# Interactions Between Maternal Characteristics and Neonatal Behavior in the Prediction of Parenting Stress and Perception of Infant Temperament

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**Background** Prenatal cocaine exposure is a marker of developmental risk. Social environmental risk factors may include maternal stress and maternal perceptions of difficult infant temperament. **Objectives** To examine factors that may predict or moderate maternal ratings of parenting stress and difficult temperament in cocaine-exposed (CE) infants. **Method** Neonatal behavior, infant temperament, parenting stress, and maternal psychopathology were measured in a large sample of infant–mother dyads with prenatal CE and a nonexposed comparison sample. Participants were drawn from an existing longitudinal data set (Maternal Lifestyle Study). **Result** Relations between neonatal behavior and infant temperament ratings were moderated by mothers' ratings of parenting stress. Relations between neonatal cry and parenting stress were moderated by maternal psychopathology ratings. Results were unrelated to drug exposure history. **Conclusions** For mothers of at risk infants (with or without prenatal CE), psychological distress affects the degree to which infant behavioral characteristics are experienced as stressful or difficult. Implications for treatment and outcome are discussed.

**Key words** cocaine; parenting stress; temperament.

Prenatal exposure to cocaine is a marker of developmental risk. Disruptions in the infant–parent dyad are an important component of this risk status (Beeghly & Tronick, 1994; Tronick & Beeghly, 1999). However, because prenatal exposure and maternal substance abuse is a marker—and not a determinant—of risk, a range of social, environmental, and biological factors will moderate developmental outcomes in this population. Therefore, an important goal for research is to identify factors that may either magnify or attenuate risk in cocaine-exposed (CE) infants. Two dyadic factors that are likely to mark a heightened risk for this vulnerable population are the degree to which mothers perceive their parental role as highly stressful and the degree to which they perceive their infant as temperamentally difficult. The goal of this study was to understand processes that may heighten or attenuate the levels of parenting stress and perceptions of infant temperament in a sample of infants exposed prenatally to cocaine.

High levels of maternal stress have been found to relate to poor behavioral outcomes in young children (Creasey & Jarvis, 1994; Goldberg et.al., 1997). In addition, maternal ratings of infant temperament have been found to predict maternal behaviors (Milliones, 1978) and child behavioral outcomes (Sanson, Oberklaid, Pedlow, & Prior, 1991). Understanding the potential

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sources of parenting stress and maternal perceptions of temperament will enhance our understanding of the psychosocial factors associated with child and dyadic functioning in at-risk populations. For infants with prenatal cocaine exposure, an understanding of relations between these dyadic factors will help to identify dyads at highest risk for subsequent developmental difficulties.

Identifying moderators of risk will help to better target prevention and treatment efforts for those infants at highest risk and for those developmental and dyadic domains of functioning that operate most strongly on developmental and mental health outcomes. For this research, we examined the role of maternal characteristics such as maternal substance abuse history and maternal psychopathology as potential moderators of longitudinal relations between neonatal behavioral characteristics and parenting stress. We were interested in ratings of parenting stress as an important outcome in and of itself. However, it was also recognized that the degree of stress that a mother experiences may also impact her perception of and reactions to her infant. Thus, we also investigated whether parenting stress would prove to moderate relations between neonatal behavior and later maternal ratings of temperament.

We assumed that there is some consistency of infant characteristics over the course of the first 4–6 months of life. Stable individual differences in infant temperament ratings have been demonstrated when infant behavioral characteristics are measured objectively and with an emphasis on such phenomena as irritability and reactivity (e.g., Korner, 1996; Riese, 1987). Research has also documented the stability of behavior and temperament for infants who presented with extremes of such behavioral tendencies or where there are other objective indices of risk (Anderson et.al., 1989; Worobey & Lewis, 1989). Thus, studies indicate that neonatal characteristics such as irritability and reactivity may have predictive validity when measured at their extremes, or for infants who may be otherwise at risk for developmental problems. Though there is some evidence for stability in temperament ratings in cocaine-exposed infants (Smith, 1999), there are likely to be individual and contextual influences on the degree of stability of temperament in infancy (Wachs & Kohnstamm, 2001). CE infants may not show the same degree of stability in temperament seen in nonexposed populations. Thus, it will be important to understand whether relations between and within behavioral domains are affected by prenatal drug exposure or other characteristics of the infant–parent dyad.

CE infants have previously been found to display atypical patterns on measures of neonatal regulation and reactivity (DiPietro, Suess, Wheeler, Smouse, & Newlin, 1995; Lester et.al., 2002). These findings have implications for the study reported here. Because at least a subset of CE neonates show a heightened pattern of reactivity, there may be an increased likelihood that these infants will be perceived as more difficult by caregivers and that this may also relate to the degree of stress that a caregiver experiences as a parent. However, it can be assumed that relations between infant temperament and maternal attitudes and behavior are bidirectional, with infant temperament and parental attitudes having reciprocal effects over time (Wachs & Kohnstamm, 2001).

An additional assumption of this study was that parent ratings of infant temperament are the product not just of infant behavior but also of parental perceptions of these behaviors (Bates, 1980). Certain behaviors, such as persistent infant crying, may be experienced as particularly stressful (Papousek & von Hofacker, 1998). However, parents vary in the degree to which they find infant behaviors stressful. For instance, Pedersen, Huffman, del Carmen, and Bryan (1996) found that pregnant women who rated recordings of unfamiliar infant cries as aversive were more likely to subsequently (i.e., 3 months postnatal) rate their own infant's temperament as fussy and difficult. These mothers also varied in their cardiac reactivity to infant cries. In other words, although objective differences in cry may be generally experienced as more or less stressful, parents differ in their reactivity and potential susceptibility to stressful infant behaviors. Research also indicates that perceived infant characteristics interact with caregiver psychopathology to predict later parental perceptions of infants as more or less stressful (Gefland, Teti, & Fox, 1992).

