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Prospective Association of Childhood Receptive Vocabulary and Conduct Problems with Self-Reported Adolescent Delinquency: Tests of Mediation and Moderation in Sibling-Comparison Analyses

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Abstract

Associations among receptive vocabulary measured at 4–9 years, mother-reported childhood conduct problems at 4–9 years, and self-reported adolescent delinquency at 14–17 years were assessed using data from a prospective study of the offspring of a large U.S. nationally representative sample of women. A novel quasi-experimental strategy was used to rule out family-level confounding by estimating path-analytic associations within families in a sibling comparison design. This allowed simultaneous tests of the direct and indirect effects of receptive vocabulary and childhood conduct problems, and of their joint moderation, on adolescent delinquency without family-level environmental confounding. The significant association of receptive vocabulary with later adolescent delinquency was indirect, mediated by childhood conduct problems. Furthermore, a significant interaction between receptive vocabulary and childhood conduct problems reflected a steeper slope for the predictive association between childhood conduct problems and adolescent delinquency when receptive vocabulary scores were higher. These findings of significant indirect association were qualitatively identical in both population-level and within-family analyses, suggesting that they are not the result of family-level confounds.

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Delinquent behavior during adolescence is common in the population, but far from universal (Loeber et al., 2012; Moffitt, 1993). Therefore, an important focus of research is on early

child characteristics that distinguish children who are at greatest risk for engaging in juvenile delinquency during the peak period of crime in adolescence (Lahey, Moffitt, & Caspi, 2003). Individual differences in cognitive ability and language skills during childhood have been one focus of this investigation (Lahey & Waldman, 2003; Lahey, Waldman, & McBurnett, 1999; Moffitt, 1993). Better developed cognitive and language skills in childhood may reduce risk for adolescent delinquency by facilitating socialization (Keenan & Shaw, 1997), by increasing opportunities to succeed in prosocial ways, and through more adaptive decision-making and inhibitory control during reward-seeking behavior (Bogg, Fukunaga, Finn, & Brown, 2012).

The correlation in the population between early deficits in language development and later antisocial behavior is well documented (Brownlie et al., 2004; Cantwell & Baker, 1987). There also is replicated evidence of an inverse association between intelligence scores and official records of criminal offending in both male and female adolescents in the population (Kratzer & Hodgins, 1999; Lipsitt, Buka, & Lipsitt, 1990; Loeber, et al., 2012; Lynam, Moffitt, & Stouthamer-Loeber, 1993; Moffitt, Gabrielli, Mednick, & Schulsinger, 1981; Moffitt & Silva, 1988). It is important to note, however, that this association has only been estimated in studies that correlate cognitive ability with antisocial behavior in persons from different families in the population. This means that the many genetic and sociodemographic factors that differ from one family to another, and that are correlated with both cognitive ability and antisocial behavior, may confound the association of interest.

One way to address the problem of confounding is to use quasi-experimental designs that rule out family level confounds (D'Onofrio, Lahey, Turkheimer, & Lichtenstein, 2013; Shadish, Cook, & Campbell, 2002; West, 2009). For example, a study of 1,116 twin pairs found intelligence test scores and conduct problems at ages 5 and 7 years to be correlated exclusively due to shared genetic influences (Koenen, Caspi, Moffitt, Rijdsdijk, & Taylor, 2006). Because these analyses were based on twin sibling correlations within families, it was possible to explore the association while controlling for genetic factors and environmental factors that make siblings similar. Studies of twins are problematic when addressing language development, however, because there is evidence that twins are not representative of all children due to their slower language development (Rutter & Redshaw, 1991).

