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The Association between Prenatal Exposure to Cigarettes and Infant and Maternal Negative Affect

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Abstract

This study examined the association between prenatal exposure to cigarettes and infant and maternal negative affect. Participants were 115 mother-infant dyads (69 prenatally exposed to cigarettes and 46 nonexposed). Infant and maternal negative affect were both assessed during the neonatal period (2–4 weeks of age) and again at 7 months of infant age. Results indicated that only prenatal exposure to cigarettes predicted infant negative affect. Infants who were prenatally exposed to more cigarettes had higher levels of negative affect at both time points. Furthermore, regression analyses indicated that both infant and maternal negative affect during the neonatal period predicted maternal negative affect at 7 months of age. These results highlight the importance of considering the reciprocal relationship between infant and maternal behavior when examining developmental outcomes among infants prenatally exposed to cigarettes.

Keywords

prenatal exposure to cigarettes; infant negative affect; maternal negative affect; cross-lagged panel design

Prenatal exposure to cigarettes has consistently been associated with adverse perinatal outcomes (Abel, 1980; Fried & O'Connell, 1987; Fried & Oxorn, 1980; Olsen, Pereira, & Olsen, 1991). In addition, a growing body of research has documented an association between prenatal exposure to cigarettes and deficits in affective behaviors and regulation. Exposed infants have been found to show deficits in arousal and attention throughout the first year of life (Franco et al., 1999; Franco et al., 2000; Fried & Makin, 1987; Jacobson, Fein, Jacobson, Schwartz & Dowler, 1984; Picone, Allen, Olsen, & Ferris, 1982; Saxton, 1978; Schuetze & Eiden, 2006; Schuetze & Zeskind, 2001; Streissguth, Barr, & Martin, 1983). Studies have also found differences in affective behaviors among exposed infants as compared to nonexposed infants as early as the neonatal period and persisting into childhood. Specifically, studies with infants and toddlers who were prenatally exposed to cigarettes have found evidence of increased irritability (Brook, Brook & Whiteman, 2000; Jacobson et al., 1984; Johnson, Vicary, Heist &

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Corneal, 2001; Ramsay, Bendersky, & Lewis, 1996; Schuetze & Zeskind, 2001). The extent to which these effects are due to the direct, teratological impact of prenatal exposure to cigarettes or are mediated by other maternal factors that are associated with maternal smoking is not clear.

Previous studies highlight the importance of examining both direct and indirect pathways to the development of affect among cigarette-exposed infants. In fact, investigators have recently suggested that one trajectory to later developmental problems among cigarette-exposed infants may be through problematic maternal characteristics (Wakschlag & Hans, 2002). Maternal negative affect may be particularly relevant when examining affect among infants prenatally exposed to cigarettes. For example, cigarette smoking has consistently been associated with higher levels of depressive symptomatology (Anda, Williamson, Escobedo, Mast, Giovino, & Remington, 1990; Breslau, Kilbey & Andreski, 1990; 1993; Fergusson, Goodwin, & Horwood, 2003) among adolescents and adults in the general population, particularly among heavy smokers (>20 cigarettes per day). Fewer studies have examined levels of depression or anxiety among pregnancy smokers, although several studies have found evidence of higher rates of depression among pregnant smokers as compared to nonsmokers (Pritchard, 1994; Schuetze & Eiden, 2006; Zhu, & Valbo, 2002). A fairly large body of literature also suggests that smoking is positively associated with hostility in the general population. Hostility is characterized by negative attitudes and beliefs towards other people and frequent and intense bouts of anger (Houston & Vavak, 1991; Miller, Smith, Turner, Guijarro & Hallet, 1996). Trait hostility consistently predicts higher smoking rates in both men and women (e.g., Lipkus, Barefoot, Williams & Siegler, 1994; Siegler, Person, Barefoot & Williams, 1992; Whiteman, Fowkes, Deary, & Lee, 1997). In addition, one recent study found that hostility during the first trimester predicted smoking during the second and third trimesters (Rodriguez, Bohlin & Lindmark, 2000).

The importance of considering negative affect of pregnant smokers is underscored by the rapidly increasing body of literature that shows a range of nonoptimal developmental outcomes among the infants and children of women with increased levels of depression and hostility. Independent of cigarette smoking, parents who exhibit higher levels of depression are less sensitive caregivers, more likely to display flatter affect during mother-child interactions and to provide less stimulation to their infants (Cohn & Campbell, 1992; del Carmen, Pederson, Huffman, & Bryan, 1993; Field, 1992; Howard et al., 1995; Jameson, Gelfand, Kuczar, & Teti, 1997; Weinberg & Tronick, 1998). Similarly, maternal anger/hostility has been found to increase negative maternal behavior among substance-using women (Eiden, Chavez, & Leonard, 1999; Hans Bernstein, & Henson, 1999). Thus, one pathway to altered infant affect may be through maternal negative affect. This is particularly true given that investigators have speculated that there is a strong neurobiologic and genetic basis to "affective temperament" (Kovacs & Devlin, 1998).

The purpose of this study was to test a conceptual model examining concurrent and longitudinal associations between infant and maternal negative affect as a function of maternal cigarette smoking during pregnancy at 2–4 weeks and 7 months of infant ages. Specifically, we hypothesized that cigarette exposed infants would have higher levels of negative affect. We also explored the possibility that maternal negative affect would explain this association and examined potential bidirectional associations between maternal and infant negative affect longitudinally.

