Developmental Psychology
2005, Vol. 41, No. 5, 711–722

0012-1649/05/$12.00 DOI: 10.1037/0012-1649.41.5.711

# Cocaine Exposure Is Associated With Subtle Compromises of Infants' and Mothers' Social–Emotional Behavior and Dyadic Features of Their Interaction in the Face-to-Face Still-Face Paradigm

E. Z. Tronick
Harvard Medical School and Children's Hospital

D. S. Messinger
University of Miami and Miller School of Medicine

M. K. Weinberg
Harvard Medical School and Children's Hospital

B. M. Lester and L. LaGasse
Brown Medical School and Women & Infants Hospital of Rhode Island

R. Seifer
Brown Medical School and Bradley Hospital

C. R. Bauer
University of Miami Miller School of Medicine

S. Shankaran
Wayne State University School of Medicine

H. Bada
University of Tennessee Health Science Center College of Medicine

L. L. Wright
National Institute of Child Health and Human Development

K. Poole
Research Triangle Institute

J. Liu
Brown Medical School and Women & Infants Hospital of Rhode Island

Prenatal cocaine and opiate exposure are thought to subtly compromise social and emotional development. The authors observed a large sample of 236 cocaine-exposed and 459 nonexposed infants (49 were opiate exposed and 646 nonexposed) with their mothers in the face-to-face still-face paradigm. Infant and maternal behaviors were microanalytically coded. No opiate-exposure effects were detected. However, mothers of cocaine-exposed infants showed more negative engagement than other mothers. The cocaine-exposed dyads also showed higher overall levels of mismatched engagement states than other dyads, including more negative engagement when the infants were in states of neutral engagement. Infants exposed to heavier levels of cocaine showed more passive–withdrawn negative engagement and engaged in more negative affective matching with their mothers than other infants. Although effect sizes were small, cocaine exposure, especially heavy cocaine exposure, was associated with subtly negative interchanges, which may have a cumulative impact on infants' later development and their relationships with their mothers.

*Keywords:* infant, mother, emotion, cocaine exposure, communication

In contrast to initial attribution of powerful disruptive effects of cocaine exposure on infant and child development, the effects of in utero cocaine exposure are now thought to have more subtle compromising effects on infant attention, arousal, and affect (for reviews, see Frank, Augustyn, Knight, Pell, & Zuckerman, 2001; Lester & Tronick, 1994; Tronick & Beeghly, 1999). At the neu-

E. Z. Tronick and M. K. Weinberg, Department of Psychiatry, Harvard Medical School and Child Development Unit, Children's Hospital, Boston, Massachusetts; D. S. Messinger, Department of Psychology and Department of Pediatrics, University of Miami, and Miller School of Medicine; B. M. Lester, Center for the Study of Children At Risk, Department of Psychiatry, and Department of Pediatrics, Brown Medical School and Women & Infants Hospital of Rhode Island, Providence, Rhode Island; L. LaGasse and J. Liu, Center for the Study of Children At Risk and Department of Pediatrics, Brown Medical School and Women & Infants Hospital of Rhode Island; R. Seifer, Center for the Study of Human Development and Department of Psychiatry and Human Behavior, Brown Medical School and Bradley Hospital, East Providence, Rhode Island; C. R. Bauer, Department of Pediatrics, University of Miami Miller School of Medicine; S. Shankaran, Department of Pediatrics, Wayne State University School of Medicine; H. Bada, Department of Pediatrics, University of Tennessee Health Science Center College of Medicine; L. L. Wright, National Institute of Child Health and Human Development, Bethesda, Maryland; K. Poole, Research Triangle Institute, Research Triangle Park, North Carolina.

Correspondence concerning this article should be addressed to D. S. Messinger, Flipse Building, P.O. Box 249229, Coral Gables, FL 33124-0751. E-mail: dmessinger@miami.edu

rophysiologic level, these compromises are believed to be the consequence of the effects of cocaine on the aminergic transduction systems of the central nervous system (Kosofsky, 1998; Mayes, 1994; Mirochnick & Meyer, 1991; Needlman & Zuckerman, 1993; Volpe, 1992). It is now also recognized that searching for a singular effect or the location of effect is misdirected and possibly fundamentally flawed (see Beeghly & Tronick, 1994, for a review). As argued by Lester, LaGasse, and Seifer (1998), cocaine is better thought of as an index variable for the effects of cocaine per se as well as for a large number of other comorbid factors. More exactly, although it is likely that cocaine has specific effects independent of other factors and that there must be an attempt to describe and quantify its specific effects, it is also the case that an understanding of the behavioral phenotypic effects of cocaine (and opiates) requires a complex systemic regulatory developmental model (Sameroff & Fiese, 2000).

As hypothesized by a number of investigators, one possible consequence of the neurophysiologic effects of cocaine exposure is a subtle disruption of the regulatory organization of social interactions between the infant and mother. Even though subtle, such disruptions may have cumulative long-term effects on the quality of social and cognitive development of infants and young children (Beeghly & Tronick, 1994; Lemelin, Tarabulsy, & Provost, 2002). The disturbance is also likely to be exacerbated by both the drug-using mother's reduced capacity to function as an adequate social partner and the exposed infant's attentional, arousal, and affective compromise (Fogel, 1993; Lester & Tronick, 1994; Tronick, Als, & Brazelton, 1980). Thus, we would expect that the disruptive effects of cocaine are likely to be found not only in the social–emotional behaviors of both the infant and the mother looked at on their own but also in the dyadic characteristics of the interaction (Tronick, 1989).

Previous studies have shown that during social interaction with children over 1 year of age, mothers who used cocaine were less sensitive and responsive to their children than nonusing mothers (Beckwith et al., 1994; Espinosa, Beckwith, Howard, Tyler, & Swanson, 2001; Swanson, Beckwith, & Howard, 2000; Ukeje, Bendersky, & Lewis, 2001). Similar findings have been reported for cocaine-using mothers of young infants. In a report from the Maternal Lifestyle Study (MLS; Bada et al., 2002; Bauer et al., 2002; Lester et al., 2002) cohort, the sample used in this study, mothers of cocaine-exposed 1-month-olds, were less flexible and engaged during a feeding interaction than mothers of nonexposed infants (LaGasse et al., 2003). Mayes et al. (1997) also found that mothers of cocaine-exposed 3- and 6-month-olds were less attentive and more interrupting with their infants during face-to-face interaction and that the dyadic organization of play was negatively affected by cocaine exposure. Relatedly, Bendersky and Lewis (1998) found that a higher proportion of heavily cocaine-exposed 4-month-old infants than nonexposed infants did not smile during a face-to-face interaction and showed negative expressions during interaction after a period of maternal nonresponsivity similar to the still face. By contrast, Mayes et al. (1997) did not find a relation between cocaine exposure and infant behavior during a face-to-face interaction.

Evaluating the effects of cocaine per se on humans is not straightforward. Cocaine exposure is not only a risk in and of itself, but it is also a marker for polydrug exposure including maternal use of opiates and other associated comorbidities. Prenatal opiate exposure is linked to decreases in neuronal density and branching (Malanga & Kosofsky, 1999). Perinatal sequelae of opiate exposure include low birth weight, newborn withdrawal, and early difficulties with neurobehavioral organization (Bada et al., 2002; Eyler & Behnke, 1999). Some evidence suggests that opiate exposure is associated with deficits in early social interactions. For example, LaGasse et al. (2003) found that opiate-exposed infants and their mothers were more aroused and had more difficulties in feeding than nonexposed infants and their mothers. During interactions with older infants, opiate-using mothers have been found to be less sensitive and responsive than other mothers (Bernstein & Hans, 1994; Hans, Bernstein, & Henson, 1999). However, it remains to be determined whether difficulties in the social interaction of opiate-exposed infants and their mothers relate to neurobehavioral difficulties of the infants, communicative difficulties of their mothers, the dyadic organization of the interaction, or some combination of these factors. It is important to note that similar questions remain about the impact of nicotine, marijuana, and alcohol for the infant–caregiver interaction (Brown, Bakeman, Coles, Sexson, & Demi, 1998; Das Eiden & Leonard, 1996; O'Connor, Sigman, & Kasari, 1992; Tronick, Frank, Cabral, Mirochnick, & Zuckerman, 1996). Thus, although this study will only examine the effects of cocaine and opiates, the findings may help elucidate the broader issues related to the effects of drugs on infant and maternal behavior and the dyadic qualities of their interaction.

Other issues also make it difficult to investigate the effects of cocaine as well as opiate exposure on human social interaction. Methodological problems including small samples of drug-exposed and comparison infants (Bendersky & Lewis, 1998; Hans et al., 1999; Mayes et al., 1997) and insufficient control of confounding variables (see, e.g., Rodning, Beckwith, & Howard, 1989) compromise many studies. More generally, large sample size studies have seldom been carried out, but even for those that have been, the level of measurement has been coarse and they have not included observational data.

The primary goal of this study was to investigate differences in infant and maternal interactive behavior and mutual regulation in a large sample of infants exposed to cocaine in utero compared with a group of infants not exposed to cocaine. A secondary goal was to investigate these effects in infants exposed to opiates in utero compared with nonopiate-exposed infants. In an attempt to overcome some of the limitations of other studies, we studied a large sample of infants in an observational paradigm, Tronick's face-to-face still-face paradigm (FFSF; Tronick, Als, Wise, & Brazelton, 1978), as part of the multisite MLS (Bada et al., 2002; Bauer et al., 2002; Lester et al., 2002). Although recognizing that an extremely large number and variety of variables may act as covariates given the risk and demographic status of the sample, we examined covariates often associated with the caregiving environment of drug-using mothers, such as socioeconomic status (SES), birth weight, prenatal exposure to alcohol, marijuana and tobacco use, child placement, and maternal depression.