A quasi-experimental design that is appropriate for the study of language development is within-family comparisons of non-twin siblings (Lahey & D'Onofrio, 2010). Because a large percentage of families in the U.S. include multiple siblings, sibling comparisons are a more easily implemented quasi-experimental strategy than those based on less common *natural experiments*, such as twinning or adoption, and the results are more representative. Sibling-comparison designs automatically and completely rule out confounding with all environmental factors that differ between families. That is, unless they vary among siblings in the same family, everything related to socioeconomic status, neighborhood, housing type, ethnicity, and all other shared environments is held constant. This is true whether these shared environments are included as measured covariates in regression models or not (Lahey & D'Onofrio, 2010). In addition, sibling comparison controls for genetic differences *between* families. Furthermore, full siblings share more of their segregating genetic variants (50% on average) than unrelated youth in different families. Nonetheless, full siblings differ from one

another in the other 50% of their polymorphic genetic variants. These genetic differences are not systematically related to some kinds of risk factors (Lahey & D'Onofrio, 2010), but as detailed below, this lack of full genetic control is relevant to the present study.

One study of official convictions for violent crimes in over 700,000 Swedish males used sibling comparisons to eliminate any confounding effects of all measured and unmeasured family-level factors (Frisell, Pawitan, & Langstrom, 2012). This study found an inverse association between intelligence *assessed in late adolescence* and official convictions for violent crimes during adolescence or early adulthood. By eliminating potential family-level confounders, this quasi-experimental study provided partial support for the hypothesis that intelligence is related to conviction for violent crime through a causal process, rather than merely being an artifact of family-level confounding variables.

In the present analyses, we test the prospective association between receptive vocabulary measured in childhood and self-reported delinquency during adolescence using a sibling-comparison design. Receptive vocabulary is of interest because it is an aspect of language development that is correlated with verbal intelligence (Dunn & Dunn, 1981), both of which are correlated with antisocial behavior. We use data from biennial assessments of the children of the prospective National Longitudinal Survey of Youth (Chase-Lansdale, Mott, Brooks-Gunn, & Phillips, 1991), conducted from 1986 through 2010. Because only a partial assessment was conducted in 2000 for budgetary reasons, however, data from that wave were not used.

We examine the predictive associations of childhood conduct problems (CP) and receptive vocabulary with later self-reported adolescent delinquency in the context of developmental models of adolescent delinquency (Hinshaw, Lahey, & Hart, 1993; Lahey & Waldman, 2003; Moffitt, 1993; Patterson, DeBaryshe, & Ramsey, 1989). These models all contain the hypothesis that childhood risk factors, such as cognitive deficits, influence risk for adolescent delinquency by increasing risk for childhood CP, which increase risk for adolescent delinquency. We address this hypothesis in two ways. First, we estimate both the direct association of receptive vocabulary scores with adolescent delinquency and their indirect association through childhood CP. Second, we test the interaction between childhood CP and receptive vocabulary scores to determine if the predictive association between receptive vocabulary in childhood and adolescent delinquency varies as a function of childhood CP and vice-versa.

METHOD

Sample

Mother-Generation Sample: The National Longitudinal Survey of Youth (NLSY79)—The NLSY79 “mother generation” survey was funded by the Bureau of Labor Statistics to study the future U.S. workforce. A nationally-representative household sample of 6,111 14–22 year old male and female youth who were not in the military was selected for the NLSY79 using a stratified and clustered design. An additional sample of 3,652 African American and Hispanic youth was selected for the NLSY79 mother-generation to

oversample these groups. The response rate for the initial NLSY79 assessment was 90% of the eligible sample.

Offspring-Generation Sample: The CNLSY79—Beginning in 1986, biennial assessments of all biological offspring of women in the NLSY79 were initiated (Chase-Lansdale, et al., 1991). In 1986, 95% of the offspring of NLSY79 mothers were assessed, with response rates for assessments across 1988 to 2010 averaging 85.7% (<http://www.bls.gov/nls/nlsy79.htm>). The participation rate for childhood cognitive assessments was 87.3% of participating families (<http://www.bls.gov/nls/nlsy79ch.htm>).

Subsamples Used in Analyses—Primarily because not all offspring of NLSY mothers had reached adolescence at the time of the last available assessment, but also because of some nonparticipation, many offspring could not be in the analyses because they had missing data on one or more of the three primary measures: Peabody Picture Vocabulary Test-Revised (PPVT; Dunn & Dunn, 1981), CP at 4–9 years, and adolescent delinquency. The population-level analyses estimated associations among these variables using data on 5,343 youth with complete data from 2,850 families. Of these families, 69.9% had at least one girl and 68.1% had at least one boy; 1,132 of the 2,850 families had singleton children.

