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Maternal age at childbirth and offspring disruptive behaviors: Testing the causal hypothesis

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Abstract

Background—Recent studies suggest that the association between maternal age at childbearing (MAC) and children's disruptive behaviors is the result of family factors that are confounded with both variables, rather than a causal effect of environmental factors specifically related to MAC. These studies, however, relied on restricted samples and did not use the strongest approach to test causal influences.

Methods—Using data on 9,171 4–9 year old and 6,592 10–13 year old offspring of women from a nationally-representative sample of U.S. households, we conducted sibling-comparison analyses. The analyses ruled out all genetic factors that could confound the association, as well as all environmental confounds that differ between unrelated nuclear families, providing a strong test of the causal hypothesis that the environments of children born at different maternal ages influence mother- and self-reported disruptive behaviors.

Results—When these genetic and environmental confounds were ruled out as alternative explanations, the relation between environments within nuclear families specifically associated with MAC and disruptive behaviors was robust, with the association being stronger for second and third-born children.

Conclusions—Environmental factors specifically associated with early MAC within nuclear families account for increased risk of offspring disruptive behaviors, especially in later-born children.

Keywords

disruptive behaviors; conduct problems; maternal age at childbearing; sibling comparisons; quasi-experiments

Women who give birth at earlier ages are more likely to have children who exhibit disruptive behaviors (DBs), behaviors that violate important norms and/or laws (Coley & Chase-Lansdale, 1998). Knowing that antisocial youth are clustered in the families of teen mothers is useful for identifying high-risk groups for targeted prevention (Ingoldsby & Shaw, 2002). It would be even more important, however, to know if some aspects of the environments of children born at different maternal ages exert causal influences on risk for offspring DBs. That

is, the correlation between maternal age at childbirth (MAC) and offspring DBs may not reflect a causal association. Rather, it could be a marker for other causal factors (selection factors), such as environmental differences between women who give birth at different ages or confounded genetic factors.

Selection effects are a concern as mothers who first give birth early in life tend to be unmarried, to co-reside with their own mothers after childbirth, and to give birth to more closely-spaced children (Moffitt & E-Risk Study Team, 2002). Young mothers also tend to have lower cognitive ability (Neiss, Rowe, & Rodgers, 2002), lower socioeconomic status, and to be delinquent (Moffitt & E-Risk Study Team, 2002; Woodward, Fergusson, & Horwood, 2001). Because these factors are all associated with offspring DBs (Jaffee, Caspi, Moffitt, Belsky, & Silva, 2001), MAC could be a non-causal correlate of any of them. Deciding if there are any causal effects of MAC on offspring DBs is of great importance, particularly in the United States where teenage birthrates remain higher than other economically developed countries (Singh & Darroch, 2000) and billions of federal dollars are spent annually on programs to prevent teen pregnancy and to support teen mothers (Hoffman, 2006).

Because MAC is part of a nexus of confounded risks for offspring DBs, it is extremely difficult to determine if MAC is causally related to offspring DBs using most research designs. Therefore, some researchers have used quasi-experimental approaches (Moffitt, 2005; Rutter, 2007) to attempt to disentangle co-occurring risks. Geronimus et al. (1994) used a cousin-comparison design to isolate the effects of maternal age on offspring adjustment using assessments of participants of the National Longitudinal Survey of Youth 1979 (NLSY79) and their young offspring assessed through 1990 ($N=1,764$). "Behavior problems" (a measure of mother-rated internalizing and externalizing problems) were equally high among cousins whose mothers were discordant for teenage childbearing, which was interpreted as indicating that between-family differences in background factors, not MAC, was responsible for increased risk. Because most women in the NLSY79 study had not yet given birth at that point, however, these conclusions were limited by the fact that data were available mostly on the offspring of mothers who had given birth at atypically early ages, which limited any test of MAC.

Turley (2003) repeated the Geronimus et al. (1994) cousin-comparison analyses using a slightly more representative sample of NLSY79 offspring who were at least 4 years old in the 1998 assessment. Focal MAC (the specific MAC for each child) was not associated with child "behavior problems", as assessed by mother-rated internalizing and externalizing problems, when using fixed-effects regressions that accounted for extended family clustering ($N=1,103$ first-born cousins) or when the analyses controlled maternal age at the birth of the first child ($N=6,050$ non-firstborn children). Turley similarly concluded that the association between MAC and offspring adjustment was due to family background factors.

