate greater perceived intensity of uplifts.

AIM scores were positively associated with intensities of both hassles and uplifts (r = .24 to .44) at 24 and 30 weeks, but not at 36 weeks. Women who perceived more non-pregnancy-specific stress (DSI) also reported greater intensity of pregnancy-specific hassles at all three gestational ages (r = .36, .34, and .27). Uplift intensity was negatively, but not significantly, related to DSI scores across gestation. This pattern of results suggests that the PES has both discriminant and convergent validity. In a separate validation study of 135 women, PES hassle frequency and intensity scores were significantly correlated with magnitude of daily stressors, state–trait anxiety, and depressive symptomatology (r ranged from .26 to .46); uplifts were unrelated (DiPietro, Hawkins, Costigan, & Millet, 2002).

Stress composite. A composite score was computed to provide an overall measure of emotional intensity. The AIM, DSI, and PES ratio values were separately standardized using Z scores at each time period and then summed.

Fetal Neurobehavioral Assessment

Fetal heart rate (FHR) and fetal movement (FM) data were collected for 50 min with a fetal actocardiograph (Toitu, MT320) with a single wide-array Doppler transducer positioned on the mother’s abdomen with an elastic belt. Details of this method have been presented in earlier reports (DiPietro et al., 1996b). FHR is determined by the processing of Doppler-generated waveforms using autocorrelation techniques in which small segments of sequential waveforms are matched to detect each serial heartbeat. FM is detected by bandpassing the high Doppler frequencies that correspond to fetal heart motions and the low frequency signals produced by maternal somatic and respiratory movements. The resultant signal is considered to correspond to fetal heart motions and the low frequency signals produced by maternal somatic and respiratory movements. The resultant signal is output in the form of spikes on a polygraphic tracing in arbitrary voltage units (Maeda, Tatsumura, & Nakajima, 1991). Studies comparing Doppler-based detection of fetal movements to those observed during real-time ultrasound demonstrate that the actograph records 91%–95% of all fetal movements whether agreement is based on time intervals or individual movements, and is equally reliable in detecting periods of quiescence. Most of the movements undetected by the actograph are small, isolated movements of extremities; virtually all (97%–98%) trunk and sustained (>1 s) movements are detected. (Besinger & Johnson, 1989; DiPietro, Costigan, & Pressman, 1999; Maeda, Tatsumura, & Utsu, 1999). Analog output for FHR and FM signals from the monitor were digitized concurrently during fetal monitoring.

Fetal Data Quantification

Fetal heart rate. The digital data underwent a series of error rejection procedures based on moving averages of acceptable values. Mean values of error rejection were 7.6%, 5.0%, and 5.2%, at 24, 30, and 36 weeks, respectively. Two FHR measures were calculated: mean FHR, the mean of the fifty 1-min epochs, and mean FHR variability, computed as the standard deviation for each 1-min epoch, averaged over the 50-min recording. Fetal movement. The actograph signal is output in arbitrary units that range from 0 to 100. A movement bout was defined as commencing each time the actograph signal attained or exceeded a predetermined level that has been consistently validated as indicative of FM. FM was defined as the overall activity level, computed as the number of movement bouts multiplied by mean movement duration, representing the total amount of time (in minutes) the fetus was moving during the 50-min recording.

Data Analysis

All fetal and maternal measures were examined for normalcy and transformed as appropriate. Changes in psychosocial measures over gestation were assessed using repeated measures analysis of variance (ANOVA); the role of maternal demographic characteristics including maternal age, level of education, and parity (nulliparous vs. multiparous) was evaluated by adding covariates to these equations. The focal analyses pertaining to the relations between fetal neurobehavioral measures and maternal stress during pregnancy were based on generalized estimating equations (GEE; Zeger & Liang, 1986). Given the longitudinal nature of the data, responses of the same fetus are expected to be correlated; these correlations must be properly represented in the statistical model to yield correct estimates of the standard errors of the parameters. The estimates of the standard errors generated by this technique are robust to misspecification of the correlation structure. GEE provides this important advantage over other less intensive analytic techniques for longitudinal data, and techniques to model change over time are becoming more prevalent in developmental research (Willett, 1997). The relation between the seven psychosocial measures and the three fetal measures across gestation were modeled using unstructured variance/covariance matrices; potential changes in these relations over gestation were also examined. Maternal demographic characteristics were included in separate models to determine whether these characteristics mediated any observed relations.