Such effects have not been studied specifically in cocaine- or drug-exposed populations. However, factors that affect whether infants are likely to be viewed as difficult and stressful may be particularly salient in drug-using populations. Mothers who have used cocaine or other drugs during pregnancy appear more likely than nondrug-using mothers to have comorbid psychiatric diagnoses and to have experienced past traumatic events (Hans, 1999). In addition, there is some evidence that as a group, mothers with a history of substance abuse experience greater levels of parenting-related stress (Kelley, 1992). The presence of psychiatric symptoms, whether for parents with or without substance abuse histories, may result in or reflect diminished personal coping resources, thereby making it more difficult for them to respond adaptively to the stressors of parenting.

This study examines the relations between neonatal behavior and later measures of parenting stress and

parental perception of temperament at 4 months of age in a sample of children with prenatal cocaine exposure and their caregivers, and a comparison sample of non-CE infants. The sample was drawn from a longitudinal study of prenatal drug exposure, the Maternal Lifestyle Study (Lester, 1998). The evidence reviewed above suggests that neonatal and parent characteristics may have interactive effects on later parenting stress and perception of temperament. However, there has been little research that has specifically addressed these issues in CE infants. The central question to be addressed in this study was whether parental characteristics, such as maternal substance abuse history, parenting stress, and psychopathology, would modify relations between objective measures of neonatal behaviors and later maternal ratings of infant temperament. Also, we tested whether maternal drug use and psychopathology interacted with neonatal behavioral characteristics to explain individual differences in parenting related stress in early infancy. To answer these questions, the linear relations between neonatal behavior and later measures of parenting stress and maternal perception of infant temperament were also examined.

## Methods

### *Subjects*

Participants were drawn from the Maternal Lifestyle Study (MLS), an investigation of the effects of prenatal cocaine or opiate exposure on child outcome in a longitudinal follow-up from 1 month to 11 years in 1,388 children divided into an exposed group and a comparison group (Lester, 1998). Infants were entered into the "exposed" group if there was either maternal report of cocaine or opiate use during the pregnancy based on hospital interview *or* positive meconium assay (positive enzyme multiple immunoassay (EMIT) screen followed by positive gas chromatography/mass spectroscopy). Infants were entered into the comparison group if there was maternal denial of cocaine or opiate use and a negative EMIT screen for cocaine and opiate metabolites. Groups were matched on prematurity, race, and sex. Infants were excluded from the MLS if they had a chromosomal abnormality or TORCH (toxoplasmosis, other agents, rubella, cytomegalovirus, herpes) infection confirmed before the 1-month assessment or if the mother planned to move outside of the study catchment area. Additional information on the severity of prenatal cocaine exposure was determined by interview with mothers at 1-month corrected age using the Maternal Inventory of Substance Use (MISU; Shankaran et.al., 1996). Dyads were classified into three groups: no prenatal exposure, some exposure, and heavy exposure (defined as reported cocaine use of ≥3 days per week during the first trimester; see Lester et.al., 2002).

MLS is conducted under the auspices of the National Institute of Child Health and Human Development (NICHD), Neonatal Research Network at Brown University, University of Miami, University of Tennessee, Memphis, and Wayne State University. MLS was given a "certificate of confidentiality" from the United States Department of Health and Human Services, which allowed the study to maintain participant confidentiality with regard to drug-use information. The certificate of confidentiality applied specifically to information regarding maternal use of drugs and left in force all reporting requirements with regard to suspicion of child abuse or child neglect. Participants were fully informed of their rights and limits as study participants, including limits to confidentiality, and informed consent was obtained from all caregivers, as approved by review boards at each study site.

For this article, children were selected from the MLS if they were in the care of their biological mother (regardless of drug exposure grouping). This resulted in a subsample of 984 children with data on measures of neonatal behavior and 4-month measures of maternal psychopathology, parenting stress, and temperament ratings. We included only biologically related dyads because we were interested in the phenomenon of prenatal cocaine exposure as related to both the infant exposed to the drug and the mother who had used cocaine during pregnancy. Because of differential rates of foster placements, infants who were excluded ($n$ = 404) were more likely to have been in the CE group than those who were retained for this study (65% vs. 40%, $\chi^2$ (1, n-1388) = 73.56, $p < .001$). Sample size for each analysis reported in this article varied slightly because of missing data. Unless otherwise noted, the children excluded from specific analyses did not differ from those included (e.g., in birth weight, race, sex, and exposure status). All infant ages reported are corrected for obstetric estimate of gestational age at birth.

### *Measures*

#### Neonatal Behavior

Neonatal measures were chosen to represent objective measures of individual differences in neonatal reactivity. Infants were assessed at 1-month corrected age with the Neonatal Intensive Care Unit (NICU)-Network Neurobehavioral Scales (NNNS; Lester & Tronick, 1994) and an acoustic analysis of infant cry. The NNNS and cry measures were aggregated into two cumulative indices, each

representing the degree to which infants were highly reactive to the procedures. A summary of these measures is below, followed by a detailed description of the aggregation process and scale development.

The NNNS was developed by the NICHD NICU Network for use in MLS and has been used previously in a study of CE newborn infants (Napiorkowski et al., 1996). The NNNS is a semistructured and comprehensive examination of neurological integrity and behavioral function in the newborn. Methods and items were adapted from the Brazelton examination and also include an assessment of stress signs that can be observed over the course of the NNNS administration. The NNNS includes 45 items administered in packages of items. In addition, there are 21 summary items that are intended to reflect overall functioning during the examination. A rating of the presence or absence of 50 stress signs, grouped into 7 categories, is also made by the examiner.