The FFSF paradigm was chosen as the observational context because of its standardized form and the strength of its findings (see Adamson & Frick, 2003, for a review). During the FFSF, infants engage in face-to-face interaction with their caretaker and also have to cope with a stressful perturbed interaction during which the caregiver becomes poker faced and vocally and gesturally unresponsive. In normal samples, the contrast between the normal interaction and the disruptive effect of the still face has been replicated in numerous studies. Studies using the paradigm have revealed differences in the behavior of infants and mothers as well as in the dyadic qualities of interactions between depressed and/or anxious mothers and their infants, male and female infants and their mothers, and prematurely born infants and their mothers, as well as other high- and low-risk groups (Adamson & Frick, 2003; Tronick, 1989). The effectiveness of the FFSF paradigm in revealing these differences is often attributed to the contrast between the stressful and nonstressful episode and the age-appropriate nature of the stress of the still face (i.e., the breaking of the interactive connection between the infant and the mother). Dependent measures from the FFSF describe infant and maternal interactive behavior as well as the dyadic characteristics of their interactions.

Three hypotheses about the social–emotional functioning of the infant, the mother, and the mother–infant dyad were evaluated. It was expected that (a) cocaine- or opiate-exposed compared with unexposed infants would evidence more negative affect, (b) cocaine- or opiate-exposed mothers compared with unexposed mothers would be more negative and less sensitive, and (c) the dyadic qualities of the interaction (e.g., affective matching) would be compromised among exposed dyads compared with unexposed dyads. As with the documented effects of cocaine and opiate exposure on other domains of infant and maternal functioning, these effects on the regulatory organization of the interaction were expected to be subtle though consistent but only in part attributable to cocaine or opiate exposure.

## Method

### *Recruitment*

The study was carried out at the four MLS sites, which are part of the National Institute of Child Health and Human Development Neonatal Research Network (Brown University, University of Miami, Wayne State University, and the University of Tennessee at Memphis). The study was approved by the institutional review board at each site. Maternal exclusion criteria included the following: younger than 18 years, psychosis or history of psychiatric institutionalization, or language barriers that prevented informed consent. Infant exclusion criteria included the following: multiple gestation, birth weight less than 501 g, gestational age greater than 42 weeks, infant unlikely to survive in the judgment of the attending physician, or being born outside one of the four hospitals in which recruitment occurred.

Meconium samples were collected in the nursery and shipped to a central laboratory (ElSohly Laboratories, Inc., Oxford, MS) for analysis of metabolites of illicit drugs (Lester et al., 2001). The assay consisted of an enzyme multiplied immunoassay technique screen for cocaine, opiates, THC, amphetamines, and PCP followed by confirmatory testing of positive screens using gas chromatography–mass spectroscopy. Also a history of maternal alcohol, marijuana, and nicotine use during the pregnancy was recorded during a hospital interview with the mother. These were considered background variables in both the exposed and unexposed groups (Lester et al., 2001).

The study definition of *exposure* was either maternal admission of cocaine or opiate use during this pregnancy based on the hospital interview or positive gas chromatography–mass spectroscopy confirmation of cocaine or opiate metabolites. *Unexposed* was defined as denial of cocaine or opiate use during this pregnancy and a negative enzyme multiplied immunoassay technique screen for cocaine and opiate metabolites. A list of possible comparison infants from the unexposed group within each center that matched an exposed group infant on race, sex, and gestational age was sent by the data center to each study site. Recruitment of all exposed infants was attempted but was not always possible. Thus, it was possible for either an exposed or comparison infant to be in the study without a match. This procedure resulted in two groups for the larger MLS study that were for the most part matched on race, sex, and gestational age (see Bauer et al., 2002, and Lester et al., 2002, for details). The follow-up phase of the study began at the 1-month visit.

Of the 1,388 mother–infant dyads (658 in the exposed group and 730 in the comparison group) who attended the 1-month visit, 1,127 attended the 4-month visit. Of these, 1,020 were videotaped in the FFSF, and 812 had at least 60 s of data for each FFSF episode, the criterion for inclusion. Cocaine ($p = .970$) and opiate ($p = .531$) exposure did not differentiate the 812 infants with at least 60 s of data per FFSF episode from the 208 infants who did not have at least 60 s of data per episode. Of the 812 dyads, data from the Maternal Interview of Substance Use (MISU) on drug use during the pregnancy, administered to the infant's biological mother at the 1-month visit, was available for 739 dyads. Because our focus was the impact of prenatal drug exposure on the mother–infant dyad, 35 nonmaternal familial caregivers and 11 nonrelated caregivers were excluded, leaving a sample of 695 biological mothers and their infants. In this final sample, there were 299 dyads seen at the Detroit site, 101 seen at the Providence site, 147 seen at the Memphis site, and 148 seen at the Miami site.

Infants with complete data (i.e., 60 s in each episode of the FFSF paradigm, 1-month MISU, and 4-month interaction with mother; $n = 695$) and infants without complete data ($n = 693$) did not differ significantly by gender, race, gestational age, birth weight, birth length, or head circumference. Caregivers with complete data, however, were more likely than caregivers with incomplete data to have private medical insurance (15.3% vs. 8.4%, respectively, $p = .001$), to have finished high school (64.9% vs. 56.3%, respectively, $p = .005$), and to currently be married or to have been married (25.9% vs. 19.0%, respectively, $p = .014$). Those with complete data were less likely to have used cocaine (34.0% vs. 52.5%, respectively, $p = .001$), marijuana (18.0% vs. 28.7%, respectively, $p < .001$), tobacco (47.2% vs. 60.6%, respectively, $p = .001$), or alcohol (56.0% vs. 62.9%, respectively, $p = .008$) during the pregnancy.

In the final sample ($n = 695$), 236 were cocaine-exposed infants and 459 infants were not exposed to cocaine. There were 49 opiate-exposed infants and 646 infants not exposed to opiates. There were 17 infants who were exposed to both cocaine and opiates. On the basis of previous studies from the MLS project (LaGasse et al., 2003; Lester et al., 2002), we included these infants in analyses of both the effects of cocaine exposure and the analyses of the effects of opiate exposure.

### *Laboratory Setting and Procedures*

Mothers brought their infant to the follow-up clinics when the infant was 4 months old (age corrected for prematurity for infants below 37 weeks gestation; Ballard et al., 1991) and administered the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). The video rooms in each site were identical and equipped with an infant seat mounted on a table, an adjustable swivel stool for the mother, two cameras (one focused on the infant, the other on the mother), a microphone, and an intercom via which mothers were given procedural instructions (Tronick et al., 1978; Weinberg & Tronick, 1994). The signals from the two cameras were transmitted through a digital timer and split-screen generator into a video recorder to produce a single image with a simultaneous frontal view of the adult's face, hands, and torso and the infant's entire body.

Mothers and infants were videotaped in Tronick's FFSF paradigm (Tronick et al., 1978) standardized across research sites. The paradigm included a 2-min face-to-face normal interaction in which the mother was instructed to play with the infant, followed by a 2-min episode in which the mother was instructed to keep a still face (i.e., to look at the infant but not to smile, talk, or touch the infant), and a second 2-min normal reunion interaction in which the mother was instructed to play with the infant. Episodes 1 and 3 were separated from the still face by a 15-s interval during which the mother turned her back and then turned toward the infant to begin the next episode. Site differences in the total length of the three episodes were small and ranged from 359 to 369 s, with a mean of 367 s.

## Coding of Data

The infants' and mothers' behaviors were coded using the Infant and Caregiver Engagement Phases (ICEP; Weinberg & Tronick, 1998). The ICEP system includes a set of mutually exclusive infant and mother phases of interactive engagement and several additional regulatory codes. The infant and caregiver behavioral interactive phases are configurations of facial expressions, direction of gaze, and vocalizations. For the infant, the engagement codes are passive–withdrawn, protest, object–environment, social monitor, and social positive engagement. For the caregiver, the engagement codes are hostile–intrusive, withdrawn, social monitor with no vocalizing, social monitor with positive vocalizing, and social positive engagement. Additional codes for the infant are oral self-comforting–mouthing, self-clasping, distancing–turning away, and autonomic stress indicators (e.g., hiccups, spitting up). Additional codes for the mothers are rough touches and violations of the still-face instructions (i.e., touching or talking to the baby).

Infant and mother ICEP engagement phases were coded in two separate viewings of the videotape. A third viewing of the tape was devoted to coding infant regulatory actions—self-comforting–mouthing, hand clasping, distancing–turning away from mother, and autonomic stress indicators—as well as mother intrusions (rough touch) and still-face procedural violations.

Coding was done from videotapes by coders masked to the exposure status of the infants. A software interface (Action Analysis Coding and Training; Oller, Yale, & Delgado, 1997) used to control the VCR desk allowed coders to indicate when a particular behavior occurred. The time code corresponding to that frame was automatically entered into a data file on the Action Analysis Coding and Training system. Tapes were played at normal speed during coding, although they were frequently stopped or run in slow motion to accurately determine the beginning and end of shifts in infant and maternal behavior.

