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Journal

Clinical Psychological Science, 2(5)

ISSN

2167-7026

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Publication Date

2014-09-01

DOI

10.1177/2167702613518046

Peer reviewed

HHS Public Access

Author manuscript

Clin Psychol Sci. Author manuscript; available in PMC 2016 March 22.

Published in final edited form as:

Clin Psychol Sci. 2014 September 1; 2(5): 591–601. doi:10.1177/2167702613518046.

Interactions Between Monoamine Oxidase A and Punitive Discipline in African American and Caucasian Men's Antisocial Behavior

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Abstract

Although previous studies have shown that interactions between monoamine oxidase A (*MAOA*) genotype and childhood maltreatment predict Caucasian boys' antisocial behavior, the generalizability of this gene-environment interaction to more diverse populations and more common parenting behaviors, such as punitive discipline in early childhood, is not clearly understood. Among 189 low-income men (44% African American, 56% Caucasian) who underwent rigorous assessments of family behavior and social context longitudinally across 20 years, those men with the low activity *MAOA* allele who experienced more punitive discipline at ages 1.5, 2, and 5 years showed more antisocial behavior from ages 15 through 20 years. Effects of punitive discipline on antisocial behavior differed by caregiver and age at which it occurred, suggesting sensitive periods throughout early childhood in which low *MAOA* activity elevated boys' vulnerability to harsh parenting and risk for antisocial behavior. This genetic vulnerability to punitive discipline—and not just extreme, maltreatment experiences—may generalize to other male populations at risk for antisocial behavior.

Keywords

antisocial behavior; gene-environment interaction; punitive discipline; monoamine oxidase A; African American

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Supplemental Material

Additional supporting information may be found at http://cpx.sagepub.com/content/by/supplemental-data

Author Contributions

D. E. Choe and D. S. Shaw developed the study concept and design. D. E. Choe conducted the analyses under the guidance of D. S. Shaw. D. E. Choe drafted the manuscript, and D. S. Shaw, L. W. Hyde, and E. E. Forbes critically revised the manuscript. All authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Parental use of punitive discipline in early childhood, such as spanking and yelling, is one of the most established risk factors for antisocial behavior (AB), yet only a fraction of exposed youths go on to develop AB (Dodge & Pettit, 2003; Gershoff, 2002). In their seminal study, Caspi et al. (2002) demonstrated a gene-environment (G×E) interaction whereby a variant in the monoamine oxidase A (*MAOA*) gene moderated effects of childhood maltreatment (e.g., physical abuse and neglect) on AB. Maltreated Caucasian boys with the low-activity *MAOA* genetic variant showed more serious AB as adults than did boys with the high-activity *MAOA* allele. Thus, genotypes that conferred low transcriptional efficiency and expression of *MAOA* identified youth more sensitive to the negative effects of childhood maltreatment on their subsequent AB.

It is increasingly recognized that interactions between environmental and genetic factors explain the development of AB better than either can alone, but several questions remain about *MAOA* interactions with caregiving experiences. Specifically, it is unclear whether (a) children from different racial-ethnic strata share similar genetic vulnerabilities to maltreatment, (b) less extreme types of harsh parenting exacerbate AB within the context of *MAOA* variability, and (c) particular phases of development represent periods of increased sensitivity to the adverse effects of harsh parenting in children who are vulnerable. These three issues were addressed in the present study, in which we examined whether individual differences in a functional polymorphism within the promoter region of the *MAOA* gene moderated the effects of parental punitive discipline in early childhood on low-income African American and Caucasian men's AB.

Monoamine oxidase is an enzyme encoded by a gene on the X chromosome that degrades monoamine neurotransmitters, such as serotonin and dopamine, which are linked to aggression (Caspi et al., 2002). The *MAOA* upstream variable number of tandem repeats (*MAOA-u VNTR*) region is a functional polymorphism that has been shown to alter transcriptional efficiency of the *MAOA* gene (Sabol, Hu, & Hamer, 1998). Alleles with 3.5- and 4-repeat sequences show high *MAOA* messenger RNA expression and high enzyme activity and, thus, likely low levels of monoamines in the brain, whereas 2-, 3-, and 5-repeat variants show low messenger RNA expression, low enzyme activity, and likely elevated monoamine levels (Sabol et al., 1998). Multiple studies have replicated interactions between *MAOA* and childhood maltreatment in relation to AB; however, differences in sample characteristics and measurement of environmental adversity have contributed to discrepant findings in the literature (Byrd & Manuck, 2013).

Studies linking interactions between *MAOA* and maltreatment to AB have focused primarily on samples of Caucasians (Caspi et al., 2002; Frazetto et al., 2007; Kim-Cohen et al., 2006) and inconsistently replicated this effect in racial-ethnic minority youth (Beaver, Nedelec, Wilde, Lippoff, & Jackson, 2011; Huang et al., 2004; Young et al., 2006). In particular, few researchers have explored G×E interactions in African American families, which is a salient limitation given African American children's disproportionately high levels of AB and exposure to harsh discipline and maltreatment (Dodge & Pettit, 2003; Gershoff, 2002). A recent meta-analysis of studies on interactions between *MAOA* and maltreatment showed that results did not vary by excluding or including samples of non-Caucasians (Byrd & Manuck, 2013); however, individual studies have reported failed replications of this G×E

interaction in small subsamples of African Americans (Reti et al., 2011; Widom & Brzustowicz, 2006). Thus, it remains unclear whether interactions between *MAOA* and early harsh parenting contribute to both Caucasian and African American men's AB, particularly for men who experienced more normative forms of punitive discipline in childhood rather than maltreatment.