Levine, Emery, & Pollack (2007) also utilized cousin-comparisons in the children of the NLSY79 (through wave 1998) to explore the association between MAC and academic skills in young childhood ($n\approx 2,900$) and problematic behavior in late childhood and early adolescence ($n\approx 1,500$). Although childhood academic achievement was not uniquely related to MAC, some problematic behaviors (grade repetition, truancy, and early sexual initiation) were strongly associated with MAC when using the fixed-effects models.

In contrast, Harden et al. (2007) found that teenage pregnancy was independently associated with offspring adjustment when using quasi-experimental approaches using a large sample of 14–39-year-olds in Australia. Teen childbirth was robustly associated with greater self-reported externalizing and internalizing problems in the offspring, using both sibling-comparison and children-of-twins analyses that ruled out the effect of extended family background factors confounded with MAC.

Several factors may account for differences in findings among these studies. The existent NLSY79 analyses were based on a highly restricted range of MAC—the children of the NLSY79 is an ongoing longitudinal study that now includes approximately 11,430 offspring, most of whom were not included in the previous analyses. These studies also mostly used broad measures of offspring adjustment, which combined mother-reported internalizing and externalizing problems, and primarily focused on the adjustment of young offspring (except Levine et al., 2007). In contrast, Harden et al. used a sample without restrictions on MAC and predicted self-reported externalizing behaviors separately from internalizing problems through young adulthood. Harden et al., however, used an exclusively Caucasian Australian sample; the results, therefore, may not generalize to the diverse U.S. population.

Comparison of Quasi-Experimental Approaches

Most quasi-experimental studies of MAC have primarily relied on cousin-comparisons to account for unmeasured factors, which do not provide the strongest test of causality for MAC. Because siblings share more genetic and environmental risks than cousins, sibling comparisons provide more comprehensive controls for confounds (Harden et al., 2007; Lahey, D'Onofrio, & Waldman, in press; Rutter, 2007). Sibling-comparison analyses can test the hypothesis that the environments of children born at different maternal ages exert influences on offspring DBs by determining if children born when their mother was younger exhibit more DBs than their *own* siblings born when their mother was older, controlling for birth order.

Such comparisons of siblings within nuclear families automatically and completely rule out as alternative explanations for the association of MAC with DBs (1) all environmental influences on DBs from any source that differ between nuclear families but are shared by the siblings within nuclear families (Rodgers, Cleveland, van den Oord, & Rowe, 2000) and (2) all genetic factors. Sibling comparisons rule out confounded genetic risk passed down from mothers (passive gene-environment correlation) because the process of meiosis *randomly* distributes genes across siblings (Rutter, 2007). Similarly, when sibling comparisons are conducted with only full siblings, the approach also excludes genes passed from different fathers to children born at different maternal ages because polymorphisms from the father are similarly distributed randomly across all of his children. Analyses including half siblings cannot do this (e.g., Harden et al., 2007), as children could receive different genetic risk for DBs from different fathers that are correlated with MAC (e.g., antisocial males may tend to father offspring with younger mothers). Sibling-comparison analyses also completely rule out active or evocative gene-environment correlation in situations in which the offspring's behavior cannot influence exposure to the environment (Lahey, D'Onofrio et al., in press; Rutter, 2007). These assumptions are met in the present analyses, as MAC precedes DBs and the child's behavior cannot influence the age at which a mother conceives and gives birth.

The *only* alternative explanations that sibling-comparison analyses do not rule out are environmental variables that are highly *correlated with MAC* among the offspring *within nuclear families* could account for the effect of MAC. Indeed, it is very likely that any environmental effect of MAC would not be due to MAC per se, but to more proximal aspects of the environment that both closely covary with MAC within families and influence risk for future DBs. Proximal environmental risk factors that could mediate the association between MAC and offspring DBs include ineffective parenting (Jaffee et al., 2001; Pogarsky, Lizotte, & Thornberry, 2003; Pogarsky, Thornberry, & Lizotte, 2006), family transitions and separation from a biological parent (Pogarsky et al., 2003), and inadequate family income (Jaffee et al., 2001).

The first important step toward understanding MAC is to determine if the environments of children born at different MACs are, in fact, specifically associated with DBs. The pressing need for rigorous tests of causal hypotheses regarding environmental factors has been noted

recently (Moffitt, 2005; Rutter, 2007). We report the results of sibling-comparison analyses of the children of the NLSY79 that rule out all between-family environmental factors that are shared by siblings and all genetic factors. Because we use data from biennial assessments of DBs conducted from 1986 through 2006, the analyses are more representative of offspring in the U.S. and are much less biased toward early MAC than previous analyses of the NLSY79. We also use both mother-reported conduct problems in 4–9 year olds and self-reported delinquency in 10–13 year olds to account for possible rater biases. Because other studies have shown that individual characteristics, such as sex and ethnicity might be moderators of the influence of MAC (Pogarsky et al., 2006), the analyses also include tests of interactions of such variables with MAC.

