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Maternal Smoking During Pregnancy and Offspring Personality in Childhood and Adulthood

Angelina R. Sutin, Heather A. Flynn, and Antonio Terracciano

Florida State University College of Medicine

Abstract

Objective—Maternal smoking during pregnancy (MSDP) has been associated with offspring internalizing and externalizing disorders. The purpose of this research is to examine whether MSDP is also associated with variations in normal personality traits in childhood and adulthood.

Method—This study uses four independent samples (total $N=16,323$) to examine whether there are mean-level differences in offspring personality traits by MSDP, controlling for relevant socio-demographic factors. Two samples are of children ($Ns=3,782$ and $3,841$) and two samples are of adults ($Ns=1,786$ and $6,914$).

Results—A meta-analysis across the four samples indicated that offspring of mothers who did smoke during pregnancy scored higher in Neuroticism ($p=.000$) and Extraversion ($p=.003$) and lower in Conscientiousness ($p=.002$) than offspring of mothers who did not smoke during pregnancy. The association between MSDP and Neuroticism and Conscientiousness held across both childhood and adulthood and when propensity score matching was used, whereas the association with Extraversion was only apparent in adulthood and did not hold with propensity scores.

Conclusions—These results suggest that MSDP is associated with individual differences in psychological traits in childhood and adulthood and may be one prenatal factor that contributes to trait Neuroticism and Conscientiousness.

Keywords

Smoking during pregnancy; Temperament; Personality traits; Intergenerational risk; Five-Factor Model

It has long been known that the health, behavior, and well-being of the mother during pregnancy has consequences for the developing fetus and subsequent health of the child. Mothers who contract rubella during pregnancy, for example, are at risk of children with eye and ear defects, heart malformations, and intellectual disabilities (Thompson, Simons, Badizadegan, Reef, & Cooper, 2014). Excessive alcohol consumption puts fetuses at risk for growth deficiencies and behavioral problems (Memo, Gnoato, Caminiti, Pichini, & Tarani,

Address correspondence to: Angelina R. Sutin, Ph.D., Florida State University College of Medicine, 1115 W. Call Street, Tallahassee, FL 32306, (850) 645-0438, Fax: (850) 645-1773, angelina.sutin@med.fsu.edu.

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2013). In addition, there is some evidence that mothers who experience significant stress during pregnancy have children with lower IQ and lower cognitive functioning (Aizer, Stroud, & Buka, 2012; King, Dancause, Turcotte-Tremblay, Veru, & Laplante, 2012). The behavior, health status, and situation of the mother during pregnancy have long-term implications for the offspring. Studies of intergenerational factors that contribute to poor health and other lifespan outcomes are needed to accelerate and refine public health prevention efforts.

Maternal smoking during pregnancy (MSDP) is a relatively common behavior despite the risk of miscarriage, complications, and birth defects (Cnattingius, 2004). Approximately 1 in 10 women report smoking cigarettes during the last three months of pregnancy, with rates up to 17% in younger women (Curtin & Mathews, 2016). The risk associated with MSDP is not limited to physical health outcomes but also extends to psychological functioning. MSDP, for example, has been linked to attention deficit hyperactive disorder (ADHD), internalizing symptoms, and conduct disorders. Children exposed to nicotine during prenatal development have more attention deficits at age 5 (Melchior et al., 2015), more symptoms of ADHD at age 8 (Kovess et al., 2015) and are at greater risk of a clinical diagnosis of ADHD by adolescence (Biederman, Monuteaux, Faraone, & Mick, 2009) than children who did not have prenatal exposure to nicotine. Compared to mothers who did not smoke during pregnancy, children of mothers who did smoke also exhibit more symptoms of anxiety and depression (McCrory & Layte, 2012); although not all find this relation (Melchior et al., 2015). Finally, MSDP is associated with conduct problems during middle school (Gaysina et al., 2013). There is debate, however, about the extent to which genetic and/or shared environmental factors account for the association between MSDP and these behavioral outcomes (D'Onofrio, Van Hulle, Goodnight, Rathouz, & Lahey, 2012) and the extent to which gene x environment interactions account for these differences (Gaysina et al., 2013). Some studies, for example, find that although there are differences in depression and anxiety by MSDP, the differences are attenuated when adjusted for unobserved familial factors (Meier et al., 2017). Interest in the relation between MSDP and psychological outcomes has focused primarily on clinical disorders and anti-social behavior. The relation between MSDP and psychological functioning, however, may have broader implications than clinical outcomes; it may also extend to basic dimensions of personality that characterize each individual's behavioral, cognitive, and emotional tendencies.

