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Arousal Modulation in Cocaine-Exposed Infants

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Abstract

The ability to modulate arousal is a critical skill with wide-ranging implications for development. In this study, the authors examined arousal regulation as a function of levels of prenatal cocaine exposure in 107 infants at 4 months of age using a “still-face” procedure. Facial expressions were coded. A greater percentage of heavily cocaine-exposed infants, compared with those who were unexposed to cocaine, showed less enjoyment during en face play with their mothers and continued to show negative expressions during the resumption of play following a period when the interaction was interrupted. This finding was independent of other substance exposure, neonatal medical condition, environmental risk, maternal contingent responsivity, and concurrent maternal sensitivity and vocalizations.

Infants prenatally exposed to cocaine may be at increased risk of poor self-regulatory capacity. State lability, irregular sleep patterns, hyperirritability, orienting and attention deficits, as well as abnormal acoustic cry characteristics, have been reported in the newborn period (Chasnoff, Griffith, MacGregor, Dirkes, & Burns, 1989; Coles, Platzman, Smith, James, & Falker, 1992; Eisen et al., 1991; Hume, O'Donnell, Stranger, Killam, & Gingras, 1993; Lester et al., 1991; Phillips, Sharma, Premachandra, Vaughn, & Reyes-Lee, 1996; Zuckerman, 1985). However, many of these studies did not control adequately for multidrug exposure and other potentially confounding variables. A recent, well-controlled study showed a lack of arousal-modulated attention soon after birth as well as 1 month later (Karmel & Gardner, 1996). This study supports a direct and long-term effect of intrauterine cocaine exposure on autoregulation of the infant's arousal and attentional systems. Deficits in attention and state or arousal regulation in tasks such as habituation, contingency learning, recognition memory, and reaction to novelty later in infancy also have been described (Alessandri, Sullivan, Imaizumi, & Lewis, 1993; Hawley & Disney, 1992; Mayes & Bornstein, 1995).

Studies with animal models such as the rat, in which many of the complexities of human research are controlled, have suggested that prenatal cocaine exposure has direct neurotoxic and long-term behavioral effects. Cholinergic and adrenergic systems, primarily in subcortical regions of the brain, appear to be affected (Dow-Edwards, 1989, 1991–1995; Dow-Edwards, Freed, & Milhorat, 1988; Hutchings & Dow-Edwards, 1991; Heyser, Spear, & Spear, 1992; Spear, Kirstein, & Frambes, 1989). If these findings apply to humans, cocaine exposure would have an impact on functional systems thought to control arousal and attention modulation, the regulation of anxiety and other emotional states, the regulation of reactivity, the level of arousal induced by novel stimulation, and the reinforcing properties of stimuli (Mayes & Bornstein, 1995).

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Such potential difficulties of arousal modulation may affect the capacity of prenatally cocaine-exposed infants to modify behavior in response to stimuli. This is a critical skill that is related to an infant's developing cognitive and emotional abilities. The regulation of emotional responses should have particularly important implications for social development and the development of a sense of self-efficacy (Cole, Michel, & Teti, 1994; Kogan & Carter, 1996; Lewis & Ramsay, 1997; Malatesta, Grigoryev, Lamb, Albin, & Culver, 1986; Thompson, 1994). Individual differences in level of arousal and the capacity to calm following arousing events are evident early in infancy (Rothbart & Derryberry, 1981; Thompson, 1994). Moreover, emotional regulation develops through the interaction between such intrinsic, apparently biologically based emotional processes and extrinsic experiential processes. Extrinsic socialization processes define how the infant interprets and manages emotional experience in the service of accomplishing goals (Bruner, 1982; Kaye, 1982; Lewis & Michalson, 1983; Malatesta et al., 1986).

Arousal modulation, like any behavioral outcome, may be affected by many factors. In addition to environmental variables that are likely to have an impact on the socialization of emotional arousal, there are other environmental and biological risk factors that may be more prevalent for infants exposed to cocaine. Distal environmental variables, such as poverty, high life stress, and social isolation of their mothers as well as more biological risk factors, such as neonatal medical complications and lower birth weight, must be considered as possible alternate explanations when examining developmental outcome of cocaine-exposed infants (Bendersky, Alessandri, Sullivan, & Lewis, 1995; Lester, Freier, & LaGasse, 1995).

A paradigm that has been used to measure an infant's emerging capacity to regulate affective state is the *still-face situation*, which presents rapid changes in emotional stimulation so that one can observe infants' responses (e.g., Carter, Mayes, & Pajer, 1990; Cohn & Tronick, 1983; Fogel, 1982; Mayes & Carter, 1990; Stoller & Field, 1982; Tronick, Als, Adamson, Wise, & Brazelton, 1978; Weinberg & Tronick, 1996). In this procedure, mothers are asked to stop interacting with their young infants after a period of play by assuming neutral facial expressions and by ceasing to talk to and touch their infants. This is followed by their resumption of the playful interaction. Studies with this paradigm involving well-educated, middle-class samples have shown that normal infants up to 6 months of age will try to reinstate the interaction during the still-face condition and, when unsuccessful, will become disengaged and negative in affect. In several recent studies, researchers have confirmed the usefulness of this paradigm in minority, low-income samples, finding response patterns consistent with previous studies (Kogan & Carter, 1996; Segal et al., 1995).

