Smoking During Pregnancy: Association with Childhood Temperament, Behavior, and Academic Performance

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Objective This study investigated the association between maternal smoking during pregnancy and ratings of offspring's temperament, behavior, and academic performance at various developmental periods in childhood. **Methods** Multivariate analyses of a birth cohort examined the outcomes for children on measures of temperament, behavior, and academic performance in infancy (6 months), at age 5, and at age 12. **Results** When controlling for maternal psychiatric hospitalization, psychological distress during pregnancy, hospitalization for accidents, socioeconomic status, age, and symptoms of upper respiratory infection and nausea, a range of associations between maternal smoking and child outcomes were observed at different ages studied. **Conclusion** Despite widespread warning regarding smoking cessation during pregnancy, the literature base on the longer-term effects beyond the neonatal and infant period is less available. This is one of the first studies to investigate the association between maternal smoking during pregnancy and child outcomes at several stages of development. The results provide evidence for the lasting effects of smoking during pregnancy on the development of the child.

Key words behavior; child outcomes; pregnancy; smoking; temperament.

The relationship between cigarette smoking and the health and behavior of the smoker has been the subject of intense interest for decades (American Academy of Pediatrics Committee on Environmental Health, 1997; Centers for Disease Control, 1993; Doll, 1995; Fielding, 1987; Slama, 1995). However, it was not until the 1980s that reports of the harmful effects of cigarette smoking during pregnancy began to proliferate. It has now been firmly established that pregnancies among women who smoke are marked by increased risk for a number of adverse prenatal and perinatal outcomes including spontaneous abortion, placenta previa, and obstetric complications (Adams, 2003; Dombrowski, Martin, & Huttunen, 2005; Magee, Hattis, & Kivel, 2004; Ojima, Uehara, Watanabe, Tajimi, Oki, & Nakamura, 2004).

Additional research provides evidence that women who smoke during pregnancy have babies who are born prematurely with greater frequency and with lower birth weights than women who do not smoke (Floyd, Rimer, Giovino, Mullen, & Sullivan, 1993; Ojima et al., 2004). It is generally understood that smoking during pregnancy has deleterious effects on the developing fetus, although the quantity of research on smoking during pregnancy is far less than that on alcohol and other drugs such as cocaine (Behnke & Eyler, 1993; Nugent, Lester, Greene, Wieczorek-Deering, & O'Mahony, 1996). The most firmly established link between maternal smoking during pregnancy and child outcomes is the association with low birth weight. Since the 1950s, epidemiological studies have consistently shown that mothers who smoke during pregnancy have children born 150–250 g lighter than nonsmoking controls (Floyd et al., 1993; Hardy & Mellitis, 1972; Magee et al., 2004). Furthermore, smoking doubles the risk of having

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an infant born weighing less than 2,500 g (United States Department of Health and Human Services, 1980). These lower birth weights are observable at all gestational ages and are thought to result from intrauterine growth retardation caused by gestational smoke exposure (Floyd et al., 1993). Recent research also has found an association in infancy with increased colic (Shenassa & Brown, 2004), delayed gross and fine motor coordination (Fried, Watkinson, Dillon, & Dulberg, 1987), increased activity level (Batstra, Hadders-Algra, & Neeleman, 2003), and Sudden Infant Death Syndrome (SIDS) (Sundell, 2004).