Personality, as operationalized by the Five Factor Model (FFM; also known as the big five), is summarized by five broad dimensions: Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness (McCrae & John, 1992). These traits have been shown to predict a range of consequential outcomes, including academic achievement (Nofle & Robins, 2007), income (Duckworth, Weir, Tsukayama, & Kwok, 2012), morbidity (A. R. Sutin, Zonderman, Ferrucci, & Terracciano, 2013) and mortality (Jokela et al., 2013). Childhood measures of temperament have been found to be antecedent to these adult personality traits and associated measures. Given the importance of personality to life outcomes, there is interest in identifying the origin of these traits. Much of the focus on the antecedents of personality has focused on their genetic origins. Behavioral genetics studies suggest that approximately 50% of the variance in both childhood temperament (the precursor to adult personality) and personality in adulthood can be attributed to genetics,

according to twin studies (Saudino, 2005; van den Berg et al., 2014). Identifying the specific genetic variants with replicable associations with personality, however, remains a challenge (de Moor et al., 2015). Environmental factors, in addition to genetics, play a significant role in the development of temperament across childhood (Hart, Atkins, & Matsuba, 2008) and personality across adulthood (Sutin, Stephan, Luchetti, Robins, & Terracciano, 2017).

Studies that provide information on the possible association between MSDP and psychological functioning are important to both advance knowledge on the developmental mechanisms leading to child temperament and adult personality and for the implementation of interventions. Brief substance use interventions for pregnant women have been found to be effective, but have not been widely disseminated (Fiore, Jaen, & Baker, 2008). Information on the potential impact of smoking and other prenatal health behaviors on lifelong child functioning and health may help highlight the need for implementation of such interventions.

Given that MSDP may be associated with internalizing symptoms, including symptoms of anxiety and depression, and with difficulties with impulse control, the association may extend to individual differences in the general tendency to experience these symptoms, specifically trait Neuroticism and Conscientiousness. We address this question with a lifespan approach to this association. First, we examine whether MSDP is associated with the development of temperamental traits related to FFM personality traits (Persistence, Emotional Reactivity, and Sociability) in two longitudinal samples of children. We use up to five repeated assessments of temperament across childhood to examine whether MSDP is associated with both the average level of the trait and with change across childhood from ages 2 to 8 in one sample and from ages 4 to 12 in a second sample (Study 1). Aspects of temperament tend to develop across childhood (Tiberio et al., 2016) and MSDP may be one predictor of individual differences in change. Previous research has found no differences in Sociability by MSDP (Ellingson, Goodnight, Van Hulle, Waldman, & D'Onofrio, 2014), but it is unclear whether this null association extends to Persistence and Emotional Reactivity. Second, we examine whether the association between MSDP and personality is also apparent in adulthood with two additional samples of participants, one of younger adults and one of middle-aged adults (Study 2). We then do a meta-analysis of the four samples to summarize the results. This approach allows us to identify the most replicable associations between MSDP and personality and to examine whether MSDP has pervasive and lasting associations with personality in both childhood and adulthood. Based on work with clinical outcomes, we expect that MSDP will be associated with higher Neuroticism (measured as Emotional Reactivity in childhood and as Neuroticism in adulthood) and lower Conscientiousness (measured as Persistence in childhood and as Conscientiousness in adulthood). We did not expect to find an association between MSDP and Extraversion/ sociability or the other FFM personality traits.

Study 1

Method

Participants and Procedure—Participants were drawn from the Longitudinal Study of Australian Children (LSAC; Australian Institute of Family Studies, 2015). LSAC consists of

two cohorts: a younger cohort whose families were recruited into the study when the study child was an infant (mothers were pregnant in 2003–2004) and an older cohort whose families were recruited into the study when the study child was 4 years old (mothers were pregnant in 1999–2000). From the younger cohort, 3,782 families had the measures of temperament every two years from child ages 2 to 8 and maternal smoking. From the older cohort, 3,841 families had the measures of temperament every two years from child ages 4 to 12 and maternal smoking. In the younger cohort, compared to families with all of the relevant data ($n=3,782$), families that did not have all of the relevant data to be included in the analysis ($n=1,325$) were more likely to be from an indigenous group, the mothers were younger and had completed less school, the family had a lower income, the child was more likely to be from a single family household, and there were more mothers who had smoked during pregnancy ($p<.01$); there was no difference in child gender. In the older cohort, compared to families with all of the relevant data ($n=3,841$), families that did not have all of the relevant data to be included in the analysis ($n=1,142$) were more likely to be from an indigenous group, the mothers were younger and had completed less school, the family had a lower income, and the child was more likely to be from a single family household ($p<.01$); there were no differences in child gender or MSDP.

Measures

Maternal cigarette smoking: At wave 1 in both cohorts, mothers were asked about their cigarette smoking behavior during pregnancy. Smoking was coded as (1) mother reported any cigarette smoking during pregnancy or (0) mother reported no cigarette smoking during pregnancy.