Method

Participants

Participants consisted of 116 mother-infant dyads recruited into a longitudinal study of cigarette exposure and infant development who completed laboratory visits at both 2–4 weeks and 7 months of age. Of these dyads, 69 consisted of infants who were prenatally exposed to cigarettes through maternal smoking during pregnancy (prenatal exposure [PE] group), and 46 consisted of infants who were not prenatally exposed to cigarettes (nonexposed group [NE]) and whose mothers were not exposed to environmental tobacco smoke (ETS) during pregnancy (see Tables 1 and 2). An outreach worker on the project staff recruited all participants after delivery from one local area hospital. Mothers ranged in age from 18 to 42 ($M = 27.82$, $SD = 6.65$). 12% of mothers were primiparous. The remaining mothers had between 2 and 8 children. The majority of mothers were African-American (68%), had high school or below education (77%) and were single (72%). The Hollingshead 2-factor index was used to calculate socioeconomic status (SES; Hollingshead, 1975). The average SES was 2.91 ($SD = 1.56$). Thus, the sample consisted of predominantly low-income families with single mothers.

Only mothers who reported using no illicit drugs (other than occasional marijuana) and no more than moderate amounts of alcohol (Average Daily Alcohol consumption of less than .50 ounces of ethanol or 1 drink a day) during pregnancy were recruited for the study. Maternal report of no illicit substance use during pregnancy was confirmed via urine toxicologies which were available for 111 of the mothers in the study. Urine screens are routinely conducted on all mothers who receive prenatal care through the hospital's prenatal clinic and are obtained at birth for the remaining mothers. Urine toxicologies consisted of standard urine screening for drug level or metabolites of cocaine, opiates, benzodiazepines, and tetrahydrocannabinol (THC). Urine was rated positive if the quantity of drug or metabolite was >300 gms/ml. All mothers recruited into this study were negative for cocaine, opiates and benzodiazepines. In addition, all infants were fullterm (>36 weeks gestational age) with no major medical problems at birth. 58% of the infants were male.

Procedure

All mothers at one local hospital were approached by study staff after delivery and were invited to participate in a study of maternal health and infant development. Interested and eligible mothers were given detailed information about the study and were then scheduled for their first laboratory visit which took place during the neonatal period between 2 to 4 weeks postpartum ($M = 3.10$, $SD = 0.66$). This visit consisted of a maternal interview used to obtain information on psychosocial functioning and substance use during pregnancy, infant physiological assessments and a 10 minute feeding session. Because of concerns about maternal literacy, all measures were administered in an interview format. Since the study was dependent on measuring behaviors in a naturalistic setting of a caregiver familiar with the infant, care was taken to identify the primary caregiver of the infant. This was defined as the adult who provided the majority of care of the infant as indicated during a phone interview conducted immediately prior to the scheduled neonatal visit. The biological mother was the primary caregiver for all but one of the infants in the study. This dyad was, therefore, not included in this sample. Thus, the final sample size was 155 mother-infant dyads. A second laboratory visit was scheduled when the infant was about 7 months old. This visit included a caregiver interview, feeding and play sessions that were videotaped, and behavioral and physiological assessments of infant reactivity and regulation. All of the 7 month assessments were conducted with the primary caregiver of the child at that time. For the current analysis, the data from the caregiver interviews at both time points were used. At both time points, the examiners were blind to group status.

The study received approval from the institutional review boards of the hospital as well as the primary institutions with which the authors are affiliated. In addition, informed written consent was obtained from all recruited participants. To meet Health Insurance Portability and Accountability Act (HIPAA) guidelines, additional written consent to view the medical records of both the mother and the infant was obtained at the time of recruitment. Participants received \$30.00 and a \$5.00 infant toy at the neonatal visit and \$40.00 and a \$10.00 infant toy at the 7 month visit for their participation.

Identification of Cigarette Exposure

The Timeline Follow-back Interview (TLFB; Sobell & Sobell, 1995), administered at the neonatal visit, was used to assess maternal smoking during pregnancy. Participants were provided a calendar and asked to identify events of personal interest (i.e., holidays, birthdays, vacations, etc.) as anchor points to aid recall. This method has been established as a reliable and valid method of obtaining longitudinal data on substance use patterns and has good test-retest reliability and is highly correlated with other intensive self-report measures and with salivary cotinine (Brown, Burges, Sales, Whiteley, Evans & Miller, 1998). The use of the TLFB at the neonatal visit for these substances resulted in the following variables for each of the substances used for the month prior to pregnancy, each trimester of pregnancy and for the 2–4 weeks following pregnancy: number of days cigarettes were smoked, average number of cigarettes smoked per week, average number of joints used per week (for marijuana), average number of standard drinks consumed per week and mean standard drinks per drinking day (for alcohol). The TLFB was again administered at the 7-month visit to assess postnatal substance use and yielded the following variables: average number of standard drinks consumed per week, average number of joints used per week and average number of cigarettes smoked per week since the neonatal visit.

In order to quantify the level of the infant's postnatal exposure to cigarette smoke, salivary cotinine levels were assessed for infants during their postnatal visit at 7 months of age. Cotinine, which is a metabolite of nicotine, is a biochemical marker which effectively quantifies exposure to cigarettes (Jarvis, 1989), and is widely used as a biochemical marker for recent passive smoke exposure of up to three days (Greenberg et al., 1991). One ml of saliva was collected from each infant by placing one end of a 6" cotton dental roll in the infant's mouth while the other end was held by the research technician. The infant was allowed to suck (mouth) the cotton roll for 1–3 minutes. Once the end was saturated, it was removed from the infant's mouth. That end was then cut and placed into the barrel of a 10cc syringe. The syringe plunger was used to express the saliva from the cotton roll into a small 0.5ml vial. Samples were frozen immediately after collection until assayed using Enzyme-linked immunosorbent assay. Cotinine levels at 7-months ranged from 0 to 1903 ng/ml ($M = 69.94$, $SD = 239.40$) for prenatally exposed infant and from 0 to 212 ng/ml ($M = 5.57$, $SD = 31.35$) for infants in the NE group (see Table 2).