The reengagement phase especially provides an opportunity to observe the infant's ability to reorganize following an emotionally distressing situation. Several studies report a carryover of increased negativity from the still-face to the following play period (Carter et al., 1990; Cohn & Tronick, 1983; Field, Vega-Lahr, Scafidi, & Goldstein, 1986; Fogel, Diamond, Langhorst, & Demos, 1982; Tronick et al., 1978; Weinberg & Tronick, 1996). In one of the few studies that closely examined this reengagement period, Weinberg and Tronick noted a rebounding of joy expressions during the reengagement period following the still-face situation to levels above those shown during initial play. However, the amount of sadness or anger was not less in the reengagement phase than it had been during the still-face situation. Kogan and Carter (1996) examined the hypothesis that reactions to reengagement may relate to the habitual mother-infant interaction pattern that is already established by 4 months of age. They suggested that infants of more sensitive mothers should be more likely to use their mothers' external regulatory support to help decrease negativity and to return to a playful state during reengagement. Global measures of the interactive pattern showed this expected relation. Mothers who were more sensitive during the first play period tended to have infants who showed less avoidant and resistant behavior and more attention-seeking/maintaining behavior

during the reengagement phase.¹ A study by Mayes, Carter, Egger, and Pajer (1991) examined differences in the infant's affect and behavior as a function of whether the mother reported feeling uncomfortable during the still-face phase. Although infants of mothers who reported feeling discomfort showed significantly more negative affect during the still-face phase and although there was a difference in some maternal behaviors during the reengagement, these differences were not related to whether the infant showed negative affect during the reengagement period. The still-face period allows one to look at the infant's reaction to an emotionally distressing situation in the absence of direct maternal interactive behavior; however, reengagement responses may be confounded by the mother's concurrent behavior (Carter et al., 1990; Tronick, Ricks, & Cohn, 1982). In addition, infants' emotional behavior during each phase is affected by their responses in previous phases (Carter et al., 1990; Kogan & Carter, 1996; Lewis, Sullivan, Ramsay, & Alessandri, 1992). Nevertheless, it appears that the infant's behavior during reengagement may be, at least in part, unrelated to either his or her mother's behavior or earlier emotional behavior (Kogan & Carter, 1996; Mayes et al., 1991). An infant's difficulties in calming him- or herself following a perturbation would be expected to have an impact on developing social relationships. Studies of infants unexposed to drugs have found that mothers are less engaging if their infants are difficult or irritable (Crockenberg & Acredolo, 1983; Linn & Horowitz, 1983). If cocaine-exposed infants have difficulty adapting their emotional responses, caregivers would have difficulty modulating their interactions to match their infants' arousal and comfort needs (Brazelton, 1982; Brazelton, Koslowski, & Main, 1974; Tronick, 1980, 1982). In addition, drug-using women have been found to have particular difficulty in the maternal role. They admit to more emotional neglect and abuse of their children, provide more chaotic homes, move more frequently, are more depressed, and have fewer material and personal resources compared with women from similar backgrounds (Bendersky, Alessandri, Gilbert, & Lewis, 1996; Hawley & Disney, 1992; Mayes & Bornstein, 1995). Factors such as poverty, instability of living conditions, and social isolation, as well as a drug-using environment and continued drug use, may contribute to the inability of mothers to be sensitive to the needs of their exposed infants (Bendersky et al., 1996; Daghestani, 1988; Frank et al., 1988; Rodning, Beckwith, & Howard, 1991). Moreover, insensitive caregiving may contribute to an infant's early difficulty coping with stressful situations. This would create an escalating spiral of negative interactions in stressful situations.

Other concomitants of cocaine use might also affect arousal regulation. Infants in poor medical condition at birth, for example, have been found to be more irritable and more difficult to console than their healthy counterparts (DiVitto & Goldberg, 1979; Field, Dempsey, & Shuman, 1981). Prenatal cocaine exposure has been associated with increased risk of medical complications and lower birth weight (McCalla et al., 1991; Ostrea, Brady, Gause, Raymundo, & Stevens, 1992; Woods, Behnke, Eyler, Conlon, & Wobie, 1995). Thus, neonatal medical condition might mediate some of the effects of cocaine exposure on arousal regulation and the capacity to calm following a perturbation (Bendersky et al., 1996). Women who use cocaine during pregnancy are also more likely to use alcohol, cigarettes, and marijuana than are women who do not use cocaine (Behnke, Eyler, Conlon, Woods, & Casanova, 1994; Bendersky et al., 1996; Coles et al., 1992; Eyler, Behnke, Conlon, Woods, & Frentzen, 1994). Prenatal exposure to alcohol, for example, has been associated with possible emotional regulation problems during infancy, including state lability, irritability, poor attention, and temper tantrums, as well as negative affect (O'Connor, Sigman, & Kasari, 1993; Streissguth, 1986). Therefore, it is necessary to control for other substance exposure in any study of cocaine effects.