Temperament: In both cohorts, parents completed age-appropriate temperament measures of Persistence (precursor to adult Conscientiousness), Emotional Reactivity (precursor to adult Neuroticism), and Sociability (precursor to adult Extraversion) at each wave. Parents completed the short version of the Toddler Temperament Scale (Fullard, McDevitt, & Carey, 1984) at age 2 (younger cohort only), the Short Temperament Scale for Children (Sanson, Smart, Prior, Oberklaid, & Pedlow, 1994) at ages 4 and 6, and the School Age Temperament Inventory (McClowery, 1995) at ages 8, 10 and 12 (ages 10 and 12 in the older cohort only). All three scales had 12 items; each had four items that measured age-appropriate indicators of Persistence (e.g., “stays with an activity for a long time”), Emotional Reactivity (e.g., “is difficult to comfort if upset”) and Sociability (e.g., “goes up to children, joins in play”). Across the longitudinal assessments, the median alpha reliability for persistence was .78 and .80, respectively, in the younger and older cohorts, the median alpha reliability for emotional reactivity was .73 and .84, respectively, in the younger and older cohorts, and the median alpha reliability for sociability was .80 and .81, respectively, in the younger and older cohorts.

Covariates: Covariates were included in the analysis that have previously been shown to be associated with maternal smoking and/or child temperament: child sex, indigenous status, mother’s age, mother’s education (coded from 1=never attended school to 6=year 12 or equivalent), family income (coded from 1 = <\$2,600 per year to 15 = >\$124,800 per year), and whether the household was headed by a single parent.

Statistical Approach—We used Hierarchical Linear Modeling (HLM; Raudenbush & Bryk, 2002) to model the trajectory of temperament in both cohorts using all available data. HLM is a flexible approach that uses each individual's time-series observations to estimate that individual's trajectory (Level 1), and those individual parameters are then the basis of group estimates (Level 2). At Level 1, a linear model was fit for each temperament dimension to capture change in temperament across childhood. A linear model was fit to be consistent with previous research on predictors of change in temperament (e.g., Ellington et al., 2014).¹ Age was centered on the grand mean for each cohort. Maternal smoking during pregnancy was entered at Level 2 as a predictor of both the intercept and slope parameters to test whether the mean-level and trajectory of the temperament dimensions differed by prenatal exposure to cigarette smoking. Demographic characteristics were included as predictors of the intercept and slope to control for potential confounding effects of maternal age, indigenous status, maternal education, family income, and single parent households.

Results

Descriptive statistics for the demographic variables at baseline are shown in Table 1. Bivariate correlations for both samples are shown in Supplemental Tables 1 and 2. Approximately 16–18% of mothers reported that they had smoked during their pregnancy with the study child. In each cohort for all three traits, the chi-square test of deviance indicated that the linear growth model was a significant improvement in fit over the baseline model ($p < .01$). In each cohort, there was significant variance around the intercept for Persistence (variance = .49 and .39, $ps < .01$, for the older and younger cohort, respectively), Emotional Reactivity (variance = .49 and .42, $ps < .01$, for the older and younger cohort, respectively), and Sociability (variance = .59 and .54, $ps < .01$, for the older and younger cohort, respectively). In addition, there was significant variability around the slope of each dimension in both cohorts (variance for all traits = .01, $p < .01$).

In both cohorts, a similar pattern emerged for the intercept of the three dimensions of temperament (Table 2): Mothers who had smoked during their pregnancy had children who scored lower in Persistence and higher in Emotional Reactivity than the children of mothers who had not smoked. MSDP was unrelated to Sociability in both cohorts.

In the younger cohort, mother's smoking during pregnancy was also associated with a decline in Persistence over the follow-up; this association did not replicate in the older cohort. Supplemental analysis that limited both samples to the same age range (both samples had assessments at child ages 4, 6, and 8) found no association between MSDP and change in Persistence between ages 4 and 8 in either sample; the association between MSDP and the intercept of the three traits was similar to the main analysis (Supplemental Table 3). The results of this supplemental analysis suggest that the association between MSDP and the average level of the traits did not depend on the age of the assessments included in the analysis. In contrast, the association between MSDP and change in Persistence might be limited to early childhood or might be a chance finding.

¹We also fit a model with a quadratic term to test whether MSDP was associated with non-linear changes in temperament across childhood. MSDP was not associated with quadratic slope and the results for the intercept and linear slope were virtually identical when this parameter was included in the model.

In Study 1, we identified replicable associations between MSDP and child temperament in two independent samples: Children of mothers who had smoked during pregnancy scored lower in the precursor to adult Conscientiousness and higher in the precursor to adult Neuroticism, than children of mothers who did not smoke during pregnancy. Study 2 extends these associations to personality traits in adulthood.

Study 2

Participants and Procedure

Study 2 used two samples of adults: one drawn from the National Longitudinal Survey of Youth Children and Young Adults (NLSY-CY; Bureau of Labor Statistics, 2015) and one from the National Child Development Survey (NCDS; Power & Elliott, 2006). The NLSY-CY is a sample of the young adult children of the women participating in the National Longitudinal Survey of Youth 79. The NCDS is a cohort study of individuals who were born during a single week in 1958 in the United Kingdom. In both samples, mothers reported on their smoking behavior during pregnancy and their offspring reported on their own personality in adulthood; personality was assessed in 2012 and 2014 in the NLSY-CY and in 2008 in the NCDS when all NCDS participants were 50 years old. A total of 1,786 participants from the NLSY-CY had information available on MSDP and personality in adulthood, and a total of 6,914 participants from the NCDS had information on MSDP and personality in adulthood.