Group differences in level of substance use during pregnancy were initially examined separately for each trimester. However, since the pattern of group differences did not vary by trimester, composite variables for total pregnancy use were created for each substance use variable. These variables were used in all subsequent analyses. The average number of cigarettes smoked per week during pregnancy for smokers ranged from .92 to 152.78 ($M = 45.47$, $SD = 37.55$).

Assessment of Maternal Negative Affect

The depression and hostility subscales of the Brief Symptom Inventory (BSI, Derogatis, 1993) were used to assess maternal negative affect (MNA) at both the neonatal and 7 month assessments. The BSI brief form of Symptom Checklist 90-R and is a mental health screening

measure widely used in a variety of clinical and research settings. The depression and hostility subscales were highly correlated at both the neonatal visit, $r(115) = .61, p < .001$, and at the 7 month visit, $r(115) = .51, p < .001$. In order to create a composite variable reflecting higher maternal negative affect, and because the inter-correlations among the two subscales at both time points were quite high, we created a composite scale averaging the 6 items from the depression subscale and the 5 items from the hostility subscale. Each of the 11 items was rated on 5-point scales ranging from 0 'not at all' to 4 'extremely'. This new scale had high internal consistency at both the neonatal (Cronbach's $\alpha = .82$) and 7 month (Cronbach's $\alpha = .84$) assessment points.

Infant Negative Affect

The sadness, distress to limitations, soothability, and fear subscales of Rothbart's Infant Behavior Questionnaire – Revised (IBQ-R; Garstein & Rothbart, 2003) were used to assess infant measure negative affect (INA) at both 2–4 weeks and 7 months of age. These subscales were all significantly inter-correlated at both the neonatal and 7 month visits (all r 's $> .29, p < .01$). In order to create a composite variable reflecting higher infant negative affect, and because the inter-correlations among the two subscales at both time points were quite high, we created a composite scale averaging the 14 items from the sadness subscale, the 16 items from the distress to limitations subscale, the 18 items from the soothability subscale and the 16 items from the fear subscales. This composite variable had adequate internal consistency at both the neonatal (Cronbach's $\alpha = .81$) and 7 month visits (Cronbach's $\alpha = .80$) for this sample.

Results

Sample Characteristics

Descriptive statistics for the demographic and risk variables for both mothers and infants in the prenatal and nonexposed groups are presented in Tables 1 and 2. Results of MANOVA with group status as the independent variable and biological mothers' age, education, socioeconomic status, parity and number of prenatal care visits as the dependent variables yielded a significant multivariate effect of group, $F(5, 109) = 4.72, p < .001, \eta_p^2 = .19$. Univariate analyses indicated that mothers who smoked cigarettes during pregnancy had significantly less education and a marginally lower SES compared to the nonsmokers. Results of MANOVA with prenatal and postnatal use of other substances as the dependent variables also yielded a significant effect of group status, $F(5, 109) = 6.2, p < .001, \eta_p^2 = .41$. Univariate analyses indicated that mothers who smoked cigarettes during pregnancy also consumed significantly more alcohol during pregnancy and smoked more cigarettes during the postnatal period than women in the nonsmoking group.

Results of MANOVA with group status as the independent variable and infant risk variables (gestational age, birth weight, head circumference, birth length) as the dependent variable yielded a significant multivariate effect of group, $F(3, 111) = 4.72, p < .001, \eta_p^2 = .09$. Infants in the prenatal exposure group weighed significantly less at birth (BW) and had a marginally lower gestational age (GA) than nonexposed infants. This MANOVA was repeated with gestational age as a covariate and birth weight, birth length and head circumference at birth as the dependent variables. Even after controlling for gestational age, infants in the prenatal exposure group weighed significantly less at birth than nonexposed infants.

Associations among Study Variables

Associations among the infant fetal growth, demographic, substance use and negative affect variables were explored using correlational analyses. We used the continuous measure of cigarette smoking during pregnancy as an indicator of the association between amount of use and other predictor and outcome variables. We also examined alcohol and marijuana use both

prenatally and postnatally as measures of other substance use. For substance exposure during pregnancy, prenatal alcohol exposure was positively associated with infant negative affect during the neonatal period. A higher average number of cigarettes smoked per week during pregnancy were also associated with increased maternal negative affect and increased infant negative affect at both time points. Marijuana use was not significantly associated with either maternal or infant negative affect. Postnatal smoking was associated with maternal negative affect at the 7 month visit. Finally, maternal education and SES were negatively associated with maternal negative affect during the neonatal period. No other demographic variables and none of the infant fetal growth variables were associated with either infant or maternal negative affect at either time point.

Group Differences in Maternal and Infant Negative Affect

A repeated measures analysis of covariance (ANCOVA) with Age (2–4 weeks, 7 months) as the within subjects factor, and group status (prenatal exposure, control) as the between subjects factor was conducted for maternal negative affect. Maternal education and SES were included as covariates because of their association with maternal negative affect during the neonatal period and average number of cigarettes smoked per week during the postnatal period was included as an additional covariate because of its association with maternal negative affect during the 7 month visit. Results indicated that maternal negative affect significantly decreased from the neonatal period to the 7 month visit, $F(1, 110) = 8.25, p < .01, \eta_p^2 = .07$, and that there was a significant main effect for group, $F(1, 110) = 9.06, p < .01, \eta_p^2 = .08$. Mothers who smoked cigarettes during pregnancy had higher levels of negative affect at both time points compared to those in the comparison group (see Table 1).