The current study used the still-face procedure to examine the capacity of infants exposed to cocaine and other substances to recover from a stressful social situation. Potentially

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¹However, there was no support for this hypothesis when microanalytic positivity and negativity of the infant during the reengagement period were examined.

confounding and mediating factors were considered in the model. These included environmental risk, neonatal medical risk, exposure to other substances of abuse, general maternal responsivity as seen during spontaneous play, as well as concurrent maternal behavior during the procedure itself. Level of cocaine exposure, whether light or heavy, was also examined as a possible discriminating factor. We expected that infants exposed to cocaine, especially heavily exposed infants, would have greater difficulty recovering their composure and resuming a pleasant interaction with their mothers.

Method

Participants

The sample consisted of 107 infants and their biological mothers who were recruited between February 1993 and December 1994 for a longitudinal study of effects of prenatal cocaine exposure on child outcome. Pregnant women attending participating hospital-based prenatal clinics and newly delivered women in the three hospitals in Trenton, New Jersey, or at the Medical College of Pennsylvania in northwest Philadelphia, were approached. Of these, 82% agreed to participate in the study. Informed consent was obtained at this time. Infants were excluded from the study if they were born prior to 32 weeks of gestation, required special care or oxygen therapy for more than 24 hours, exhibited congenital anomalies, were exposed to opiates or phencyclidine in utero, or if their mothers were less than 15 years of age or were infected with HIV. All mothers were inner-city clinic patients, predominantly African American (87%), with 10% Caucasian and 3% Hispanic. Participation was voluntary, and incentives were provided in the form of vouchers for use at local stores. Only 2 mothers received no prenatal care. Participants were a mean age of 18.7 weeks ($SD = 2.8$) at the time of the study. All participants lived with their biological mothers.

Substance use information was obtained through a semistructured interview. Within 2 weeks of the infant's birth, we conducted interviews in an exam room at the hospital, in the mother's room on the maternity ward if she had just delivered, in our laboratories near the hospitals, or in the woman's home. These were administered by trained interviewers—substance abuse counselors or study personnel trained in substance use interview techniques by the counselors and a clinical psychologist. The drug use interview contained questions about the frequency of the mother's use of prescription and nonprescription medications; the frequency, amount, and trimester of her use of cocaine, alcohol, cigarettes, marijuana, opiates, phencyclidine and other street drugs, as well as tranquilizers, amphetamines, and barbiturates; the form of cocaine she used; the disruptiveness of substance abuse to her life; and the history of her substance abuse.

Substance use interview information was confirmed by the analysis of the newborns' meconium samples as well as results of prenatal and neonatal urine screens, if available. The infants' meconium samples were screened with radioimmunoassay followed by confirmatory gas chromatography/mass spectrometry for the presence of benzoyl ecgonine (cocaine metabolite), cannabinoids, opiates, amphetamines, and phencyclidine. Information obtained by interview was corroborated by biological markers in 107 out of 110 cases. The three cases in which women denied cocaine use but had positive meconium screens were eliminated from the study.

We determined that 38% (41) of the women used cocaine. Almost all of the women who used cocaine (98%) also admitted that they used cigarettes, alcohol, or marijuana during the pregnancy. Of the cocaine users, the majority smoked crack (56%), 17% snorted cocaine, and 28% smoked freebase cocaine. The majority used the drug during all three trimesters (56%), whereas 10% said they used cocaine only in the first trimester, 5% only during the second trimester, 12% only in the third trimester, with the remainder of the group reporting use during

some combination of two trimesters. The proportion of the sample using cocaine is not representative of cocaine use during pregnancy in these cities because a special effort was made to recruit cocaine users. Only 5 women in the total sample reported binge use of alcohol. *Bingeing* was defined as the occasional consumption of a larger number of drinks than the amount reported to be usual.