The literature on the longer-term effects beyond the fetal, neonatal, and infant period is less well developed. There is some evidence that children born to mothers who smoked during pregnancy are at higher risk of cognitive, academic, and auditory processing deficits (Bauman, Flewelling, & LaPrelle, 1991; Butler & Goldstein, 1973; Fogelman & Manor, 1988; Fried & Watkinson, 1988; Fried & Watkinson, 1990; Fried, Watkinson, & Gray, 2003; McCartney & Fried, 1993; McCartney, Fried, & Watkinson, 1994; Olds, Henderson, & Tatalbaum, 1994; Sexton, Fox, & Hebel, 1990). There also is evidence that children born to mothers who smoked during pregnancy are at higher risk for behavioral and psychological problems such as hyperactive behavior, conduct disorder, and antisocial disorder (Denson, Nanson, & McWatters, 1975; Fergusson, Horwood, & Lynskey, 1993; Fergusson, Woodward, & Horwood, 1998; Fried, Watkinson, & Gray, 1992; Kristjansson, Fried, & Watkinson, 1989; Milberger, Bieberman, Farone, Chen, & Jones, 1996; Naeye & Peters, 1984; Rantakallio & Koiranen, 1987; Sexton et al., 1990; Silberg, Parr, Neale, Rutter, Angold, & Eaves, 2003; Streissguth et al., 1984; Wakschlag et al., 1997). Of these behaviors, the association with increased activity level has been the most frequently studied (Denson et al., 1975; Fergusson et al., 1993; Fried et al., 1992; Milberger et al., 1996; Naeye & Peters, 1984; Streissguth et al., 1984). In addition, other researchers have examined the relationship with children's externalizing problems. Fergusson et al. (1993) and Fergusson et al. (1998) report persistent dose–response relationships with mothers who smoked the greatest amount during pregnancy having children with significantly higher behavior problems than those who did not smoke. Wakschlag et al. (1997) also reported an association between maternal smoking during pregnancy and conduct disorder among boys. However, recent studies by Maughan et al. (2004) and Silberg et al. (2003) suggest that the association with conduct disorder may be specious. These researchers indicate that the association may be better accounted for by such genetic and environmental factors as biological parents' own antisocial behavior, maternal depression, and exposure to a disadvantaged family environment. With limited exception, very few studies have examined outcomes beyond infancy. Even fewer have investigated outcomes at more than one developmental period.

Attempts to understand the effects of cigarette smoke on child development are hampered by at least two sets of problems. First, researchers studying the teratogenic effects of cigarette smoke at the physiological level are faced with a substance that is very complex. A cigarette is estimated to contain 3,000–4,000 compounds and the impact of only a small subset of these compounds has been researched (Hoffmann, Djordjevic, & Hoffmann, 2003). It is now recognized that cigarettes contain many chemical compounds and that a significant proportion of these compounds cross the placental barrier (Jones et al., 1989). Some of the chemicals are known to have toxic effects if consumed in sufficient amounts including lead, cadmium, carbon monoxide, arsenic, cyanide, and nicotine (Stevens, Becker, Krumpos, Lanz, & Tolan, 1988).

Second, researchers studying the long-term effect of cigarette smoking have found that cigarette smoking does not have a singular effect, but is associated with a variety of social and psychological characteristics that put parents and their children at increased risk of some of the same behaviors that are attributed to exposure to cigarette smoke (Graham, 1995; Isohanni et al., 1995). For instance, mothers who smoke during pregnancy are often more impulsive, experience greater psychological distress, and are younger than their nonsmoking pregnant counterparts (Adams, 2003; Cherry & Kiernan, 1976; Rantakallio, 1979). As a result of these factors, experts still disagree about the effects of exposure to cigarette smoking on the development of the child. Part of that reason may be related to the fact that very few studies had the capacity to investigate the adverse impact at more than one developmental period while controlling for at least some of the myriad of confounding social and psychological characteristics noted above.

The primary purpose of this article is to report the results of a research effort designed to augment the understanding of long-term effects of maternal smoking on child temperament, behavior, and academic outcomes. This study investigates the association between maternal smoking during pregnancy and temperamental, behavioral, and educational outcomes in offspring at various stages of development: infancy, age 5, and age 12.

Materials and Method

Participants

Participant data were obtained from the Helsinki Longitudinal Project, a prospective study of the antecedents and sequelae of early childhood temperament. The total sample consisted of all children (n = 6,401) born between July 1, 1975, and June 30, 1976, in Helsinki, Finland, and the adjacent suburbs of Vantaa and Espo. The cohort size was adjusted by eliminating data for one twin of each twin pair. This adjustment resulted in a final cohort of 6,388 children.

Expectant mothers at each prenatal visit to a government prenatal clinic were asked to complete a questionnaire describing their somatic and psychological health during the past month of pregnancy. Mothers were informed that participation was voluntary and that data were being conducted for research purposes. Temperament data for the infant and preschool periods were collected at well-baby clinics. Visits at approximately 6 months and 5 years were part of the regularly scheduled pattern of visits of all mothers in the region. Assisted by attending nurses, mothers voluntarily completed questionnaires on their children's temperament at 6 months and 5 years. Data for the school-age period (age 12) consisted of information from school records regarding academic performance and ratings of child temperament and behavior problems obtained from the teachers.