A repeated measures analysis of covariance (ANCOVA) with Age (2–4 weeks, 7 months) as the within subject factor, and group status (prenatal exposure, control) as the between subjects factor was conducted for infant negative affect. Demographic, substance exposure or infant growth variables that were correlated ($p < .10$) with infant negative affect at either time point were used as covariates. Thus, covariates included were maternal alcohol use during pregnancy and maternal smoking during the postnatal period. Results indicated that NA significantly increased from the neonatal period to 7 months of age, $F(1, 111) = 15.49, p < .001, \eta_p^2 = .14$. In addition, there was a significant main effect of group, $F(1, 111) = 3.63, p < .05, \eta_p^2 = .07$. Infants who were prenatally exposed to cigarettes had higher levels of NA than nonexposed infants.

Model Testing

The next step was to test the conceptual model using path analysis (see Figure 1). One primary purpose for this model testing was to examine concurrent and longitudinal associations between prenatal cigarette exposure, maternal negative affect, and infant negative affect, in the context of other substance use and relevant demographic variables. A baseline model was tested that included paths from prenatal cigarette exposure and maternal negative affect during the neonatal period to infant negative affect during the neonatal period. This model included paths from maternal negative affect during the neonatal period to maternal negative affect at 7 months infant age and paths from infant negative affect during the neonatal period to infant negative affect and maternal negative affect at 7 months infant age. Maternal alcohol use during pregnancy and SES were also included in this model because of their associations with negative affect. This model also included covariances among predictors, between maternal and infant NA at 7 months of age, between alcohol use during pregnancy and infant negative affect during the neonatal period, and between prenatal and postnatal smoking. This model marginally fit the data, $X^2(11) = 21.00, p = .04, CFI = .95, RMSEA = .09 (CL_{.90} = .02, .15)$. Because of this marginal fit, we decided to trim the nonsignificant paths in the conceptual model to determine if these changes resulted in an improved fit for the model. This final model fit the data well,

$X^2(17) = 23.10, p = .15, CFI = .97, RMSEA = .05 (CL_{.90} = .00, .10)$ ¹. As indicated in Figure 2, infants who were prenatally exposed to more cigarettes had more negative affect during the neonatal period and at 7 months of age and had mothers with higher levels of maternal negative affect during the neonatal period. Infant negative affect during the neonatal period predicted maternal negative affect at 7 months of age, but the directional path from maternal negative affect in the neonatal period to infant negative affect at 7 months was not significant. There was significant stability in maternal negative affect from the neonatal to the 7 month assessment, although as indicated in the ANOVA, maternal negative affect decreased over time. There was also significant stability in infant negative affect from the neonatal to the 7 month assessment.

Discussion

A growing body of research has suggested that infants who were prenatally exposed to cigarettes may have higher levels of negative affect than nonexposed infants. Furthermore, recent studies have suggested that maternal characteristics may be one pathway through which behavioral and regulatory problems develop among children prenatally exposed to cigarettes. As such, the major goal of this study was to examine the association between prenatal exposure to cigarettes, maternal negative affect and infant negative affect across the first seven months of life.

These results did indicate a direct association between prenatal exposure to cigarettes and infant negative affect such that infants who were prenatally exposed to cigarettes had higher levels of negative affect than nonexposed infants at both time points. Furthermore, this increased infant negative affect appears to be stable across the first 7 months of life suggesting that this is not a transitory effect of prenatal exposure to cigarettes. This finding lends further support to previous studies that have found an association between prenatal exposure to cigarettes and increased infant and toddler negativity (Brook, Brook & Whiteman, 2000; Jacobson et al., 1984; Johnson, Vicary, Heist & Corneal, 2001; Ramsay, Bendersky, & Lewis, 1996; Schuetze & Zeskind, 2001). This finding may have significant implications for later functioning and may be one pathway to the increased risk for oppositional behavior and conduct disorder consistently reported among cigarette-exposed children (Day, Richardson, Goldschmidt, & Cornelius, 2000; Wakschlag & Hans, 2002; Weissman, Warner, Wickramaratne & Kandel, 1999).

These data also indicated that infant negative affect during the neonatal period predicted maternal negative affect at 7 months of age. This may reflect the increased stress associated with parenting a more irritable infant and is consistent with a transactional model that views development as a process in which both the infant and caregiver mutually and continually influence each other (Sameroff, 1975). In fact, infant characteristics such as a difficult temperament are widely believed to significantly affect caregiver behavior (Bates, 1989; Rothbart, 1989; Rothbart & Ahadi, 1994; Rothbart & Posner, 1985; Thomas & Chess, 1977) and are associated with disruptions in mother-infant interactions (Campbell, 1979; Milliones, 1978; Pianta, Sroufe, & Egeland, 1989). Our findings that heightened infant negative affect during the neonatal period predicted increased maternal negative affect when the infants were 7 months old is consistent with a model that temperamental characteristics, specifically negative emotionality or irritability, directly influences parental behaviors, e.g., infant negative affect causes caregivers to respond in more negative or inappropriate ways to

¹Because maternal depression has consistently been associated with adverse developmental outcomes in the infants, this final model was rerun with depression as the measure of maternal negative affect rather than the composite variable consisting of depression and hostility. There was virtually no difference in the model fit, $X^2(17) = 24.5, p = .11, CFI = .95, RMSEA = .06 (CL_{.90} = .00, .13)$. In addition there were no substantive differences in the association between variables in the model.