The cocaine-exposed infants were divided further into those whose mothers reported using cocaine less than twice per week on average (*light exposure*, $n = 17$), and those whose mothers used cocaine at least twice per week (*heavy exposure*, $n = 24$). Exposure is described in terms of the number of days per month that cocaine was used because the purity and dosage of street drugs is so variable. The definitions of heavy and light exposure have been used in other studies (e.g., Jacobson & Jacobson, 1996; Jacobson, Jacobson, Sokol, Martier, Ager, & Shankaran, 1994). The women who used cocaine frequently during pregnancy also consumed a larger number of daily alcoholic drinks than did any other group ($p < .05$, Duncan's multiple-range test; 1 drink = 1 oz [29.57 ml] liquor, 4 oz [118.28 ml] wine, or 12 oz [354.84 ml] beer; unexposed, $M = 0.05$, $SD = 0.19$; lightly exposed, $M = 0.35$, $SD = 0.57$; heavily exposed, $M = 1.29$, $SD = 1.87$), $F(2, 104) = 15.89$, $p < .001$. Both cocaine-using groups smoked significantly more cigarettes every day than the women who did not use cocaine but did not differ from each other (unexposed, $M = 3.3$, $SD = 6.5$; lightly exposed, $M = 8.1$, $SD = 10.0$; heavily exposed, $M = 10.0$, $SD = 8.3$), $F(2, 104) = 8.10$, $p < .001$. The difference in the number of marijuana joints smoked per day was not significant (unexposed, $M = .04$, $SD = .25$; lightly exposed, $M = .13$, $SD = .25$; heavily exposed, $M = .16$, $SD = .44$), $F(2, 104) = 1.61$, *ns*.

Procedure

Infants and their mothers were ushered into a playroom where the infants were placed in an infant seat on a table at the mothers' eye level. Mothers were seated facing their infants and were asked to interact with them. They were told to talk to and to touch their infants. This play period lasted 2 min, after which mothers were told to stop interacting and to drop their heads. This turn-away period lasted for 45 s. Mothers then resumed interacting as before for 1 min. Infants and mothers were videotaped throughout the procedure.

Environmental Measures

Environmental risk score. Information about the mother's age, living arrangements, educational achievement, sources of income, social support, life stressors, child-care arrangements, and information about her other children, was obtained by structured interviews conducted at the time of the laboratory visit. Table 1 presents the variables used to compute a cumulative environmental risk measure. These variables were converted to standard scores and combined into a cumulative risk score that was scaled to have a mean of 50 and a standard deviation of 10. The range for the sample was 11.00 to 81.39. Such aggregate variables are more stable than any individual measure, and there is increased power to detect effects of the environment because errors of measurement decrease as scores are summed (Wachs, 1991). Similar cumulative environmental risk measures have been found to account for more variance in child outcome variables than single factors, including socioeconomic status (Bendersky & Lewis, 1994; McGauhey, Starfield, Alexander, & Ensminger, 1991; Sameroff, Seifer, Baldwin, & Baldwin, 1993; Sameroff, Seifer, Barocas, Zax, & Greenspan, 1987; Stanton, McGee, & Silva, 1991).

Contingent responsivity score. In addition to the distal variables incorporated into the environmental risk score, direct measures of maternal-infant interaction constituting proximal environmental factors are important mediators of child outcome (e.g., Lewis & Coates, 1980; Lewis & Lee-Painter, 1974; Sigman & Parmelee, 1979). To examine this, we computed the amount of contingent responsivity displayed by the mother during a 5-min spontaneous play

session that occurred earlier in the same 4-month laboratory visit. Mothers and their infants were provided with a standard array of age-appropriate toys that were placed on a blanket on the floor. Mothers were asked to play as they normally did at home and were told that they could hold the infant if they desired. The 1st, 3rd, and 5th min of this play session were coded second-by-second by one coder for the occurrence of 11 infant and 12 maternal behaviors, such as vocalizations, touches, looks, smiles, or shows a toy. Any maternal behavior that occurred within 3 s of the onset of any infant behavior was considered to be a contingent response (Lewis & Goldberg, 1969). The proportion of the infant's behaviors to which the mother responded within 3 s, corrected for the frequency of infant behaviors, was the total contingent responsivity score used in this study. The coder was blind to the drug exposure status of the infants.

Concurrent maternal behavior. Group differences in infants' expressions may be influenced by maternal behavior during the interactive play phases of the en face procedure itself. To ensure that infant reactions were independent of maternal behavioral differences, maternal behaviors during the minute prior to and following the drop phase were coded on a 5-point scale ranging from *very negative/insensitive* to *very positive/highly sensitive*. Maternal sensitivity was rated only during en face play prior to the head drop and during the reengagement period because there were no differences in maternal behavior during the head drop phase. In addition, total duration of maternal vocalizations was recorded during en face play and during reengagement. Two coders simultaneously rated all dyads. Interrater reliability was 95% for the maternal sensitivity rating both during en face play and during reengagement. There was 98% agreement for the duration of vocalizations during en face play and 99% during the reengagement period. Any discrepancies were discussed, and a consensus score was agreed on. Coders were blind to the drug exposure status of the infants.