In the NLSY, compared to offspring with complete data, offspring who participated in either the 2012 and 2014 assessment but did not have complete data for analysis ($n=5,478$) were older ($p<.01$) but did not differ in gender, education, race, mother's age, mother's education, whether from a single parent household and MSDP.

In the NCDS, compared to offspring with complete data, offspring who were not included in the analysis ($n=11,644$) were more likely to be male, from a single parent home, and lower social class in childhood (all $ps<.05$); there was no difference in MSDP. Most of the offspring not included in the analysis were not included because they were not assessed in adulthood.

Measures

Maternal smoking—In both samples, mothers were asked about their cigarette smoking behavior during pregnancy. As part of their regular assessments in the NLSY79, female participants were asked about whether they were currently pregnant or had been pregnant since their last NLSY assessment. Participants who responded yes were then asked about their cigarette smoking behavior during the pregnancy. Mothers of the NCDS participants reported on their smoking as part of the first assessment, which generally occurred the day the study child was born. Smoking was coded as (1) mother reported any cigarette smoking during pregnancy or (0) mother reported no smoking during pregnancy.

Personality—Participants in the NLSY-CY completed the Mini International Personality Item Pool (Mini-IPIP; Donnellan, Oswald, Baird, & Lucas, 2006). The Mini-IPIP is a 20-item measure with four items per domain. Participants in the NCDS completed the 50-item

version of the IPIP (Goldberg et al., 2006), which measures personality with 10 items per domain. Both the Mini-IPIP and the full IPIP have demonstrated reliability (e.g., internal consistency, test-retest reliability) and predictive validity for important outcomes (Donnellan et al., 2006; Goldberg et al., 2006). For the IPIP and the mini-IPIP, the alpha reliabilities were, respectively, .88 and .43 for Neuroticism, .87 and .67 for Extraversion, .78 and .57 for Openness, .82 and .54 for Agreeableness, and .77 and .51 for Conscientiousness.

Covariates—Covariates in the analysis were offspring sex, offspring age (NLSY-CY only), offspring ethnicity (NLSY-CY only), offspring education, mother's age, early life socioeconomic status (mother's years of education in the NLSY-CY and family social status in the NCDS), and single parent households.

Statistical Approach

We used Multivariate Analysis of Covariance (MANCOVA) to examine whether there were differences in personality between participants who had been exposed to MSDP versus those who had not been exposed. The five traits were entered as the dependent variables, maternal smoking was entered as the independent variable, and the covariates were included as control variables.

Results

Descriptive statistics for the demographic variables for both samples are shown in Table 3. Bivariate correlations for both samples are shown in Supplemental Tables 4 and 5. Across the two samples, 26% and 32% of mothers reported that they had smoked during their pregnancy with the study child in the NLSY-CY and the NCDS, respectively.

Results of the MANCOVA for each sample are presented in Table 4. In the NLSY-CY, similar to Reactivity in childhood, adult offspring of mothers who had smoked during pregnancy scored higher in Neuroticism. Surprisingly, and in contrast to the childhood findings, these participants also scored higher in Extraversion compared to the offspring of mothers who had not smoked during pregnancy. Adult offspring of mothers who had smoked during pregnancy also scored lower in Conscientiousness, although the statistical power was not sufficient for this difference to be significant ($p=.12$). There was no difference in either Openness or Agreeableness. The results were similar when the analysis was limited to one random sibling per family ($n=1,401$). Specifically, offspring of mothers who had smoked during pregnancy scored higher in Neuroticism than offspring of mothers who had not smoked ($p<.05$) and the mean-difference approached significance for Conscientiousness ($p=.09$) and Extraversion ($p=.07$). The results were also similar when weights were applied to account for the interdependence: The differences in Neuroticism remained significant ($p<.05$), whereas the differences for both Extraversion and Conscientiousness approached significance (both $ps=.09$).

In the NCDS, a significant difference emerged for Conscientiousness: Adult offspring exposed to MSDP scored lower in Conscientiousness than adult offspring who had not been exposed. Similar to the NLSY-CY, MSDP was also associated with higher Extraversion. Finally, although adult offspring of mothers who had smoked during pregnancy scored

higher in Neuroticism than adult offspring whose mothers had not smoked, this association only approached significance ($p=.05$).