Methods

Sample

The initial NLSY79 sample included a nationally representative sample of 6,111 individuals and an over-sample of 3,652 Hispanics and African Americans between the ages of 14–22 years based on a stratified and clustered household probability sampling approach. Because all eligible individuals in each household were selected, multiple females from the same homes were included. Participants were assessed annually from 1979 to 1994 and biennially since then. The current report is based on 4,912 females with a child who was at least four years old in 2004. The initial NLSY79 assessment had a response rate of 90%, with retention rates $\geq 90\%$ during the first 16 waves. Probability weights for the maternal sample, which were used in all analyses, enabled estimates of population-based parameters. Additional details of the NLSY79 (Baker & Mott, 1989) and the sample are available (D'Onofrio et al., 2008).

Biennial assessment of the biological offspring of the NLSY79 women began in 1986. Most mothers participated in each assessment: 95% in the initial assessment and 90% on average in subsequent waves (Chase-Lansdale, Mott, Brooks-Gunn, & Phillips, 1991). The current analyses are based on mother reports of conduct problems of 4–9 years old children ($N=9,171$) and self-reported delinquency from 10–13 year old children ($N=6,592$), assessed through the 2006 interviews.

Measures

Mothers reported their age at the birth of each child. Because the NLSY79 is an ongoing longitudinal study, there is greater range and variability in MAC for the sample of mother-rated DBs ($M=25.3$ years, $Var=32.1$, $min=14$, $25^{th}\%=21$, $75^{th}\%=29$, $max=44$) than for the sample with available child self-reported DBs ($M=23.8$ years, $Var=22.6$, $min=13$, $25^{th}\%=20$, $75^{th}\%=27$, $max=35$). It is also important to note the sample of self-reported DBs was born to younger mothers on average (details in appendix). MAC was centered on age 18 for ease of interpretation.

The NLSY79 assessed numerous characteristics of the mothers that covary with MAC between nuclear families. In 1980 the women completed the Armed Services Vocational Aptitude Battery of intellectual assessments and indicated their highest grade completed by 2004. Family income at the mother's age of 30 years was assessed based on income from all adults in the household. When the NLSY79 mothers were 15–22 years old, their participation in 12 delinquent behaviors was assessed using items from the Self-Reported Delinquency (SRD) interview (Elliott & Huizinga, 1983). Correlations between average MAC for offspring in each family and each covariate are in Table 1. The women also reported their race-ethnicity, coded as Hispanic, African American, or non-African American/non-Hispanic.

Mother-Reported Child Conduct Problems—In each assessment, NLSY79 mothers rated their children on the Behavior Problem Index, which includes 13 items from the Child Behavior Checklist with strong associations with the externalizing factor (Peterson & Zill, 1986). Factor analyses of the items (D'Onofrio et al., 2008) showed that the items loaded on 3 factors: conduct problems (CPs), oppositional problems, and attention/impulsivity problems. The 7 CP items (cheats or tells lies; has trouble getting along with teachers; disobedient at home; disobedient at school; bullies or is cruel or mean to others; breaks things on purpose or deliberately destroys his/her own or another's things; and does not seem to feel sorry after misbehaving) overlap considerably with those used in other population-based longitudinal studies (review in Lahey et al., 2006). It is important to note that the measure does not measure conduct disorder symptoms, per se. Standardized z-scores for CPs were calculated within each age, and, for children assessed repeatedly, average scores across ages of 4 and 9 years were calculated. The variable was transformed using a well-validated approach (van den Oord et al., 2000) and standardized for ease of interpretation. The measure of CPs is highly stable across this age range (D'Onofrio et al., 2007); correlates highly with other concurrent measures of adjustment; and is a good predictor of future criminal convictions in adolescence (with no sex differences in the assessment of criterion validity) while controlling sex, race-ethnicity, and family income (Lahey et al., 2006).