In many studies in the literature on *MAOA*, researchers have not assessed common parenting behaviors of punitive spanking and yelling that often precede child abuse and exist along a dimension of harsh to abusive parenting, which limits their generalizability to severe maltreatment. Researchers have tended to recruit severely disturbed clinical samples of youth (e.g., Frazetto et al., 2007; Huang et al., 2004; Young et al., 2006) or children with documented histories of maltreatment, such as child abuse and neglect confirmed by county court records (Cicchetti, Rogosch, & Thibodeau, 2012; Weder et al., 2009; Widom & Brzustowicz, 2006). Aside from their focus on extreme cases in the population (14% of U.S. children are estimated to have experienced maltreatment in 2011; Finkelhor, Turner, Shattuck, & Hamby, 2013), researchers often aggregate assessments of maltreatment up to age 11 or 15 when they test interactions with *MAOA* (Caspi et al., 2002; Huang et al., 2004; Weder et al., 2009; Young et al., 2006), thereby preventing tests of the developmental timing of harsh-parenting effects on AB, as well as of specificity in the adult source of harsh treatment (i.e., mother, father, or nonfamilial adult).

Thus, it is possible that failed attempts to replicate G×E interactions with *MAOA* were due in part to too narrow an assessment of rare maltreatment experiences (e.g., child abuse and neglect), too broad a developmental time frame for its consideration (i.e., both childhood and adolescence), and variation among who reported or committed maltreatment. A developmentally informed selection of typical parenting behaviors that amplify risk for AB and an identification of particular sources of punishment are warranted for the present study to expand the range of experiences that contribute to AB in vulnerable youth.

Parental use of punitive discipline, specifically spanking, has been shown to peak in frequency at ages 2 and 3 (Holden, Coleman, & Schmidt, 1995), but approximately 94% of parents in a nationally representative U.S. sample reported using punitive discipline by the time their children were 4 or 5 years old (Straus & Stewart, 1999). Accordingly, exposure to punitive discipline from infancy through the preschool years is associated with more serious and stable conduct problems than are punitive experiences occurring later in development (Keiley, Howe, Dodge, Bates, & Pettit, 2001). One of the only G×E interaction studies to have used prospective assessments of physical discipline in early childhood identified their interactions with *MAOA* in predicting Caucasian men's delinquent behavior (Edwards et al., 2010); however, the study's measure of delinquency was an aggregate of assessments made between ages 6 and 22 years, and thus, it was unclear at what developmental phase these problems emerged. Researchers have elucidated life-course-persistent and adolescent-limited trajectories of AB that differ in levels of risk exposure in childhood, with the former faring worse on parents' harsh and inconsistent discipline, as well as children's early behavioral problems (Moffitt & Caspi, 2001). To the best of our knowledge, researchers have not examined whether parental use of punitive discipline during early childhood contributes to AB in both adolescence and adulthood in individuals with vulnerable *MAOA*

alleles. Moreover, in no *MAOA* study that we know of have researchers controlled for children's early externalizing problems or used observational measures of harsh parenting during toddlerhood.

The current study offers multiple advantages in elucidating G×E interactions in the development of AB. First, compared with researchers who relied on retrospective self-reports of childhood maltreatment (Frazetto et al., 2007; Reti et al., 2011; Young et al., 2006), we collected prospective data on punitive discipline using multiple informants and methods, including observations. Second, researchers who aggregate measures of the environment throughout childhood and adolescence (e.g., Huang et al., 2004; Weder et al., 2009) obscure potential differences in vulnerability to environmental risk across developmental periods. We examined punitive discipline at multiple points in early childhood because of its salience and robust association with conduct problems during this time and to specify which caregiver and at what age punitive experiences elevated risk for AB (Gershoff, 2002; Holden et al., 1995). In addition, we included AB outcomes in adolescence and young adulthood to elucidate the developmental context in which AB was expressed.

Third, in G×E studies, researchers often target small subgroups of the general population, such as clinical samples (e.g., Frazetto et al., 2007; Young et al., 2006) or children with documented maltreatment (e.g., Cicchetti et al., 2012; Widom & Brzustowicz, 2006). Our community sample of Caucasian and African American men was at risk for AB because of their low-income status, which makes our sample generalizable to a large portion of the overall population and one at high risk for AB. Fourth, inconsistent replication of G×E interactions across racial-ethnic groups prompted us to examine whether interactions between *MAOA* and punitive discipline would predict AB for both Caucasian and African American men. Given that studies have indicated racial-ethnic variation in *MAOA* allele frequencies (e.g., Sabol et al., 1998), we conducted analyses separately by race. Last, we used prospective data on early externalizing behavior to control for patterns of childhood-onset AB and their associations with punitive discipline, thereby considering potential G×E correlations (Moffitt, 2005) and reducing third-variable threats to this study's internal validity (Hutchison, Stallings, McGeary, & Bryan, 2004; Zintzaras & Lau, 2008). We hypothesized that punitive discipline in early childhood would predict more AB in adolescence and young adulthood only among African American and Caucasian men with the low-activity *MAOA* allele.