Supplemental Analysis

Meta-analysis: To summarize the results across the four samples, we did a random-effects meta-analysis using the Comprehensive Meta-Analysis program. We based the meta-analysis on the exact p -value and sample size of each sample (total $N=16,232$; Figure 1)². Heterogeneity was assessed using the Q statistic and I^2 . Similar to the results in the individual studies, the strongest associations were for Neuroticism and Conscientiousness: MSDP was associated with scoring higher in Neuroticism-related traits (point estimate=.128, 95% CI=.057, .198, $p<.001$) and lower in Conscientiousness-related traits (point estimate=-.110, 95% CI=-.039, -.180, $p=.002$). The association with Extraversion was small but also significant: MSDP was associated with scoring higher in Extraversion-related traits (point estimate=.050, 95% CI=.018, .091, $p=.003$). There was significant heterogeneity for Neuroticism (Q -value=9.363, $p<.05$ and $I^2=67.959$) and Conscientiousness (Q -value=9.259, $p<.05$ and $I^2=67.600$) but not for Extraversion (Q -value=2.44, $p>.05$ and $I^2=0$).

Propensity score analysis: There is debate in the literature about the proper way to account for genetic and environmental factors that may confound the relation between MSDP and offspring outcomes (D'Onofrio et al., 2012; Gaysina et al., 2013). In addition to sibling-comparison designs, propensity score matching has been proposed to account for pre-existing differences across children with differential exposure to MSDP (Palmer et al., 2016). Propensity score matching is often used in observational studies when the sample cannot be randomized; the matching attempts to mimic randomization by creating two groups that are comparable on observed covariates (Rosenbaum & Rubin, 1983). Propensity scores are estimated from the identified set of covariates as the probability of group assignment based on these baseline covariates (Austin, 2011). Propensity scores are typically estimated through logistic regression from the predicted probability of belonging to one group or the other (MSDP versus no MSDP in the current analysis). Propensity scores reduce differences between groups down to a one score. The two groups can then be balanced on this one score and thus on the covariates. Propensity scores are then typically used in one of four ways (Austin, 2011): (1) matching (two groups are matched on similar scores), (2) stratification (the sample is divided into strata based on propensity scores), (3) regression adjustment (propensity scores included as a covariate), or (4) weighting (cases are weighted by the propensity score). Per recommendations of Austin (2011), the present analysis used matching.

The results of the matched samples using propensity scores are shown in Table 5. To facilitate comparisons across samples, personality scores were standardized before analysis. The pattern of differences for both the Neuroticism-related traits and the Conscientiousness-related traits was similar to the findings from the full sample, with the exception that the

²We re-analyzed the data from the LSAC samples to facilitate interpretation of the meta-analysis. Specifically, we took the mean of each temperament dimension across all longitudinal assessments. Then, similar to the adult samples, we did a MANCOVA with the temperament dimensions as the dependent variables, MSDP as the independent variable, and the covariates as controls. We used the p -value and samples sizes from this analysis for the meta-analysis.

differences for Conscientiousness in the adult sample were in the same direction but below the threshold of significance given the smaller sample size. The results of the meta-analysis, however, were similar to that of the full sample for both Conscientiousness (point estimate $-.124$, 95% CI $-.218, -.030$, $p=.010$; $Q=10.46$, $p=.015$; $I^2=71.321$) and Neuroticism (point estimate $-.140$, 95% CI $-.055, .226$, $p=.001$; $Q=8.605$, $p=.035$; $I^2=65.135$). In contrast, the difference in Extraversion was only apparent for the NCDS and was not supported by the meta-analysis (point estimate $-.01$, 95% CI $-.068, .097$, $p=.730$; $Q=7.968$, $p=.047$; $I^2=62.351$).

Discussion

Across four samples that ranged in age from childhood to middle adulthood, three different measures of personality, and using different approaches to account for potential confounders, MSDP was associated with lower Conscientiousness and higher Neuroticism. Specifically, offspring of mothers who had smoked cigarettes during pregnancy scored lower in Persistence and higher in Emotional Reactivity in childhood and lower in Conscientiousness and higher in Neuroticism in young and middle adulthood. Surprisingly, MSDP was also associated with higher Extraversion, but this association did not hold when using propensity score matching. These results suggest that MSDP may be one intergenerational factor that contributes to the development of individual differences in Neuroticism and Conscientiousness-related traits across the lifespan.

Adult Conscientiousness is a multifaceted trait with deep roots in child temperament. Consistent with the literature on MSDP and ADHD, the children of mothers who had smoked during pregnancy were less persistent and more impulsive. In addition to its relation with child temperament, MSDP was also associated with mean-level differences in Conscientiousness in adulthood. This pattern suggests that the association with MSDP is apparent past childhood into differences in the general tendency to be less organized and disciplined in adulthood. Effective self-control, in both childhood and adulthood, is associated with a range of consequential outcomes across adulthood, including incarceration (Moffitt et al., 2011), obesity (Sutin & Terracciano, 2016), and Alzheimer's Disease (Terracciano et al., 2014). Children exposed to MSDP may face significant deficits in self-regulation that appear early in life and consolidate into lower Conscientiousness by adulthood.