## Reliability of ICEP Coding

Approximately three quarters of coding was conducted at a central site, and one quarter of coding was conducted at a second data collection site. All coders were trained by an author of the coding system, and all coding was supervised by a PhD psychologist. All coders were trained to reliability with a gold standard sample of 10 tapes. Reliability denoted agreement $\geq$ 80% and Cohen's kappa (Cohen, 1960), which corrects for chance agreement $\geq$ .70. Ongoing reliability was then assessed on a random 15% of sessions and included regular cross-checks between the two coding sites. Percentage agreement and kappas were high for the duration measures: infant engagement (85%, $\kappa$ = .74), mother engagement (84%, $\kappa$ = .76), maternal still-face violations (99%, $\kappa$ = .73), infant self-comforting–mouthing (96%, $\kappa$ = .74), and infant hand clasping (97%, $\kappa$ = .72). Intraclass correlations were high for measures of frequency: distancing (.88), autonomic stress indicators (.90), and rough touches (.89). Intraclass correlations are a ratio of participant variance to all other variance including differences between coders. The high intraclass correlations indicate that coders concurred that certain participants had high levels of a behavior and other participants had low levels of a behavior.

## Data Reduction and Dependent Measures

Dependent measures for the infant, mother, and dyad were as follows:

1. The proportion of time the infant or mother was in each ICEP phase calculated by dividing the total time each code occurred by the total length of the episode.

2. The proportion of matches or mismatches between mother and infant behavior defined on the basis of previous work (Tronick & Cohn, 1989; Weinberg et al., 1999). Prior to the matching analyses, ICEP phases were combined to form three engagement states: negative, neutral, and positive. For the infant, negative engagement consisted of the passive–withdrawn and protest phases, neutral engagement consisted of object–environment and social monitor, and positive engagement consisted of the social positive engagement phase. For the mother, negative engagement consisted of the hostile–intrusive and passive–withdrawn phases, neutral engagement consisted of the social monitor without vocalizing phase, and positive engagement consisted of the social monitor with positive vocalizing and social positive engagement phases. Matching was defined as the extent to which mothers and infants shared joint negative, neutral, or positive states at the same moment in time (see Table 4, which will be discussed later in the text). Mismatching was defined as any nonshared dyadic state in which the mother and infant were not in the same engagement state (e.g., infant neutral and mother negative; see Table 4).

3. Infant oral self-comforting and self-clasping calculated as the proportion of time of their occurrence in an episode. Infant distancing from the mother, infant autonomic stress indicators, and mother rough touches were calculated as frequencies per minute.

## Covariates

Given the risk and demographic status of the sample and the known relations among these and the interaction variables, we used a set of covariates to control for their effects. Covariates included the Index of Social Position score from the Hollingshead Scale (SES; Hollingshead, 1978); infant birth weight; geographic site; and alcohol, marijuana, and tobacco use. In addition, involvement with Child Protective Services (CPS) and maternal depression scores on the BDI were evaluated as potential mediator or moderator variables.

The pattern of drug use reported in the MISU was used to generate polydrug covariates for alcohol, marijuana, and tobacco by averaging reported use across the three trimesters of pregnancy. Using cutoffs, we reduced use of different substances to three categories (heavy, some, and no use) on the basis of published thresholds for medical, neurobehavioral outcome, and previous work on patterns of use (LaGasse et al., 2003; Lester et al., 2002). For cocaine, heavy use was defined as at least 3 days per week during the first trimester. Any other cocaine use was considered some use. For alcohol, heavy use was defined as $\geq$ .50 oz of absolute alcohol per day (one standard drink). For marijuana, heavy use was defined as $\geq$ .50 joints per day. For tobacco, heavy use was defined as $\geq$ 10 cigarettes per day. Involvement with CPS was defined as family contact with CPS in reference to the study child either at the 1-month visit or in the period between the 1-month and 4-month visit.

## Statistical Analysis

The ICEP data were tested with four sets of analyses. These analyses used Type III sum of squares and an alpha level of .05. Effect sizes are presented as partial eta squared ($\eta_p^2$), which indicates variance explained;

this is computed as effect variance divided by the sum of effect and related error variance. Using Cohen's (1988) criteria for variance explained, .01 is a small effect size, .06 is a medium effect size, and .14 is a large effect size. Analyses of infant behavior involved all three episodes of the FFSF as repeated measures, whereas analysis of maternal and dyadic behaviors involved only the play and reunion episodes as repeated measures. Interactions between exposure and FFSF episode were only reported in the context of significant exposure effects.

Analysis 1 was a 2 × 2 analysis of variance (ANOVA) simultaneously examining cocaine and opiate-exposure effects. Analysis 2 was an analysis of covariance (ANCOVA) examining the identical cocaine and opiate effects controlling for the covariate set. Cocaine × Opiate interaction effects were examined in both these analyses but were removed from the analysis if they were not significant.

Analysis 3 was a one-way ANOVA examining the effects of heavy, some, and no cocaine use. For this analysis, participants ($n = 92$) were excluded if there was evidence of opiate use during the pregnancy or if a participant classified as a cocaine user on the basis of perinatal measures denied cocaine use during the 1-month interview. Thus, the sample for the third and fourth analyses consisted of 603 participants. Analysis 4 was a one-way ANCOVA contrasting the same three quantities of cocaine use groups while controlling for the covariate set. In Analyses 3 and 4, simple contrasts were only used to follow up significant overall group differences. Significant covariate effects are reported for both Analyses 2 and 4.

CPS involvement was confined to cocaine- and/or opiate-exposed dyads in all but two cases, suggesting CPS involvement was a marker for salient exposure effects. For this reason, CPS involvement was screened as a mediator of cocaine and opiate-exposure effects. Within the cocaine-exposure group, CPS involvement showed univariate associations with only one outcome (see below).

We expected higher depressive symptomatology scores among exposed mothers and evaluated the potential for BDI scores (Beck et al., 1961) to mediate or moderate exposure effects. Although high in both groups, there were no differences between the BDI scores of cocaine-exposed ($M = 9.85$, $SD = 9.17$) and nonexposed ($M = 8.90$, $SD = 8.63$) mothers, $F(1, 680) = 1.78$, $p = .183$. Thus, although BDI scores were high in both groups, the BDI did not fulfill criteria as a mediator or moderator variable.

## Results

### Neonatal, Maternal, and Exposure Characteristics

Neonatal characteristics of the infants are presented in Table 1. Infants prenatally exposed to cocaine had lower birth weights than infants not exposed to cocaine ($p = .049$). There were no statistically significant differences between the cocaine-exposed and nonexposed groups on gestational age, length, head circumference, or sex. There were no statistically significant differences between the opiate-exposed and nonexposed groups on gestational age, birth weight, length, head circumference, or sex.

Demographic information on mothers is presented in Table 2. Mothers who had used cocaine were more likely to be older, less likely to be married, more likely to have used Medicaid, and more likely to have fewer years of education than mothers who had not used cocaine. Mothers who had used opiates were more likely to be White and more likely to be older than mothers who had not used opiates. CPS involvement was significantly associated with both cocaine exposure and opiate exposure.

Information on tobacco, alcohol, and marijuana use is presented in Table 3. Infants exposed to cocaine were significantly more likely to be exposed to tobacco, alcohol, and marijuana than infants not exposed to cocaine. Infants exposed to opiates were significantly more likely to be exposed to tobacco than infants not exposed to opiates, but they did not differ on alcohol or marijuana exposure.

### Overall Mother and Infant Response to the FFSF Paradigm

A manipulation check indicated that, as instructed, mothers spent the vast majority of time during the still face engaged in impassive social monitoring of their infants ($M = .942 \pm SEM = .005$). The proportion of time mothers violated the instructions for the still face (e.g., by smiling at, touching, or talking to the infant) was low and did not differ between cocaine-exposed ($M = .017 \pm SEM = .011$) and nonexposed ($M = .026 \pm SEM = .009$) dyads ($p = .316$) or between opiate-exposed ($M = .032 \pm SEM = .005$) and nonexposed ($M = .011 \pm SEM = .018$) dyads ($p = .248$).

A protocol check indicated that, in general, infant protest, object engagement, and self-regulatory behaviors (with the exception of autonomic stress indicators) increased from the play to the still-face episode, whereas social monitor and social positive engagement decreased (see Table 4). The reunion episode was characterized by an increase in protest compared with the first play episode, but there was also a rebound in social positive engagement after the still face though not to the level found in the first play episode. These findings, including the rebound of positive engagement, closely mimic previous findings (Weinberg & Tronick, 1996).