infants' needs (Crockenberg, 1986). In fact, the present findings are similar to those of previous studies that, independent of substance use, have found that caregivers who perceive their infant as more difficult displayed poorer quality parenting behaviors and decreased maternal sensitivity to their infants during interactions (Clark, Hyde, Essex, & Klein, 1997; Feldman, Greenbaum, Mayes & Erlich, 1977; Spangler, 1990; Zahr, 1991). Although the present study did not assess maternal responses to infant behaviors, it is reasonable to expect that increased maternal negative affect may lead to less sensitive caregiving responses. In fact, Papousek and Papousek (1990) argue that it is the accumulation of risk factors, such as increased maternal negative affect and increased infant negative affect that are associated with nonoptimal parenting behaviors. Similar effects have also been demonstrated among other high-risk substance-exposed populations. Specifically, O'Connor and colleagues (1992) found that infants who had been prenatally exposed to alcohol displayed more negative affect at one year of age which, in turn, was associated with more negative maternal behaviors during a free play interaction.

Interestingly, we did not find that maternal negative affect during the neonatal period predicted infant negative affect at 7 months of age which is contrary to a large body of literature highlighting the influence of maternal depression on infant affect (e.g., Cohn & Tronick, 1989; Huot, Brennan, Stowe, Plotsky, & Walker, 2004; Zuckerman, Bauchner, Parker & Cabral, 1990) as early as the neonatal period (Hart, Field & Roitfarb, 1999). Our failure to find an association between maternal and infant negative affect is particularly surprising given that our measure of infant negative affect was based on maternal report alone. There has been considerable discussion regarding the possible influence of maternal negative affect, especially depression, on maternal reports of children's behavior (e.g., Briggs-Gowan, Carter, & Schwab-Stone, 1996; Chilcoat & Breslau, 1997; Fergusson, Lynskey & Horwood, 1993). Sophisticated analytic models have demonstrated support for both the hypothesis that children of mothers with a history of psychiatric problems have higher behavior problems and the hypothesis that mothers with a history of psychiatric disorder over-report negative behavior in their children (Chilcoat & Breslau, 1997). Thus, it is somewhat surprising that we did not find an association between maternal negative affect and negative infant affect. One explanation for this finding may be that infant negative affect in the neonatal period accounted for most of the variance in infant negative affect at 7 months. Most previous studies have not examined this issue using a cross-lagged panel design such as the one used in this study. Use of such designs examine if there are longitudinal associations among variables after accounting for within time correlations and autocorrelations.

Our findings of a direct pathway between prenatal exposure to cigarettes and increased negative affect suggests that this finding is not the result of over-reporting of negative affect by mothers with higher levels of negative affect. However, future studies should examine whether maternal reports of increased negative affect are associated with differences in negative affect during observational scenarios.

In addition to the potential bias due to method variance because all measures were based on maternal self-reports, an additional limitation of this study concerns the assessment of cigarette exposure in these women. The accurate assessment of prenatal substance use is always difficult. Pregnant women are often hesitant to divulge information regarding the use of substances during pregnancy and accurate recall may be difficult. Although we did assess salivary cotinine levels in the infants to confirm postnatal exposure to cigarettes for the infants, no biomarker was collected to confirm maternal reports of cigarette smoking during pregnancy. However, in spite of this limitation and the possibility that some women in the control group may have misreported their smoking, it is important to note that there were consistent group differences in negative affect.

Despite these limitations, the findings are important because they lend further support to the importance of considering maternal psychosocial functioning when examining the association between prenatal exposure to cigarettes and infant outcomes. In addition, our finding that infant affect predicts maternal affect highlights the importance of considering the development of cigarette exposed infants from a transactional perspective and suggest that infant characteristics may shape maternal behaviors during the first year of life. Future studies should explore the long-term implications of this path of influence on the mother-child relationship as well as on toddler and child outcomes.

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References

- Abel EL. Smoking during pregnancy: A review of effects on growth and development of offspring. *Human Biology* 1980;52:593–626.
- Anda RF, Williamson DF, Escobedo LG, Mast EE, Giovino GA, Remington PL. Depression and the dynamics of smoking: A national perspective. *Journal of the American Medical Association* 1990;264:1541–1545. [PubMed: 2395193]
- Bates, JE. Concepts and measures of temperament. In: Kohnstamm, GA.; Bates, JE.; Rothbart, MK., editors. *Temperament in childhood*. Chichester, New York, Brisbane: Wiley; 1989. p. 3-26.
- Breslau N, Kilbey MM, Andreski P. DSM-III-R nicotine dependence in young adults: Prevalence, correlates and associated psychiatric disorders. *Addiction* 1990;89:743–754. [PubMed: 8069175]
- Breslau N, Kilbey MM, Andreski P. Nicotine dependence, major depression: New evidence from a prospective investigation. *Archives of General Psychiatry* 1993;50:31–35. [PubMed: 8422219]
- Briggs-Gowan, Carter, & Schwab-Stone (1996).
- Brook J, Brook D, Whiteman M. The influence of maternal smoking during pregnancy on the toddler's negativity. *Archives of Pediatric & Adolescent Medicine* 2000;154:381–385.
- Brown RA, Burges ES, Sales SD, Whiteley JA, Evans DM, Miller I. Reliability and validity of a smoking timeline follow-back interview. *Psychology of Addictive Behaviors* 1998;12:101–112.
- Campbell SBG. Mother-infant interaction as a function of maternal ratings of temperament. *Child Psychiatry and Human Development* 1979;10:67–76. [PubMed: 527392]
- Chilcoat HD, Breslau N. Does psychiatric history bias mothers' reports? An application of a new analytic approach. *Journal of the American Academy of Child and Adolescent Psychiatry* 1997;36:971–979. [PubMed: 9204676]
- Clark R, Hyde JS, Essex MJ, Klein MH. Length of maternity leave and quality of mother-infant interactions. *Child Development* 1997;68:364–383. [PubMed: 9180007]
- Cohn, JF.; Campbell, SB. Influence of maternal depression on infant affect regulation. In: Cicchetti, D.; Toth, S., editors. *Developmental perspectives on depression*. 4. Rochester, NY: University of Rochester Press; 1992. p. 103-130.
- Cohn JF, Tronick EZ. Specificity of infants' response to mothers' affective behavior. *Journal of the American Academy of Child and Adolescent Psychiatry* 1989;28:242–248. [PubMed: 2925579]
- Crockenberg SB. Are temperamental differences in babies associated with predictable differences in care giving? *New Directions in Child Development* 1986;31:53–73.
- Day N, Richardson G, Goldschmidt L, Cornelius M. Prenatal tobacco exposure and preschooler behavior. *Journal of Behavioral and Developmental Pediatrics* 2000;21:180–188.
- Del Carmen R, Pedersen FA, Huffman LC, Bryan YE. Dyadic distress management predicts subsequent security of attachment. *Infant Behavior and Development* 1993;16:131–147.
- Derogatis, LR. *The Brief Symptom Inventory (BSI) administration, scoring, and procedures manual*. Minneapolis, MN: National Computer Systems; 1993.