Within-family sibling comparisons were conducted on data from 4,211 youth in 1,718 families with at least one sibling with non-missing data on all variables. Compared to the remainder of the CNLSY sample, youth in this group had mothers who first gave birth at younger ages (21.3 vs. 22.1 years, $p = .08$) and were more likely to be African American (32% vs. 25%, $p < .001$) or Hispanic (22% vs. 17% $p < .001$) than the rest of the sample. These differences are significant owing to the large sample size, but the population-based regression analyses adjust for these differences by including these variables as covariates. The analyzed subsample did not differ from the remaining sample in mean household income or sex distribution.

Measures

Demographics—Mother's age at the birth of her first child was calculated by subtracting the mother's date of birth from her first child's date of birth. Total family income was defined as the total income received by the mother's household from all sources when she was 30 years of age (in inflation-adjusted 1986 dollars), logged and standardized (mean = 0; standard deviation = 1). Race-ethnicity was determined by maternal report. Children were classified as full or half-siblings using the NLSY algorithm based on direct questions on family relationships and other variables (Beasley, Rodgers, Bard, Hunter, & Meredith, 2013).

Receptive Vocabulary—The PPVT (Dunn & Dunn, 1981) was administered during childhood. We took the average across waves of PPVT age-normed scores assessed during ages 4–9 years (6,096 children were assessed once and 2,454 additional children had two PPVT assessments), and, for model fitting, we standardized the result to have mean 0, standard deviation 1, for the overall CNLSY sample.

Childhood CP (4–9 years)—Beginning in 1986, mothers rated their children's behavior using the Behavior Problem Index (BPI; Peterson & Zill, 1986). The BPI was created for the CNLSY by selecting the items from the Child Behavior Checklist (Achenbach, 1978) that had the strongest correlations with their corresponding CBCL factor scores (Peterson & Zill, 1986). Mothers rated each of their children using a 3-point scale for each item: *often true* = 3, *sometimes true* = 2, or *not true* = 1. We used mean ratings of BPI items selected a priori and confirmed in confirmatory factor analysis of items referring to disruptive behavior (D'Onofrio et al., 2008) to create a conduct problem score: “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.” Across the 10 assessments over ages 4–13 years, the range of Cronbach's alpha coefficients ranged from .68–.80, median = .74 (Lahey et al., 2006). These childhood conduct problem items used in the CNLSY overlap substantially with those used in previous population-based longitudinal studies (Moffitt, Caspi, Dickson, Silva, & Stanton, 1996). This measure of childhood CP is valid in the sense of robustly predicting convictions for nontrivial offenses during adolescence in the CNLSY (Lahey, et al., 2006). For the present analyses, the conduct problem scores were the average of all assessments conducted during ages 4 through 9 years. The resulting score ranged from 0 to 13 with a 25th percentile of 1, a median of 2, and a 90th percentile of 4.7.

Youth-Reported delinquency (ages 14–17 years)—Beginning in 1994, youth reported on seven delinquency items based on the Self-Reported Delinquency (SRD) interview (Elliott & Huizinga, 1983), which is a reliable and valid benchmark measure used in delinquency research (Loeber, Farrington, Stouthamer-Loeber, & Van Kammen, 1998; Moffitt, et al., 1996). These items (scored 0 = no; 1 = yes) were: “hurt someone bad enough to need bandages or a doctor;” “lied to parent about something important;” “taken 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 ran away from home.” The mean of these items was multiplied by 7 and rounded to create an adolescent delinquency scale. Across ages 14–17, the range of Cronbach's alphas for this measure was .57–.80, median = .65.