Self-Reported Delinquency—Offspring who were between the ages of 10 and 13 were administered 7 delinquency items based on the SRD interview. The SRD is reliable and valid and is a benchmark measure in contemporary delinquency research (Loeber, Farrington, Stouthamer-Loeber, & Van Kammen, 1998; Moffitt, 1990). The 7 SRD delinquency items used were: hurt someone bad enough to need bandages or a doctor; lied to parent about something important; took something from a store without paying for it; intentionally damaged or destroyed property that didn't belong to you; had to bring your parent(s) to school because of something you did wrong; skipped a day of school without permission; and staying out overnight without permission. The items assess high-prevalence acts that correlate highly with more serious antisocial behaviors from the SRD. Select waves of the NLSY included 10 additional items from the SRD. The 7-item scale correlated highly with ($r > 0.90$) the 17-item scale across late child and early adolescence. The measure also independently predicts later criminal convictions, controlling for numerous background characteristics, with no evidence of sex differences in the criterion validity (Lahey, Van Hulle, D'Onofrio, Rodgers, & Waldman, in press). Thus, the 7-item scale is a strong index of delinquent behaviors that assesses liability for socially-significant problems. The mean level of self-reported delinquency (transformed and standardized) was analyzed.

Statistical Analyses

Regression-based analyses of the association between MAC and offspring DBs were conducted using Hierarchical Linear Models (HLMs) to account for the nested nature of the data. Five models were fit to mother and self-reported DBs. Model 1 fit an HLM that examined the unadjusted association between MAC and offspring DBs, controlling for sex and birth order of the offspring. Model 2 explored whether offspring sex influenced the magnitude of the association between MAC and DBs. Model 3 investigated whether the association between MAC and DBs was moderated by birth order. The moderating influence of family race/ethnicity was also tested, with null findings (see appendix).

The analyses took advantage of the fact that the CNLSY includes multiple offspring per mother. Model 4 estimated the association between MAC and DBs both *within* and *between* mothers. The within-mother analyses determined if differences in MAC among the sibling offspring of each mother are associated with offspring DBs (i.e. do children born to younger mothers have more DBs than their siblings born when the same mothers were older?). If environmental

factors associated with MAC are causal influences on DBs, the association would be found within mothers (Rodgers et al., 2000). Sibling comparisons were made by taking the deviation of the focal MAC for each child from the mother's mean MAC across all of her pregnancies. The model also compared unrelated offspring, a between-family estimate of MAC, by including the average MAC for all siblings in a nuclear family in the HLM, in addition to the deviation score. The between and within estimates for the interaction terms were similarly calculated as means and deviations at each level. The sibling comparison models only tested within-family parameters of moderating variables that were child-specific (e.g., birth order). The statistical approach provides correct between- and within-family estimates (Neuhaus & McCulloch, 2006) and yields exactly the same parameter estimates as fixed-effect models (Greene, 2003; see appendix). For further details concerning the analyses, including explanations of HLM and algebraic models, see D'Onofrio et al. (2008) and Harden et al. (2007).

Model 5 compared siblings in the subsample of nuclear families in which all children were full siblings to exclude the possibility that the MAC effect is actually the result of genetic or environmental factors associated with different fathers of half siblings born at different ages. A series of sensitivity analyses were conducted to test whether the results were robust to alternative methods of controlling for confounds and different assumptions (see appendix).

Results

Mother-Reported Child CPs

Model 1 indicated that for every one year increase in MAC offspring CPs was reduced by 0.031 standard deviations ($p < .001$, $\beta = -0.18$), controlling for offspring gender and birth order. Offspring sex robustly moderated the association with MAC; results presented in Model 2. The MAC effect differed significantly by sex ($b_{\text{interaction}} = .006$, $p < .05$), with the magnitude being larger in boys. Model 3 examined the possible moderating effect of birth order. Second and third-born offspring of young mothers (at age 18) had more CPs ($b = .10$ SD/birth order), and the results suggest that association between MAC and DBs was stronger for second and third-born offspring ($b_{\text{interaction}} = -.006$, $p < .001$), as illustrated in Figure 1 (Panel A). The figure presents the estimated unadjusted relations between MAC and offspring CPs for the first three male and female children in each family. Regression parameters for the MAC-CPs association for each gender and birth order are also presented in the appendix.

