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Parental bad habits breed bad behaviors in youth: Exposure to gestational smoke and child impulsivity

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ABSTRACT

In utero exposure to cigarette smoke has been shown to have an adverse effect on healthy brain development in childhood. In the present study, we examine whether fetal exposure to mild and heavy smoking is associated with lower levels of impulsivity and cognitive control at age 10. Using a sample of 2120 children from the Québec Longitudinal Study of Child Development, we examine the association between gestational cigarette smoke exposure and fourth grade teacher reports of impulsivity and classroom engagement which represent behavioral indicators of executive functions. When compared to children of non-smokers, children of mothers who reported smoking heavily during pregnancy (10 or more cigarettes per day) were rated by their fourth grade teachers as displaying higher levels of impulsive behavior, scoring.112 standard deviation units higher than children of non-smokers. Children of mothers who smoked heavily were also less engaged in the classroom, scoring.057 standard deviation units lower than children of women who did not smoke. These analyses were adjusted for many potentially confounding child and family variables. Exposure to perinatal nicotine may compromise subsequent brain development. In particular, fetal nicotine may be associated with impairment in areas recruited for the effortful control of behavior in later childhood, a time when task-orientation and industriousness are imperative for academic success.

1. Introduction

Unfavorable fetal environments can impede subsequent child development and increase individual susceptibility to disease throughout the lifespan (Barker, 1998). In industrialized countries, as many as 25% of children are exposed to nicotine during gestation (Beck et al., 2002). Because nicotine crosses the placental barrier, it can interfere with healthy fetal development. Randomized experimental designs with animals confirm a causal relationship whereby direct prenatal exposure to nicotine evokes mutations in neural brain cell proliferation and subsequent differentiation. These processes can in turn compromise cortical functioning and development (Slotkin et al., 2011). It is reasonable to expect similar epigenetic sequelae in humans exposed to nicotine. If disruptions in the development of prefrontal brain areas persist through later developmental stages, they are likely to foster enduring risk for poor executive control in later childhood.

Epidemiological studies suggest that maternal gestational smoking is related to serious long-term risks for the development of children. These include neurocognitive deficits that affect child cognitive and behavioral functioning (Brennan et al., 2002; Ekblad et al., 2010; Gilman et al., 2008; Linnet et al., 2003). Gestational smoking is also associated with ADHD and reduced general intellectual ability (Brennan et al., 2002; Button et al., 2005; Fergusson and Lloyd, 1991; Gilman et al., 2008; Linnet et al., 2003).

Exposure to maternal smoking may disrupt early brain growth because it can interfere with the flow of oxygen and nutrients to the developing fetus and lead to increases in toxic carbon monoxide in the gestational environment (Slotkin et al., 2002). In addition, cigarette smoke increases activation of nicotine receptors in the developing fetus. Repeated activation of nicotine receptors can eventually disrupt the neurotransmitter systems involving adrenaline, noradrenaline, and dopamine (Brennan and Arnsten, 2008). The regulation and maintenance of optimal levels of these neurotransmitters are essential for the proper functioning of the prefrontal cortex, which plays an important role in the willful control of behavior.

In childhood, one of the core symptoms of ADHD is impulsivity, which reflects poor behavioral inhibition, inattentiveness, and restlessness in social and academic domains (Barkley, 1997). Children who meet the clinical criteria for ADHD are likely to experience severe impairments in their academic and social functioning (Barkley, 2002). Nevertheless, even children who present non-clinical levels of impulsivity are at risk of facing challenges with successful lifelong adjustment (Currie and Stabile, 2006). As early as kindergarten, impulsive

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children have more difficulty with academic achievement and adjustment in the classroom and are more likely to be held back a grade (Duncan et al., 2007; Pagani et al., 2001, 2010a). Within typically developing populations, children who are more impulsive are also at greater risk of early involvement in addictive behaviors such as gambling and substance abuse (Pagani et al., 2009; Vitaro et al., 2001). Further contributing to its social and individual burden, impulsivity that persists into adulthood is associated with poor occupational performance, adverse health outcomes, and impaired interpersonal functioning (Barkley, 2002).

Although studies have shown a link between exposure to gestational tobacco and child ADHD diagnosis (Mick et al., 2002; Milberger et al., 1996), research has yet to use a population-based sample to assess whether exposure is prospectively associated with impulsivity and applied measures of cognitive control in the classroom. Because prefrontal brain areas play a key role in helping children complete goal-directed behavior, follow procedures, and remain on-task, it is likely that children exposed to gestational tobacco smoke might show less engagement in the elementary level classroom. Academic trajectories tend to stabilize by the middle of elementary school, thus setting the course for high school achievement and academic persistence (Entwisle et al., 2005). Moreover, goal-directed classroom behavior is a precursor to later adult workplace behavior (Farkas, 2003). As such, examining productive behavior in the fourth grade classroom provides a useful indicator of children's eventual academic attainment and personal success (Duncan et al., 2007). Furthermore, a putative test of long-term negative influence becomes more compelling if the prospective associations endure over the long-term. For these reasons, our outcomes are assessed in the fourth grade.