Method

Participants

Participants were from an ongoing longitudinal study of child development that began in 1991 with the recruitment of 310 low-income infant boys and mothers from Women, Infant, and Children Nutritional Supplement Program clinics in a metropolitan area. Assessments were conducted almost annually at homes or laboratory settings with primary caregivers and boys from ages 1.5 through 20 years. When the boys were 5 years old, 191 alternative caregivers participated; most were biological fathers (81%), followed by stepfathers or boyfriends of mothers (9%), grandparents (5%), and others (5%). At age 15, boys invited a

friend to home assessments to rate the target child's problem behavior. The present study included 189 men (44% African American, 56% Caucasian) who provided DNA samples at age 17 (for sample details, see Shaw, Hyde, & Brennan, 2012). These men and those excluded from analyses did not differ on sociodemographic variables, externalizing behavior, or maternal punitiveness at ages 1.5, 2, and 5 years.

DNA extraction and genotyping

DNA was isolated from saliva samples using the Oragne DNA self-collection kit following manufacturer instructions (DNA Genotek Inc., Ottawa, Ontario, Canada). *MAOA-u VNTR* sequences, located between bands Xp 11.23 and Xp 11.4, were identified using polymerase chain reaction and gel electrophoresis. Hardy-Weinberg equilibrium could not be calculated due to men having only one *MAOA* allele. *MAOA-u VNTR* genotyping resulted in four variants with lengths of 2, 3, 4, and 5, consistent with previous translations (Sabol et al., 1998). Participants with the 4-repeat length were classified as "high" on *MAOA* activity, whereas participants with 2-, 3-, and 5-repeat lengths were classified as "low." The classification of the extreme lengths 2 and 5 is still a matter of debate (Kim-Cohen et al., 2006), but only 9 individuals possessed these alleles. Therefore, men who were hemizygous for the 3- and 4-repeat alleles were compared with one another in all analyses as the low-*MAOA*-activity (*MAOA*-L) and high-*MAOA*-activity (*MAOA*-H) groups, respectively. Results remained the same after we added participants with extreme lengths to the *MAOA*-L group.

Measures

Punitive discipline—When children were 1.5 and 2 years of age, the Early Parenting Coding System (Shaw et al., 1998) was used to code observations of maternal punitiveness during laboratory tasks with toddlers; the tasks were designed to elicit varying levels of stress in mothers and children. Observers used a global code to rate maternal punitiveness during cleanup and puzzle-teaching tasks when the boys were 1.5 years old, and the same global code was used to rate maternal punitiveness during cleanup tasks when the boys were 2 years old. *Punitiveness* was defined as the extent to which the mother was too strict, demanding, or harsh, considering the child's behavior. Global ratings were made using a 4-point scale ($\kappa = .94$). When children were 5 years old, mothers and alternative caregivers reported how often in an average week they threatened, spanked or slapped, or yelled in anger to discipline their child; responses were made using a 6-point scale on the Parental Responses to Child Misbehavior Questionnaire (Holden et al., 1995). Items were summed to create punitive discipline scores for each caregiver with adequate internal consistency (mean $\alpha = .69$).

Externalizing behavior—Mothers rated the frequency of 1.5-year-old children's aggressive and oppositional behaviors during the past month using the Toddler Behavior Checklist (Larzelere, Martin, & Amberson, 1989). Responses were made using a 4-point scale, and items were summed into an externalizing behavior score with high internal consistency ($\alpha = .92$). At age 2, children's aggressive and destructive behaviors during the past 2 months were reported by mothers; responses were made using a 3-point scale, and items were summed into an externalizing behavior score ($\alpha = .88$) on the Child Behavior

Checklist 2–3 (Achenbach, 1992). At age 5, children's conduct problems were reported by mothers and alternative caregivers using the Child Behavior Checklist 4–18 (Achenbach, 1991), and items were summed into externalizing behavior scores (mean α = .88).

Antisocial behavior—Peers rated the frequency of 15-year-old target youths' AB during the past year using the Self-Report of Delinquency Questionnaire (Elliott, Huizinga, & Ageton, 1985). The questionnaire items were administered with a 3-point scale and were summed into an AB score (α = .94). At age 17, participants rated their agreement to statements endorsing reactive violence (i.e., violence in response to provocation) and a culture of violence (i.e., general view of violence as an acceptable activity) using the Attitudes Towards Violence Scale (Funk, Elliott, Urman, Flores, & Mock, 1999); responses were made on a 5-point scale, and items were summed into a violent attitudes score (α = .83). Juvenile court records were obtained from local county offices, after caregivers (87%) provided written permission, when participants were 14 to 18 years old (mean age = 16.8 years). Petitions were equivalent to charges filed against participants in juvenile court for breaking the law. Of the 189 participants, 175 (93%) had court data; of these, 53 (28%) had at least one petition. At age 20, participants completed a measure of the frequency of their AB during the past year using Self-Report of Delinquency Questionnaire items (Elliott et al., 1985), scores from which were summed into an AB score (α = .90).