Psychosocial Measures

Mean values for the psychosocial measures are presented in Table 2, along with results of repeated measures ANOVA for change over gestation. AIM scores became significantly lower with advancing gestation, indicating lessening emotional intensity, whereas appraisal of DSI did not change. There were trends to experience more pregnancy-specific hassles and reduced intensity of uplifts, but these changes were not reflected in the number of uplifts or the intensity of hassles. In general, women were more uplifted than hassled by their pregnancies; mean ratio scores were below 1.00.

Psychosocial values were inconsistently related to maternal sociodemographic characteristics. Maternal age was not significantly related to any measure, and parity was associated only with AIM scores, F(1, 50) = 4.53, p < .05, with first-time mothers displaying higher affective intensity across gestation. Three psychosocial variables were significantly associated with maternal education: positive associations with the DSI, F(1, 50) = 4.15, p < .05, negative relations with frequency of pregnancy-specific uplifts,
Fetal Neurobehavioral Measures

Mean values for the fetal measures used in the analysis are presented in Table 3. Although raw values are shown in the table, the FM data underwent a square-root transformation to normalize its distribution.

Results of the GEE analyses for the psychosocial measures, including the parameter estimate, SE, and Z values, are presented in Table 4. Few relations emerged among either FHR measure and the psychosocial variables. Only the frequency of pregnancy-specific hassles across gestation attained a trend-level relation with FHR ($Z = -1.73, p = .08$). However, the analysis for time effects indicated that the nature of the relation between two associations changed significantly over gestation. In contrast to AIM values at 24 and 30 weeks, those at 36 weeks were significantly and negatively associated with FHR (parameter estimate = $-4.02$, $SE = 1.73$, $Z = -2.32$, $p < .05$). For FHR variability, the frequency of pregnancy-specific hassles was unrelated earlier in gestation but significantly related at 36 weeks (parameter estimate $= .0052$, $SE = .0025$, $Z = 2.08$, $p < .05$).

Analyses revealed robust and consistent relations between psychosocial measures and fetal motor activity (see Table 4). Higher levels of FM were significantly associated with greater affective intensity (AIM) and more pregnancy-specific hassles, and there was a trend association with higher non-pregnancy-specific daily stress appraisal ($p = .08$, see next section). In contrast, greater frequency and higher intensity of uplifts were significantly associated with less fetal motor activity. Higher fetal activity was associated with higher negative valence of intensity ratings based on the pregnancy-specific ratio score. We detected no changes over time (gestation) in the manner in which fetal activity was associated with the psychological measures.

To provide visual representation of the relation between stress and fetal motor activity, we used the stress composite score to classify individuals into high-stress ($Z > 0$) versus low-stress ($Z \leq 0$) groups. This stratification yielded 28, 23, and 28 participants in the low-stress group at 24, 30, and 36 weeks, respectively, and 24, 27, and 23 participants in the high-stress group. Because of missing data on the AIM, 50 and 51 cases are available for this analysis at 30 and 36 weeks, respectively. The relation between fetal motor activity and the maternal stress composite was significant (parameter estimate $= -2.48$, $SE = 0.84$, $Z = -3.21$, $p < .01$). Figure 1 presents the average fetal motor activity data modeled for each group.

Effects of Maternal Age, Education, and Parity

Maternal sociodemographic characteristics were not consistently associated with fetal heart rate or fetal movement. Maternal education was significantly and positively associated with FHR variability, $F(1, 50) = 5.77, p < .05$. Adding maternal characteristics into the GEE models did not alter any observed relations.
with one exception: The association between the DSI and fetal movement increased from the trend level indicated in Table 4 to a significant one ($Z = 1.97, p < .05$) when maternal education was controlled.