- Eiden RD, Chavez F, Leonard KE. Parent-infant interactions in alcoholic and control families. *Development and Psychopathology* 1999;11:745–762. [PubMed: 10624724]
- Feldman R, Greenbaum CW, Mayes LC, Erlich SH. Change in mother-infant interactive behavior: Relations to change in the mother, the infant, and the social context. *Infant Behavior & Development* 1977;20:151–163.
- Fergusson DM, Goodwin RD, Horwood LJ. Major depression and cigarette smoking: Results of a 21-year longitudinal study. *Psychological Medicine* 2003;33:1357–1367. [PubMed: 14672244]
- Fergusson DM, Horwood LJ, Lynskey MT. Maternal smoking before and after pregnancy: Effects on behavioral outcomes in middle childhood. *Pediatrics* 1993;92:815–822. [PubMed: 8233743]
- Field TM. Interventions in early infancy. *Infant Mental Health Journal* 1992;13:329–333.
- Franco P, Groswasser J, Hassid S, Lanquart JP, Scaillet S, Kahn A. Prenatal exposure to cigarette smoking is associated with a decrease in arousal in infants. *Journal of Pediatrics* 1999;135:34–38. [PubMed: 10393601]
- Franco P, Chabanski S, Szliwowski H, Dramaix M, Kahn A. Influence of maternal smoking on autonomic nervous system in healthy infants. *Pediatric Research* 2000;47:215–220. [PubMed: 10674349]
- Fried PA, Makin JE. Neonatal behavioral correlates of prenatal exposure to marihuana, cigarettes, and alcohol in a low risk population. *Neurobehavioral Toxicology and Teratology* 1987;9:1–7.
- Fried PA, O'Connell CM. A comparison of the effects of prenatal exposure to tobacco, alcohol, cannabis, and caffeine on birth size and subsequent growth. *Neurobehavioral Toxicology and Teratology* 1987;9:79–85.
- Fried, PA.; Oxorn, H. *Smoking for two: Cigarettes and pregnancy*. New York: Free Press; 1980.
- Gartstein MA, Rothbart MK. Studying infant temperament via the Revised Infant Behavior Questionnaire. *Infant Behavior and Development* 2003;26:64–86.
- Greenberg RA, Bauman KE, Stecher VJ, Keyes LL, Glover LH, Haley NJ, Stedman HC, Loda FD. Passive smoking during the first year of life. *American Journal of Public Health* 1991;81:850–853. [PubMed: 2053659]
- Hans SL, Bernstein VJ, Henson LG. The role of psychopathology in the parenting of drug-dependent women. *Development & Psychopathology* 1999;11:957–977. [PubMed: 10624734]
- Hart S, Field T, Roitfarb M. Depressed mothers' assessments of their neonates' behaviors. *Infant Mental Health Journal* 1999;20:200–210.
- Hollingshead, AB. Four Factor Index of Social Status. 1975. Unpublished manuscript
- Houston BK, Vavak CR. Cynical hostility: Developmental factors, psychosocial correlates, and health behaviors. *Health Psychology* 1991;10:9–17. [PubMed: 2026134]
- Howard J, Beckwith L, Espinosa M, Tyler R. Development of infants born to cocaine-abusing women: Biologic/maternal influences. *Neurotoxicology and Teratology* 1995;17:403–411. [PubMed: 7565486]
- Huot RL, Brennan PA, Stowe ZN, Plotsky PM, Walker EF. Negative affect in offspring of depressed mothers is predicted by infant cortisol levels at 6 months and maternal depression during pregnancy, but not postpartum. *Annals of the New York Academy of Sciences* 2004;1032:234–236. [PubMed: 15677418]
- Jacobson SW, Fein GG, Jacobson JL, Schwartz PM, Dowler JK. Neonatal correlates of prenatal exposure to smoking, caffeine, and alcohol. *Infant Behavior and Development* 1984;7:253–265.
- Jameson PB, Gelfand D, Kuczar E, Teti DM. Mother-toddler interaction patterns associated with maternal depression. *Developmental Psychopathology* 1997;9:557–590.
- Jarvis MJ. Application of biochemical intake markers to passive smoking measurement and risk estimation. *Mutation Research* 1989;222:101–110. [PubMed: 2645516]
- Johnson CH, Vicary JR, Heist CL, Corneal DA. Moderate alcohol and tobacco use during pregnancy and child behavior outcomes. *Journal of Primary Prevention* 2001;21:367–379.
- Kovacs M, Devline B. Internalizing disorders in childhood. *Journal of Child Psychology and Psychiatry* 1998;39:47–63. [PubMed: 9534086]
- Lipkus IM, Barefoot JC, Williams RB, Siegler IC. Personality measures as predictors of smoking initiation and cessation in the UNC Alumni Heart Study. *Health Psychology* 1994;13:149–155. [PubMed: 8020458]