Model 4 used the multiple levels of analyses in the NLSY79 and children of NLSY79 samples to compare siblings differentially exposed to MAC within nuclear families. The comparison of unrelated offspring again suggested an association that was stronger for first-born males ($b = -.032$ SD/yr., $p < .001$) than females ($b = -.024$ SD/yr.). The effects of MAC also depended on the birth order of the offspring ($b_{\text{interaction}} = -.004$, $p < .05$) when comparing unrelated individuals. The within-family, sibling comparisons indicated a significant association for first-born boys ($b = -.024$ SD/yr., $p < .001$) and girls ($b = -.021$ SD/yr.), indicating that some environmental factor(s) associated with being born to a younger mother increase risk for offspring DBs. Offspring born to young mothers had more CPs ($b = .09$ SD/birth order). Birth order also moderated the effect of MAC ($b_{\text{interaction}} = -.008$), indicating the association between MAC and CPs is stronger in later born offspring. Panel B in Figure 1 illustrates the association between MAC and offspring CPs using the estimates from Model 4. The associations are quite similar to Panel A, demonstrating that the within-family sibling-comparison approach only slightly attenuated the relation between MAC and offspring CPs.

Parameter estimates from Model 5, in which analyses were restricted to only families with full siblings, were essentially identical to those in the analyses based on all siblings. When comparing full siblings the association between MAC and DBs was large for first born male

($b = -.036$ SD/yr., $p < .0001$) and female ($b = -.32$ SD/yr., $p < .0001$) offspring. Again, second and third-born offspring of young mothers had more CPs ($b = .07$ SD/birth order), and the magnitude of the MAC-CPs association was larger for later born children ($b_{\text{interaction}} = -.006$).

Child-Reported Delinquency

MAC was inversely associated with offspring self-reported delinquency in Model 1 ($b = -.032$ SD/yr., $\beta = -.19$, $p < .001$). Model 2 suggested that offspring gender may moderate the association, but the strength of the association was only marginally greater in males ($b_{\text{interaction}} = .009$, $p = .06$). Model 3 indicated that second and third-born offspring of young mothers had substantially higher rates of delinquency ($b = .27$ SD/birth order), and that birth order moderates the association ($b_{\text{interaction}} = -.014$, $p < .0001$), with the association being larger for later born offspring. Panel A in Figure 2 graphically presents the estimated levels of delinquency for the first three boys and girls in each family.

Model 4, the sibling-comparison model, yielded similar results. The association between MAC and delinquency was robust for first-born males ($b = -.024$) and females ($b = -.020$) when comparing siblings. Birth order for young mothers was associated with substantial increased risk of delinquency ($b = .29$ SD/birth order). Birth order also moderated the association between MAC and CPs ($b_{\text{interaction}} = -.012$, $p < .0005$). Panel B in Figure 2 graphically presents the results of the sibling comparisons in Model 4. Model 5, the comparison of full siblings, resulted in comparable findings, indicating that environmental or genetic influences from different fathers do not explain the association between MAC and child delinquency.

Sensitivity Analyses

Additional models that included maternal age at the birth of the first child *and* focal MAC for all second-born and subsequent children, a common test of selection factors (Turley, 2003), revealed that focal MAC remained a significant predictor of offspring DBs, with estimates comparable to those presented in Model 1. Regression analyses controlling for the measured covariates indicated that focal MAC was uniquely associated with both measures of DBs when statistically controlling for the confounds. Sibling comparisons, ignoring the moderating effects of offspring gender and birth order, are also presented in the appendix. Odds ratios associated with yearly increases in MAC predicting high DBs (the top 10% of each measure) are also presented. Each year delay in first MAC was associated with a reduction in the high CPs ($OR = 0.92$) and delinquency group ($OR = 0.95$).

Discussion

The present analyses support the hypothesis that environmental factors specifically associated with MAC exert a causal influence on risk for offspring DBs in a number of ways. First, the association between focal MAC and DBs was statistically robust when siblings were compared within families (i.e., children born to younger mothers had more DBs on average than their siblings born at older maternal ages). Second, the association remained statistically robust when only full-siblings were compared within nuclear families. An inference that some aspects of the environments of offspring of younger mothers exerts a *causal* effect on offspring DBs is supported because these sibling-comparison analyses of full siblings controlled for (1) all environmental factors that are correlated with MAC that differ between nuclear families and are shared by siblings within nuclear families and (2) all genetic factors that vary among siblings. Third, the association between focal MAC and DBs was statistically robust when controlling maternal age at her first childbirth and when statistically controlling for statistical covariates that are highly correlated with MAC between families (see appendix).