About 55% of the mothers chose to participate in the pregnancy questionnaire portion of the study. The data available at the three postnatal assessment waves depended on parental agreement to participate at that time. This sampling outcome mandated that the study be conceptualized as three related outcome studies as opposed to a longitudinal study in which those students with complete data were analyzed across the assessment waves (see Table I for sampling details). This sampling outcome raises issues of ascertainment bias. The three samples were compared to each other and to the total sample on an extensive array of demographic variables, maternal mental health characteristics, smoking behavior, symptom patterns during pregnancy, and childhood temperament scores (Table II). These analyses revealed few significant differences with two exceptions. Children for whom infant temperament data were available were born approximately one month earlier during the cohort year and contained approximately 9% more firstborn children than the total cohort. It is likely that these differences reflect initial eagerness on the part of the clinic staff and first-time mothers to participate in the study. The children assessed at age 5 and age 12 were very similar to the children assessed in infancy. Taken together, these analyses support the assertion that there was little ascertainment bias.

Material

Pregnancy Questionnaire

At each prenatal visit, expectant mothers completed a 15-item questionnaire that asked about their somatic and mental health symptoms during the past month. The questionnaire included nine symptoms of somatic health: Four of these were incorporated into the original questionnaire because they were indicative of upper respiratory infection (fever, cough, rhinitis, and sore throat), and five were incorporated as more general symptoms of illness (nausea diarrhea, fatigue, sleep problems, muscle pain, and headache). At each prenatal visit, the expectant mother indicated whether the symptom occurred (yes or no) during the past month, and how long the symptoms lasted (1–3 days, 3–7 days, and 7 days). In the current study, only the occurrence of the symptoms was coded. For purposes of this study, we aggregated the symptoms of fever, cough, diarrhea, nausea, and headache into a single variable. These were the

Table I. Number of Children in Each Sample

Sample	*n*	Percent of cohort	Percent with maternal pregnancy data[a]
Cohort	6,388	100	
With pregnancy data	3,489	54.5	
Infant (6 months) sample	2,001	31.2	
With pregnancy data	965	15.1	48.2
Preschool (age 5) sample	1,097	17.2	
With pregnancy data	676	10.5	61.6
School-age (age 12) sample	1,289	20.2	
With pregnancy data	381–420	~6.6	~32.5

[a]Percent of the subsample for whom maternal pregnancy data were also available.

Table II. Comparison of Entire Cohort and that Portion of the Cohort for whom Mothers Completed Symptom Questionnaires During Pregnancy

Characteristic	Cohort (*SD*)	Subsample with pregnancy data (*SD*)
Gender	52.7% male	53.0% male
Maternal parity	56.7% primipara	57.7% primipara
	43.3% multipara	42.3% multipara
Mean maternal age	27.26 years (4.51)	27.33 (4.30)
Mean paternal age	29.28 years (5.33)	29.17 (4.92)
Mean number of older siblings	0.74 (0.92)	0.68 (0.84)
Mean socioeconomic status	2.77 (1.41)	2.78 (1.39)

variables on which the frequency distribution was greatest [the other variables had very low frequencies of occurrence or might have been a symptom of pregnancy itself (muscle pain)]. Thus, if an expectant mother experienced four of these symptoms during the past month, they obtained a score of "4" for that assessment. The questionnaire also contained six items related to maternal psychological distress during pregnancy. The questions were: Have you been mentally or "psychologically" distressed (e.g., worried)? Have you been depressed? Have you been nervous or restless? Have you experienced anxiety because of receiving bad news? Has your mood been changing (i.e., lots of ups and downs)? Have you noticed that your mood is different from your mood before pregnancy? All questions had a three level response format (no, some, and remarkable) indicating severity. An initial attempt was made to create separate scales from these six items. However, all questions were moderately to highly correlated (.58 to .86), and all loaded on a single factor in an exploratory factor analysis, so they were aggregated into a single measure. The assessment of smoking behavior also was obtained from this questionnaire. Mothers were asked to indicate if they smoked prior to this pregnancy and if so for how many years. In another question, they were asked to indicate how much they smoked per day on average for the past month. Response options were none, one to five cigarettes per day, and six or more cigarettes per day.

Mothers who responded to the questionnaires completed 1 to 16 different questionnaires. In cases in which the mother completed only one questionnaire, that became the data analyzed for the trimester in which the data were obtained. If more than one questionnaire were obtained for a given trimester, the questionnaire that indicated the highest level of symptoms (distress; symptoms of infection) for that trimester was the one used. This was done on the grounds that a spike in symptoms of upper respiratory infection during one month indicated that an infection occurred during that trimester. Also, in cases of inconsistency in cigarette smoking during a trimester, the highest number was used.