Using a representative birth cohort of children born in the province of Quebec, we examine the hypothesis that exposure to gestational tobacco smoke is associated with higher impulsivity and lower levels of classroom engagement by age 10. In the present study, we are interested in estimating the independent contribution of perinatal tobacco exposure on later cognitive control skills. Because a number of studies have shown that the relationship between perinatal smoking and cognitive outcomes is reduced when perinatal and family environmental characteristics are taken into account (Maughan et al., 2004), we control for known risk factors in our study.

2. Methods

2.1. Participants

Analyses were conducted using data from the Québec Longitudinal Study of Child Development (QLSCD). This sample originates from a randomly selected stratified sample of 2837 infants born between 1997 and 1998 in Quebec, Canada. At the inception of the study 93 children were deemed ineligible and 172 were untraceable due to incorrect coordinates. Of the 2572 remaining children, 14 were unreachable and 438 refused participation. Beginning at 5-months, 2120 infants were followed up annually for the early childhood phase representing 91% of the eligible target population. Of these, 39% were firstborn. Baseline measures were taken when children were 5 months old. Follow-up of children occurred at 122 months. For each data collection wave, informed consent was obtained from parents. During the school-age phase, teachers and children also gave consent. As in all longitudinal studies there was incomplete data on some of the measures at each data collection wave. Participants were included in the analytical sample if they had complete data on maternal reports of perinatal smoking ($n = 2110$ from the original sample at 5-months).

2.2. Outcome measures (end of fourth grade)

2.2.1. Impulsivity

Teachers rated 9 items reflecting inattentiveness, restlessness, and poor behavioral inhibition. These included: Could not sit still, Was restless and hyperactive; Has trouble sticking to any activity; Could not stop fidgeting; Was impulsive, acted without thinking; Had difficulty waiting for his or her turn; Could not settle down to do anything for more than a few moments; Was easily distracted; Was inattentive; and Was unable to concentrate, could not pay attention for long ($\alpha = .91$).

2.2.2. Classroom engagement

Teachers rated 11 items related to cognitive control, task-orientation, effort in the classroom: Follows directions; Follows rules; Follows instructions; Completes work on time; Works independently; Listens Attentively; Works cooperatively with other children; Works neatly and carefully; Puts a lot of effort into work; Participates in class; and Ask questions when he/she does not understand ($\alpha = .94$) (Pagani et al., 2010a, 2010b). Items were rated on a Likert scale with response options from: 1 (never); 2 (rarely); 3 (sometimes); 4 (often); to 5 (always).

2.3. Predictors

When children were 5 months, mothers self-reported their smoking behavior during pregnancy. Mothers responded to two questions “Did you smoke during pregnancy?” and “How many cigarettes did you smoke while pregnant?”. These questions have been validated in this population previously (Huijbregts et al., 2006, 2007). Based on their responses, mothers were classified into one of three groups: 0 perinatal smoking, 1–9 cigarettes per day, or more than 10 cigarettes per day. The same or similar groupings have been used in the previous studies (Button et al., 2005; Huijbregts et al., 2006; Maughan et al., 2004) Approximately 25% of mothers reported smoking during pregnancy which is consistent with the prevalence rates found in other studies (Breslau et al., 2005; Maughan et al., 2004).

2.4. Control variables

Data on potential child, family, and socio-economic confounders were obtained from parents and through direct observation. Mothers self-reported alcohol consumption (coded as 0 = no alcohol consumption or 1 = alcohol consumption) and illicit drugs (coded as 0 = no drug consumption or 1 = drug consumption). Weight for gestational age was derived from birth records and was standardized by gender and week of gestation using Canadian norms (Kramer et al., 2001). Children were coded as either 0 (normal weight) or 1 (below the 10th percentile). Child sex was also derived from birth records.

Parental history of antisocial behavior during adolescence and adulthood was assessed at baseline when children were 5 months. Five questionnaire items were derived from the NIMH-Diagnostic Interview Schedule. Adolescent items included: Starting fights; Theft, Involvement with youth protection or police; Expulsion or suspension from school; Truancy; and Running away from home. Adult items included: Arrests; Being fired from a job; Trouble at work, with family, or with the police due to drug or alcohol abuse; Starting fights (fathers only); and Hitting or throwing things at the spouse or partner (mothers only).