**Discussion**

The results of this study contribute to the emerging understanding of the complex manner in which aspects of maternal psychological functioning during pregnancy provide a context for the developing fetus, and this is the first study to demonstrate longitudinal proximal effects on fetal neurobehavior. Associations between maternal and FHR measures were weaker than expected, with significant associations detected between only one maternal measure and each cardiac measure, only at 36 weeks. However, fetal motor activity was robustly associated with maternal measures across gestation. Women who were more affectively intense, appraised their daily lives as more stressful, and reported more frequent pregnancy-specific hassles had more active fetuses. The direction of these findings supports existing anecdotal and research reports (Heppner & Shahidullah, 1990; Ianniruberto & Tajani, 1981; Sontag & Wallace, 1934; Van den Bergh et al., 1989). The finding that women who perceived their pregnancy to be more intensely and frequently uplifting and who had a more positive emotional valence toward pregnancy had less active fetuses provides new information regarding the role of positive maternal emotions. Although each psychological measure was significantly related to motor activity (this was true for the DSI when the confounding influence of maternal education was controlled), the strongest associations were found for pregnancy-specific variables, particularly the combined hassles and uplifts score. This pattern of findings suggests that pregnancy-specific measures may indeed be the most relevant measures of stress or emotional arousal when collecting data during pregnancy.

Models that have been proposed to explain how maternal stress and affect may influence pregnancy outcomes and offspring development have focused on maternal and fetal HPA axis activation, production of related neuropeptides, and targets within the central nervous system (Wadhwa, Sandman, & Garite, 2001; Weinstock, 2001). Maternal stress can influence the fetus directly, through transport of neuropeptides, and indirectly, through alterations in maternal-fetal blood flow. Bradycardia, hypoxemia, and hypotension have been observed within a minute of induced maternal stress in nonhuman primate fetuses, with values returning to normal following stressor termination (Myers, 1975) or sedation (Morishima, Pedersen, & Finster, 1978). Although the placenta metabolizes up to 80% of maternal cortisol, a significant correlation between maternal and fetal levels has been documented (Gittau, Cameron, Fisk, & Glover, 1998). Investigation of the role of maternal and fetal hemodynamics in relation to maternal anxiety indicates that women with higher state and trait anxiety have reduced uterine artery blood flow (Teixeira, Fisk, & Glover, 1999) and that fetuses of more anxious women show evidence of altered cerebral and arterial blood flow (Sjostrom, Valentin, Thelin, & Marsal, 1997). Although the current study did not measure maternal anxiety, the mechanisms through which anxiety and other stress responses are transduced to the fetus are likely to be similar.

Our findings of the positive relations between maternal affective intensity, pregnancy-specific and non-pregnancy-specific stress appraisal, and fetal activity level are consistent with an interpretation of chronic sympathetic activation. Less clear is the mechanism underlying the negative relations between uplifts and activity level, in part because of the limited amount of research investigating maternal psychological factors that enhance pregnancy outcomes. The current findings support the hypothesis that appraisal of pregnancy as more uplifting than hassling signifies an adaptation to pregnancy that is associated with reduced maternal arousal. We are not able to explain why few relations were detected between maternal measures and FHR, nor why significant relations between FHR and the AIM, and pregnancy-specific hassle frequency and variability emerged only at 36 weeks. Ironically, had FHR been measured only at 36 weeks, as is common in cross-sectional fetal research, we would have been more confident in this association than we are given the inconsistencies in measures and timing we observed here. Further, although an interpretation of sympathetic activation would be appropriate to the variability finding, it is contrary to the heart rate results. A previous report found a negative relation between non-pregnancy-specific daily hassles combined with uplifts and FHR variability (DiPietro et al., 1996b). Because neither of the current measures was constructed in the same manner as in the prior report, a post hoc analysis was conducted to determine if a similar measure constructed for pregnancy-specific hassles and uplifts confirmed the earlier re-
It did: The total number of items endorsed as either hassles or uplifts was negatively associated with FHR variability ($Z = -2.22, p < .05$).

What is the relevance of detecting maternal effects on the neurobehavioral development of the fetus? Evidence is accumulating in support of a predictive relation between aspects of fetal functioning and postnatal psychophysiology and behavior, including consistencies in heart rate (DiPietro, Costigan, Pressman, & Doussard-Roosevelt, 2000; Lewis, Wilson, Ban, & Baume, 1970), behavioral state regulation (DiPietro, Costigan, & Pressman, 2002; Groome, Swiber, Atterbury, Bentz, & Holland, 1997), and motor activity (Almli, Ball, & Wheeler, 2001; DiPietro, Bornstein et al., 2002; Groome et al., 1999). The “maternal womb environment” has been estimated to account for a substantial proportion of variance in child IQ, although potential mechanisms have not been specified (Devlin, Daniels, & Roeder, 1997). Fetal behavior serves as a subtle indicator of the fetal nervous system (James, Pillai, & Smoleniec, 1995; Krasnegor et al., 1998). Even if the influence of maternal stress and affective factors on the intrauterine milieu is minor, small changes early in ontogeny can significantly alter the trajectory of development, resulting in exaggerated, not mitigated, effects during the postnatal period and beyond.