Data analysis plan

We examined *MAOA* allele frequencies and group differences by *MAOA* and race in SPSS. We then used M*plus* 5.3 to estimate race-specific multiple-group models that compared *MAOA*-L and *MAOA*-H men on the effects of punitive discipline on AB and accounted for men's early externalizing behavior and its associations with punitive discipline. Multiple-group modeling offers advantages over standard ordinary least-squares regression approaches in testing G×E interactions with full information maximum likelihood estimation of missing data. Maximum likelihood with robust standard errors estimated missing data in models with observational data on maternal punitiveness to account for their nonnormal distributions. No other variable had distribution scores that indicated nonnormality; thus, full information maximum likelihood was used in models without observational data. Chi-square difference tests (or Satorra-Bentler scaled difference chi-square tests for maximum likelihood with robust standard errors) and the standard practice of fixing and releasing cross-group equality constraints were conducted to identify estimated effects in models that differed across *MAOA* groups, as indicated by significant chi-square difference values and improvements in model fit (Satorra & Bentler, 2001). Results include model chi-square, comparative fit index (CFI), estimated root-mean-square error of approximation (RMSEA), and standardized root-mean-square residual (SRMR). According to Kline (2005), SRMR less than .10 is favorable, RMSEA less than or equal to .05 indicates a close fit, CFI greater than .95 reflects a good fit, and non-significant, low chi-square values are desired. Within the text, we report effect sizes as standardized betas and the amount of variance in antisocial outcomes explained by predictors as R^2 values; however, *p* values for betas are from their unstandardized estimates, which we also report in tables summarizing results of our models.

Results

MAOA allele frequencies and group differences

Table 1 shows the sample distribution by race and polymorphism of the *MAOA* gene. We found *MAOA* allele frequencies similar to frequencies shown in previous studies (Reti et al., 2011; Sabol et al., 1998; Widom & Brzustowicz, 2006). *MAOA*-L and *MAOA*-H men did not differ at ages 1.5, 2, or 5 on caregiver education level, occupational status, or family income. Mothers of *MAOA*-H men showed more punitiveness toward 2-year-old boys (M = 1.32, SD = 0.61) than did mothers of *MAOA*-L men (M = 1.05, SD = 0.21), $t(144) = -4.33$, $p < .001$, 95% confidence interval (CI) = [–0.40, –0.15].

We found race differences for sociodemographic indicators and juvenile petitions. Caucasian mothers had higher occupational status (M = 2.74, SD = 2.07) than did African American mothers (M = 2.11, SD = 1.78) when boys were 5 years old, $t(152) = 2.09$, $p = .038$, 95% CI = [0.04, 1.24]. Caucasian mothers had more educated partners (M = 12.82, SD = 2.01) than did African American mothers (M = 12.14, SD = 1.18) when boys were 2 years old, $t(109) = 2.33$, $p = .022$, 95% CI = [0.10, 1.27]. Caucasian mothers had partners with higher occupational status (M = 3.43, SD = 1.97) than did African American mothers (M = 2.02, SD = 1.71) when boys were 1.5 years old, $t(136) = 4.07$, $p < .001$, 95% CI = [0.72, 2.08]. Caucasian mothers had partners with higher occupational status (M = 3.14, SD = 1.88) than did African American mothers (M = 2.34, SD = 2.00) when boys were 2 years old, $t(120) = 2.14$, $p = .035$, 95% CI = [0.06, 1.54]. Caucasian mothers had partners with higher occupational status (M = 3.51, SD = 1.77) than did African American mothers (M = 2.63, SD = 1.71) when boys were 5 years old, $t(101) = 2.25$, $p = .027$, 95% CI = [0.10, 1.66]. Caucasian families had higher incomes (M = $1,231, SD = $707) than did African American families (M = $802, SD = $519) when boys were 1.5 years old, $t(176) = 4.68$, $p < .001$, 95% CI = [$248, $609]. Caucasian families had higher incomes (M = $1,292, SD = $730) than did African American families (M = $806, SD = $499) when boys were 2 years old, $t(172) = 5.23$, $p < .001$, 95% CI = [$302, $669]. Caucasian families had higher incomes (M = $1,773, SD = $906) than did African American families (M = $1,229, SD = $777) when boys were 5 years old, $t(162) = 3.99$, $p < .001$, 95% CI = [$275, $814]. Last, African American men received more juvenile petitions (M = 0.88, SD = 1.42) than did Caucasian men (M = 0.38, SD = 0.83), $t(111) = -2.66$, $p = .009$, 95% CI = [–0.87, –0.13]. Results did not change appreciably when we controlled for sociodemographic variables.

Evidence of G×E interactions

Figure 1 shows four sets of scatter plots with best-fitting regression lines indicating G×E interactions. Table 2 summarizes the four corresponding sets of multiple-group models supporting our hypothesis that punitive discipline predicts more AB only among *MAOA*-L African American and Caucasian men. Across all models, punitive discipline was unrelated to *MAOA*-H men's AB, and G×E interactions were found when we controlled for men's early externalizing behavior.

Table 2 and Figure 1a show significant effects of maternal punitiveness at age 1.5 on AB at age 20 for *MAOA*-L African American (R^2 = .32) and Caucasian (R^2 = .20) men.

Preliminary models showed no main effects of *MAOA* genotype on age 20 AB. Figure 1b and Table 2 show significant effects of maternal punitiveness at age 2 on AB at age 15 for *MAOA*-L African American (R^2 = .16) and Caucasian (R^2 = .07) men. Preliminary models showed one genetic main effect for Caucasian men such that *MAOA*-H predicted more maternal punitiveness at age 2 than did *MAOA*-L (β = 0.23, p = .002). No genetic main effect was found for African American men. Maternal punitiveness at ages 1.5 and 2 predicted more AB at ages 20 and 15, respectively, among all *MAOA*-L men.