Table 1
*Neonatal Characteristics of Cocaine-Exposed and Opiate-Exposed Infants and Comparison Groups*

| Characteristic | Cocaine exposed ($n = 236$) | Noncocaine exposed ($n = 459$) | $p$ | Opiate exposed ($n = 49$) | Nonopiate exposed ($n = 646$) | $p$ |
|---|---|---|---|---|---|---|
| Mean gestational age (weeks) | 37.3 ± 3.3 | 37.0 ± 3.6 | .248 | 37.5 ± 3.4 | 37.1 ± 3.5 | .455 |
| Gestational age < 38 weeks | 93 (39.4%) | 200 (43.6%) | .292 | 18 (36.7%) | 275 (42.6%) | .425 |
| Gestational age < 33 weeks | 21 (8.9%) | 59 (12.9%) | .122 | 5 (10.2%) | 75 (11.6%) | .766 |
| Birth weight (gm) | 2,567 ± 772 | 2,700 ± 876 | .049 | 2,719 ± 822 | 2,650 ± 846 | .522 |
| Birth weight < 2,500 gm | 96 (40.7%) | 184 (40.1%) | .880 | 19 (38.8%) | 261 (40.4%) | .823 |
| Length at birth (cm) | 46.5 ± 5.0 | 47.2 ± 5.2 | .096 | 47.2 ± 4.8 | 46.9 ± 5.2 | .751 |
| Head circumference (cm) | 32.0 ± 3.0 | 32.3 ± 3.2 | .229 | 32.2 ± 2.9 | 32.2 ± 3.2 | .904 |
| Male | 128 (54.2%) | 248 (54.0%) | .959 | 27 (55.1%) | 349 (54.0%) | .884 |

*Note.* Values with the ± symbol indicate the mean plus or minus the standard deviation. The other values are total numbers, with percentages in parentheses.

Table 2
*Maternal Characteristics of Cocaine-Exposed and Opiate-Exposed Infants and Comparison Groups*

| | Cocaine exposed ($n$ = 236) | | Noncocaine exposed ($n$ = 459) | | | Opiate exposed ($n$ = 49) | | Nonopiate exposed ($n$ = 646) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Maternal characteristic | $n$ | % | $n$ | % | $p$ | $n$ | % | $n$ | % | $p$ |
| Race–ethnicity | | | | | .857 | | | | | .035 |
| Black | 183 | 77.5 | 345 | 75.2 | | 31 | 63.3 | 497 | 76.9 | |
| White | 35 | 14.8 | 77 | 16.8 | | 15 | 30.6 | 97 | 15.0 | |
| Hispanic | 16 | 6.8 | 31 | 6.8 | | 3 | 6.1 | 44 | 6.8 | |
| Other | 2 | 0.8 | 6 | 1.3 | | 0 | 0.0 | 8 | 1.2 | |
| Age | | | | | .000 | | | | | .004 |
| 18–25 | 39 | 16.5 | 212 | 46.2 | | 10 | 20.4 | 241 | 37.3 | |
| 26–35 | 166 | 70.3 | 206 | 44.9 | | 28 | 57.1 | 344 | 53.3 | |
| 36–49 | 31 | 13.1 | 41 | 8.9 | | 11 | 22.4 | 61 | 9.4 | |
| Marital status | | | | | .000 | | | | | .070 |
| Married | 27 | 11.4 | 123 | 26.9 | | 12 | 25.0 | 138 | 21.4 | |
| Never married | 192 | 81.4 | 322 | 70.3 | | 31 | 64.6 | 483 | 74.8 | |
| Divorced | 17 | 7.2 | 13 | 2.8 | | 5 | 10.4 | 25 | 3.9 | |
| Insurance | | | | | .000 | | | | | .827 |
| Medicaid | 212 | 89.8 | 341 | 74.3 | | 38 | 77.6 | 515 | 79.7 | |
| Self-pay | 13 | 5.5 | 16 | 3.5 | | 2 | 4.1 | 27 | 4.2 | |
| Private–HMO | 10 | 4.2 | 96 | 20.9 | | 9 | 8.4 | 97 | 15.0 | |
| Unknown | 1 | 0.4 | 6 | 1.3 | | 0 | 0.0 | 7 | 1.1 | |
| Education | | | | | .000 | | | | | .835 |
| $<$ 12 years | 109 | 46.2 | 135 | 29.4 | | 19 | 38.8 | 225 | 34.8 | |
| 12 years | 89 | 37.7 | 203 | 44.2 | | 20 | 40.8 | 272 | 42.1 | |
| $\geq$ 13 years | 38 | 16.1 | 121 | 26.4 | | 10 | 20.4 | 149 | 23.1 | |
| CPS involvement | | | | | .000 | | | | | .014 |
| No | 152 | 64.4 | 462 | 98.5 | | 37 | 75.5 | 567 | 87.8 | |
| Yes | 84 | 35.6 | 7 | 1.5 | | 12 | 24.5 | 79 | 12.2 | |

*Note.* CPS = Child Protective Services.

Maternal behavior and dyadic engagement were examined in the play and reunion episodes but not during the experimenter-elicited still face. There were changes in mothers' behavior between these two episodes (see Table 4). Mothers showed an increase in negative engagement and social monitor with no vocalizing from the play episode preceding the still-face to the reunion episode following the still face. Mothers also showed more social positive engagement in the play compared with the reunion episode.

There were changes in matching between the play and reunion episodes (see Table 4). Positive dyadic matches decreased from the play to the reunion episodes. Mismatched states involving either infant or mother negative engagement increased between the play

Table 3
*Drug Exposure Characteristics of Cocaine-Exposed and Opiate-Exposed Infants*

| | Cocaine exposed ($n$ = 236) | | Noncocaine exposed ($n$ = 459) | | | Opiate exposed ($n$ = 49) | | Nonopiate exposed ($n$ = 646) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Drug use characteristic | $n$ | % | $n$ | % | $p$ | $n$ | % | $n$ | % | $p$ |
| Tobacco | | | | | .000 | | | | | .000 |
| High | 93 | 39.4 | 52 | 11.3 | | 23 | 46.9 | 122 | 18.9 | |
| Some | 112 | 47.5 | 95 | 20.7 | | 12 | 24.5 | 195 | 30.2 | |
| None | 31 | 13.1 | 312 | 68.0 | | 14 | 28.6 | 329 | 50.9 | |
| Alcohol | | | | | .000 | | | | | .544 |
| High | 70 | 29.7 | 18 | 3.9 | | 8 | 16.3 | 80 | 12.4 | |
| Some | 126 | 53.4 | 220 | 47.9 | | 21 | 42.9 | 325 | 50.3 | |
| None | 40 | 16.9 | 221 | 48.1 | | 20 | 40.8 | 241 | 37.3 | |
| Marijuana | | | | | .000 | | | | | .572 |
| High | 19 | 8.1 | 8 | 1.7 | | 3 | 6.1 | 24 | 3.7 | |
| Some | 91 | 38.6 | 44 | 9.6 | | 11 | 22.4 | 124 | 19.2 | |
| None | 126 | 53.4 | 407 | 88.7 | | 35 | 71.4 | 498 | 77.1 | |

*Note.* Seventeen infants who were exposed to both cocaine and opiates are listed in both exposure groups.

Table 4
*Infant and Mother Behavior and Dyadic Interaction Regardless of Exposure Status*

| Measure | Play | Still face | Reunion | $F^a$ | $p$ | $\eta_p^2$ |
|---|---|---|---|---|---|---|
| Infant engagement | | | | | | |
| Passive–withdrawn | .000 ± .000 | .002 ± .001 | .002 ± .001 | 0.40 | .673 | .001 |
| Protest | $.035 \pm .005_a$ | $.154 \pm .011_b$ | $.150 \pm .011_b$ | 28.42 | .000 | .039 |
| Object | $.501 \pm .011_a$ | $.573 \pm .011_b$ | $.470 \pm .011_a$ | 12.82 | .000 | .018 |
| Social monitor | $.338 \pm .009_a$ | $.249 \pm .009_b$ | $.280 \pm .009_c$ | 18.13 | .000 | .026 |
| Social positive | $.108 \pm .006_a$ | $.019 \pm .002_b$ | $.075 \pm .004_c$ | 51.96 | .000 | .070 |
| Mother engagement | | | | | | |
| Negative | .006 ± .001 | | .015 ± .001 | 28.01 | .000 | .039 |
| Social monitor (no vocalizing) | .106 ± .005 | | .141 ± .007 | 11.08 | .001 | .016 |
| Social monitor (positive vocalizing) | .589 ± .008 | | .617 ± .008 | 2.83 | .093 | .004 |
| Social positive | .278 ± .008 | | .203 ± .007 | 31.11 | .000 | .043 |
| Dyadic matches | | | | | | |
| Negative | .001 ± .001 | | .004 ± .001 | 3.17 | .075 | .005 |
| Neutral | .094 ± .005 | | .103 ± .006 | 1.70 | .198 | .002 |
| Positive | .102 ± .005 | | .071 ± .004 | 19.51 | .000 | .027 |
| Total | .197 ± .006 | | .177 ± .006 | 6.23 | .013 | .009 |
| Dyadic mismatched phases | | | | | | |
| Infant negative–mother neutral | .008 ± .002 | | .032 ± .004 | 10.55 | .001 | .015 |
| Infant negative–mother positive | .026 ± .003 | | .114 ± .008 | 30.07 | .000 | .042 |
| Infant neutral–mother negative | .004 ± .001 | | .011 ± .001 | 20.85 | .000 | .029 |
| Infant neutral–mother positive | .725 ± .008 | | .620 ± .010 | 21.80 | .000 | .031 |
| Infant positive–mother neutral | .003 ± .000 | | .002 ± .000 | 0.04 | .847 | .000 |
| Infant positive–mother negative | .000 ± .000 | | .001 ± .000 | 0.83 | .364 | .001 |
| Total | .765 ± .007 | | .778 ± .007 | 3.80 | .052 | .005 |
| Infant self-regulation | | | | | | |
| Mouthing | $.063 \pm .006_a$ | $.115 \pm .008_b$ | $.068 \pm .006_a$ | 4.70 | .009 | .007 |
| Self-clasp | $.063 \pm .005_a$ | $.121 \pm .007_b$ | $.052 \pm .005_a$ | 17.55 | .000 | .025 |
| Distancing | $.217 \pm .026_a$ | $.480 \pm .039_b$ | $.300 \pm .028_a$ | 11.60 | .000 | .016 |
| Autonomic stress indicators | .247 ± .057 | .259 ± .062 | .314 ± .068 | 0.90 | .370 | .001 |
| Mother disregulatory actions: rough touches | .210 ± .038 | | .196 ± .037 | 0.00 | 1.000 | .000 |