Hospitalization Data

Two additional variables were incorporated into our analysis—maternal hospitalization for psychiatric outcomes and maternal hospitalization for accidents. Mothers were categorized into either a psychiatrically hospitalized group or a nonpsychiatrically hospitalized group according to whether the mother had been admitted at any point in her life to a hospital for psychiatric conditions based on International Classification of Disease psychiatric diagnoses. Maternal hospitalization for accidents was coded in the same fashion as psychiatric hospitalization. Maternal hospitalizations for accidents was conceived as an indicator, albeit a very indirect and rough one, of impulsivity or the tendency to engage in high-risk behavior.

Since mothers who smoke during pregnancy are rated as more impulsive, and impulsivity in biological parents is linked to impulsivity in offspring, hospitalization for accidents was controlled for within this study. Hospitalization data were ascertained through a review and coding of Finnish hospitalization records.

Infant Temperament Questionnaire

Mothers rated their infants on a 71-item version of the Carey Infant Temperament Questionnaire (Carey, 1970) when their children were 6 months of age. Based on an exploratory factor analysis using maximum likelihood factor extraction methods (Martin, Wisenbaker, Baker, & Huttunen, 1997), five infant temperament factors were derived and used in this analysis: biological irregularity, threshold, distress to novelty, activity/intensity, and fussy/demanding.

Preschool Temperament Questionnaire

Mothers also rated their preschoolers on a 72-item version of the Thomas, Chess, and Korn Parent Temperament Questionnaire (Thomas & Chess, 1977) when their children were 5 years of age. Based on an exploratory factor analysis, eight preschool temperament factors were derived (Martin et al., 1997) and used in the analysis: negative emotionality; inhibition; negative persistence; biological irregularity; emotional intensity; threshold; activity level; and unhappy/nonadaptive.

School-Age Temperament Questionnaire

Teachers rated the 12-year-old children on the Keogh Teacher Temperament Survey. The following variables contained on this survey were used in the analysis: task orientation; task persistence; inhibition; and emotional reactivity.

School-Age Behavior Problems Questionnaire

Teachers also rated the 12-year-old children on the Lambert, Hartsough-Wrede Adjustment Difficulty Scale, a measure of behavior problems. This scale was an adaptation by Wrede for the Finnish population of the original Lambert-Hartsough Adjustment Difficulty Scale (Lambert & Hartsough, 1973). Item content deals with learning, immaturity, and social–emotional problems. The following six variables were used in this scale: learning problems, distractibility, aggression, immaturity, negative emotionality, and social withdrawal.

Student Grade Reports

During the 1980s, Finnish elementary schools graded children on a 10-point scale, with a 10 indicating exceptional performance. One summative index of academic performance (e.g., Mean Academic Grade) was used in this study, which was the mean grade for all subjects excluding physical education, art, music, practical skills, and behavior. Children were also rated on their carefulness and precision in completing assignments.

Methods

In order to determine whether maternal smoking is related to childhood temperament, behavior, and academic performance, a series of Multivariate Analysis of Covariances (MANCOVAs) were calculated in which one independent variable was the smoking behavior of the mother during pregnancy (none, one to five cigarettes per day, and six or more per day), and the other independent variable was the gender of the child. Control variables included socioeconomic status, maternal age, psychological distress during pregnancy, maternal prior psychiatric hospitalization, maternal hospitalization for accidents, and symptoms of upper respiratory infection and nausea during pregnancy.

Results

Infancy

During infancy five temperamental characteristics were assessed: distress to novelty, biological irregularity, activity level/emotional intensity, stimulation threshold, and the tendency to engage in fussy and demanding behavior. A MANCOVA was calculated across all temperament (i.e., dependent) variables. The independent variables were maternal smoking during pregnancy (three levels: none, one-five cigarettes per day, and six or more per day) and child gender. Control variables included socioeconomic status, maternal age, psychological distress during pregnancy, maternal prior psychiatric hospitalization, maternal hospitalization for accidents, and aggregated symptoms of fever, cough, diarrhea, nausea, and headache during pregnancy. There was a significant MANCOVA (Wilks lambda = 0955; $F(78/5,536) = 1.36$; $p < .05$). Follow-up analysis of covariances (ANCOVAs) revealed a significant maternal smoking effect for distress to novelty, biological irregularity, and a marginal, but nonsignificant, effect for activity/intensity (Table III). Contrary to expectation,