Neonatal medical condition. Prenatal and neonatal medical data were abstracted by nurses from hospital records. They were used to complete a neonatal medical risk scale consisting of 35 possible complications (Hobel, Hyvarinen, Okada, & Oh, 1973). Variables included general factors (e.g., low birth weight, fetal anomalies, and feeding problems), respiratory complications (e.g., congenital pneumonia, apnea, and meconium aspiration syndrome), metabolic disorders (e.g., failure to gain weight and hypoglycemia), cardiac problems (e.g., murmur and cardiac anomalies), hematologic problems (e.g., anemia and sepsis), and central nervous system (CNS) problems (e.g., CNS depression and seizures). Variables were weighted and summed to obtain the risk score, which ranged from 0 to 10. In addition, birth weight and gestational age were noted.

Dependent Measures

Facial expressions. Facial expressions were coded from the videotapes with the Maximally Discriminative Facial Coding System (MAX; Izard, 1983). Facial expressions were coded every second during the last 15 s of the first 2-min interaction period (Play 1), the 45 s during which the mothers withdrew their attention (drop), and the first 45 s following the resumption of the interaction (Play 2). The last 15 s of the first interaction period were considered representative of the undisturbed en face interaction behavior. With the volume off, positions of the brows, eyes, and mouth were coded. Facial expressions were then identified on the basis of MAX formulas, and their frequencies were tabulated for each phase of the procedure. Infants were identified by number only, and coders were blind to substance exposure status. Coders were trained to achieve an intercoder agreement within 1 s of at least .85. Duplicate coding of 10% of the sample resulted in a Cohen's kappa of .77 across all emotion codes. Enjoyment, anger, sadness, and fear were the emotional expressions used in the analyses because of their clear emotional valences. The three negative expressions—anger, sadness, and fear—were combined into a single negative expression score. Fear and sadness occur with relatively low

frequency in this procedure, and several researchers have questioned whether discrete negative expressions at this age correspond to well-differentiated states (Lewis & Michalson, 1983; Matias & Cohn, 1993).

Results

Medical and Environmental Scores

Table 2 presents the neonatal medical and environmental risk scores, the maternal contingent responsivity score, the concurrent maternal sensitivity scores, and the duration of maternal vocalizations during the en face and reengagement phases for the cocaine-exposed and unexposed groups. The exposed group was further divided into those lightly and heavily exposed to cocaine, and the means for these groups are presented in the third and fourth columns of Table 2. The cumulative risk scores were scaled so that a higher score represents a greater risk. The difference in the cumulative neonatal medical risk score between the total exposed and unexposed groups was significant, $t(105) = -4.2, p < .001$. Infants who were exposed to cocaine had a significantly greater number of medical complications around the time of birth. Comparison of the unexposed, lightly exposed, and heavily exposed groups indicated a significant difference, $F(2, 104) = 17.50, p < .001$. Post hoc comparisons with the Duncan's multiple-range test revealed that infants in the heavily exposed group had significantly higher risk scores than did those in the other two groups that did not differ from each other ($p < .05$).

The exposed infants also had significantly higher cumulative environmental risk scores, $t(105) = -0.7, p < .01$. Comparison among the three exposure groups indicated a significant difference, $F(2, 104) = 4.10, p < .02$, with children of heavy cocaine-using women having significantly higher environmental risk than either of the other groups. Although the environmental risk of the lightly exposed group was higher than that of the unexposed, the difference was not statistically significant.

The maternal contingent responsivity score did not differ between groups. Mothers in all exposure groups responded contingently to their infants' behaviors about 50% of the time in the free-play setting. Similarly, neither the maternal sensitivity ratings nor the amount of vocalization during both the en face and the reengagement phases differed by exposure group. The difference in gender distribution was not significant across the exposure groups.

Maternal Interaction

Although there were no exposure group differences in maternal responsivity during free play or maternal sensitivity and vocalization during the interactive phases of the still-face procedure, point biserial correlation analyses were performed between each of the maternal interaction variables and the infants' emotional responses to see whether maternal behavior affected the infants' emotional expressions. These analyses indicated that there was a relation between the concurrent maternal interaction variables and the infants' expressions of joy. The maternal sensitivity rating and the amount of vocalization were positively related to whether infants expressed joy during the en face phase ($r = .29, p < .01$; $r = .32, p = .001$, for sensitivity and vocalization, respectively). Maternal sensitivity was related to infants' facial expressions of joy during reengagement ($r = .31, p = .001$). The more sensitive and verbally stimulating mothers tended to have infants who showed more joy during the en face and the reengagement episodes. The concurrent maternal interaction variables were unrelated to negative expressions during en face and reengagement. Total maternal contingent responsivity during free play was also unrelated to the emotional expressions during the still-face procedure.