*Note.* Infant and mother engagement, matching, mismatching, and infant oral self-comforting are measured as proportion of time in the protocol. Infant distancing, infant autonomic indicators, and mother rough touch are measured as frequency per minute. All measures are reported as means plus or minus standard errors of the means. $F$ and $p$ values indicate overall effects between episodes. Different subscripts indicate significantly different means ($p < .05$) between episodes; they are only relevant for codes measured during the still face. Partial eta squared ($\eta_p^2$) is a ratio of variance accounted for by an effect to the sum of effect and related error variance. According to Cohen's (1988) criteria, .01 is a small effect size and .06 is a medium effect size.
[a] $df$s = 2, 691 for infant engagement, infant self-regulation, and autonomic stress indicators. $df$s = 1, 692 for mother engagement, dyadic matches, dyadic mismatched phases, and mother disregulatory actions.

and reunion episodes, whereas mismatched states characterized by mother positive–infant neutral decreased. The overall total of matched states decreased from the play to the reunion episode so that the overall total of mismatched states increased.

### Interactive Behavior of Cocaine-Exposed Infants and Mothers

*Infants.* There were interactive behavioral differences between the cocaine-exposed and the nonexposed infants (see Table 5). After covariate adjustment, cocaine-exposed infants showed a lower mean proportion of object engagement and a higher proportion of social monitoring than infants not exposed to cocaine. After covariate control, cocaine-exposed infants exhibited fewer autonomic stress indicators than nonexposed infants (see Table 5).

*Mothers.* There were significant differences in the interactive behavior of cocaine-using and nonusing mothers (see Table 5). An interaction effect indicated that mothers of cocaine-exposed infants showed especially high proportions of negative engagement during the reunion compared with the initial play episode ($p$ = .026, $\eta_p^2$ = .007). Mothers of cocaine-exposed infants also showed generally higher proportions of negative engagement across the FFSF than mothers of nonexposed infants, although this effect was not significant after covariate adjustment. There were no significant cocaine-exposure differences in mothers' rough touch.

*Dyadic characteristics.* There were differences in the dyadic features of the interaction between cocaine-exposed and nonexposed dyads (see Table 5). Mismatches in which infants were neutral and mothers negative were higher among cocaine-exposed dyads than among nonexposed dyads, an effect that remained significant after covariate adjustment. After covariate adjustment, cocaine-exposed dyads also showed a higher proportion of total mismatches than nonexposed dyads.

### Interactive Behavior of Opiate-Exposed Infants and Mothers

There were no significant main effects of opiate exposure on infant, mother, or dyadic behaviors as evaluated with the ICEP. The only outcome that involved a Cocaine Exposure × Opiate Exposure interaction effect was infant distancing ($p$ = .047, $\eta_p^2$ = .006). Follow-up analyses did not, however, reveal significant cocaine-exposure effects in either the opiate-exposed or nonopiate-exposed groups.

Table 5
*Comparisons of Face-to-Face Still-Face Paradigm Outcomes by Cocaine Exposure and by Opiate Exposure*

| | Prenatal cocaine exposure | | | | | | Prenatal opiate exposure | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No ($n$ = 459) | Yes ($n$ = 236) | Unadjusted | | Adjusted | | No ($n$ = 646) | Yes ($n$ = 49) | Unadjusted | | Adjusted | |
| Measure | $M \pm SEM$ | $M \pm SEM$ | $p$ | $\eta_p^2$ | $p$ | $\eta_p^2$ | $M \pm SEM$ | $M \pm SEM$ | $p$ | $\eta_p^2$ | $p$ | $\eta_p^2$ |
| Infant engagement | | | | | | | | | | | | |
| Passive withdrawn | .000 ± .001 | .002 ± .001 | .179 | .003 | .669 | .000 | .002 ± .001 | .000 ± .002 | .432 | .001 | .585 | .000 |
| Protest | .112 ± .016 | .112 ± .018 | .983 | .000 | .472 | .001 | .113 ± .008 | .110 ± .028 | .913 | .000 | .825 | .000 |
| Object | .526 ± .019 | .507 ± .022 | .300 | .002 | **.017** | **.008** | .511 ± .010 | .522 ± .034 | .737 | .000 | .538 | .001 |
| Social monitor | .282 ± .015 | .303 ± .017 | .158 | .003 | **.012** | **.009** | .292 ± .008 | .292 ± .027 | .982 | .000 | .878 | .000 |
| Social positive | .066 ± .006 | .067 ± .007 | .814 | .000 | .763 | .000 | .068 ± .003 | .065 ± .012 | .837 | .000 | .689 | .000 |
| Mother engagement | | | | | | | | | | | | |
| Negative | .009 ± .002 | .013 ± .002 | **.011** | **.009** | .134 | .003 | .011 ± .001 | .011 ± .003 | .825 | .000 | .749 | .000 |
| Social monitor | .113 ± .011 | .108 ± .013 | .657 | .000 | .062 | .005 | .124 ± .006 | .096 ± .021 | .193 | .002 | .355 | .001 |
| Social monitor (positive vocalize) | .620 ± .015 | .622 ± .017 | .893 | .000 | .434 | .001 | .601 ± .008 | .641 ± .027 | .146 | .003 | .224 | .002 |
| Social positive | .226 ± .014 | .234 ± .016 | .604 | .000 | .390 | .001 | .243 ± .007 | .217 ± .025 | .209 | .002 | .304 | .002 |
| Dyadic matching phases | | | | | | | | | | | | |
| Negative | .002 ± .001 | .002 ± .001 | .590 | .000 | .886 | .000 | .003 ± .001 | .001 ± .002 | .506 | .001 | .484 | .001 |
| Neutral | .092 ± .010 | .088 ± .012 | .705 | .000 | .245 | .002 | .099 ± .005 | .081 ± .018 | .328 | .001 | .560 | .000 |
| Positive | .084 ± .008 | .089 ± .010 | .609 | .000 | .688 | .000 | .087 ± .004 | .086 ± .015 | .927 | .000 | .825 | .000 |
| Total | .178 ± .012 | .179 ± .013 | .926 | .000 | .129 | .003 | .189 ± .006 | .168 ± .021 | .333 | .001 | .425 | .001 |
| Dyadic mismatching phases | | | | | | | | | | | | |
| Infant negative–mother neutral | .017 ± .005 | .017 ± .005 | .980 | .000 | .789 | .000 | .020 ± .003 | .013 ± .009 | .400 | .001 | .534 | .001 |
| Infant negative–mother positive | .069 ± .010 | .067 ± .012 | .848 | .000 | .574 | .000 | .069 ± .005 | .066 ± .019 | .851 | .000 | .773 | .000 |
| Infant neutral–mother negative | .007 ± .001 | .011 ± .001 | **.001** | **.016** | **.026** | **.007** | .008 ± .001 | .009 ± .002 | .670 | .000 | .723 | .000 |
| Infant neutral–mother positive | .679 ± .016 | .689 ± .018 | .549 | .001 | .220 | .002 | .672 ± .008 | .696 ± .029 | .419 | .001 | .451 | .001 |
| Infant positive–mother neutral | .002 ± .001 | .002 ± .001 | .860 | .000 | .567 | .000 | .003 ± .000 | .001 ± .001 | .406 | .001 | .372 | .001 |
| Infant positive–mother negative | .000 ± .000 | .000 ± .000 | .091 | .004 | .082 | .004 | .000 ± .000 | .000 ± .000 | .396 | .001 | .289 | .002 |
| Total mismatching | .773 ± .013 | .785 ± .015 | .362 | .001 | **.022** | **.008** | .773 ± .007 | .785 ± .023 | .602 | .000 | .661 | .000 |
| Infant self-regulation | | | | | | | | | | | | |
| Mouthing | .083 ± .010 | .081 ± .012 | .780 | .000 | .838 | .000 | .082 ± .005 | .082 ± .019 | .975 | .000 | .831 | .000 |
| Clasping hands | .085 ± .009 | .077 ± .011 | .417 | .001 | .860 | .000 | .077 ± .005 | .084 ± .017 | .677 | .000 | .943 | .000 |
| Distancing | .293 ± .051 | .367 ± .059 | .156 | .003 | .180 | .003 | .347 ± .027 | .313 ± .093 | .730 | .000 | .827 | .000 |
| Autonomic indicators | .254 ± .109 | .162 ± .126 | .408 | .001 | **.044** | **.006** | .267 ± .057 | .150 ± .198 | .568 | .000 | .578 | .000 |
| Mother disregulation: rough touch | .152 ± .065 | .116 ± .075 | .586 | .000 | .316 | .001 | .208 ± .034 | .060 ± .118 | .228 | .002 | .570 | .000 |

*Note.* Infant and mother engagement, matching, mismatching, and infant oral self-comforting are measured as proportion of time in the protocol. Infant distancing, infant autonomic indicators, and mother rough touch are measured as frequency per minute. Proportions of engagement states do not sum to one. Very small proportions of unscorable portions of the sessions are not included in the infant and mother engagement states. Exposure by episode interactions are described in the text. Partial eta squared ($\eta_p^2$) is a ratio of variance accounted for by an effect to the sum of effect and related error. According to Cohen's (1988) criteria, .01 is a small effect size and .06 is a medium effect size. Boldface $p$ and $\eta_p^2$ values indicate significant effects.