Table III. Association of Maternal Smoking During Pregnancy with Infant and Preschool Temperament

	Maternal smoking during pregnancy				
	None	1–5 per day	6 plus per day	*f*	*p*
Infant (age 6 months) temperament characteristics[a]					
Distress to novelty					
M	.09	–.06	–.10	2.99	<.05
SD	.98	1.00	1.04		
Biological irregularity					
M	.03	–.24	–.10	3.66	<.05
SD	1.01	0.94	0.97		
Activity/intensity					
M	–.10	–.02	.10	2.36	<.10
SD	1.00	1.00	1.04		
Preschool (age 5) temperament characteristics[b]					
Threshold					
M	.06	.06	–.18	2.77	<.10
SD	.89	1.05	1.01		
Activity level					
M	–.11	.11	.23	5.68	<.01
SD	1.02	.91	1.00		
Nonadaptive/unhappy					
M	.03	–.18	–.16	2.72	<.10
SD	1.02	1.06	.92		
Negative emotionality					
M	.06	–.14	–.18	3.13	<.05
SD	1.03	1.10	.98		

Means are in *z*-score form and have been adjusted for covariates.

[a]Sample size: none, 694; 1–6 cigarettes per day, 104; 6 or more cigarettes per day, 167.

[b]Sample size: none, 458; 1–6 cigarettes per day, 87; 6 or more cigarettes per day, 131.

mothers who smoked heavily rated their infants as less distressed by novelty and as having less biological irregularity. The effect size was in the .20 to .27 range. There were no maternal smoking by child–gender interactions.

Preschool Period

At age 5, eight temperamental characteristics were assessed: negative emotionality, inhibition, activity level, task persistence (scored in nonpersistent direction), biological irregularity, emotional intensity, stimulation threshold, the tendency to be slow to adapt to change and mood. A MANCOVA was calculated in which the categorical variables were maternal smoking (three levels) and child gender. Controls were the same as the analysis for infancy. A significant MANCOVA was obtained (Wilks lambda = 0.969, $F(8, 716) = 2.91$, $p < .005$). No significant maternal smoking by child–gender interaction was obtained. Follow-up ANCOVAs revealed significant main effects for maternal smoking for two preschool characteristics—activity level, negative emotionality—and marginal, but nonsignificant, effects for two characteristics—stimulation threshold and nonadaptive/unhappy (Table III). In the case of activity level, the effect of smoking was in the expected direction (smoking was associated with higher activity level). However, mothers who smoked described their preschool children as more adaptive and happy and as exhibiting less negative emotionality and lower stimulation threshold. The effect size was in the .21 to .33 standard deviation unit range.

School Age (Age 12)

A maternal smoking (three levels) and by child gender MANCOVA was performed across all six of the behavior problems rated by teachers. Controls were the same ones used for analyses at the infant and preschool period. A significant main effect for smoking was obtained (Wilks lambda = 0.951; $F(5, 538) = 3.59$, $p < .01$), but no significant smoking by child–gender interaction was obtained. Follow-up ANCOVAS revealed that there were significant effects for three of the six behavior problems. Children of mothers who smoked during pregnancy were rated by teachers as being more distractible, expressing more negative emotionality, and displaying greater immaturity (Table IV). There were marginal, but nonsignificant effects for aggression and learning problems. There was no effect for social withdrawal. In all cases, light smokers exhibited intermediate levels of the problem between those reported for nonsmokers and for heavy smokers. Effect sizes were in the moderate range, with most above .25 standard deviation units.

Teachers also completed the Keogh Teacher Temperament Survey when the children were 12 years of age. Four characteristics were assessed: task persistence, emotional reactivity, task orientation, and social inhibition. A similar analysis was done which resulted in a significant effect for maternal smoking (Wilks lambda = 0.973, $F(1, 381) = 3.58$, $p < .05$). Follow-up ANCOVAS for each temperament trait revealed that emotional reactivity and task orientation were associated with maternal smoking (Table IV). Mothers who smoked during pregnancy had children whose teachers rated them as less task oriented in school and as more emotionally reactive to stresses and provocations in the classroom. Social inhibition and task persistence were not related to maternal smoking. Effects sizes for the two significant associations were in the moderate range.