These analyses support and extend the results of the extant sibling comparison study of MAC (Harden et al., 2007), which was not able to restrict the analyses to full siblings and was based on a sample homogeneous in race/ethnicity. The differences in conclusions between previous studies of NLSY79 offspring (Geronimus et al., 1994; Turley, 2003) and the current report could be due to many factors. First, the previous studies were based on the first offspring, who were disproportionately born to younger mothers, restricting the range of MAC. Because essentially all NLSY79 childbearing was completed by 2006 and the current analyses are based on ratings of children as young as 4 years, the selection bias due to restricted MAC is quite small for the current analyses, providing a greater range of MAC in the present analyses. Second, the present analyses did not dichotomize MAC (comparing teenage childbearing to later childbearing), which reduces the statistical power to find associations. Third, we used specific measure of child DBs rather than a global measure of adjustment that combined internalizing and externalizing problems.

To our knowledge, this is the first examination of whether birth order moderates the effects of MAC. It is extremely important for prevention science that second and third-born offspring born to young mothers are at substantially greater risk of engaging in DBs, especially self-reported delinquency. For example, the third-born male to an 18 year old woman has approximately a .50 standard deviation increase in self-reported delinquency compared a first-born male. It will be essential to understand the meaning of this interaction to fully understand maternal age effects. Although the association between MAC and DBs for first born children may not appear to be dramatic, every year delay in first MAC was associated with an 8% reduction in the risk of offspring being in the high CPs group and a 5% reduction in risk of being in the high delinquency group (see appendix for additional information). Thus, programs that delay the age at first childbirth could also have important societal implications.

The current results only examined the effects of MAC on childhood DBs (through age 13). Given the current structure of the children of the NLSY79 sample, we did not test the hypothesis that the effects of MAC are *larger* for adolescent delinquency (Brooks-Gunn & Furstenberg, 1986). Because most of the offspring of the NLSY79 are not yet teenagers, such an analysis would have to rely on a sample with a severely restricted range of MAC. As the offspring of women in the NLSY79 continue to be followed it will be possible to test the effects of MAC on later adjustment. The assessment of DBs used in the current analyses also did not fully assess all possible DBs, including behaviors that might be better indicators for females (e.g., Zoccolillo, 1993). Sibling-comparison analyses rely on the assumption that the results of families with multiple offspring are comparable to families with one children, as the within-mother estimates can only be based on mothers with multiple offspring (D'Onofrio et al, 2008).

Thus, the present findings suggest that the prevailing view—MAC is only related to offspring DBs because of background family factors—is incorrect. In contrast, our analyses of the NLSY support the causal hypothesis that environmental influences on CPs associated with MAC are independent of both genetic confounds and between-family environmental confounds. These results suggest that further reductions in early childbearing, especially if mothers delay having more than one child, may reduce future levels of DBs in children. In addition, these findings set the stage for informative future analyses of the proximal causal environmental influences on child DBs in the future. An important task for future research will be to identify the specific environmental factors (e.g. differences in parenting practices, family transitions, and family income) associated with MAC that vary within families and are the proximal environmental influences of DBs. These proximal factors would be key targets for randomized trials of programs to prevent offspring DBs.

Key Points

- Previous research has suggested that familial confounds are responsible for the increased risk for conduct problems among offspring born to young mothers.
- The results of the current study suggest children born to young mothers are at significantly increased risk for engaging in conduct problems, particularly second and third-born children.
- In contrast to previous research, the association between maternal age at childbearing and offspring conduct problems was not fully explained by background factors that differ *between* families (e.g., environmental factors that similarly influence all siblings in a family or genetic factors passed down from mothers and fathers).
- The results suggest that environmental factors specifically associated with early maternal age at childbearing *within* nuclear families account for increased offspring disruptive behaviors, consistent with a causal environmental hypothesis.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Abbreviations

MAC	maternal age at childbirth
DBs	disruptive behaviors
CPs	conduct problems

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Appendix

Sample

Distribution of Maternal Age at Childbearing for the Sample with Mother-Rated Conduct Problems Scores for First Three Children Born in the Family

Birth Order	N	Mean	Var	Min	Max
1	3809	23.129	27.947	14.0	42.0
2	3061	25.867	27.987	15.0	43.0
3	1450	27.634	26.039	17.0	44.0

Distribution of Maternal Age at Childbearing for the Sample with Child-Rated Delinquency Scores for First Three Children Born in the Family

Birth Order	N	Mean	Var	Min	Max
1	2967	21.948	20.663	13.0	35.0
2	2146	24.573	18.555	15.0	36.0
3	974	26.184	16.144	15.0	36.0

Additional Analyses

Family race-ethnicity did not moderate the association between MAC and offspring conduct problems. Dummy codes were used to compare different racial/ethnic groups. African American and Hispanic families were compared to non-African American/non-Hispanic families. While controlling for the main effect of the dummy codes for race/ethnicity, the interaction between MAC and African American status ($b_{\text{interaction}} = -.006$, $SE = .004$, $p = .20$) and Hispanic status ($b_{\text{interaction}} = -.005$, $SE = .006$, $p = .36$) suggest that the magnitude of the association between MAC and offspring CPs is not moderated by family race/ethnicity.