### Interactive Differences Among the Heavy, Some, and No-Cocaine-Exposure Groups on Infant, Maternal, and Dyadic Measures

Overall differences among the three level of exposure groups (see Table 6) are presented in terms of follow-up contrasts between pairs of groups. There were significant interactions between exposure level and FFSF episode in levels of infant passive–withdrawn engagement after covariate adjustment ($p = .013$, $\eta_p^2 = .015$) indicating increased proportions among heavily exposed infants in the reunion episode. There were also main effects for passive–withdrawn engagement. Infants with heavy levels of cocaine exposure compared with infants with no exposure showed significantly more passive–withdrawn engagement after covariate adjustment.

Mothers with some cocaine exposure engaged in less social monitoring without vocalizing than mothers in the no use group, after covariate adjustment. An interaction effect indicated that dyads with heavy cocaine-exposure levels had higher levels of negative matching in the reunion episode compared with other dyads that remained significant after covariate adjustment ($p = .021$, $\eta_p^2 = .013$). Dyads with heavy exposure showed higher rates of negative matching than dyads with no exposure, after covariate adjustment. Dyads with some cocaine exposure engaged in more positive matching than dyads with no exposure, after covariate adjustment.

### Covariate Effects: Infant, Maternal, and Dyadic Measures

Regardless of group membership, the following covariate effects emerged in analyses of the presence and absence of cocaine and opiate exposure, analyses of degree of cocaine exposure, and univariate analyses of the association between the covariate and the outcome. Higher SES was associated with lower levels of mother social monitoring without vocalizing. Higher birth weight was associated with greater levels of infant object engagement. Higher levels of maternal alcohol use were associated with higher levels of infant autonomic stress indicators. Site differences were prevalent, occurring in all analyses except those involving infant social positive engagement, mother social positive engagement, dyadic positive matching, and infant autonomic responses. Site differences are common in multisite studies (Vohr et al., 2004) including the MLS (Lester et al., 2002). These differences were not analyzed because they reflect

Table 6
*Face-to-Face Still-Face Paradigm Outcomes by Level of Cocaine Exposure*

| Measure | Heavy ($n$ = 46) $M \pm SEM$ | Some ($n$ = 133) $M \pm SEM$ | Not exposed ($n$ = 424) $M \pm SEM$ | Unadjusted $p$ | Unadjusted $\eta_p^2$ | Adjusted $p$ | Adjusted $\eta_p^2$ |
|---|---|---|---|---|---|---|---|
| Infant phases | | | | | | | |
| Passive withdrawn | $.010 \pm .002_a$ | $.001 \pm .001_b$ | $.001 \pm .001_b$ | **.000** | **.028** | **.003** | **.019** |
| Protest | .124 ± .029 | .102 ± .017 | .113 ± .010 | .776 | .001 | .926 | .000 |
| Object | .514 ± .035 | .511 ± .021 | .520 ± .011 | .918 | .000 | .072 | .009 |
| Social monitor | .279 ± .028 | .292 ± .016 | .284 ± .009 | .872 | .000 | .100 | .008 |
| Social positive | .060 ± .012 | .080 ± .007 | .066 ± .004 | .154 | .006 | .063 | .009 |
| Mother phases | | | | | | | |
| Negative | .015 ± .003 | .010 ± .002 | .009 ± .001 | .213 | .005 | .267 | .004 |
| Social monitor (no vocalizing) | .162 ± .021 | .111 ± .013 | .127 ± .007 | .121 | .007 | **.045** | **.010** |
| Social monitor (positive vocalizing) | $.532 \pm .028_a$ | $.608 \pm .016_b$ | $.602 \pm .009_b$ | **.046** | **.010** | .106 | .008 |
| Social positive | .270 ± .026 | .257 ± .015 | .236 ± .009 | .289 | .004 | .143 | .007 |
| Dyadic matched phase | | | | | | | |
| Negative | $.008 \pm .002_a$ | $.001 \pm .001_b$ | $.002 \pm .001_b$ | **.015** | **.014** | **.019** | **.013** |
| Neutral | .121 ± .019 | .093 ± .011 | .101 ± .006 | .455 | .003 | .074 | .009 |
| Positive | .077 ± .016 | .105 ± .009 | .083 ± .005 | .085 | .008 | **.045** | **.011** |
| Total | .206 ± .022 | .200 ± .013 | .187 ± .007 | .516 | .002 | .951 | .000 |
| Dyadic mismatched phase | | | | | | | |
| Infant negative–mother neutral | $.038 \pm .009_a$ | $.013 \pm .005_b$ | $.020 \pm .003_{a,b}$ | **.049** | **.010** | .117 | .007 |
| Infant negative–mother positive | .069 ± .019 | .063 ± .011 | .070 ± .006 | .885 | .000 | .972 | .000 |
| Infant neutral–mother negative | .007 ± .002 | .009 ± .001 | .006 ± .001 | .216 | .005 | .491 | .002 |
| Infant neutral–mother positive | .638 ± .030 | .681 ± .017 | .669 ± .010 | .468 | .003 | .505 | .002 |
| Infant positive–mother neutral | .002 ± .001 | .003 ± .001 | .002 ± .000 | .779 | .001 | .513 | .002 |
| Infant positive–mother negative | .000 ± .000 | .000 ± .000 | .001 ± .000 | .269 | .004 | .534 | .002 |
| Total | .755 ± .024 | .769 ± .014 | .769 ± .008 | .855 | .001 | .650 | .001 |
| Infant self-regulation | | | | | | | |
| Mouthing | .074 ± .019 | .082 ± .011 | .083 ± .006 | .905 | .000 | .768 | .001 |
| Clasping hands | .073 ± .017 | .073 ± .010 | .081 ± .006 | .775 | .001 | .959 | .000 |
| Distancing | $.573 \pm .098_a$ | $.389 \pm .058_{a,b}$ | $.300 \pm .032_b$ | **.020** | **.013** | .079 | .009 |
| Autonomic indicators | .141 ± .202 | .201 ± .119 | .311 ± .066 | .572 | .002 | .067 | .009 |
| Mother disregulation: rough touch | .289 ± .129 | .186 ± .076 | .228 ± .043 | .776 | .001 | .616 | .002 |

*Note.* Infant and mother engagement, matching, mismatching, and infant mouthing are measured as proportion of time in the protocol. Infant distancing, infant autonomic indicators, and mother rough touch are measured as frequency per minute. Different subscripts indicate that the overall unadjusted $p$ was below .05 and that there were significantly different unadjusted means between the subscripted level of use groups. Partial eta squared ($\eta_p^2$) is a ratio of variance accounted for by an effect to the sum of effect and related error variance. According to Cohen's (1988) criteria, .01 is a small effect size and .06 is a medium effect size. Boldface $p$ and $\eta_p^2$ values indicate significant effects.

demographic particularities specific to different geographic regions, which were not captured by other covariates.

## Discussion

Prenatal cocaine is thought to have a subtle but potentially telling impact on social and emotional development (Eyler & Behnke, 1999; LaGasse, Lester, & Seifer, 1999; Malanga & Kosofsky, 1999). Using a large multisite sample, the current study found evidence of differences in the social–emotional behavior of cocaine-exposed infants and mothers and in their dyadic interchanges. The data indicated that exposed infants engaged in more social monitoring of their mothers and less engagement with objects than nonexposed infants. Infants exposed to cocaine also showed higher rates of autonomic stress indicators (such as hiccupping and spitting up) than nonexposed infants. Mothers of cocaine-exposed infants showed heightened levels of negative engagement particularly while infants were in neutral states. Mothers and infants in the cocaine-exposed group also spent a higher proportion of time in mismatched engagement states than mothers and infants in the nonexposed group. As expected from previous work (Lester, LaGasse, & Seifer, 1998; Lester et al., 2002), these effects were subtle and effect sizes were small.

Infants with heavy levels of cocaine exposure showed heightened passive–withdrawn engagement and distancing. Mothers of infants with heavy cocaine exposure spent more time engaged in social monitoring without vocalizations and less time engaged in social monitoring accompanied by positive vocalizations than other mothers. Infants and mothers in the heavy cocaine-exposure group matched each other's negative engagement states for more time and spent more time in mismatched states in which the infant was negative and the mother neutral than other infants and mothers regardless of exposure. Furthermore, heavy exposed pairs matched each other's positive engagement states for a smaller proportion of time.

Findings of negative engagement in cocaine-exposed infants and mothers dovetail with the results of previous investigations, which had only shown either infant or mother effects (Beeghly, Frank, Rose-Jacobs, Cabral, & Tronick, 2003; Bendersky & Lewis, 1998; LaGasse et al., 2003; Mayes et al., 1997). The current study and that of Bendersky and Lewis (1998) also converge in showing that negative engagement was most evident when the dyad was attempting to cope with age-appropriate stressors such as the still-face or the reunion episode that follows it. High negative affect during the reunion episode of the FFSF paradigm, especially evident among heavily cocaine-exposed infants, has also been reported in studies of depressed dyads (Weinberg, Olson, Beeghly, & Tronick, in press).