For the cry analyses, a cry-eliciting stimulus was administered to the infant's foot, and cries were subsequently analyzed off-line by a computer system designed for this purpose (Cry Research, Inc., Brookline, MA) and used previously in studies of drug-exposed infants (Corwin et.al., 1992; Lester et.al., 1991). Cry was analyzed for latency to cry, number and length of utterances, and a number of acoustic features.

The NNNS and cry measures were used in this study as objective measures of neonatal reactivity. A cumulative index approach was used to aggregate variables from these procedures into composite measures of neonatal reactivity. Each item from the NNNS and the Cry analysis was dichotomized so as to reflect extreme responding or scores. Dichotomization was on an item-by-item level, with dichotomized items being summed to create two continuous variables, one for the NNNS procedure and one for cry measure. Final items included in the NNNS and cry aggregate measures, as well as a description of these items, are presented in Appendices A and B, along with estimates of internal consistency.

For each item on the NNNS, children whose item score was in the upper or lower (depending the direction of scoring) quintile of respondents received a code of "1" to indicate an extreme score. Nonextreme responders received a code of "0". This upper or lower quintile rule was altered for some items to ensure that only clinically meaningful scores were coded as extreme (e.g., where the original cut point would have resulted in the assignment of a score of "1" to behaviors that would be considered normative based on guidelines in the NNNS scoring manual). The final set of items was determined through an a priori, iterative process of selecting those items that on face value reflected high temperamental reactivity, and then excluding the remaining variables that reduced the internal consistency of the scale. The resulting scale included 38 items from the NNNS ($\alpha$ = .72). The potential range for the cumulative NNNS risk score was 0–38. Items with missing data received a score of 0. Only children with scores on 75% of NNNS items were included in the analyses.

Cry variables were dichotomized in a similar manner to the NNNS variables so as to identify children most highly reactive to the eliciting stimulus. Cry variables were dropped from the final scale if they reduced internal consistency. The resulting scale included 12 items ($\alpha$ = .59). For each item a child could receive a score of either 1 (risk) or 0 (no risk). The resulting aggregate measure had a potential range of 0–12. Thus, cry cumulative index scores reflect extremes in the duration and intensity of the cry response.

**4-Month Outcome Variables**

Caregivers were administered a series of self-report questionnaires when infants were 4-months corrected age. Because of variations in reading competency in the MLS sample, these questionnaires were read to all mothers. The Brief Symptom Inventory (BSI; Desrogatis, 1993) was administered as measure of maternal psychopathology. The total score (Global Severity Index) was used in this study. The Parenting Stress Inventory (PSI; Abidin, 1983) was used to assess the degree of parenting stress experienced by caregivers. The shortened 36-item version of the PSI was used. The PSI yields a total score and 3 factor scores (Parental Distress, Parent–Child Dysfunctional Interaction, and Difficult Child). A sum of the Parental Distress and Parent–Child Dysfunctional Interaction scores were used for the this study to avoid confounding the measure of parenting stress with ratings of infant temperament. Finally, a modified version of the Infant Behavior Questionnaire (IBQ; Rothbart, 1981) was administered as a measure parent-reported child temperament (modifications, approved by M. K. Rothbart, included simplification of language for the MLS population and reduction of response scale to five points). The IBQ yields six summary scales: Activity Level, Smiling and Laughter, Distress to Novelty, Distress to Limitations, Soothability, and Duration of Orienting. The Distress to Novelty and Distress to Limitations scales were used for this study. These scales were chosen because of our interest in examining relations between reactivity at the two age points.

## Results

Results are presented in three sections. First, descriptive statistics will be presented for the 1- and 4-month measures, including both child and maternal variables. Second, correlation analyses of relations amongst study variables will be presented. And third, a series of hierarchical regression analyses are presented as a test of the main question posed by this study: whether child and parent variables would interact in their prediction of parenting stress and temperament ratings. We note here that there were a small number of dyads in the CE group who also had prenatal opiate exposure (36 of 394; 9% of the CE sample included in these analyses). The analyses reported below were run with and without these 36 dyads, and exclusion of these children did not significantly affect the results. Thus, because the interest in this article was to examine relations between maternal and infant characteristics in the first 4 months of life, we retained the data for these dyads and will refer to the two groups as CE and nonexposed.

### *Preliminary Analyses*

Children in the exposed group were lower in SES (socioeconomic status) than those in the nonexposed group (see Table I). The analysis with the 3-group exposure severity score also revealed a significant effect of prenatal cocaine exposure on SES scores, $F(2,957) = 6.97$, $p = .001$. Nonexposed dyads were higher in SES than dyads in the "heavy" exposure group ($p = .001$), but the light exposure group did not differ from either the nonexposed or heavy exposure groups. Exposed dyads did not differ from nonexposed on PSI scores. However, when tested with the three group severity variable a group difference in PSI scores did emerge $F(2, 942) = 7.71$, $p < .001$. Multiple comparisons indicated that the nonexposed dyads had lower PSI scores than both the light exposure group ($p = .01$) and the heavy exposure group ($p = .001$). Otherwise, there were no other significant differences between exposed and nonexposed children on the study variables. The PSI total scores were distributed in a similar manner to the norms for this measure. Across cohorts, 53% scored above the median, and 24% scored above the 80th percentile on this measure. However, 28% of the overall sample scored above clinical cutoff on the total score of the BSI (32% for the CE group, 26% for the nonexposed group; $\chi^2$ (1,984) = 4.75, $p = .03$).

It should be noted that this study required the selection of biologic mothers. Infants from excluded dyads (i.e., in foster care) received lower ratings on the IBQ Distress to Limitations scale, were slightly lower in birth weight (2434 g vs. 2647 g), and received marginally higher scores on the NNNS cumulative score. Caregivers of excluded dyads had lower scores on the PSI and BSI.