Unstandardized regression coefficients for MAC and mother-reported conduct problems estimated separately by gender and birth order.

Birth Order	Male	Female
1	-.039	-.019
2	-.036	-.038

Birth Order	Male	Female
3	-.054	-.054

Note. Each cell represents an independent regression analysis conducted on the offspring meeting the specific criteria. All $p < .05$. Unstandardized regression coefficients are in standard deviation units (Z-score).

Unstandardized regression coefficients for MAC and child-reported delinquency estimated separately by gender and birth order.

Birth Order	Male	Female
1	-.034	-.013
2	-.041	-.048
3	-.062	-.042

Note. Each cell represents an independent regression analysis conducted on the offspring meeting the specific criteria. All $p < .05$. Unstandardized regression coefficients are in standard deviation units (Z-score).

A model predicting mother-rated conduct problems (ages 4–9) in all second-born and subsequent children ($N=5,357$) from focal MAC and MAC for the first child revealed that focal MAC remained a robust predictor ($b=-.031$, $SE=.004$, $p<.0001$). The estimate was comparable to Model 1, which estimated the association between focal MAC and offspring conduct problems in the entire sample. MAC for the first child also predicted conduct problems ($b=-.012$, $SE=.005$, $p<.05$).

A model predicting child-reported delinquency (ages 10–13) in all second-born and subsequent children ($N=3,625$) from focal MAC and MAC for the first child revealed that focal MAC remained a robust predictor ($b=-.026$, $SE=.006$, $p<.0001$). The estimate was comparable to Model 1, which estimated the association between focal MAC and offspring conduct problems in the entire sample. MAC for the first child also predicted conduct problems ($b=-.028$, $SE=.007$, $p<.0001$).

HLMs were fit to the data to assess whether focal MAC was associated with each measure of DBs while statistically controlling for the measured covariates (maternal intellectual abilities, highest grade of education, income at the age of 30, and history of delinquency). Multiple imputation was used to account for missing data. Over 80% of the women with children had responses for each covariate.

Predicting mother-rated conduct problems (controlling for statistical covariates)

	b	SE	p
Focal MAC	-0.021	0.003	<.0001
Focal MAC*sex	0.006	0.003	<.05
Focal MAC*birth order	-0.006	0.001	<.0001

Predicting child-rated delinquency (controlling for statistical covariates)

	b	SE	p
Focal MAC	−0.024	0.004	0.0010
Focal MAC*sex	0.009	0.004	<.05
Focal MAC*birth order	−0.014	0.002	<.0001

Analyses which controlled for the number of assessments included in the estimation of DBs, controlled for the oldest age at which DBs were assessed, and predicted highest level of DBs across the age ranger rather than the average DBs resulted in comparable findings. Results available upon request.

Comparisons ignoring interactions with offspring gender and birth order (see Supplemental Figure Below)

Outcome	Unrelated Comp		Sibling Comp^a		Full Sibling Comp^a	
	b	SE	b	SE	b	SE
Mother-reported Conduct Problems	−.031	.002	−.030	.004	−.039	.007
Child-reported Delinquency	−.032	.003	−.031	.005	−.043	.009

Note. The analyses controlled for the fixed effects of offspring gender and birth order. All $p < .05$.

^aEquivalent results were obtained when conducting a fixed effects model based on alternative parameterizations of sibling comparisons—using the deviation scores of the dependent and independent variables (Neuhaus & McCulloch, 2006).

Because there is no consensus among statisticians on how to calculate standardized estimates using multilevel or hierarchical linear models, we dichotomized each measure of DBs so that we could estimate odds ratios. The odds ratios estimate the percent reduction of children in the high DBs group (defined by the top 10% of children) associated with each year delay in MAC.