Emotional Responsivity

Distributions by each group of the mean proportions of time during which the different emotional expressions were exhibited during the en face, drop, and reengagement phases were examined. The distributions were positively skewed with many zero scores. Because of this, parametric analyses were not appropriate.² Therefore, analyses were conducted on the percentages of infants showing enjoyment or negative expressions in each phase. Table 3 presents the percentage of infants showing enjoyment and negative expressions during each phase for the unexposed and total cocaine-exposed group and then for the exposed group, which was divided into those lightly or heavily exposed. Group differences within each phase were analyzed with chi-square analyses. Post hoc comparisons among the unexposed, lightly, and heavily exposed groups were performed if the overall chi-square was significant.

Joy. During en face, the percentages of infants showing joy in response to their mothers' playful talking and touching was not significantly different for the exposed compared with the unexposed infants. When the three exposure groups were compared, the overall difference did not reach significance, $\chi^2(2, N = 107) = 4.9, p < .09$, however significantly fewer heavily exposed infants than unexposed showed joy during this phase, $\chi^2(1, N = 90) = 4.7, p < .05$. There were no group differences in enjoyment during the drop or reengagement phases.

The pattern of joy expressions over phases was analyzed with the McNemar change test. This is the appropriate nonparametric statistic for comparing correlated dichotomous variables (Siegal & Castellan, 1988). The binomial distribution was used to test the significance of the differences. Changes in the percentages of infants expressing joy were compared for the total group as well as separately for the unexposed, the total exposed, and the lightly and heavily exposed subgroups. The percentages of infants showing an expression in each phase were compared with every other phase (e.g., the percentage of all infants showing joy during en face was compared to the percentage showing joy during drop and then during reengagement). The percentage of infants showing joy during drop was also compared to the percentage showing joy during reengagement. These comparisons were made separately for each exposure group. Overall, the pattern of joy expressions varied across the three phases as expected. The percentage of all groups combined showing enjoyment decreased significantly during head drop ($p < .002$) and increased again during reengagement ($p < .001$). However, the change in expressions of joy reached significance for the unexposed group only (en face-drop, $p < .01$; drop-reengagement, $p < .001$; en face-reengagement, *ns*).

Negative expressions. Group differences in negative expressions were examined. The only significant group difference was during the reengagement phase, in which more exposed than unexposed infants showed negative expressions during reengagement, $\chi^2(1, N = 107) = 5.8, p < .02$. The analysis comparing all three groups also indicated a significant difference, $\chi^2(2, N = 107) = 6.1, p < .05$. A larger percentage of infants in the heavily exposed than in the unexposed group showed negative expressions during reengagement, $\chi^2(1, N = 90) = 5.5, p < .02$. An intermediary percentage of infants in the lightly exposed group showed negative expressions, but this was not different from either of the other groups.

The pattern of change in negative expressions across the phases was opposite to that shown for enjoyment. Although low during en face, the percentage of the total group showing distress increased significantly when mothers dropped their heads ($p < .001$). The percentage exhibiting negative expressions decreased, but not significantly, when play was resumed. For the unexposed group, the percentage of infants showing negative expressions increased significantly between en face and drop ($p < .001$) and decreased from drop to reengagement

²Group and phase differences for the mean data of the log transformed duration of emotion variables paralleled those of the dichotomized variables, however statistical analyses were precluded due to the excessively skewed distributions.

($p < .05$). The total exposed group showed a significant increase in the percentage of infants showing negative expressions between en face and drop ($p < .001$), but there was no difference in the percentage showing negative expression in reengagement compared to that in drop. Both groups showed an increase in the percentage showing distress during reengagement compared to that during en face ($p < .01$, for both unexposed and exposed). There was no significant difference in the pattern of change in negative expressions across phases between the lightly exposed and heavily exposed groups.

Accounting for control variables. Logistic regression analyses were undertaken in an attempt to control for other possible predictive variables, including environmental ones. Amounts of other prenatal substance exposures, neonatal medical risk, general environmental risk, and the more proximal maternal interaction variables were considered as potential confounders of the cocaine effect. Only the variables with zero-order correlations with the outcome that were significant at a level $\leq .10$ were used in the regressions as control variables. Including only variables related to the outcome significantly reduces the number of variables entered into the regression analyses and increases the power to detect an effect by reducing the error term. The variables that correlated with the percentage of infants showing enjoyment during en face play were the maternal sensitivity rating ($r = .29$, $p < .01$) and the duration of vocalization ($r = .32$, $p < .01$) during this phase. Neonatal medical risk also was significantly related to expressions of joy during en face play ($r = -.21$, $p < .03$). Exposure to alcohol, cigarettes or marijuana, the environmental risk score, and the maternal responsivity score were unrelated to joy during this phase. For the regression analysis, level of cocaine exposure was dummy coded such that two dichotomous exposure variables were entered, one representing the effect of light exposure, the other representing heavy exposure. The percentage of infants showing enjoyment during en face was the outcome variable in a logistic regression analysis in which the maternal sensitivity rating and the duration of vocalization during this phase were entered in a first step as control variables; the light cocaine exposure variable was entered in a second step, the heavy exposure variable was entered in a third step, and the neonatal medical risk score was entered in a fourth step. Neonatal medical risk was entered last because it was related to both the cocaine exposure and the joy variable. It was possible that this risk score was a mediator of cocaine effects on the outcome and so was entered after the exposure variables to ensure that any cocaine exposure effect was not obscured by having first removed the variance attributable to neonatal medical risk.