### *Correlation Analyses*

Correlation analyses examining the relations amongst study variables are presented in Table II. SES correlated significantly with five of the six measures (two neonatal measures and four measures at 4-months of age). Lower SES was related to greater neonatal reactivity, higher ratings of distress to novelty and limits, and higher parenting stress and psychological distress in mothers. NNNS scores were significantly and positively related to 4-month Distress to Limits scores, whereas Cry scores

**Table I.** Descriptive Statistics and Mean Comparisons for 1- and 4-Month Variables

| | Comparison group ($n = 590$) | | Exposed group ($n = 394$) | | |
|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *p* |
| SES (continuous)[a] | 29.69 | 10.72 | 27.25 | 9.85 | <.001 |
| Low (IV) | 55% | | 64% | | |
| Mid–high (I–III) | 45% | | 36% | | |
| Birth weight (g) | 2666 | 872 | 2619 | 785 | *ns* |
| NNNS reactivity | 5.04 | 3.58 | 5.22 | 3.72 | *ns* |
| Cry reactivity | 1.36 | 1.58 | 1.42 | 1.61 | *ns* |
| PSI | 70.02 | 17.33 | 71.11 | 17.52 | *ns* |
| BSI | 0.58 | 0.58 | 0.61 | 0.59 | *ns* |
| IBQ Distress novel | 2.35 | 0.65 | 2.39 | 0.66 | *ns* |
| IBQ Distress limit | 2.53 | 0.55 | 2.53 | 0.60 | *ns* |

BSI = Brief Symptom Inventory; IBQ = Infant Behavior Questionnaire; NNNS = NICU Neonatal Neurobehavioral Scale; PSI = Parenting Stress Index; SES = socioeconomic status.

[a]Socioeconomic status measured by a revised version of the Hollingshead Index of Social Position (LaGasse et.al., 1999). This revision allows for the application of the SES measure to nonnuclear families. The scale retains the traditionally weighted educational and occupational scale scores.

**Table II.** Intercorrelations Amongst Study Variables

| Variable | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1-Month | | | | | | |
| 1. SES | — | — | — | — | — | — |
| 2. NNNS reactivity | −.05 | — | — | — | — | — |
| 3. Cry Reactivity | −.08** | .07* | — | — | — | — |
| 4-Months | | | | | | |
| 4. IBQ Distress to novelty | −.13** | .02 | .10** | — | — | — |
| 5. IBQ Distress to limits | −.07* | .09** | .02 | .39** | — | — |
| 6. BSI | −.14** | −.01 | −.01 | .16** | .27** | — |
| 7. PSI | −.24** | .01 | .03 | .25** | .35** | .46** |

BSI = Brief Symptom Inventory; IBQ = Infant Behavior Questionnaire; NNNS = NICU Neonatal Neurobehavioral Scale; PSI = Parenting Stress Index; SES = socioeconomic status (see note to Table I).
*$p \le .05$. **$p \le .01$. ***$p \le .001$.

were positively related to Distress to Novelty scores. Neither the NNNS nor the Cry scores were correlated with maternal ratings of parenting stress or psychopathology.

Amongst 4-month measures, consistent correlations were observed between scores on the IBQ scales, PSI, and BSI scores. Higher parenting stress was related to higher maternal ratings of infants' distress to novelty and limitations. Maternal ratings of infant distress to novelty and distress to limitations were both positively correlated with maternal psychological distress, as measured by the BSI. The IBQ Distress to Limitations scores correlated at above .25 for both PSI and BSI scores. In addition, the measure of parenting stress (PSI) and maternal psychopathology (BSI) were moderately correlated.

## *Regression Analyses*

A series of hierarchical regression analyses were performed to test whether the influence of early infant behavioral characteristics on later parenting stress and temperament ratings would vary depending on factors in the infant–parent dyad. In each regression model, drug exposure, SES, child gender, and MLS study site were entered at step 1 (study site was entered because it was a common finding that infants differed on a variety of MLS variables across study site). Neonatal Cry and NNNS scores were entered at the second step to model the main effect of neonatal behavior on later maternal and temperament measures. The main effects of the maternal ratings were entered at step 3. The interaction terms relevant for each hypothesis were entered at the fourth step in each model. For the models testing the interactions between maternal drug abuse (infant exposure status) and neonatal behavioral measures, variables were entered in three steps, with the interaction terms entered at the final step in the model. For these analyses, two sets of regressions were performed, one using the two-group exposure variable and one using the three-group exposure severity measure.

### Parenting Stress Ratings

Maternal psychopathology ratings explained a significant amount of variance in parenting stress (PSI scores) after controlling for child gender, exposure status, and neonatal behavior (see Table III). There was some evidence for an effect of exposure status (i.e., maternal cocaine or opiate use during pregnancy) on parenting stress, although this effect was not significant after controlling for maternal psychopathology (BSI scores). SES scores explained a significant amount of variance in later PSI scores, with lower SES being associated with higher scores on the PSI. There was a significant interaction between BSI scores and the Cry index in predicting parenting stress ($\alpha$ = .111, $p$ < .05). We examined regression slopes within BSI quartile ranges. This analysis indicated that the relation between neonatal cry and