The preceding results would logically lead to an expectation of lower achievement levels of children whose mothers smoked during pregnancy. The data available allowed for the use of two summary grades. One was an end-of-year grade for the carefulness and precision with which the child did their work. The other is the numerical mean of all grades given for the year. The latter grade included course work in science, language arts, and mathematics. A MANCOVA was calculated across these two grades in a manner similar to the previous analyses. There was a significant association for maternal smoking (Wilks lambda = 0.974, $F(2, 242) = 3.29$, $p < .05$). Follow-up ANCOVAS demonstrated that the association between smoking and both the carefulness/precision grade and the overall academic grade were significant (Table IV). In both cases, children of mothers who were smokers during pregnancy performed significantly more poorly than children of nonsmoking mothers. The effect size was in the .30 to .40 standard deviation unit range.

Discussion

The results of this study suggest that the smoking behavior of mothers during pregnancy is associated with childhood temperament, behavior, and academic performance. In particular, infants of mothers who smoked during pregnancy are less distressed by novel stimulation and less biologically irregular. As preschool children, they are more active, but, contrary to expectation, more adaptive/happy (nonsignificant) and lower in negative emotionality. At age 12, these children are more distractible, higher in negative emotionality, less mature, less task oriented, and more emotionally reactive. At age 12, these children also are less careful and

Table IV. Association of Maternal Smoking During Pregnancy with Temperamental, Behavioral, and Academic Outcomes at Age 12

	Maternal smoking during pregnancy				
	None	1–5 per day	6 plus per day	*f*	*p*
Behavioral characteristics at age 12[a]					
Learning problems					
M	3.68	3.79	4.38	2.42	<.10
SD	2.42	2.48	2.67		
Distractibility					
M	3.89	4.42	4.85	4.06	<.05
SD	2.63	2.85	2.81		
Immaturity					
M	3.68	3.96	4.58	3.97	<.05
SD	2.38	2.34	2.79		
Aggression					
M	3.27	3.78	3.94	2.53	<.10
SD	2.44	2.69	2.67		
Negative emotionality					
M	3.61	3.74	4.34	3.34	<.05
SD	2.09	2.12	2.37		
Temperament characteristics at age 12[b]					
Task orientation					
M	41.58	40.49	38.17	3.65	<.05
SD	9.96	10.06	11.03		
Emotional reactivity					
M	10.69	11.06	12.44	3.75	<.05
SD	4.62	4.49	5.38		
School grades at age 12[c]					
Carefulness/precision					
M	8.98	8.73	8.69	3.12	<.05
SD	1.05	1.07	0.89		
Overall academic average					
M	8.00	7.97	7.72	4.56	<.01
SD	0.68	0.74	0.76		

Means have been adjusted for covariates.

[a]Sample size: none, 271; 1–6 cigarettes per day, 57; 6 or more cigarettes per day, 92.

[b]Sample size: none, 260; 1–6 cigarettes per day, 56; 6 or more cigarettes per day, 89.

[c]Sample size: none, 245; 1–6 cigarettes per day, 52; 6 or more cigarettes per day, 84.

precise in completing school work and are less competent academically.

It is noteworthy that the effects for some variables were in the opposite direction to that predicted. One of the more intriguing findings is that children of smoking mothers displayed less distress to novelty and less negative emotionality as infants and preschoolers, but more negative emotionality and emotional reactivity as school-aged children. One possible explanation for this finding is that at a younger age a generalized sensitivity to stimuli is being measured whereas at an older age the personality dimension of neuroticism and an irritable, unhappy temperament is being evaluated. From another angle, it may be that the infants and preschool-aged children of smoking mothers are less responsive to environmental change or novelty whereas children of nonsmokers were more aware of their environments in infancy and early childhood. At later ages this may manifest in the tendency to engage in high-intensity behaviors to enhance cerebral stimulation (see Eysenck, 1991 for an explanation of this theory in adults). This line of thinking might explain, to some extent, the higher levels of activity found at age 5 and the differential findings regarding negative emotionality at age 5 and 12. Another possible reason for the divergent results at the different ages is the fact that teachers supplied data at age 12, but parents supplied data in infancy and at age 5. In addition, the instruments used are different, and the two groups of informants bring different bias to their tasks. Additional studies regarding these age-related differences are clearly warranted.

When the cohort children were 12 years of age, teachers were asked to rate the children's behavior.