Table 2 and Figure 1c present significant effects of alternative caregivers' punitive discipline at age 5 on violent attitudes at age 17 for *MAOA*-L African American (R^2 = .23) and Caucasian (R^2 = .25) men. Preliminary models showed a genetic main effect for African American men such that *MAOA*-L predicted more externalizing problems at age 5 than did *MAOA*-H (β = –0.30, p = .038). No genetic main effect was found for Caucasian men. In addition, Figure 1d and Table 2 show significant effects of alternative caregivers' punitive discipline on AB at age 20 for *MAOA*-L African American (R^2 = .30) and Caucasian (R^2 = .33) men, and although a similar pattern was found for *MAOA*-H Caucasian men, the relation between their AB and early punitive discipline was smaller and nonsignificant (R^2 = .09). Again, preliminary models showed a genetic main effect for African American men in which *MAOA*-L predicted more externalizing problems at age 5 (β = –0.29, p = .044). No genetic main effect was found for Caucasian men. Thus, alternative caregivers' punitive discipline at age 5 predicted greater violent attitudes and AB only among *MAOA*-L men.

We also found race-specific G×E interactions. Multiple-group models showed an interaction between *MAOA* and mothers' punitive discipline at age 5 that predicted African American men's juvenile petitions, $\chi^2(2, N = 76) = 1.55$, p = .462, CFI = 1.0, RMSEA = .00, SRMR = .08. Mothers' punitive discipline predicted more juvenile court petitions among *MAOA*-L African American men (β = 0.41, p = .008) but not among *MAOA*-H African American men (β = –0.02, p = .913), $\Delta\chi^2(1, N = 76) = 4.07$, $p < .05$. No genetic main effect was found for African American men in a preliminary model.

For Caucasian men, multiple-group modeling showed an interaction between *MAOA* and maternal punitiveness at age 1.5 that predicted violent attitudes at age 17, $\chi^2(1, N = 104) = 0.77$, p = .379, CFI = 1.0, RMSEA = .00, SRMR = .04. Maternal punitiveness predicted greater violent attitudes for *MAOA*-L Caucasian men (β = 0.41, $p < .001$, R^2 = .28) but not among *MAOA*-H Caucasian men (β = 0.01, p = .924, R^2 = .02), $\Delta\chi^2(1, N = 104) = 25.82$, $p < .001$. No genetic main effects were found.

All G×E interactions remained significant when reanalyzed with African American and Caucasian men combined in a larger sample with greater statistical power. All unreported models testing G×E interactions are summarized in Table S1 in the Supplemental Material available online. Although not shown for the sake of brevity, three additional multiple-group models showed evidence of G×E interactions solely for African American men (i.e., among *MAOA*-L men, age 5 maternal punitive discipline predicted AB at age 15 and maternal punitiveness at age 2 predicted greater violent attitudes at age 17 and juvenile court petitions). In sum, 9 out of 16 possible combinations of study variables (56%) showed G×E interactions in the hypothesized direction when reanalyzed with the entire sample.

Discussion

Interactions between *MAOA* genotype and parental punitive discipline throughout early childhood predicted greater violent attitudes, juvenile arrests, and AB in young men. These findings support evidence that maltreated racial-minority children—not just Caucasians—with *MAOA*-L are at increased risk for AB (Cicchetti et al., 2012; Weder et al., 2009) and expand research that focuses on childhood maltreatment in two important ways. First, this G×E interaction extends to low-income African American men. Second, the environmental context for this effect includes common forms of punitive discipline in early childhood, not simply more rare and extreme experiences of maltreatment. Although some evidence has suggested that punitive discipline does not harm all children, even mild levels predict a range of severities in adjustment problems and can escalate to abuse (Edwards et al., 2010; Gershoff, Lansford, Sexton, Davis-Kean, & Sameroff, 2012). *MAOA*-L boys—whether of African or European heritage—may be particularly vulnerable to mild forms of harsh parenting.

A strong theoretical rationale guided our investigation of early childhood antecedents of AB and our extension of *MAOA* interactions to punitive parenting behaviors more frequently used in low-income families (Gershoff, 2002; Straus & Stewart, 1999). Studies in which maltreated children are compared with nonmaltreated children have produced findings of limited generalizability by focusing on abuse and neglect, which may contribute to null findings by preventing analysis of youth with a broader range of experiences with caregivers. In one study, *MAOA*-L children developed aggressive behavior when exposed to low to moderate levels of trauma, whereas children exposed to extreme trauma developed aggression regardless of genotype; this finding suggests that *MAOA* may identify youth who are more vulnerable to the effects of trauma at moderate levels, whereas extreme trauma is a risk regardless of genotype (Weder et al., 2009). Observations and caregiver reports of punitive discipline informed our continuous scales, thereby yielding greater effect sizes and statistical power than categorical variables (Hutchison et al., 2004). Our measures captured a fairly common experience in early childhood and provided consistent evidence that even mild punitive experiences predict more AB in *MAOA*-L men. These findings support literature that links punitive discipline in early childhood to youths' AB (Dodge & Pettit, 2003; Edwards et al., 2010) and demonstrate a genetic vulnerability that may explain why only a fraction of children exposed to harsh parenting show delinquent behavior as adolescents (Moffitt, 2005).

In studies on G×E interactions with *MAOA*, researchers also tend to aggregate experiences of maltreatment throughout childhood and adolescence (e.g., Huang et al., 2004), which contributes to imprecise measurement of the timing of maltreatment and precludes exploration of sensitive periods during which harsh treatment is more likely to result in AB. Punitive experiences occurring before age 6 have been shown to contribute to more chronic and severe AB than has punitive discipline at later ages (Keiley et al., 2001), but the moderation of such experiences by genotype has been examined in only one study of Caucasian boys (Edwards et al., 2010). Accordingly, we examined punitive experiences at ages 1.5, 2, and 5 and found that punitive discipline at each age in early childhood predicted

more AB in adolescence and young adulthood for *MAOA*-L African American and Caucasian men.