**Table III.** Hierarchical Multiple Regressions Predicting 4-Month Parenting Stress (β's Denoted for Each Step in Model)

| Step | Variables | *df* | $\Delta R^2$ | $\beta^1$ | $\beta^2$ | $\beta^3$ | $\beta^4$ |
|---|---|---|---|---|---|---|---|
| 1 | Sex | | | | | | |
| | Exposure | | | .060* | .060* | | |
| | SES | | | −.258**** | −.258**** | −.193**** | −.190**** |
| | Site | (4, 964) | .072**** | .085*** | .084*** | | |
| 2 | Cry | — | | | | | |
| | NNNS | (2, 962) | .001 | — | | | |
| 3 | BSI | (1, 961) | .166**** | — | — | .415**** | .412**** |
| 4 | BSI × Cry | — | — | — | | | .111** |
| | BSI × NNNS | (2, 959) | .006** | — | — | — | |

Model: $R^2$ = .244, $F(9, 958)$ = 34.36, $p$ < .001.
BSI = Brief Symptom Inventory; NNNS = NICU Neonatal Neurobehavioral Scale; SES = socioeconomic status.
*$p \le .10$. **$p \le .05$. ***$p \le .01$. ****$p \le .001$.

later parenting stress was somewhat stronger for dyads where the mother was experiencing greater degrees of psychological distress. However, the relations between Cry and PSI scores were not significant within these subgroups of BSI scores, even for the upper quartile. Additional analyses were performed by splitting the BSI sample by criteria defined in the BSI manual, which defines a case in two different ways: (a) individuals with scores above the 90th percentile of the normative distribution on the GSI and (b) individuals with elevations on two or more BSI subscales. We split the sample in these two ways and examined regression slopes and correlations between the Cry and PSI scores. The resulting regression coefficients were not significantly different than 0.

A separate analysis was performed to test the effect of the cocaine exposure-by–neonatal behavior interaction on later PSI scores. The interaction between prenatal CE and neonatal behavior was not a significant predictor of maternal self-reported parenting stress on the PSI. This was true for models using the two-group exposure status variable and the three-group exposure severity variable.

**Temperament Ratings**

The second hypothesis for this study was whether neonatal reactivity (rated from the NNNS and Cry scales) would predict later maternal ratings of infant temperament, and whether parenting stress and psychopathology would moderate such relations. The Distress to Limitations scale from the IBQ was chosen as the dependent measure of temperament because of its conceptual similarity to the measures of neonatal reactivity employed in this study. Results are presented in Table IV. NNNS, parenting stress, and parent psychopathology self-report scores each showed significant unique relations to IBQ ratings after controlling for effects of gender, SES, and study site. Thus, children who showed more reactivity on the NNNS and whose mothers reported more parenting related stress and psychological distress were rated as being higher in distress to limitations at 4 months of age.

In addition to these main effects, there was a significant interaction between parenting-stress and neonatal reactivity on the NNNS in predicting maternal ratings of infants' distress to limitations. We investigated this interaction between PSI and NNNS scores by examining the relation between NNNS scores and IBQ Distress to Limitations ratings within quartile ranges of the PSI distribution. These analyses indicated that this relation was stronger in dyads where mothers reported higher parenting-related stress, specifically for dyads with PSI scores in the upper two quartiles of the distribution. Separate regression analyses for the dyads above and below the PSI median were run. Covariates were entered at the first step (gender, exposure, SES, and study site), and the NNNS variable was entered at the second step. NNNS scores did not add significantly to the model for low PSI dyads. In fact, the overall model for this subgroup was nonsignifican, Model: $R^2 = 0.009$, $F(4, 467) < 1$. For the high PSI subgroup, NNNS scores showed a significant unique relation with IBQ scores after controlling for covariates, $\Delta R^2 = .036$, $p < .001$, Model: $R^2 = 0.04$, $F(4, 465) = 3.80$, $p = .002$. This interaction is illustrated in Figure 1 where the relations between NNNS and IBQ scores are plotted for dyads below and above the median split in PSI scores.

We also examined the relation between PSI scores and IBQ Distress to Limitation scores within ranges of

**Table IV.** Hierarchical Multiple Regression Predicting 4-Month Maternal Ratings of Infant Distress to Limitations (β's Denoted for Each Step in Model)

| Step | Variables | *df* | $\Delta R^2$ | $\beta^1$ | $\beta^2$ | $\beta^3$ | $\beta^4$ |
|---|---|---|---|---|---|---|---|
| 1 | Sex | | | | | | |
| | Exposure | | | | | | |
| | SES | | | −.078** | −.075** | | |
| | Site | (4, 934) | .008 | .051 | .063* | | |
| 2 | Cry | — | | | | | |
| | NNNS | (2, 932) | .008** | — | .089*** | .097*** | −.229 |
| 3 | PSI | — | — | | | .189**** | |
| | BSI | (2, 930) | .093**** | — | — | .184**** | .162** |
| 4 | PSI × Cry | — | — | — | | | |
| | PSI × NNNS | — | — | — | | | .312** |
| | BSI × Cry | — | — | — | | | |
| | BSI × NNNS | (4, 926) | .009** | — | — | — | |

Model: $R^2 = .119$, $F(12, 926) = 10.39$, $p < .001$.

BSI = Brief Symptom Inventory; NNNS = NICU Neonatal Neurobehavioral Scale; PSI = Parenting Stress Index; SES = socioeconomic status.

*$p \leq .10$. **$p \leq .05$. ***$p \leq .01$. ****$p \leq .001$.