- Miller TQ, Smith T, Turner C, Guijarro M, Hallet A. A meta-analytic review of research on hostility and physical health. *Psychological Bulletin* 1996;119:322–348. [PubMed: 8851276]
- Milliones J. Relationship between perceived child temperament and maternal behaviors. *Child Development* 1978;49:1255–1257.
- O'Connor MJ, Sigman M, Kasari C. Attachment behavior of infants exposed prenatally to alcohol: Mediating effects of infant affect and mother-infant interaction. *Development and Psychopathology* 1992;4:243–256.
- Olsen J, Pereira A, Olsen SF. Does maternal tobacco smoking modify the effect of alcohol on fetal growth? *American Journal of Public Health* 1991;81:69–73. [PubMed: 1983919]
- Papousek M, Papousek H. Excessive infant crying and intuitive parental care: Buffering support and its failures in parent-infant interaction. *Early Child Development and Care* 1990;65:117–126.
- Pianta RC, Sroufe LA, Egeland B. Continuity and discontinuity in maternal sensitivity at 6, 24, and 42 months in a high risk sample. *Child Development* 1989;60:481–487. [PubMed: 2924663]
- Picone TA, Allen LH, Olsen PN, Ferris ME. Pregnancy outcome in North American women. II. Effects of diet, cigarette smoking, stress, and weight gain on placentas, and on neonatal physical and behavioral characteristics. *American Journal of Clinical Nutrition* 1982;36:1214–1224. [PubMed: 7148740]
- Pritchard CW. Depression and smoking in pregnancy in Scotland. *Journal of Epidemiology and Community Health* 1994;48:377–382. [PubMed: 7964337]
- Ramsay DS, Bendersky MI, Lewis M. Effect of prenatal alcohol and cigarette exposure on 2- and 6-month-old infants' adrenocortical reactivity to stress. *Journal of Pediatric Psychology* 1996;21:833–840. [PubMed: 8990727]
- Rodriquez A, Bohlin G, Lindmark G. Psychosocial predictors of smoking and exercise during pregnancy. *Journal of Reproductive and Infant Psychology* 2000;18:203–223.
- Rothbart, MK. Temperament and development. In: Kohnstamm, JA.; Bates, JE.; Rothbart, MK., editors. *Temperament in childhood*. Chichester, New York, Brisbane: Wiley; 1989. p. 187-248.
- Rothbart MK, Ahadi SA. Temperament and the development of personality. *Journal of Abnormal Psychology* 1994;103:55–66. [PubMed: 8040481]
- Rothbart, MK.; Posner, MI. Temperament and the development of self-regulation. In: Hartlage, LC.; Telzrow, LF., editors. *The neuropsychology of individual differences: A developmental perspective*. New York, London: Plenum Press; 1985. p. 93-123.
- Sameroff AJ. Early influences on development: Fact or fancy? *Merrill Palmer Quarterly* 1975;20:275–301.
- Saxton DW. The behavior of infants who mothers smoke in pregnancy. *Early Human Development* 1978;2:363–369. [PubMed: 750194]
- Schuetze P, Eiden RD. The Association Between Maternal Cocaine Use During Pregnancy and Physiological Regulation in One-Month Old Infants: An Examination of Possible Mediators and Moderators. *The Journal of Pediatric Psychology*. 2006
- Schuetze P, Zeskind PS. Relation between prenatal exposure to cigarettes and behavioral and physiological measures of autonomic regulation in neonates. *Infancy* 2001;2:371–383.
- Siegler IC, Person BL, Barefoot JC, Williams RB. Hostility during late adolescence predicts coronary risk factors at mid-life. *American Journal of Epidemiology* 1992;136:146–154. [PubMed: 1415138]
- Sobell, LC.; Sobell, MB. *Alcohol Timeline Followback Users' Manual*. Toronto, Canada: Addiction Research Foundation; 1995.
- Spangler G. Mother, child, and situational correlates of toddlers' social competence. *Infant Behavior and Development* 1990;13:405 – 419.
- Streissguth AP, Barr HM, Martin DC. Maternal alcohol use and neonatal habituation assessed with the Brazelton scale. *Child Development* 1983;54:1109–1118. [PubMed: 6354622]
- Thomas, A.; Chess, S. *Temperament and development*. New York: Brunner/Mazel; 1977.
- Wakschlag L, Hans SL. Maternal smoking during pregnancy and conduct problems in high-risk youth: A developmental framework. *Development and Psychopathology* 2002;14:351–369. [PubMed: 12030696]

- Weinberg MK, Tronick EZ. The impact of maternal psychiatric illness on infant development. *Journal of Clinical Psychiatry* 1998;59:53–61. [PubMed: 9559760]
- Weissman MM, Warner V, Wickramaratne PJ, Kandel DB. Maternal smoking during pregnancy and psychopathology in offspring followed to adulthood. *Journal of the American Academy of Child and Adolescent Psychiatry* 1999;38:892–899. [PubMed: 10405508]
- Whiteman MC, Fowkes FGR, Deary IJ, Lee AJ. Hostility, cigarette smoking and alcohol consumption in the general population. *Social Science Medicine* 1997;44:1089–1096. [PubMed: 9131733]
- Zahr L. Correlates of mother-infant interaction in premature infants from low socioeconomic backgrounds. *Pediatric Nursing* 1991;17:259–264. [PubMed: 2062586]
- Zhu S, Valbo A. Depression and smoking during pregnancy. *Addictive Behaviors* 2002;27:649–658. [PubMed: 12188598]
- Zuckerman BS, Bauchner H, Parker S, Cabral H. Maternal depressive symptoms during pregnancy and newborn irritability. *Developmental and Behavioral Pediatrics* 1990;11:190–194.