It is worth noting that age-specific effects of punitive discipline on AB differed by caregiver. Not surprising, fathers and boyfriends of mothers played important roles in *MAOA*-L men's AB. In previous studies, researchers might have assessed paternal maltreatment inadvertently through retrospective self-reports, but no researchers have both prospectively assessed fathers' punitive discipline and found it to interact with children's genotype in predicting their AB. Some evidence has suggested that fathers are more physically punitive than are mothers (Gershoff, 2002), which could explain why alternative caregivers' (mostly fathers) punitive discipline at age 5 more reliably predicted men's violent attitudes and AB than did maternal punitiveness at any particular age. Nonetheless, we demonstrated that paternal punitive discipline in the early school years consistently predicted *MAOA*-L men's AB in late adolescence and young adulthood, whereas mothers' punitive discipline appeared to be more noxious in toddlerhood.

We replicated interactions between *MAOA* and punitive discipline in relation to more AB in low-income African American and Caucasian men, which suggests that they share a genetic vulnerability to harsh caregiving similar to maltreated Caucasian men in New Zealand (Caspi et al., 2002), England (Kim-Cohen et al., 2006), and throughout the United States (e.g., Beaver et al., 2011; Weder et al., 2009; Widom & Brzustowicz, 2006). Some research has suggested that punitive discipline is a more robust predictor of AB for Caucasian youth than for African American youth because of more normative attitudes favoring its use in African American families, which are associated with fewer subsequent adjustment problems in African American children (Dodge & Pettit, 2003; Gershoff, 2002). Other studies have shown that effects of punitive discipline on children's conduct problems are not moderated by race, despite African American mothers' endorsing more punitive behaviors than Caucasian mothers (Gershoff et al., 2012). Our findings indicate more similarities than differences between low-income African American and Caucasian youth when their *MAOA* genotype is considered, as well as enduring consequences of punitive experiences from early childhood for all *MAOA*-L men.

A few caveats to this study warrant consideration. We relied on caregivers' reports of children's race rather than genetic ancestry markers; however, researchers using ancestry markers have found that genetically distinct clusters corresponded well with self-reported race (Reti et al., 2011). Racial-ethnic differences in AB and *MAOA* allele frequencies confound tests of G×E interactions with mixed-race samples (Hutchison et al., 2004), which may explain discrepant findings in the literature. Although researchers use various approaches to control for racial-ethnic heterogeneity (e.g., ancestral covariates; Weder et al., 2009), race-specific analyses complement full- sample tests of G×E interactions and reduce confounds of racial-ethnic variation in allele frequencies (Zintzaras & Lau, 2008). Regardless of whether we combined Caucasian and African American men or considered them separately, we found that *MAOA*-L exacerbated risk for AB posed by punitive discipline. Although this study, relative to epidemiological investigations, included modest numbers of young men, studies with samples smaller than that of Caspi et al. (2002; N = 1,037) are no less likely to replicate their findings (Byrd & Manuck, 2013). The advantages

of a smaller sample included rigorous assessments of parenting and AB that permitted a multi-method, multi-informant approach with observational data; longitudinal measurement spanning nearly 20 years; and investigation of multiple sources of punishment and developmental periods.

Although the current study contributes to the literature in several ways, we believe there is still much work to be done. Four major advances are needed to promote the broader field of G×E interaction studies in clinical science and developmental psychopathology. First, little attention has been paid to development in terms of the timing of exposure (i.e., Are there relative sensitive periods?) and the timing of adverse outcomes. Thus, gene-environment-development studies are sorely needed (Vrieze, Iacono, & McGue, 2012). For both a developmental and a biological perspective, we may expect the interaction of *MAOA* genotype and parenting practices to extend only to certain experiences occurring in certain developmental periods (e.g., harsh parenting in early childhood) and only to certain outcomes (e.g., AB that persists into late adolescence and adulthood).

Second, gene-environment-development studies are probably the tip of the iceberg in terms of complexity. Multiple genes of small effects are likely to interact with multiple environments to lead to many outcomes. Thus, models in which cumulative genetic risk (Nikolova, Ferrell, Manuck, & Hariri, 2011), environmental risk (Sameroff, Seifer, Zax, & Barocas, 1987), or other interactions (e.g., gene-environment-environment and gene-gene-environment models; Kaufman et al., 2004) are tested in all likelihood reflect the true state of influence on human behavior (Bogdan, Hyde, & Hariri, 2012).

Third, “environments” vary enormously in the extent to which they can contain G×E correlation (Jaffee, 2011; Manuck & McCaffery, 2010). Genetic characteristics may influence behavioral phenotypes and adverse environments that contribute to AB. For example, we found that among Caucasian men, *MAOA* genotype was directly related to maternal punitiveness at age 2, whereas African American men’s early externalizing behavior was associated with maternal punitiveness at age 1.5 only among those men with low *MAOA* activity. Both findings emphasize correlations between genotype and early punitive experiences through potential evocative effects. Thus, more studies are needed that use twin, adoption, or natural experiment designs to strengthen confidence in environmental effects as “true” experiential effects (Costello, Compton, Keeler, & Angold, 2003; Reiss & Leve, 2007).