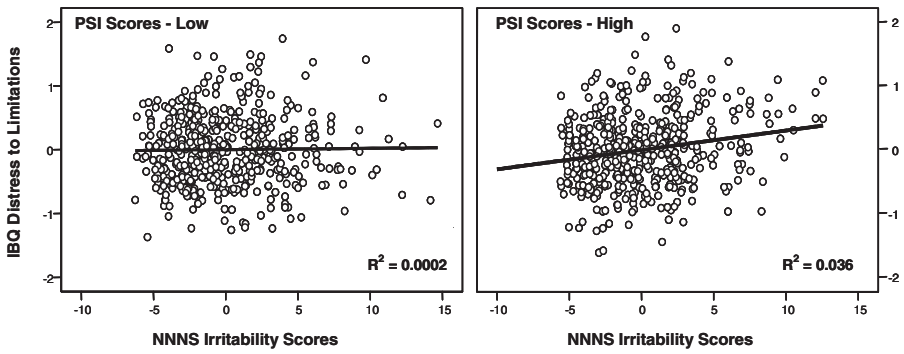


**Figure 1.** Relations between NNNS irritability scores at 1-month and IBQ Distress to Limitations ratings at 4-months within subgroups of dyads with high and low parenting related stress ratings (grouped above and below the median of the sample).

the NNNS scale. This analysis indicated that the relation between PSI and IBQ scores were of similar magnitude (and in the same direction) for both children with high and low NNNS reactivity scale scores. Overall, these analyses indicate that reactivity at 1 month as measured by the NNNS is predictive of IBQ Distress to Limitations ratings at 4 months, but that this relation is moderated by the degree of parenting related stress experienced by mothers.

A separate analysis was performed to test the effect of the cocaine exposure-by–neonatal behavior interaction on the maternal ratings of infant temperament. As with the analysis of parenting stress ratings, the interaction between prenatal CE and neonatal behavior was not a significant predictor of mothers' rating of the IBQ Distress to Limitation scale. Again, no exposure by neonatal behavior interaction was found for either the two-group exposure variable or the three-group exposure severity variable.

It is possible that the observed interaction between PSI and NNNS scores in predicting 4-month distress to limitations reflected dyads where infants were most consistently reactive during the first 4 months of life. As reported above, we did observe some modest stability of individual differences in reactivity from 1 to 4 months of age (i.e., there was a significant relation between NNNS scores and 4-month distress to limitations ratings). However, the interaction between NNNS and IBQ Distress to Limitations scores in explaining variance in PSI scores at 4 months was nonsignificant. This was tested by regressing NNNS scores, IBQ scores, and the NNNS–IBQ interaction on 4-month PSI scores. As with the other regression models, gender, exposure status, SES, and site were entered at an initial step in the model. The overall model was significant, Model: $R^2 = 0.13$, $F$ (7, 931) = 20.50, $p < 0.001$. IBQ Distress to Limits scores added significantly to the model, $\Delta R^2 = .063$, $p < .001$. Neither NNNS scores nor the NNNS–IBQ interaction added significantly to the model.

## Discussion

The results of this study revealed that in two cohorts of infant–mother dyads, one with prenatal cocaine or opiate exposure and a nonexposed control sample, neonatal behavioral characteristics and certain maternal psychological characteristics interacted to predict maternal ratings of temperament, and maternal self-reports of parenting stress. Specifically, an accumulation of behavioral signs of extreme neonatal reactivity on a behavioral examination (the NNNS) predicted higher maternal ratings of infant reactivity (IBQ Distress to Limitations) at 4-months corrected age, though primarily for dyads where the mother was experiencing more stress related to parenting. There was some indication that extreme characteristics of neonatal cry interacted with maternal psychopathology in predicting self-reported parenting stress 3 months later. However, maternal psychopathology was otherwise unrelated to earlier measures of neonatal cry and behavior. Thus, maternal characteristics (stress and psychopathology) interacted with neonatal reactivity to explain variability in later maternal ratings of parenting stress and maternal ratings of infant temperament. These interactive effects were most evident in accounting for variance in mothers' temperament ratings at 4 months.

These results were not affected by mothers' substance abuse history. Substance use or exposure groupings did not differ on study variables. In addition, substance use or exposure did not interact with neonatal behavior to predict 4-month outcome measures. These findings do not support the prediction that maternal substance abuse history would moderate the ways in which mothers perceived their infants. Rather, these findings suggest that the degree to which neonatal reactivity

explains variation in later maternal ratings of infant temperament is dependent on the general level of parenting stress experienced by mothers, regardless of whether they had used cocaine and/or opiates during pregnancy.

Prior research has indicated that parental ratings of infant temperament are influenced both by variation in objectively measured infant behavior patterns and by antecedent parental behavior patterns (Anderson et.al., 1989; Crockenberg & Acredolo, 1983). This study did not compare parental perception of temperament to objective indices of infant behavior measured at the same time. However, we did observe a small but significant relation between 1-month observations and 4-month ratings of infant reactivity. In so far as parent ratings reflect both objective and perceived individual differences in infant behavior, this can be interpreted as showing only a modest level of stability in early infant behavior, at least within the domain of reactivity. We did not find evidence that levels of parenting stress depended on the degree of stability in high infant reactivity, although alternate study designs would be able to address this question more directly. Thus, although not the only possible interpretation, the results reported here are at least consistent with the view that parents vary in how they react to and experience the early behavioral characteristics of their infants (e.g., Wachs & Kohnstamm, 2001). The important finding here is that these processes are at play in dyads with and without a history of prenatal drug exposure and use.

The exclusionary criteria used in selecting dyads for the analyses in this article may help to explain the null findings for the main effects of prenatal drug exposure. This leads us to be cautious when drawing conclusions about the neurobehavioral functioning of CE infants on the neonatal behavioral examination (the NNNS) and the cry analyses. Subjects included in this study were more extreme in their neonatal cry and behavior than those excluded from analyses (i.e., those included had higher scores on the NNNS and Cry cumulative measures). Furthermore, those excluded from analyses were more likely to have been exposed to cocaine and opiates during pregnancy. These differences suggest that the results reported here should not form the basis for conclusions about drug exposure effects on the early behavioral presentation of drug-exposed infants. Rather, these results suggest that, regardless of exposure status, the manner in which caregivers react to and cope with challenging infant behaviors can be expected to affect infant development.