Lack of effective self-regulation is also a core component of Neuroticism (Robinson, 2007). Individuals who score higher on Neuroticism tend to experience more negative emotions and have difficulty managing their stress (Penley & Tomaka, 2002). The association between MSDP and neuroticism-related traits was consistent across the four samples: Children of mothers who had smoked during pregnancy were more difficult to comfort and more moody than the children of mothers who had not smoked and the adult offspring of mothers who had smoked during pregnancy were more prone to experiencing negative emotions. Previous research has found that children of mothers who smoked during pregnancy also have more symptoms of anxiety and depression in childhood (McCrory & Layte, 2012), although not all find this relation (Melchior et al., 2015). The current research suggests that MSDP is also

a risk factor for a trait disposition toward experiencing anxiety and depression, in addition to an increased risk for the experience of acute symptomatology.

Surprisingly, there was also an association between MSDP and higher Extraversion in adult offspring. Of the three traits that were measured in both childhood and adulthood, this trait was the only one that showed some divergence across the two life periods. That is, there was no association between MSDP and either the mean-level or trajectory of Sociability, the childhood temperamental antecedent to adult Extraversion. This difference could be due to differences in how Sociability is measured versus how Extraversion is measured, with specific aspects of Extraversion more sensitive to MSDP than others. It could also be a developmental difference in that the association is delayed and not apparent until adulthood. Of note, however, previous research using the NLSY sample found no association between MSDP and sociability in childhood (Ellingson et al., 2014) and these differences in adulthood were not apparent in the propensity score analysis. MSDP was not consistently associated with the other two FFM traits, Openness and Agreeableness, measured in adulthood.

There may be direct biological mechanisms and broader environmental mechanisms that contribute to the relation between MSDP and personality. MSDP, for example, has been associated with alterations in both brain structure and function. Adolescents whose mothers had smoked during pregnancy have been found to have a thinner orbitofrontal cortex, an area critical for self regulation (Toro et al., 2008). Differences in neural outcomes by MSDP are also observed in adulthood. Young adults who had been prenatally exposed to nicotine showed less activity in the anterior cingulate cortex and the inferior frontal gyrus during a task that required inhibitory control compared to young adults who had not been exposed (Holz et al., 2014). Individuals who score higher in Neuroticism and lower in Conscientiousness likewise show less activity in these areas during tasks of inhibitory control (Rodrigo et al., 2016). Thus, the neural structures and functions associated with MSDP are integral to Neuroticism and Conscientiousness and may be one mechanism through which MSDP contributes to the development of these traits. This association is also supported by animal research that finds that offspring prenatally exposed to nicotine display more hyperactive (Schneider, Bizarro, Asherson, & Stolerman, 2012) and anxious (Santiago & Huffman, 2014) behavior, although not necessarily more impulsive behavior (Mitchell et al., 2012).

In addition to the association between MSDP and neural correlates, there may be other biological mechanisms that contribute to the relation between MSDP and personality. The association may be due, for example, to shared genetics between mother and child and gene-environment correlations. That is, there may be genes that both increase the mother's propensity to smoke during pregnancy and also contribute to the child's psychological development (Rice et al., 2009). Further, there is the potential for gene x environment interactions, such that some children with a specific genetic profile are more sensitive to the effect of MSDP on development than children with different genetic profiles (Brennan et al., 2011).

Environmental mechanisms may also contribute to the relation between MSDP and personality. Mothers with less education and fewer economic resources are more likely to smoke during pregnancy (Cui, Shooshtari, Forget, Clara, & Cheung, 2014). Economic hardships may thus contribute to both MSDP and child behavioral outcomes. Other factors associated with lower socioeconomic status may also be early life antecedents that contribute to the development of child temperament and ultimately adult personality. Children who grow up in poverty-stricken neighborhoods, for example, decrease in traits related to resilience and control over time compared to children from more affluent neighborhoods, even after controlling for the family's SES (Hart et al., 2008). SES and other characteristics of the smokers have drastically changed over the past 60 years (Pierce, 1989; Wallace, Stratton, & Bonnie, 2007), and despite such differences, we found similar associations in offspring of mothers who were pregnant in 1958 UK to 2000 in Australia. Rather than a direct causal effect of prenatal nicotine exposure, some sibling studies suggest that these confounding factors, as well as shared genetics, account for the association between MSDP and behavioral outcomes (e.g., D'Onofrio et al., 2012). Others have questioned sibling comparisons (Gaysina et al., 2013), and note that as in the current study, the associations tend to hold controlling for socioeconomic and other confounders.