In this analysis, the addition of light cocaine exposure in a second step did not contribute significantly to the predictive model after the significant variance in joy associated with the two control variables was removed in Step 1. There was a significant increase in the prediction of the model when the heavy cocaine exposure variable was added in Step 3, $\chi^2(1, N=107) = 3.9$, $p < .05$. Heavy exposure was associated with fewer participants showing joy (Wald = 3.71, $p = .05$). Neonatal medical risk did not significantly contribute when added in the last step.

In examining negative expressions during reengagement, we found that the only potentially confounding variable was maternal sensitivity during this phase ($r = -.16$, $p = .10$). It was entered in Step 1 of a logistic regression analysis predicting percentage of infants showing negative expressions during reengagement. The addition of light cocaine exposure in Step 2 did not contribute significantly. The addition of the heavy exposure variable in Step 3 did contribute to the model, $\chi^2(1, N = 107) = 5.7$, $p < .02$. Heavy exposure was associated with more infants showing negative expressions (Wald = 5.5, $p < .02$).

Discussion

The results of this study support the hypothesis that prenatal exposure to cocaine, particularly heavy exposure, may affect an infant's capacity for arousal modulation. In this social situation

at 4 months of age, a significantly greater number of infants heavily exposed to cocaine in utero appeared less able to recover from a stressful episode. This appeared to be independent of likely confounding variables, such as environmental risk, neonatal medical condition, and exposure to other toxins, as well as concurrent maternal interactive behavior.

The expected pattern of change in affect in this modified still-face procedure is low negative and high positive emotion during initial en face play with the mother, an increase in negative and a decrease in positive emotion during the period when the mother drops her head and withdraws her attention, and then a rebounding of positive and a drop in negative emotions when the mother again reengages her infant in en face interaction. Although this pattern was evident for the group of infants unexposed to cocaine, it was less characteristic of the cocaine-exposed group and, in particular, those who were heavily exposed. The heavy exposure group showed the least change over phases in the percentage of infants responding to their mothers with positive affect and no decline in the percentage who continued to show negative affect when their mothers attempted to reengage them in pleasant interaction.

Young infants are expected to rely on their caregivers to help structure their level of arousal (Emde, 1980; Fogel et al., 1982; Gianino & Tronick, 1988; Kogan & Carter, 1996; Stern, 1974, 1985; Tronick et al., 1982). For example, in infants up to 6 months of age, maternal positive expressions generally precede infant positive expressions, and mothers usually remain positive until the infant becomes disengaged (Cohn & Tronick, 1983; Stern, 1977). Mothers may be providing external support that helps their infants maintain a positive emotional state for longer periods of time. Furthermore, by 4 months of age, an infant has already developed generalized expectancies about the social world through interactions with the caregiver (Cohn, Matias, Tronick, Connell, & Lyons-Ruth, 1986; Lewis & Goldberg, 1969). Thus, the infant's expectation about a mother's behavior, as well as the actual degree of stimulation and support provided during the still-face procedure, might mediate the infant's emotional responses. This is supported by Kogan and Carter's (1996) findings during reengagement and by those of several other researchers who looked at the effect on the infant's behavior during the still-face period itself (Cohn et al., 1986; Stoller & Field, 1982; Tronick et al., 1982). The current study partially supports this because maternal sensitivity and vocalizations were related to infants' positive emotional reactions. Women who used cocaine during pregnancy, and who may continue to be drug users, can reasonably be expected to be less sensitive, stimulating, and responsive in their interactions with their infants (Bauman & Dougherty, 1983; Bernstein, Jeremy, Hans, & Marcus, 1984; Burns & Burns, 1988; Burns, Chethik, Burns, & Clark, 1991; Gottwald & Thurman, 1994). The current study found no evidence, however, that mothers who used cocaine in this sample were any less stimulating (no differences in amount of vocalization) or sensitive (no differences in sensitivity ratings) during the initial en face play period or the reengagement period than women who did not use cocaine during pregnancy. Moreover, there were no group differences in the amount of contingent responsivity (about 50% of the infants' behaviors were responded to within 3 s) during a separate spontaneous play episode at the same age. Therefore, it is unlikely that these maternal interaction variables mediated the difference in emotional arousal among the exposure groups. The contingent responsivity rate of 50% shown by the mothers in this study is comparable to that shown in another study in our laboratory with the same methodology with a middle-class sample. Thus, these mothers as a group are not less responsive to their infants' behaviors in laboratory interactions at 4 months.