Neither objective neonatal cry nor neonatal behavior was directly related to later parenting stress and maternal psychopathology. The study design and nature of the measures used may have limited the possibility of observing such relations. If neonatal cry and behavior had been measured differently, for instance, so as to sample extremes in the duration of cry or other behaviors over time, we may indeed have found such relations (see Papousek & von Hofacker, 1998). In addition, objective measures of child behavior and parental stress may be more tightly related when these domains are assessed concurrently.

In addition, we observed only modest relations between behavioral measures in neonatal period and temperament measured at 4 months of age. Aspects of our measurement may have attenuated relations between the 1- and 4-month measures. Past findings of stability of individual differences in infant temperament across time have used behavioral observations (vs. parent report) at both time points (e.g., Riese, 1987), whereas this study utilized behavior observation at time 1 and parent ratings at time 2. In addition, it should be noted that the internal consistency of the cry scale used in this study was somewhat low. This reflects measurement error that limits the magnitude of relations that could be observed between cry and other variables.

But beyond these measurement and methodological factors, the small (though significant) relations between 1- and 4-month reactivity scores (i.e., 1-month NNNS scores and 4-month IBQ Distress to Limitations ratings) suggests that there was variability in the degree to which infants displayed stable characteristics in the domain of early reactivity. The interaction between NNNS and PSI scores in predicting 4-month temperament ratings is consistent with differential stability in early temperament ratings (resulting in higher parenting stress for those with high 1- and 4-month reactivity ratings), but is also consistent with differential parent perceptions of infant behavioral tendencies. As argued above, our data are suggestive of the latter of these two possibilities, but these results are not definitive in this regard.

Clearly there are several alternative, though not mutually exclusive, scenarios that may explain the interactions observed in this study. First, the moderating effect of parenting stress on the relation between objective measures of neonatal behavior and later subjective maternal ratings of infant temperament may be driven by a subset of children who evidence persistent irritable and difficult behaviors over the first 4 months of life. We could not test this mechanism because objective measures of infant behavior at 4-months of age were not available. However, there is prior evidence for stability

in temperamental reactivity in the neonatal period and early infancy (Korner, 1996; Worobey & Lewis, 1989).

Second, highly reactive neonates may elicit caregiver behaviors that may either potentiate or moderate these initial qualities. Highly stressed mothers may be less able to respond to infants' difficult behaviors in a positive or sensitive manner. Their subsequent ratings of difficult temperament may be an accurate view of their infant's temperamental qualities, even if these qualities were in part shaped by earlier parental behavior (see Crockenberg & Acredolo, 1983). Maternal psychopathology or parenting stress may also serve to alter the manner in which parents respond to infants. This effect may in part operate on the salience that mothers attach to infant behaviors, such as distress signs, although some recent research suggests that this effect may differ in direction (i.e., increased or decreased salience) depending on maternal diagnosis (e.g., Schuetze & Zeskind, 2001). This interpretation may be highly relevant to the relation between 1-month reactivity and 4-month distress to limitations ratings. The behavioral index of reactivity derived from the NNNS reflects perhaps a more subtle flavor of difficult or challenging behaviors than would be reflected in, for example, extreme and persistent cries. Thus, the behavioral tendencies reflected in the NNNS measure may not be seen as universally aversive, but rather may elicit different parental reactions depending on the degree of parenting stress experienced by a mother.

Third, parents who rate their children as difficult at 4 months of age may be partially accurate in their ratings of infant temperament, although their general level of parenting stress may result in exaggerated ratings of their infants' temperamental qualities. Past research showing that parental characteristics affect the perceptions of infant cries is consistent with this view (Crowe & Zeskind, 1992; Pedersen et.al., 1996). This hypothesis could be tested by examining discrepancies between subjective (parental) and objective (laboratory) ratings of infant behavior.

In conclusion, the results of this study can be viewed at multiple levels. On one level, it may be that a confluence of maternal and infant risk factors, in the wider context of socioeconomic risks, may portend later developmental and dyadic difficulties. On another level, it may be that more specific patterns in the infant–parent dyadic relationship will provide a glimpse into the mechanisms for these broader risks. Such mechanisms would conceivably include mismatches between objective measures and subjective ratings of infant cry and behavior (Lester et.al., 1995; Pedersen et.al., 1996), reactivity of mothers to infant cry and behavior (Crowe & Zeskind, 1992; Pedersen et.al., 1996), and failures of the dyad to manage developmental challenges (Beeghly & Tronick, 1994). In this regard, evidence that there are concurrent relations between parental perception of infant irritability and parental responsiveness (Owens, Shaw, & Vondra, 1998) points to one potential linkage between caregiver experiences of neonatal difficult behavior, parenting stress, and infant outcomes.

These conclusions should not be taken as a wholly pessimistic view of the outcome of children with prenatal cocaine exposure. Recent evidence suggests that intervention programs, including those that target both children and caregivers, can have a positive effect on child outcomes in this at-risk population (Claussen, Scott, Mundy, & Katz, 2004). Although it is not yet clear which types of interventions can reduce parenting stress in dyads with prenatal cocaine exposure, the effect of dyadic psychotherapies on parenting stress and parental attitudes has been documented in other populations (Cohen, Lojkasek, Muir, Muir, & Parker, 2002; Feinfield & Baker, 2004). Recent evidence also suggests that parenting stress and parenting attitudes may moderate outcomes in at-risk drug-exposed populations (Andra & Thomas, 1998; Schuler, Nair, & Black, 2002).