Figure 1.
Conceptual Model.

Figure 2.
Final Model.

Table 1

Group Differences for Maternal Characteristics and Substance Use

Variables	Non-Smokers			Smokers			t
	M	n = 46	SD	M	n = 69	SD	
Demographic Characteristics							
Age (years)	28.46		5.51	27.38		7.35	.84
Education (years completed)	12.46		1.82	11.18		1.36	4.27***
SES (Hollingshead two-factor)	3.26		1.79	2.68		1.35	1.98 ⁺
Prenatal Care (# of visits)	13.91		6.93	12.09		7.09	1.33
Parity	3.07		1.48	3.35		1.82	-.99
% Single	72%			64%			$\chi^2 = 4.31$
Substance Use During Pregnancy							
Average # of cigarettes/week	0		0	46.78		39.76	5.97***
Average # of standard drinks/week	.03		.07	2.23		6.13	-2.4 *
Average number of drinks consumed/drinking day	.64		1.35	1.21		3.08	-2.35 *
Average # of joints/week	2.82		13.48	2.30		10.07	.23
Postnatal Substance Use							
Average # of cigarettes/week	5.76		73.64	50.37		49.49	-5.6***
Average # of standard drinks/week	.35		.64	1.20		4.44	-1.23
Average # joints/week	.76		4.62	3.02		9.31	-1.46
Maternal Negative Affect							
Neonatal Visit	.08		.12	.26		.36	-3.15**
Postnatal Visit	.04		.07	.17		.22	-3.75***

⁺ Note: $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$.

Table 2

Group Differences for Infant Characteristics

Variables	Nonexposed			Exposed			t
	M	SD	n = 46	M	SD	n = 69	
Sex (% male)	46%			55%			$\chi^2 = 2.58$
Fetal Growth							
Gestational age (weeks)	39.41	1.26		38.87	1.44		1.98*
Birth Weight (grams)	3406.71	543.05		3161.15	577.18		2.11*
Birth Length (cm)	49.55	4.58		48.69	5.12		.83
Birth Head Circumference (cm)	33.78	1.38		34.03	1.61		-.77
Apgar 1	8.62	1.17		8.43	1.77		1.07
Apgar 2	8.95	.22		8.85	.61		.32
Neonatal Variables							
Age at Neonatal Visit (weeks)	3.15	.74		3.07	.86		.48
Weight at Neonatal Visit (grams)	4541.78	730.09		3968.21	775.60		2.39*
Length at Neonatal Visit (cm)	52.15	4.70		51.21	4.05		.06
Head circumference-Neonatal Visit (cm)	36.78	1.97		36.48	1.91		.20
Infant Negative Affect	3.45	1.09		4.09	1.20		-3.03**
Postnatal Variables							
Age at 7 Month Visit	32.31	2.95		32.46	3.32		-.25
Weight at 7 Month Visit (grams)	9250.54	2504.02		8215.48	1059.02		-1.27
Length at 7 Month Visit (cm)	69.82	7.38		68.19	4.00		.84
Head circumference-7 Month Visit (cm)	44.56	2.35		43.91	1.81		-.30
Cotinine Levels	5.57	31.35		69.94	239.39		-2.84**
Infant Negative Affect	2.99	.78		3.58	1.34		-2.19*

* Note: $p < .05$

** $p < .01$

*** $p < .001$.

Table 3

Associations among Study Variables in Conceptual Model

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Maternal Education (years)													
2. SES	.49***												
3. Gestational Age (weeks)	.04	.18											
4. Birth Weight (grams)	.03	.19	.54***										
5. Average # cigarettes/week during pregnancy	-.30**	-.14	-.25*	-.26**									
6. Average # of standard drinks/week during pregnancy	-.31***	-.06	-.01	.12	.33**								
7. Average # of joints/week during pregnancy	.02	.04	.09	-.17	-.08	-.06							
8. Average # cigarettes/week - postnatal	-.25**	-.06	-.31**	-.15	.63***	.22*	-.05						
9. Average # of standard drinks/week - postnatal	.05	.14	.08	.04	.00	.21*	.01	.17					
10. Average # of joints/week - postnatal	-.01	.16	.02	-.07	-.07	-.07	.36***	.12	.07				
11. Maternal Negative Affect - neonatal	-.31***	-.24**	-.06	-.04	.46***	.24*	-.08	.17	.11	-.16			
12. Maternal Negative Affect - 7 months	-.15	-.08	-.17	-.09	.20*	.11	-.03	.21*	.13	.00	.47***		
13. Infant Negative Affect - neonatal	-.16	.07	-.10	.09	.42***	.34***	-.15	.23*	.01	-.01	.21*	.35***	
14. Infant Negative Affect - 7 months	-.13	-.18	-.12	-.08	.23*	.11	-.16	.21*	.13	.06	.13	.20*	.53***

* Note: $p < .05$

**

 $p < .01$ *** $p < .001$