Fourth, identifying mechanisms that mediate the link between these G×E interactions and outcomes is critical to understanding points in the etiological chain in which to intervene. For example, studies that incorporate physiology at multiple levels, especially brain structure, and function as mediators of these effects can help specify how genes and experiences “get under the skin” to increase risk for maladaptive behavior (Bogdan et al., 2012; Hyde, Bogdan, & Hariri, 2011). Beyond these major advances, studies on the specific *MAOA*-by-parenting interaction can be further strengthened by examining the specificity of outcomes. For example, researchers could examine whether these results are stronger for specific subtypes of youth with high AB (i.e., those youth with callous-unemotional traits, those youth comorbid for substance use).

These findings are an important step toward understanding how genetic characteristics and childhood experiences interact to contribute to the development of AB in low-income boys. The present research shows that parenting practices within the typical range—not merely extreme social stressors, such as maltreatment—can play a strong role in the development of AB for those youth who are genetically vulnerable. By pursuing critical next steps in the examination of G×E interactions in a deeper, more nuanced way and beginning to address how these interactions might vary in their influence at different points in development, we will be closer to understanding this pernicious social and mental health problem.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding

This research was supported by National Institute on Drug Abuse Grants DA25630 and DA26222 awarded to D. S. Shaw and E. E. Forbes.

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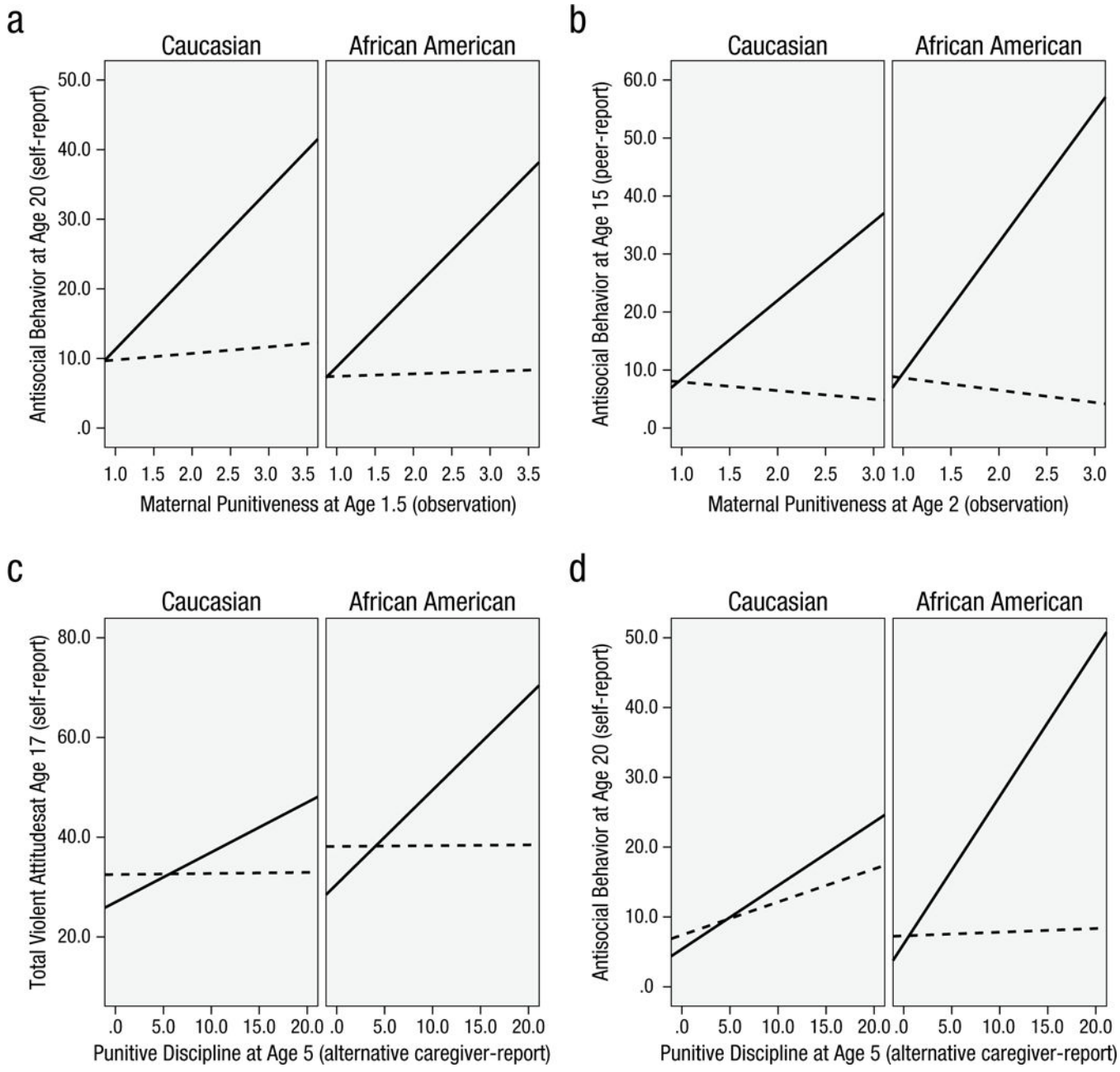

Fig. 1.