Odds Ratios Associated with Maternal Age at Childbearing Predicting Top 10% of Mother and Self-Reported Disruptive Behavior

Birth Order	Mother CD		Self-reported Delinquency	
	Unadjusted	Sibling comp	Unadjusted	Sibling comp
1	0.914	0.924	0.950	0.948
2	0.910	0.912	0.914	0.906
3	0.907	0.900	0.860	0.865

Note. The coefficients are based on the Model 3 (unadjusted) and Model 4 (sibling comp), without the moderating effects of offspring gender (thus the coefficients are the same for males and female). Only coefficients based on MAC are presented. Full results available upon request. $p < .05$ for all estimates for first-born offspring. Estimates for second and third-born offspring are based on the interaction of MAC and MAC*birth order terms.

Figure 1.

The Unadjusted (A) and Adjusted (B) Association between Maternal Age at Childbirth and Mother-Rated Conduct Problems

Note. The first panel (A) illustrates the unadjusted statistical relation. The second panel (B) illustrates the relation using a sibling-comparison approach (based on Model 4). Estimates were only provided for maternal ages with greater than 5 offspring.

Figure 2.

The Unadjusted (A) and Adjusted (B) Association between Maternal Age at Childbirth and Child-Rated Delinquency

Note. See note for Figure 1.

Table 1

Correlations among mean MAC and Maternal Covariates

Variable	1	2	3	4	5	6
1. Mean MAC	-					
2. Age First Childbearing	.89*	-				
3. Intellectual Abilities	.32*	.39*	-			
4. Highest Grade	.42*	.46*	.55*	-		
5. Maternal Income 30 yrs. old	.16*	.16*	.19*	.18*	-	
6. History of Delinquency	-.07*	-.07*	-.07*	-.09*	-.03	-

Note. Mean MAC is the average age at which each woman had all her children. Correlations are based on five multiply imputed datasets to account for missing values.
* $p<.05$.

Table 2
Hierarchical Linear Models of Maternal Age at Childbirth and Mother-Reported Offspring Conduct Problems

Parameter	Model 1		Model 2		Model 3		Model 4		Model 5 ^a	
	b	SE	b	SE	b	SE	b	SE	b	SE
Maternal Age at Childbearing										
Focal MAC	-.031*	.002	-.034*	.002	-.029*	.002				
Focal MAC * Sex			.006*	.003	.006*	.003				
Focal MAC * Birth Order					-.006*	.001				
Sibling Comparison							-.024*	.004	-.036*	.008
Sibling Comparison * Sex							.003	.004	.004	.006
Sibling Comparison * Birth Order							-.008*	.001	-.006*	.003
Unrelated Comparison							-.032*	.004	-.026*	.005
Unrelated Comparison * Sex							.008*	.004	.007	.004
Unrelated Comparison * Birth Order							-.004*	.002	-.004	.003
Offspring Gender	-.28*	.02	-.35*	.04	-.35*	.04	-.42*	.08	-.40*	.13
Birth Order	.03*	.01	.03*	.01	.10*	.02	.09*	.02	.07*	.02

Note. Conduct problems are distributed as standard deviations. Mothers' age at the birth (MAC) of her children is measured in years after the age of 18. Offspring gender was coded 0=male, 1=female. Birth order was distributed from 0 (first-born child) to 9 (tenth-born child) so that the estimate for MAC would correspond to the relation between for MAC for the first child in each family.

* $p < .05$.

^a Only included children ($N=4,608$) from families in which all the children were full siblings.

Table 3
Hierarchical Linear Models of Maternal Age at Childbirth and Child-Reported Delinquency

Parameter	Model 1		Model 2		Model 3		Model 4		Model 5 ^a	
	b	SE	b	SE	b	SE	b	SE	b	SE
Maternal Age at Childbearing										
Focal MAC	-.032*	.003	-.036*	.004	-.027*	.004				
Focal MAC * Sex			.009	.005	.008	.005				
Focal MAC * Birth Order					-.014*	.002				
Sibling Comparison							-.024*	.006	-.034*	.011
Sibling Comparison * Sex							.004	.004	.005	.010
Sibling Comparison * Birth Order							-.012*	.003	-.017*	.006
Unrelated Comparison							-.028*	.005	-.029*	.006
Unrelated Comparison * Sex							.011*	.005	.008	.008
Unrelated Comparison * Birth Order							-.016*	.003	-.020	.004
Offspring Gender	-.39*	.02	-.49*	.06	-.49*	.06	-.57*	.12	-.57*	.19
Birth Order	.15*	.01	.15*	.01	.27*	.02	.29*	.03	.32*	.05

Note. Delinquency is distributed as standard deviations. See note on Table 1.

* $p < .05$.

^a Only included children ($N=3,219$) from families in which all the children were full siblings.