There is debate about the robustness of the association between MSDP and psychological and psychopathological functioning in offspring (D'Onofrio et al., 2012; Gaysina et al., 2013; Palmer et al., 2016). Most well powered studies have found psychological differences in offspring by whether their mother smoked during pregnancy (e.g., greater externalizing symptomology; D'Onofrio et al., 2012; Gaysina et al., 2013; Kovess et al., 2015; Palmer et al., 2016). These studies, however, have also shown that unobserved factors account for this association. As such, there may be environmental and/or genetic exposures that co-vary with MSDP that explain why there are differences in psychological functioning by MSDP. This issue is far from resolved. At the same time, even if there is not a direct biological cause of prenatal nicotine exposure on psychological differences, MSDP is at least a proxy for a prenatal environment or genetic vulnerability that is associated with differences in key dimensions of personality in both childhood and adulthood.

The use of multiple samples in the present research shows that these associations are not limited to one period in life. Personality development is a process that unfolds across the lifespan (Shiner, Masten, & Roberts, 2003; Terracciano, McCrae, Brant, & Costa, 2005). The research in this area is typically splintered into childhood temperament versus adult personality despite the recognition that temperament matures into adult personality. Whereas there has been great interest in environmental factors that contribute to the development of childhood personality traits (Hart et al., 2008), there has been less emphasis on identifying early childhood factors that contribute to adult traits. Interest in adult personality development has focused more specifically on how life events in adulthood change the trajectory of the traits (Specht, Egloff, & Schmukle, 2011). There is also limited research on neonatal factors that contribute to adult personality, such as breastfeeding (Sutin, Stephan, & Terracciano, 2016). The present research indicates that an environmental factor experienced prenatally has potential long-term associations with personality. The lack of an association between MSDP and change in the temperamental traits suggests that there is an effect of MSDP on the average level of the trait but that this difference does not increase or decrease

over time. The similar findings across childhood, young adulthood, and middle adulthood suggest that these mean-level differences emerge early and are apparent at least into middle adulthood; older adult samples are now needed to determine whether these differences remain in old age. In addition to age, the use of multiple samples also indicates that the associations are similar across different cohorts, time periods, and cultural context. The United Kingdom and Australia generally have more social safety net programs than in the United States, especially for children and families that help to keep children out of poverty (Gould & Wething, 2012). As such, socioeconomic indicators likely contribute differently by country, yet the associations are similar despite these differences.

The present research had several strengths, including four large, independent samples that ranged in age from 2 to 50, measures of both childhood temperament and adult personality, and cohorts that spanned generations and cultures. There are also some limitations that could be addressed in future research. First, MSDP was assessed through mother self-report of cigarette smoking during pregnancy. Although up to 32% of mothers across the samples reported smoking during pregnancy, it is possible that it is an underestimate because of socially desirable responding, especially in the more recent cohorts. This issue, however, likely attenuates the associations found in the present research. The study also did not have information on the level and timing of cigarette use, including patterns of use preconceptually and across the pregnancy. There may be a critical or sensitive period that increases the risks associated with MSDP more than during other periods. Quitting smoking during the early or later months of pregnancy might be differentially associated with offspring outcomes. Second, we did not have longitudinal personality data on the adult samples; it is thus unclear whether MSDP is associated with personality development in adulthood or whether MSDP is associated with differences in personality in both childhood and adulthood personality when using the same sample. From the child samples, however, the present findings indicate that there is a more consistent effect on the average level of the trait rather than its trajectory, which suggests that the difference may be apparent over time. Third, we did not have parent reports of their own personality. It may be the case, for example, that mothers with a certain personality profile are more likely to smoke during pregnancy (Maxson, Edwards, Ingram, & Miranda, 2012) and are also more likely to have offspring who score lower in traits related to self-regulation independently from nicotine exposure. Although there is evidence for a genetic component to personality, the correlation between parent and child personality tends to be small (Bratko, Butkovič, Vukasivić, Keresteš, & Brković, 2014; Pilia et al., 2006). Future research would thus benefit from objective measures of MSDP (e.g., cotinine) to address the potential underreporting of MSDP, repeated measurements of personality across adulthood to address whether the effects are associated with personality development in adulthood, and measures of parent personality to address whether parent personality accounts for the pattern of results. It is particularly important to compare the offspring of mothers who did and did not stop smoking early in the pregnancy to examine the impact of smoking cessation on the offspring personality and other outcomes.

Despite these limitations, the results have theoretical implications for personality development. The results implicate a behavior and possibly a toxin in the origin of personality traits. Coupled with the literature on the effects of prenatal exposure to nicotine

on brain development, it suggests areas of the brain that may be of particular importance to personality. The development of personality starts at conception and the prenatal environment may have life-long associations with trait psychological functioning.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Forest plot of the mean differences in Neuroticism, Extraversion, and Conscientiousness by maternal smoking during pregnancy.

Table 1

Descriptive Statistics for the Study 1 Samples

Demographic Factor	Cohort	
	Older	Younger
Child Sex (female)	49%	49%
Indigenous	2%	2%
Mom age	34.75 (5.13)	31.36 (5.12)
Mom education	5.27 (1.03)	5.49 (.89)
Family income	10.59 (2.63)	10.43 (2.56)
Single parent	12%	7%
Smoked during pregnancy	18%	16%

Note. $N=3,841$ for the older cohort and $N=3,782$ for the younger cohort.