Scatter plots with best-fitting regression lines showing correlations between (a) self-reported antisocial behavior at age 20 and maternal punitiveness observed at age 1.5 (*MAOA*-L Caucasian men: R^2 = .17; *MAOA*-L African American men: R^2 = .30), (b) peer-reported antisocial behavior at age 15 and maternal punitiveness observed at age 2 (*MAOA*-L Caucasian men: R^2 = .08; *MAOA*-L African American men: R^2 = .14), (c) self-reported violent attitudes at age 17 and alternative-caregiver-reported punitive discipline at age 5 (*MAOA*-L Caucasian men: R^2 = .15; *MAOA*-L African American men: R^2 = .27), and (d) self-reported antisocial behavior at age 20 and alternative-caregiver-reported punitive discipline at age 5 (*MAOA*-L Caucasian men: R^2 = .13; *MAOA*-L African American men: R^2

= .34; *MAOA*-H Caucasian men: R^2 = .03). *MAOA* = monoamine oxidase A gene; *MAOA*-L = low *MAOA* activity; *MAOA*-H = high *MAOA* activity.

Table 1

Sample Distribution by Race and Polymorphism of the Monoamine Oxidase A (*MAOA*) Gene

	Number of repeats at *MAOA* gene promoter region			
Race	**2**	**3**	**4**	**5**
African American men (*n* = 83)	5 (6)	35 (42.2)	41 (49.4)	2 (2.4)
Caucasian men (*n* = 106)	–	32 (30)	72 (68)	2 (2)

Note: Data are *n* (%).

Table 2

Multiple-Group Models Showing Interactions Between Monoamine Oxidase A (*MAOA*) and Punitive Discipline (PD) in Early Childhood and Their Effects on Antisocial Behavior (AB) While Accounting for Men's Early Externalizing Behavior (EB)

	Low-activity *MAOA* group			High-activity *MAOA* group					
Variable and racial group	**PD→AB**	**EB→AB**	**PD↔EB**	**PD→AB**	**EB→AB**	**PD↔EB**	**$\Delta\chi^2$ (*df*)**	**χ^2 (*df*)**	**SRMR**
Age 1.5 maternal punitiveness and age 20 AB									
African American	9.67 (2.08) 0.43*** R^2 = .32	0.15 (0.04) 0.26***	2.44 (1.23) 0.27*	–1.31 (2.80) –0.05 R^2 = .22	0.15 (0.04) 0.48***	0.55 (0.48) 0.13	82.81 (2)***	0.60 (1)	.03
Caucasian	7.46 (3.15) 0.26* R^2 = .20	0.13 (0.07) 0.26*	2.97 (2.29) 0.50	1.04 (2.98) 0.04 R^2 = .04	0.13 (0.07) 0.20*	–0.01 (0.42) 0.00	28.96 (2)***	0.09 (1)	.01
Age 2 maternal punitiveness and age 15 AB									
African American	23.07 (2.71) 0.41*** R^2 = .16	–0.31 (0.16) –0.17	0.41 (0.32) 0.24	–3.56 (3.51) –0.20 R^2 = .09	–0.31 (0.16) –0.22	0.41 (0.32) 0.07	5.11 (1)*	0.40 (2)	.04
Caucasian	14.16 (2.66) 0.27*** R^2 = .07	0.09 (0.11) 0.08	–0.28 (0.23) –0.18	–1.33 (2.67) –0.08 R^2 = .01	0.09 (0.11) 0.07	–0.28 (0.23) –0.07	3.92 (1)*	0.53 (2)	.02
Age 5 alternative caregiver PD and age 17 violent attitudes									
African American	1.34 (0.64) 0.44* R^2 = .23	0.14 (0.38) 0.08	12.12 (5.05) 0.50*	0.45 (0.52) 0.19 R^2 = .11	–0.46 (0.28) –0.35	12.12 (5.05) 0.38*	4.78 (2)	0.93 (1)	.09
Caucasian	1.40 (0.49) 0.54** R^2 = .25	–0.48 (0.26) –0.36	9.71 (3.12) 0.43**	–0.03 (0.35) –0.01 R^2 = .00	0.04 (0.13) 0.05	9.71 (3.12) 0.33**	5.95 (2)	0.23 (1)	.03
Age 5 alternative caregiver PD and age 20 AB									
African American	1.44 (0.63) 0.49* R^2 = .30	0.18 (0.17) 0.10	11.89 (5.01) 0.50*	–0.10 (0.33) –0.07 R^2 = .04	0.18 (0.17) 0.22	11.89 (5.01) 0.36*	4.77 (1)*	1.17 (2)	.09
Caucasian	1.66 (0.52) 0.61** R^2 = .33	–0.56 (0.27) –0.40*	9.72 (3.19) 0.42**	0.22 (0.40) 0.08 R^2 = .09	0.27 (0.14) 0.27	9.72 (3.19) 0.33**	7.22 (2)*	0.30 (1)	.03

Note: The table presents unstandardized effects, standard errors (in parentheses), and standardized effects within each low- and high-activity *MAOA* group column, that is, *b* (*SE*) **β**. Chi-square differences scores indicate unstandardized and standardized effects in PD→AB columns that significantly differ between *MAOA* groups in gene-environment interactions. All model chi-square *p* values exceed .30, all comparative fit index values equal 1.00, and all root-mean-square error of approximation values equal .00. All standard errors *and p* values are from unstandardized estimates. R^2 values represent amount of variance in AB explained by PD and EB. SRMR = standardized root-mean-square residual.

* $p < .05$.

** $p < .01$.

*** $p < .001$.