These findings have implications for the development of these infants. The fact that more heavily exposed infants could not sustain a positive play interaction and could not recover from the apparent negative affect that developed when their mothers turned away, despite equally sensitive and stimulating caregivers, suggests that prenatal exposure to cocaine may have a specific impact on an infant's capacity for self-regulation. These findings are consistent with

those reported by others in the newborn and early infancy periods (Chasnoff et al., 1989; DiPietro, Suess, Wheeler, Smouse, & Newlin, 1995; Gottwald & Thurman, 1994; Karmel & Gardner, 1996; Phillips et al., 1996; Schutter & Brinker, 1992; Zuckerman, 1985). However, this study could not rule out the possibility that under normal circumstances outside of the laboratory, mothers who used cocaine during pregnancy may be less consistent in their interactive behavior than the other mothers in the study. Thus, the possibility remains that the arousal regulation deficit that is apparent in many of the heavily exposed infants is due, at least in part, to extrinsic conditions. Whatever the causal factors, such early difficulties may have repercussions for long-term social and cognitive development.

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Table 1

Variables Constituting the Risk Scores

Score type and variable	Scale range
Environmental risk	
Maternal race	0 = <i>White</i> ; 1 = <i>non-White</i>
Maternal living situation	0 = <i>lives with 1 or more adult</i> ; 1 = <i>lives with child or children only</i>
No. children under 18 years of age in mother's household	Higher no. = higher risk
Maternal social support network size	Smaller no. = higher risk ^a
Maternal life stressors	Higher no. = higher risk ^b
Maternal postnatal cocaine use	0 = <i>not used since deliver</i> ; 1 = <i>used since delivery</i>
Regularity of child's schedule	Less regular = higher risk ^c
Stability of child's surroundings	Less stable = higher risk ^c
No. of regular caregivers	More = higher risk ^c
Maternal level of education	0 = <i>high school graduate</i> ; 1 = <i>less than high school education</i>
Main source of income	0 = <i>not on public assistance</i> ; 1 = <i>on public assistance</i>
Neonatal medical risk	
Hobel Neonatal Risk Scale	More complications = higher score ^d

^a Norbeck Social Support Questionnaire (Norbeck, Lindsey, & Carrieri, 1981).

^b Based on Prenatal Social Environment Inventory (Orr, James, & Casper, 1992).

^c Family Chaos Scale, Family Child Study of Affective and Anxiety Disorder, Grant MH44755 (Sameroff, 1989).

^d Hobel, Hyvarinen, Okada, and Oh, 1973.

Table 2
Maternal and Infant Characteristics of Substance Exposure Groups

Variable	Unexposed(<i>n</i> = 66)		Exposed(<i>n</i> = 41)		Exposed			
					Lightly(<i>n</i> = 17)		Heavily(<i>n</i> = 24)	
	M	SD	M	SD	M	SD	M	SD
Neonatal medical risk score	0.38 ***	0.80 _a	1.63	2.21	0.65	0.86 _a	2.32	2.61 _b
Environmental risk score	47.44 **	10.98 _a	53.25	10.62	51.32	11.22 _{a,b}	54.62	10.19 _b
Maternal contingent responsivity score	0.50	0.15	0.50	0.13	0.52	0.13	0.49	0.13
Maternal sensitivity								
En face	4.29	0.87	4.17	1.02	4.06	1.14	4.25	0.94
Reengagement	4.27	0.93	4.08	0.98	3.88	1.11	4.23	0.87
Maternal vocalization								
En face	45.75	11.83	42.65	14.16	43.13	12.95	42.33	15.18
Reengagement	45.15	10.15	45.37	10.07	43.31	9.60	46.86	10.36

Note. Subscripts denote the significance of post hoc comparisons. Values with different subscripts are significantly different ($p < .05$). Values with both subscripts are not significantly different from either of the other groups.

**
 $p < .01$.

***
 $p < .001$.

Table 3
Percentage of Participants Showing Positive and Negative Emotional Responsivity by Exposure Group and Phase

Phase	Enjoyment				Negative expressions			
	Unexp (<i>n</i> = 66)	Exp (<i>n</i> = 41)	Exp		Unexp (<i>n</i> = 66)	Exp (<i>n</i> = 41)	Exp	
			Lightly (<i>n</i> = 17)	Heavily (<i>n</i> = 24)			Lightly (<i>n</i> = 17)	Heavily (<i>n</i> = 24)
En face	59	44	59 _{a,b}	33 _b	14	22	18	25
Drop	35	32	41	25	50	56	53	58
Reengagement	71	61	77	50	35 _a	59	53 _{a,b}	63 _b

Note Subscripts denote the significance of post hoc comparisons. Values with different subscripts are significantly different ($p < .05$). Values with both subscripts are not significantly different from either of the other groups. Unexp = unexposed; Exp = exposed.