Clarifying child and parent characteristics that serve to protect against the risks posed by prenatal drug exposure is a critical goal for research. The degree of stress experienced by mothers may impact reactions to infant behaviors and the quality of the dyadic relationship. For some dyads, this may serve to accentuate the risks associated with prenatal drug exposure. However, by the same token, for mothers experiencing less parenting related stress, the effect may be to ameliorate risk factors by altering in a positive fashion the perceptions of infant behavioral characteristics and improving infant–parent interactions. In other words, the degree of parenting stress experienced by mothers of drug-exposed infants may operate as both a risk and protective factor. To the extent that parenting stress and attitudes can be modified, these factors are potentially important targets of intervention.

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# Appendix A

NICU Neonatal Neurobehavioral Scale: Items Included in the NNNS Risk Score

| Description | Pre-cut range[a] | Normal[b] | Cut[c] | Percentile[d] | Description[e] |
|---|---|---|---|---|---|
| Posture | 1–5 | 4 | 5 | 85 | Abnormal posture |
| Movement | 1–3 | 2 | 3 | 91 | Excessive movement |
| Plantar grasp | 1–4 | 3 | 4 | 88 | Excessive response |
| Babinski | 1–4 | 3 | 4 | 90 | Excessive response |
| Leg resistance | 1–5 | 5 | 5 | 87 | Extremely strong resistance |
| Leg movements | 1–5 | 5 | 5 | 73 | Extremely strong movements |
| Popliteal angle | 1–6 | 5 | 5 | 82 | Angle less than 80 degrees |
| Scarf sign | 1–4 | 4 | 4 | 88 | Elbow does not reach nipple |
| Forearm resistance | 1–5 | 4 | 4 | 74 | Strong to extreme resistance |
| Arm movements | 1–5 | 4 | 4 | 75 | Strong to extreme movements |
| Rooting | 1–5 | 4 | 4 | 97 | Very vigorous or turn away |
| Sucking | 1–7 | 4 | 4 | 81 | Exaggerated, disorganized, or dysfunctional |
| Grasp of hands | 1–4 | 4 | 4 | 90 | Prolonged or excessive grasp |
| Truncal tone | 1–5 | 4 | 4 | 80 | Partial or total hypertonic response |
| Pull to sit | 1–11 | — | 8 | 83 | No head lag, hypertonic, or back arch |
| Stepping | 1–6 (7) | 4 | 5 | 98 | Exaggerated or hypertonic (“scissoring” responses coded as = 0) |
| Ventral suspension | 1–6 | 3 | 4 | 71 | Sustained, hypertonic, or inconsistent |
| Incurvation | 1–4 | 3 | 4 | 95 | Exaggerated response |
| Crawling | 1–4 | 3 | 4 | 95 | Prolonged or exaggerated response |
| Head raise in prone | 1–6 | 4 | 5 | 87 | Long or extremely long head raise |
| Cuddle in arm | 1–9[f] | — | 8 | 88 | Resists being held |
| Cuddle on shoulder | 1–9[f] | — | 7 | 85 | No participation or resistance |
| Deviaton of head and eye | 1–5 (6) | 4 | 5 | 98 | Exaggerated response (eyes in opposite direction recoded as = 0) |
| Tonic neck reflex | 1–4 | — | 4 | 98 | Well-marked to exaggerated response |
| Moro reflex | 1–5 | 4 | 5 | 99 | Exaggerated response |
| General tone | 1–10 | — | 8 | 81 | Hypertonic when handled 75+% of time |
| Motor maturity | 1–9[f] | | 8 | 84 | Jerky with mild to severe overshooting |
| Consolability | 1–10[f] | — | 8 | 77 | Needed at least wrap + hold + rocking, or was not consolable |
| Peak of excitement | 1–9 | — | 8 | 70 | State 6 2+ times, but difficult to console |
| Rapidity of build-up | 1–12 | — | 9 | 81 | Reached state 6 during first one-third of examination |
| Irritability | 1–9 | — | 9 | 74 | Fussy or irritable in 8+ exam packages |
| Spontaneous activity | 1–6 | — | 5 | 89 | Continuous movement (may be consolable) |
| Elicited activity | 1–6 | — | 5 | 89 | Continuous movement (may be consolable) |
| Tremulousness | 1–9 | — | 7 | 87 | 3+ instances when in state 4 or lower |
| Amount of startle | 1–9 | — | 4 | 88 | 2+ startles (except on Moro) |
| Lability of states | 1–9 | — | 6 | 81 | 14+ state changes |
| 1st predominant state | 1–6 | — | 6 | 86 | State 6 (crying) |
| 2nd predominant state | 1–6 | — | 6 | 78 | State 6 (crying) |

Number of items, 38; Alpha = .72.

[a]Range of scores for item prior to the risk present (1) versus absent (0) categorization. Pre-cut range does not include scores for missing data.

[b]Where applicable, the score identified as normative in the NNNS administration and scoring manual.

[c]The cut point chosen for each NNNS item.

[d]The percentile score associated with the chosen cut score.

[e]Description of item responses receiving risk score of 1.

[f]For these items, coding was reversed prior to risk categorization.

## Appendix B

Acoustic Cry Analyses: Items Included in the Cry Risk Score

| Variable description | Cut score (value) | Percentile |
|---|---|---|
| Number of utterances | >18 | 82 |
| Number of short utterances | >25 | 81 |
| Duration of utterance | <.82 | 20 |
| Inter-utterance interval | <.64 | 20 |
| Mean mode changes per utterance | >4.33 | 83 |
| Mean median energy | >6196.3 | 80 |
| Mean median phonation F0 | >527.3 | 80 |
| Mean median phonation F1 | >1910.3 | 93 |
| Mean median dysphonation F1 | >2144.0 | 80 |
| Mean median phonation F2 | >4257.3 | 80 |
| Duration of utterance 2 | <.84 | 21 |
| Inter-utterance interval | <.41 | 20 |

Number of items, 12; alpha = .59