In general, the relations between maternal and fetal functioning observed were consistent over the gestational period studied. This fails to support reports that stressors present earlier in gestation exert more profound influences on infant neurobehavior in non-human primates (Schneider, Roughton, Koehler, & Lubach, 1999), gestational duration (Glynn, Wadhwa, Dunkel-Schetter, Chicz-Demet, & Sandman, 2001), neonatal vagal tone (Ponirakis et al., 1998) and childhood temperament (Martin et al., 2000). However, at least one study reports that the effect of prenatal anxiety on outcomes is strongest in the last trimester (O’Connor et al., 2002). The only gestational age effects in the current study involved significant associations at 36 weeks for fetal heart rate measures when none were detected before. Data collection could not commence until the second trimester because of the technical constraints of FHR monitoring; thus the lack of time effects may be a result of the compressed (i.e., 12-week) gestational period studied. The results specific to heart rate as gestation progressed, however, may reveal a cumulative effect of distress during pregnancy on the developing autonomic nervous system that provides a burden to the fetus but is mediated through different mechanisms than those with persistent effects.

Pregnant women’s affective intensity declined linearly from mid-pregnancy to term. Although this may seem counter to the prevailing lay sentiment regarding pregnancy, physiological evidence indicates that women display sympathetic hypoarousal in the third trimester (Matthews & Rodin, 1992; Schulte, Weisner, & Allolio, 1990). However, there was also a tendency toward greater negative appraisal of pregnancy (more hassles, less intense uplifts) during this time period. This is the same pattern of findings found for non-pregnancy-specific hassles and uplifts reported on a somewhat larger sample (Thompson et al., 1997), but changes detected in the current study were small and inconsistent within the PES measure. No corresponding change in report of non-pregnancy-specific stress was observed.

Figure 1. Average fetal motor activity with standard error bars at three gestational ages, modeled by dichotomized scores on the maternal stress composite.
Do these findings point to an effect of extrinsic environmental stressors or intrinsic maternal psychological patterns that govern appraisal of the stressfulness of their environment? Within-subject stability of all the psychosocial measures in the 12 weeks spanning the 24th and 36th weeks of pregnancy was high. Although the measure specifically designed to assess a personality state, affective intensity, had the highest stability values, both pregnancy-specific and nonspecific stress measures yielded values in the range of those typically associated with traits. This phenomenon likely reflects the mediating influence of personality and affective characteristics on a participant’s appraisal of daily stressors. Although there are clear theoretical reasons for distinguishing the role of exogenous stressors from trait-based affective factors in their effects on the developing fetus and infant, only studies of sudden, naturalistic stressors (e.g., earthquakes; Glynn et al., 2001) begin to provide such an opportunity. However, such studies cannot offer the prospective design necessary for complete interpretation. Because our sample was limited to middle-class, well-nourished, healthy women with normal pregnancy outcomes, we believe the findings detected in this study reflect influences that are more inherent in the woman than in the environment. However, the role of environmental stressors may occupy a more central role in other populations, particularly those of economically disadvantaged women.

Human research on the association between maternal psychological functioning and fetal behavior always raises the possibility that the observed relation is mediated by another, unmeasured factor, including genetic contributions. However, elicitation of disruptions to normal development by exogenous administration of adrenocorticotropic hormone in animal studies supports some role of HPA activation in mediating observed effects (Schneider, Coe, & Lubach, 1992). Beyond this, the most significant limiting factor in the interpretation of the results presented in this report is our reliance on self-report of maternal stress. The fetus can be affected by maternal stress appraisal only to the extent that these emotions are transduced into physiological signals. The use of paper-and-pencil assessments introduces noise into the taste of discerning the role of maternal stress appraisal only to the extent that these emotions

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