Parental and family characteristics were measured when children were 5 months.

Maternal involvement and responsiveness were measured using the Home Observation for Measurement of the Environment (HOME) — Infant version (Caldwell and Bradley, 1994). Trained examiners made assessments after observing mother–child interactions for a period of 3 h. Involvement was measured using 5 items: Provides toys that challenge child to develop new skills; Structures child's play periods; Interacts with her child while engaged in other tasks; Encourages her child's progress; and Values educational toys (<alpha> = .85). Responsiveness was also measured using 5 items: Responds verbally to child vocalizations or verbalizations; Vocalizes spontaneously (words or sounds) to the child; Speaks to baby in a distinct, clear, and audible manner; Tells child name of object or

person during the visit, and Spontaneously praises the child at least twice (<alpha>=.85).

When children were 5 months, mothers also self-reported their age at child's birth, depressive symptoms using the modified lifetime depression section of the Diagnostic Interview Scale (DIS), and family configuration (two parent = 1 and not = 0) and functioning based on 12 items designed to measure family communication, problem solving, control of disruptive behavior, and demonstrations of affection (Epstein et al., 1983). Finally, an index of socioeconomic status was derived from mother and father reports of income, level of education, and occupational prestige.

2.5. Data analysis

It was possible to predict incomplete data from variables in our analytic sample. As a result, having met the assumption of "missing at random" as defined by Graham, we imputed all missing data (Graham, 2009). Multiple imputations were conducted using NORM software (Schafer, 1999). Depending on the available and valid observations from the original data set, NORM imputes missing data by drawing upon values from the conditional distribution of the variables. Estimations are made using an iterative method based on expectation maximization. We then estimate two ordinary least-squares regressions in which children exposed to moderate and high levels of perinatal smoke are simultaneously compared to unexposed children on fourth-grade classroom engagement and impulsivity, respectively. This estimated relation would provide support for a biological mechanism linking early perinatal exposure to nicotine with later education and mental health trajectories. To best ensure an unbiased estimation of our effects, we account for third variable bias by statistically controlling for known perinatal risk factors, parental characteristics, and socio-economic factors which might account for the relationship between our predictor and outcome variables (Breslau et al., 2005).

3. Results

Table 1 reports descriptive statistics for independent, dependent, and control variables. Boys scored higher on impulsivity $t(2207) = 15.23$, ($x = 3.07$ vs. $x = 1.49$), $p < .001$ and lower on classroom engagement $t(2207) = 16.34$ ($x = 2.28$ vs. $x = 3.25$) than girls, $p < .001$.

3.1. Adjusted findings

As reported in Table 2, children of mothers who smoked heavily during gestation were rated as more impulsive by fourth grade teachers than children whose mother's did not smoke, scoring.112 standard deviation units higher on impulsivity than children of non-smokers. Children of mothers who smoked heavily scored.057 standard deviation units lower on fourth grade classroom engagement than children of women who did not smoke. Our adjusted model assessing both outcomes, controls for child sex, concurrent age in months, child exposure to perinatal drinking and exposure to elicit drugs, weight-for-gestational age, socioeconomic status, family configuration, parent antisocial symptoms and maternal involvement, responsiveness, depressive symptoms, and age at child's birth.

4. Discussion

As children move from grade to grade in elementary school, being able to pay attention and effectively control one's behavior in the classroom become key ingredients of academic success and eventual high school completion (Duncan et al., 2007; Mischel et al., 1989; Pagani et al., 2010a). Children's ability to inhibit impulsive behavior, remain focused, and show task-orientation is likely to partially emerge in response to the development of the prefrontal cortex, which regulates attention and the effective top–down control of behavior.

In our representative population-based study of typically developing children, exposure to gestational smoke was associated with behavioral problems 10 years later. Compared to their non-exposed counterparts, children exposed to 10 cigarettes or more per day during gestation (14% of our population-based sample) were rated by their teachers as showing more signs of behavioral impulsivity and lower levels of task-orientation and compliance. These results were obtained above and beyond a number of potential confounders including parental antisocial symptoms, socioeconomic status, and exposure to perinatal alcohol and other illicit drugs. From a developmental perspective, risks associated with perinatal tobacco exposure are likely to culminate in the experience of increased difficulty in the academic context. An increase in personal dispositions towards costly impulsive behavior also augments the risk for the adoption of risky health-related behavior.