These data were important in the context of the current research for two reasons. First, these data allow for a determination of whether differences observed by mothers at an earlier age are also seen by teachers. Second, these data provide clues regarding the developmental trajectory of children prenatally exposed to cigarette smoke. The results suggest that children of women who smoked during pregnancy performed more poorly academically, had more difficult temperaments, and greater behavioral problems than their peers. This result is consistent with the results of other research (e.g., Fried et al., 2003). Moreover, if maternal prenatal smoking is associated with reduced ability to benefit from instruction, then this could result from at least two mechanisms: reduced ability to learn or reduced attentional control and motivation. The data available from this study do not directly address the first mechanism, but strongly address the second. That is, the effect of prenatal exposure to cigarette smoke is shown to have effects on activity level and on attentional phenomena, which are known to affect learning. An additional explanation, which was not addressed by this research, is that mothers who smoked had poorer attentional control and/or poorer abstract learning abilities. Thus, these mothers may have provided a less than adequate learning environment. Another possible explanation involves a genetic mechanism. Perhaps children inherited some of these traits from their mothers. The role of genetics in relation to gestational cigarette exposure is a needed avenue of future research.

In summary, subtle associations of maternal smoking with child behavior were observed in infancy and at age 5. In infancy and age 5, most of the associations were not in the hypothesized direction, with the exception of increased activity level at age 5. By age 12, more pervasive academic, behavioral, and temperament associations were seen in the hypothesized direction and consistent with the extant research base, even though the ratings were obtained in a different setting, and were obtained from a different rater (teachers) than had provided the ratings in early childhood (parents). By age 12, children of smokers were about one third of a standard deviation more problematic in the classroom and experienced poorer academic performance. All behavioral and temperamental effects were on increased externalizing or impulsive behavior.

Several caveats must be acknowledged to fully interpret these data. No data were available on maternal smoking after pregnancy. Several studies have shown that the prevalence of smoking after pregnancy for mothers who smoke during pregnancy is high; even for those that smoked before pregnancy and stopped during pregnancy, 70% resume after child birth (Fingerhut, Kleinman, & Kendrick, 1990). Therefore, some of the effects observed for maternal smoking could result from exposure to second-hand smoke during the first 12 years of life because the mothers who smoked during pregnancy likely smoked up to the time the child was 12 years old. Furthermore, maternal smoking during pregnancy may also influence the developing child through another less direct mechanism. Smoking during pregnancy is associated with younger mothers, mothers who experience greater psychiatric distress, greater somatic illness, and greater poverty (Cherry & Kiernan, 1976; Dombrowski, Martin, & Huttunen, 2003; Eysenck, 1991; Graham, 1995). Although we attempted to control for these psychosocial factors within our study, it is possible that the reported effects of smoking may be better explained by these environmental or cultural aspects. In addition, perhaps, certain cognitive, temperamental, and behavioral characteristics observed in children were acquired through genetic transmission. In this study, we attempted to control for some of the genetic effects through use of maternal hospitalization for mental health problems and accidents as covariates. Another limitation must be acknowledged. Smoking, drinking, and other forms of drug use are correlated, and some of the resulting effects may have been related to maternal drug use during pregnancy. This study was unable to control for pregnancy drug and alcohol use, which is a clear limitation. Finally, the use of self-report survey data may pose additional limitations. Smoking during pregnancy is viewed as socially unacceptable behavior, and respondents may have tended to deny smoking or minimize the number of reported cigarettes smoked during pregnancy.

The findings of this study lend additional support for the urgent need to implement smoking cessation and education programs consistent with those discussed by the Public Affairs Committee of the Teratology Society (Adams, 2003). These programs should be especially targeted at younger pregnant mothers with less than a high-school education. It also might be prudent to increase smoking cessation program training for mental health professionals who can provide services to pregnant women. Finally, insurance companies and other agencies ought to consider increasing their awareness of the deleterious proximal and distal outcomes associated with smoking during pregnancy and might be well advised to establish policies that underwrite the cost of smoking cessation or prevention treatment for pregnant mothers. Although we do not have data to substantiate

this position, we contend that the long-term cost of exposure to cigarette smoke during pregnancy likely outweighs the short-term cost of underwriting smoking cessation or prevention treatment programs for pregnant mothers. Pregnancies among women who smoke during pregnancy are marked by increased risk of spontaneous abortion, placenta previa, babies with low birth weight, prematurity, and sudden death. This study adds to the literature by demonstrating that smoking during pregnancy increases offspring risk for adverse temperamental, behavioral, and academic outcomes across several stages of the developmental period.

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