The seven items in the short delinquency scale were selected by the CNLSY because they were high-prevalence acts that were highly correlated with more serious delinquent acts. In 1994, 1996, and 1998, the young adult delinquency scale included 10 additional items: gotten into a fight at school or work; other than from a store, taken something not belonging to you that was worth less than \$50; other than from a store, taken something not belonging to you that was worth than \$50 or more; used force to get money or things from someone else; hit or seriously threatened to hit someone; attacked someone with the idea of seriously hurting or killing them; tried to con someone; taken a vehicle without the owner's permission; broke into a building or vehicle to steal something or just to look around; and knowingly held or sold stolen goods. This comprehensive list of 17 SRD delinquency items provided a standard for evaluating the validity of the 7-item adolescent delinquency scale

that was administered in all assessments. The 7-item scale was highly correlated with the 17-item scale at $r = .80$ to $.81$ at each age between 14 and 17 years, showing that the 7-item scale provides a strong index of the full range of adolescent delinquent behaviors. We took the average of all ratings on the seven items obtained during ages 14 through 17 years, multiplied by seven and rounded to the nearest whole number. The resulting scale ranged from 0 to 14, and was highly skewed, with 27% zeros and 31% ones.

We validated the 7-item SRD delinquency scale in the present sample using analyses controlling the youth's sex, family income, maternal age at first birth, and race-ethnicity using the criterion of at least one conviction for a nontrivial criminal offense not including drug possession during adolescence. Using logistic regression, the odds of conviction were 1.78, 95% CI [1.37 – 2.33], 1.94, 95% CI [1.64 – 2.31], 2.14, 95% CI [1.80 – 2.55], and 2.01, 95% CI [1.70 – 2.38] times greater for *each* 1 standard deviation (SD) difference in youth-reported delinquency behavior at ages 14, 15, 16, and 17 years of age, respectively. For example, the rates of conviction among three groups of youth who were below the mean in delinquency ($n = 1036$), between the mean and +1 SD above the mean ($n = 231$), and >1 SD above the mean in delinquency ($n = 318$) at age 14 were 6.0%, 9.5%, and 23.0%, respectively.

Data Analysis

We conducted analyses to estimate the direct and indirect associations of self-reported adolescent delinquency to PPVT and parent-reported childhood CP in two ways:

1. *Population-level analyses.* Analyses were conducted using data from the subsample of all children with nonmissing variables on the three variables, including families with singletons, to estimate associations in the population. These population-level analyses estimated the associations in two-level (offspring within mother) random effects models that included the child's sex, race-ethnicity, mother's age at first birth, and the log of family income as covariates to adjust for differences between the analyzed sample and the full sample of children of NLSY mothers.
2. *Within-family analyses.* In addition, because the childhood predictors of PPVT and CP are potentially confounded with environmental variables that differ between families in the population-level analyses, we also conducted comparisons of siblings within families to eliminate family-level confounding (Neuhaus & McCulloch, 2006). In broad overview, we pursued a novel within-family (sibling comparison) modeling scheme embedded in a log-linear regression model with random effects, interaction terms, and a negative binomial response distribution, all conducted using survey weights and accounting for clustering in the NLSY survey design. These analyses followed the path models (Loehlin, 1992) in Figure 1, allowing simultaneous estimation of the direct and indirect effects of receptive vocabulary and childhood CP (Preacher, Zyphur, & Zhang, 2010), and estimation of their joint moderation, on adolescent delinquency, while ruling out all family-level environmental confounds.

Each individual's mean delinquency score during adolescence was rounded to the nearest whole number, and delinquency score was modeled as a count variable in log-linear

regression models for negative binomial responses. The conduct problem response variable was modeled as a continuous response using linear random effects regression models. Owing to the averaging of scores across waves, conduct problems were not as skewed as the delinquency variable, and the use of a linear model for conduct problems dovetailed better, in the context of the Figure 1 path models, with models for delinquency in which conduct problem score is a predictor.

Within-family comparisons of siblings estimated the association of childhood CP with the *deviation* of each sibling's predictors (e.g., PPVT score) from the *mean* of those predictors among all siblings in the family. In these analyses, it was not necessary to control for between-family variables such as mother's age at first birth because they are automatically controlled; we did however control for child's sex and birth order using deviation scores (Lahey & D'Onofrio, 2010; Neuhaus & McCulloch, 2006). Similar analyses estimated the association of adolescent delinquency with the deviation of each sibling's predictors, including PPVT score and childhood CP, from the family mean of those predictors.