Numbers are either percentages or means (standard deviations). Education was rated on a scale from 1 (*never attended school*) to 6 (*year 12 or equivalent*). Family income was rated on a scale from 1 ($< \$2,600$ per year) to 15 ($> \$124,800$ per year).

Table 2

The Association Between Maternal Smoking During Pregnancy and the Mean-level and Trajectory of Parent Ratings of Temperament in Study 1

Temperament Dimension	Cohort			
	Older		Younger	
	Intercept	Slope	Intercept	Slope
Persistence	-.16 (.03) **	.00 (.01)	-.08 (.03) *	-.03 (.01) **
Emotional Reactivity	.14 (.03) **	.00 (.01)	.13 (.04) **	-.01 (.01)
Sociability	.01 (.04)	.00 (.00)	.02 (.04)	.00 (.01)

Note. $N=3,841$ for the older cohort and $N=3,782$ for the younger cohort. Estimates (standard errors) are from hierarchical linear models controlling for the demographic and social covariates.

*
 $p < .01$.

**
 $p < .01$.

Table 3

Descriptive Statistics for the Study 2 Samples

Demographic Factor	NLSY-CY	NCDS
Child Sex (female)	50%	52%
Child age	25.71 (5.48)	58
Child Education	12.89 (2.32)	2.34 (1.76)
Ethnicity (white)	46%	100%
Ethnicity (African American)	32%	–
Ethnicity (Hispanic)	22%	–
Mom age	25.72 (5.15)	27.53 (5.59)
Early life SES		
Mother's education	12.43 (2.26)	–
Family social class	–	3.10 (1.29)
Single parent	28%	3%
Smoked during pregnancy	26%	32%

Note. $N=1,786$ for the NLSY and $N=6,907$ for the NCDS. Numbers are either percentages or means (standard deviations). NLSY-CY=National Longitudinal Study of Youth-Children and Young Adults. NCDS=National Child Development Study.

Table 4

The Association Between Maternal Smoking During Pregnancy and the Mean-level of Offspring Personality in Adulthood in Study 2

Trait	NLSY		NCDS	
	MSDP (No)	MSDP (Yes)	MSDP (No)	MSDP (Yes)
Neuroticism	2.41 (.02)	2.55 (.04)**	2.78 (.01)	2.82 (.02) [†]
Extraversion	3.42 (.03)	3.53 (.05)*	3.21 (.01)	3.26 (.02)*
Openness	3.80 (.02)	3.78 (.04)	3.53 (.01)	3.56 (.01)*
Agreeableness	3.84 (.02)	3.84 (.04)	4.06 (.01)	4.09 (.01)
Conscientiousness	3.84 (.02)	3.78 (.04)	3.76 (.01)	3.72 (.01)*

Note. $N=1,786$ for the NLSY and $N=6,907$ for the NCDS. Estimated marginal means (standard errors) by mother's who smoked during pregnancy. MSDP=maternal smoking during pregnancy. NLSY-CY=National Longitudinal Study of Youth-Children and Young Adults. NCDS=National Child Development Study.

[†]
 $p=.05$.

*
 $p<.05$.

**
 $p<.01$.

Table 5

The Association Between Maternal Smoking During Pregnancy and Standardized Mean-level of Offspring Personality Using Propensity Score Matching

	MSDP (No)	MSDP (Yes)	MSDP (No)	MSDP (Yes)
	<u>Older LSAC</u>		<u>Younger LSAC</u>	
Temperament				
Persistence	-.07 (.03)	-.24 (.03) **	.02 (.04)	-.14 (.03) **
Reactivity	.08 (.04)	.19 (.03) **	.00 (.03)	.20 (.02) **
Sociability	.03 (.03)	-.01 (.03)	.03 (.04)	-.02 (.03)
	<u>NLSY</u>		<u>NCDS</u>	
Personality				
Neuroticism	-.03 (.05)	.16 (.05) **	-.01 (.02)	.05 (.02) †
Extraversion	-.02 (.05)	.04 (.05)	-.06 (.02)	.02 (.02) *
Openness	-.02 (.05)	-.07 (.05)	-.09 (.02)	-.02 (.02) *
Agreeableness	.07 (.05)	-.07 (.05) *	-.04 (.02)	.01 (.02)
Conscientiousness	.03 (.05)	-.05 (.05)	-.01 (.02)	-.05 (.02)

Note. $N=1350$ for Older LSAC; $N=1136$ for Younger LSAC; $N=841$ for NLSY. $N=4325$ for NCDS. Temperament and personality dimensions were standardized before analyzed. MSDP=maternal smoking during pregnancy. NLSY-CY=National Longitudinal Study of Youth-Children and Young Adults. NCDS=National Child Development Study.

†
 $p=.05$.

*
 $p<.05$.

**
 $p<.01$.