Distortions of infants' engagement with people are likely to compromise social, emotional, and even cognitive development (Brazelton, Koslowski, & Main, 1974; Hans, 1989; Lemelin et al., 2002; Lester & Tronick, 1994; Sameroff & Fiese, 2000; Tronick & Weinberg, 1997). The higher level of monitoring of the cocaine-exposed infants suggests a higher level of vigilance by these infants and/or an inability to fully self-regulate higher levels of arousal. The passive–withdrawn behavior and the lower level of object engagement by the exposed infants suggest that they may be compromising not only their engagement with people but also their engagement with objects. Infants of depressed mothers evidence a similar pattern of behavior (Tronick & Weinberg, 1997).

The observed covariate effects broaden our understanding of the operation of cocaine beyond its specific effects. Higher SES was associated with lower levels of mother neutral social monitoring as was some exposure rather than no cocaine exposure. Lower birth weight and cocaine exposure were each independently associated with lower levels of infant object engagement. Higher levels of maternal alcohol use and the absence of cocaine exposure were each independently associated with higher levels of infant autonomic stress indicators.

Multiple comparisons were conducted in this study. One quarter of the presence of cocaine-exposure effects tested (see Table 5) and approximately one fifth of the level of cocaine-exposure effects (see Table 6) achieved significance. Using an alpha level of .05, we expected one 20th of the effects tested to show significant results by chance alone. It is, of course, possible that some of the significant results could be due to chance. Yet adoption of too stringent an alpha level might inadvertently lead to mistakenly accepting the null hypothesis that exposure group differences do not exist (Jacobson & Jacobson, 1996). Our confidence in the accuracy of our inferences is strengthened by the fact that the size of the effects is consistent with the findings from other studies of exposure effects on other areas of functioning and by the relative consistency of cocaine (rather than opiate) exposure findings in analyses.

No cocaine-exposure effect accounts for more than 3% of the relevant variance (effect variance plus between participant variance related to the effect); that is, partial eta squared never exceeded .03. Using Cohen's (1988) criteria for variance explained, we found small effect sizes. By contrast, the size of within-subject effects associated with the still-face protocol were in the small to medium range, accounting for a maximum of 7% of the relevant variance.

In contrast to the cocaine-exposed dyads, no interactive difficulties were found for opiate-exposed infants, caretakers, and dyads. One possible explanation is that opiate exposure has a strong immediate impact during the neonatal period (i.e., a withdrawal syndrome) and that early neurobehavioral dysregulation evident in the 1-month interactions of these infants is ameliorated by 4 months of age (see LaGasse, et al., 2003). It is noteworthy that in this sample, dyads exposed to opiates were less likely to be of minority status and the mothers were older than mothers without opiate exposure. The opiate and nonopiate-exposure groups also did not differ on socioeconomic variables such as maternal education and marital status. This makes the current group of opiate-exposed infants different from other samples that show more risk for child and maternal interactive deficits (Hans, 1989).

The infants displayed more negative affect, object engagement, and self-regulatory behaviors and less social positive engagement in the still-face than in the previous face-to-face play episode. The infants also evidenced the expected increase in negative affect and the prototypical rebound of positive social engagement from the still-face to the reunion episode (Weinberg & Tronick, 1996). These effects reflect both the carryover of the negative experience from the still face into the reunion and the release of positive affect with the resumption of play.

The exposed infants' reaction to the FFSF suggests that the basic social–emotional competencies of these infants remain intact. Like other infants, these 4-month-olds reacted to the mother's breaking of social connection with the expectancy that she should be engaged with them. An important implication of the integrity of their interactive and regulatory capacities is that these infants are able to learn and adapt to changes in the interaction. Additionally, despite their interactive problems, the exposed infants' still-face reaction suggests that their mothers are able to provide some level of affective and social nourishment to their infants. These findings are a source for optimism for their later development and for the effects of intervention.

Of concern is that the exposed infants' interactions with the mother were more negative than what is typically observed in nonexposed dyads. Most striking at the interactive level is the finding, both before and after statistical controls, that cocaine-exposed dyads engaged in mismatching in which the infant was neutrally engaged but the mother was negatively engaged (Espinosa et al., 2001; Rodning et al., 1989; Swanson et al., 2000). In samples where there is no drug use, maternal negative engagement during social interaction with the infant is extremely rare (Weinberg, Tronick, Cohn, & Olson, 1999). It is our belief that this neutral–negative mismatch generates frustration and anger in the infant and distrust of the mother (Tronick & Weinberg, 1997), an affective reaction that may compromise future interactions and may be related to later outcomes such as the quality of infant attachment especially if it is a stable chronic pattern.

The findings that the infants in the exposure groups were more likely to be exposed to other substances (e.g., alcohol, tobacco) emphasize that cocaine is a marker for other toxic exposures. Consequently, the observed effects point toward a complex assemblage of factors that lead to interactive difficulties. Nonetheless, the covariate control findings indicate that cocaine exposure has a specific effect on the social-interactive behavior of the infant, caretaker, and dyad and that these effects may show a dose response relationship. In general, the extent of these difficulties is consonant with Lester's interpretation that the neurobehavioral effects of exposure are subtle (Lester et al., 1998, 2002). Further, the findings indicate that although cocaine has specific effects independent of other factors that can be described, we also believe that an understanding of the behavioral phenotypic effects of cocaine (and opiates) requires a complex systemic regulatory developmental model.

This project is the first large-scale study to evaluate the early social–emotional interactions of cocaine and opiate-exposed infants and their mothers. Significant strengths of the study are the large sample size of the cocaine group, the evaluation of covariates, and the use of observational data. A limitation of the study is that the opiate-exposed group was substantially smaller than the cocaine-exposed group and that therefore there was more power to detect cocaine rather than opiate effects. Another limitation is that many dyads were excluded from the analyses because of incomplete FFSF data and/or incomplete data on the MISU. Proportions of cocaine-exposed and opiate-exposed infants who participated in the FFSF did not differ from the proportions of nonexposed infants indicating that exposure did not diminish infants' capacity to engage in this paradigm. However, caregivers who had both FFSF and interview data were of slightly higher SES (e.g., more likely to have private insurance, to have finished high school, and to be or have been married) and were less likely to have used cocaine or marijuana during pregnancy. Thus, as is the case for most studies, these findings are not generalizable to infants who are most at risk because of cocaine exposure and SES.

The findings from this and other studies suggest that phenotypic behavioral effects are the product of the interaction over time of the specific independent effects of different factors (e.g., cocaine) and the interactive effects of a large assemblage of other factors (e.g., birth weight; Lester et al., 1998; Sameroff & Fiese, 2000). One suggestion is to conceptualize behavioral normalcy or deviance as emerging from the ongoing chronic actions and interactions of an ensemble of protective and risk factors. The successful regulation of these factors moves the child along one or another of a large array of normative developmental pathways, whereas dysregulation impels the child along one or another deviant pathway. Further, some factors such as SES operate at a macrolevel and contextual level, whereas other factors such as interactive matching and mismatching operate at a microtemporal level. The operation of microtemporal factors is such that even small effects at one point in time may accumulate and have large effects over time. Thus, in this study, even though the observed infant, mother, and interactive effects were small, their eventual accumulated effect on developmental outcome may be significant. Longitudinal follow-up is necessary to determine whether these deficits become more or less pronounced with development.

## References

Adamson, L., & Frick, J. (2003). The still-face: A history of a shared experimental paradigm. *Infancy, 4,* 451–473.

Bada, H., Bauer, C. R., Shankaran, S., Lester, B., Wright, L. L., Das, A., et al. (2002). Central and autonomic system signs with in utero drug exposure. *Archives of Disease in Childhood Fetal and Neonatal Edition, 87*(2), F106–F112.

Ballard, K. L., Khoury, J. C., Wedig, K., Wang, L., Eilers-Walsman, B. L., & Lipp, R. (1991). New Ballard Score, expanded to include extremely premature infants. *Journal of Pediatrics, 119,* 417–423.

Bauer, C., Shankaran, S., Bada, H. S., Lester, B., Wright, L., Krause-Steinrauf, H., et al. (2002). The Maternal Lifestyle Study: Drug exposure during pregnancy and short-term maternal outcomes. *American Journal of Obstetrics and Gynecology, 186,* 487–495.

Beck, A. T., Ward, C. H., Mendelson, M., Mock, J., & Erbaugh, J. (1961). An inventory for measuring depression. *Archives of General Psychiatry, 4,* 561–571.

Beckwith, L., Rodning, C., Norris, D., Phillipsen, L., Khandabi, P., & Howard, J. (1994). Spontaneous play in two-year-olds born to substance-abusing mothers. *Infant Mental Health Journal, 15*(2), 189–201.

Beeghly, M., Frank, D., Rose-Jacobs, R., Cabral, H., & Tronick, E. (2003). Level of prenatal cocaine exposure and infant–caregiver attachment behavior. *Neurotoxicology and Teratology, 25,* 23–38.