One limitation of the present study is that it is not possible to establish causality given the observational nature of our design. As such it remains possible that unmeasured characteristics of children, their families, or their environment explain the observed relationship between the predictor and lagged outcome variables. In particular, it was not possible to tease out the role of genetic influences on later child behavior. Maternal smoking may represent a biological marker of genetic predisposition toward impulsive behavior. One study employing a genetically-informed design found that the association

Table 1
Descriptive Statistics for independent, dependent, and control characteristics.

	Mean (SD)	Min	Max	N
Independent variables (gestation)				
No perinatal smoking	.75 (.43)	0	1	2010
Mild perinatal smoking	.11 (.32)	0	1	2010
Heavy perinatal smoking	.14 (.35)	0	1	2010
Dependent variable (120 months)				
Classroom Engagement	3.04 (.69)	0	4	2010
Impulsivity	2.31 (2.37)	0	10	2010
Child and family controls (gestation and 5 months)				
Perinatal drinking	.35 (.48)	0	1	2010
Perinatal drug use	.01 (.12)	0	1	2010
Low birth weight	.12 (.42)	0	2	2010
Sex	.51 (.50)	0	1	2010
Maternal depression	1.41 (1.35)	0	9.23	2010
Parent antisocial				
Maternal involvement	4.77 (2.38)	0	10	2010
Maternal responsiveness	6.67 (1.65)	.26	10	2010
Family functioning				
Maternal age	29.28 (5.20)	16	45	2010
Socioeconomic Status	0 (1.00)	−2.84	3.66	2010
Family configuration	.81 (.39)	0	1	2010

Table 2
Association between perinatal tobacco exposure and classroom engagement and hyperactivity by grade 4.

Independent variables	Classroom engagement	Impulsivity
1. Heavy smoke exposure	−.104* (.042)	.825*** (.148)
2. Mild smoke exposure	.072 (.044)	.137 (.153)
Adjusted R square	.166	.156

No exposure = reference group. Model controls for perinatal exposure to alcohol and illicit drugs, weight for gestational age, child sex, maternal depression, parent antisocial behavior, maternal responsiveness and involvement, family functioning, maternal age, family configuration, socio-economic status, and child age in months at the end of the fourth grade.
*** $p > .001$.
* $p > .05$.

between perinatal smoke exposure and later antisocial behavior is reduced once the influences of genes are taken into account (Maughan et al., 2004). Nevertheless, even though partial mediation occurred in that study, a significant and unique association between maternal smoking and later child antisocial behavior remained present. Finally, objective measures of perinatal smoking were not available. Although some mothers might have underreported smoking for social desirability motives, self-reports of perinatal smoking have been shown to correlate well with physiological measurements of cotinine, nicotine's main metabolite (Law et al., 2003; Pickett et al., 2005). Similarly, objective measures of impulsivity and attention and of Intellectual ability would have further strengthened the findings of the present study. Future studies ought to examine the possibility of a causal relationship between perinatal smoke exposure and later attention control. Since random assignment of children to gestational smoking would be unethical, evidence of a causal association could be shown through the effectiveness of randomized control-group studies designed to reduce maternal smoking. Fortunately, there are some studies which suggest that heavy smokers represent a population that is amenable to reductions in smoking behavior (Hegaard et al., 2003; Valbös and Nylander, 1994).

Some researchers have advocated that exposing children to cigarette smoke should be construed as a form of child maltreatment because it represents an avoidable source of harm to the health and well-being of children (Braillon et al., 2010). The present study provides evidence that gestational smoke is prospectively associated with long-term reductions in children's ability to inhibit impulsive behavior in the classroom. The possibility of identifying preventable prenatal risk factors for serious behavior problems remains important. Impulsivity can impede childhood trajectories towards positive adjustment and adaptation in later adolescence and adulthood. Because it is related to industriousness and task-orientation, classroom engagement relates directly to children's academic achievement and psychosocial adjustment in middle childhood (Fredricks et al., 2004). Children who have a hard time negotiating with the challenges of the elementary school classroom are at elevated risk of facing future school failure and high school dropout (Entwisle, et al., 2005). Failing to complete high school is associated with a cascade of subsequent health problems which include a higher lifetime probability of experiencing poverty (Card, 1999), more involvement in unhealthy lifestyles (Freudenberg and Ruglis, 2007; Hargreaves et al., 2008), and greater likelihood of participation in criminal and aggressive behavior (Ellickson and McGuigan, 2000). The results of the present study support continued public health efforts to encourage mothers to stop or reduce smoking during gestation.

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The *Institut de la statistique du Québec* (ISQ) collected and managed the data. All three authors have had full access to all data in the study and take responsibility for its integrity and the accuracy of its analysis. The present research does not present any conflicts of interests. Caroline Fitzpatrick wrote the first draft of the manuscript.

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