Beeghly, M., & Tronick, E. Z. (1994). Effects of prenatal exposure to cocaine in early infancy: Toxic effects on the process of mutual regulation. *Infant Mental Health Journal, 15*(2), 158–175.

Bendersky, M., & Lewis, M. (1998). Arousal modulation in cocaine-exposed infants. *Developmental Psychology, 34,* 555–564.

Bernstein, V. J., & Hans, S. L. (1994). Predicting the developmental outcome of two-year-old children born exposed to methadone: Impact of social–environmental risk factors. *Journal of Clinical Child Psychology, 23,* 349–359.

Brazelton, T. B., Koslowski, B., & Main, M. (1974). *The origins of reciprocity: The early mother–infant interaction.* New York: Wiley.

Brown, J. V., Bakeman, R., Coles, C. D., Sexson, W. R., & Demi, A. S. (1998). Maternal drug use during pregnancy: Are preterm and full-term infants affected differently? *Developmental Psychology, 34,* 540–554.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurements, 20,* 37–46.

Cohen, J. (1988). *Statistical power analysis for the social sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Das Eiden, R., & Leonard, K. E. (1996). Paternal alcohol use and the mother–infant relationship. *Development and Psychopathology, 8,* 307–323.

Espinosa, M., Beckwith, L., Howard, J., Tyler, R., & Swanson, K. (2001). Maternal psychopathology and attachment in toddlers of heavy cocaine-using mothers. *Infant Mental Health Journal, 22,* 316–333.

Eyler, F. D., & Behnke, M. (1999). Early development of infants exposed to drugs prenatally. *Clinics in Perinatology, 26*(1), 107–150.

Fogel, A. (1993). *Developing through relationships: Communication, self, and culture in early infancy.* London: Harvester-Wheatsheaf.

Frank, D. A., Augustyn, M., Knight, W. G., Pell, T., & Zuckerman, B. (2001). Growth, development, and behavior in early childhood following prenatal cocaine exposure: A systematic review. *Journal of the American Medical Association, 285,* 1613–1625.

Hans, S. L. (1989). Development and consequences of prenatal exposure to methadone. *Annals of the New York Academy of Sciences, 562,* 195–207.

Hans, S. L., Bernstein, V. J., & Henson, L. G. (1999). The role of psychopathology in the parenting of drug-dependent women. *Development and Psychopathology, 11,* 957–977.

Hollingshead, A. B. (1978). *Two-factor index of social status*. New Haven, CT: Yale University Press.

Jacobson, J. L., & Jacobson, S. W. (1996). Methodological considerations in behavioral toxicology in infants and children. *Developmental Psychology, 32,* 390–403.

Kosofsky, B. E. (1998). Cocaine-induced alterations in neurodevelopment. *Seminars in Speech and Language, 19,* 109–121.

LaGasse, L., Lester, B., & Seifer, R. (1999). Interpreting research on prenatal substance exposure in the context of multiple confounding factors. *Clinics in Perinatology, 26*(1), 39–54.

LaGasse, L., Messinger, D., Lester, B. M., Seifer, R., Bauer, C. R., Shankaran, S., et al. (2003). Prenatal drug exposure and maternal and infant feeding behavior. *Archives of Disease in Childhood, 88,* F391–F399.

Lemelin, J.-P., Tarabulsy, G. M., & Provost, M. A. (2002). Relations between measures of irritability and contingency detection at 6 months. *Infancy, 3,* 543–554.

Lester, B. M., ElSohly, M., Wright, L., Smeriglio, V., Verter, J., Bauer, C., et al. (2001). The Maternal Lifestyles Study (MLS): Drug use by meconium toxicology and maternal self-report. *Pediatrics, 107,* 309–317.

Lester, B. M., LaGasse, L. L., & Seifer, R. (1998, October 23). Cocaine exposure and children: The meaning of subtle effects. *Science, 282,* 633–634.

Lester, B. M., & Tronick, E. Z. (1994). The effects of prenatal cocaine exposure and child outcome. *Infant Mental Health Journal, 15*(2), 107–120.

Lester, B. M., Tronick, E. Z., LaGasse, L., Seifer, R., Bauer, C., Shankaran, S., et al. (2002). The Maternal Lifestyle Study (MLS): Effects of substance exposure during pregnancy on neurodevelopmental outcome in one-month old infants. *Pediatrics, 110,* 1182–1192.

Malanga, C. J., III, & Kosofsky, B. E. (1999). Mechanisms of drugs of abuse on the developing fetal brain. *Clinics in Perinatology, 26*(1), 17–38.

Mayes, L. C. (1994). Neurobiology of prenatal cocaine exposure effect on developing monamine systems. *Infant Mental Health Journal, 15,* 121–130.

Mayes, L. C., Feldman, R., Granger, R. H., Haynes, O. M., Bornstein, M. H., & Schottenfeld, R. (1997). The effects of polydrug use with and without cocaine on mother–infant interaction at 3 and 6 months. *Infant Behavior and Development, 20,* 489–502.

Mirochnick, M., & Meyer, J. (1991). Circulating catecholamine concentrations in cocaine-exposed neonates: A pilot study. *Pediatrics, 88,* 481–485.

Needlman, R., & Zuckerman, B. (1993). Cerebrospinal fluid monoamine precursors and metabolites in human neonates following in utero cocaine exposure: A preliminary study. *Pediatrics, 92,* 55–60.

O'Connor, M. J., Sigman, M. D., & Kasari, C. (1992). Attachment behavior of infants exposed prenatally to alcohol: Mediating effects of infant affect and mother–infant interaction. *Development and Psychopathology, 4,* 243–256.

Oller, D. K., Yale, M. E., & Delgado, R. E. (1997, April). *Development of coordination across modalities of communication: Coding and analysis tools.* Paper presented at the Biennial Meeting of the Society for Research in Child Development, Washington, DC.

Rodning, C., Beckwith, L., & Howard, J. (1989). Characteristics of attachment organization and play organization in prenatally drug-exposed toddlers. *Development and Psychopathology, 1,* 277–289.

Sameroff, A. J., & Fiese, B. H. (2000). Models of development and developmental risk. In C. H. Zeanah Jr. (Ed.), *Handbook of infant mental health* (2nd ed., pp. 3–19). New York: Guilford Press.

Swanson, K., Beckwith, L., & Howard, J. (2000). Intrusive caregiving and quality of attachment in prenatally drug-exposed toddlers and their primary caregivers. *Attachment & Human Development, 2,* 130–148.

Tronick, E. Z. (1989). Emotions and emotional communication in infants. *American Psychologist, 44,* 112–119.

Tronick, E. Z., Als, H., & Brazelton, T. B. (1980). Monadic phases: A structural descriptive analysis of infant–mother face to face interaction. *Merrill Palmer Quarterly, 26*(1), 3–24.

Tronick, E. Z., Als, H., Wise, S., & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. *Journal of the American Academy of Child & Adolescent Psychiatry, 17,* 1–13.

Tronick, E. Z., & Beeghly, M. (1999). Prenatal cocaine exposure, child development, and the compromising effects of cumulative risk. *Clinics in Perinatology, 26,* 151–171.

Tronick, E. Z., & Cohn, J. F. (1989). Infant–mother face-to-face interaction: Age and gender differences in coordination and the occurrence of miscoordination. *Child Development, 60,* 85–92.

Tronick, E. Z., Frank, D. H., Cabral, H., Mirochnick, M., & Zuckerman, B. (1996). Late dose-response effects of prenatal cocaine exposure on newborn neurobehavioral performance. *Pediatrics, 98,* 76–83.

Tronick, E. Z., & Weinberg, M. K. (1997). Depressed mothers and infants: Failure to form dyadic states of consciousness. In L. Murray & P. J. Cooper (Eds.), *Postpartum depression and child development* (pp. 54–81). New York: Guilford Press.

Ukeje, I., Bendersky, M., & Lewis, M. (2001). Mother–infant interaction at 12 months in prenatally cocaine-exposed children. *American Journal of Drug & Alcohol Abuse, 27,* 203–224.

Vohr, B., Wright, L., Dusick, A., Perritt, R., Poole, W., Tyson, J., et al. (2004). Center differences and outcomes of extremely low birth weight infants. *Pediatrics, 113,* 781–789.

Volpe, J. J. (1992). Effect of cocaine use on the fetus. *The New England Journal of Medicine, 327,* 399–404.

Weinberg, M. K., Olson, K. L., Beeghly, M., & Tronick, E. Z. (in press). Effects of maternal depression and panic disorder on mother–infant interactive behavior in the face-to-face still-face paradigm. *Infant Mental Health Journal.*

Weinberg, M. K., & Tronick, E. Z. (1994). Beyond the face: An empirical study of infant affective configurations of facial, vocal, gestural, and regulatory behaviors. *Child Development, 65,* 1503–1515.

Weinberg, M. K., & Tronick, E. Z. (1996). Infant affective reactions to the resumption of maternal interaction after the still-face. *Child Development, 67,* 905–914.

Weinberg, M. K., & Tronick, E. Z. (1998). *Infant and caregiver engagement phases system.* Boston: Harvard Medical School.

Weinberg, M. K., Tronick, E. Z., Cohn, J. F., & Olson, K. L. (1999). Gender differences in emotional expressivity and self-regulation during early infancy. *Developmental Psychology, 35,* 175–188.

Received February 3, 2004
Revision received February 10, 2005
Accepted February 22, 2005 ■