Models for CP and adolescent delinquency were jointly fitted and tested in Mplus version 7 (Muthén & Muthén, 2013) (Mplus scripts available from the last author upon request) using two-level random effect models with a random intercept for both CP and adolescent delinquency at the mother (family) level. Analyses were survey weighted at the mother level to represent the offspring of the NLSY79 population, and standard errors accounted for clustering of mothers in the original NLSY79 households. The same covariates were included in each model for both population-based and sibling comparisons, but results for covariates that differ only between families and not within families (e.g., race-ethnicity) are not tabled for the sibling-comparison analyses.

Path Models Tested—At both population and within-family levels, associations among receptive vocabulary, childhood CP, and adolescent delinquency were tested in three sequenced path models:

- Model 1.** The associations between PPVT scores and adolescent delinquency were tested without childhood CP in the model.
- Model 2.** This model was the same as Model 1, but each child's CP score was added as a predictor of adolescent delinquency in addition to PPVT scores. The direct association of PPVT and childhood CP is estimated in this model. In addition, as depicted in Figure 1A, both the direct effect (path c) and the indirect effect (path a + b) of PPVT on adolescent delinquency through childhood CP were estimated in this model (Preacher et al., 2010).
- Model 3.** This model was the same as Model 2, but also tested the PPVT-by-childhood CP interaction in the prediction of adolescent delinquency. Direct and indirect associations of PPVT with adolescent delinquency were estimated in these models, as well. When the interaction of PPVT and childhood CP is in the model for adolescent delinquency, the direct and indirect effects of PPVT on delinquency become non-linear because PPVT influences delinquency through its influence on CP, and the CP effect is

moderated by PPVT. As a result, the effect of a difference in PPVT on the mean of adolescent delinquency is different for different reference values of PPVT. We present direct and indirect effects for z-scored PPVT equal to reference values of -1 , 0 , $+1$. The direct effect of PPVT is the effect on delinquency that arises in the path model for differences in PPVT, holding childhood CP constant (i.e., blocking changes in PPVT from having any effect on childhood CP). The indirect effect is the difference between the total and the direct effect. Owing to the interaction term, the direct effect of PPVT will depend on the value of CP. We use the expected value of CP corresponding to the mean of the adjusters and to each of the reference values of PPVT. We obtained estimates using the model constraint utility in Mplus that allows for estimation and testing of non-linear functions of estimated parameters.

Sensitivity Analyses Using Families with Only Full Siblings—In sensitivity analyses, sibling-comparison Models 2 and 3 were repeated using only families with full siblings, comprising 2,629 of the 4,211 youth in multi-sibling families. All children in the sample are the biological offspring of NLSY mothers. In the CNLSY sample, all half siblings had the same biological mother but different biological fathers. Because families with children born to more than one biological father are common in the U.S., the most representative analyses are based on all full and half siblings in NLSY families. Nonetheless, sibling-comparison analysis of only full siblings further reduces confounding due to any differences in environments and genetics between half siblings.

RESULTS

Descriptive Analyses

Zero-order Pearson correlations among the primary measures of receptive vocabulary at 4–9 years, mother-rated CP at 4–9 years, and self-reported delinquency at 14–17 years are presented in Table 1. These are presented separately for all children in the population-level analyses ($N = 5343$; above the diagonal) and for children in families with >1 child whose data are used in sibling comparisons ($N = 4211$; below the diagonal). These correlations were modest in size, but significant at $p < .001$ in these large samples.

Results of Path Models

Association of Receptive Vocabulary with Childhood CP—To simplify the presentation, the results for different parts of the two path models illustrated in Figure 1 are presented in different tables. The results for path a in Figure 1A (in which childhood CP is the response variable) are presented in Table 2, followed by the results for the paths in which adolescent delinquency is the response variable in Table 3.

As reported in the left-hand column of Table 2, there was a significant association between receptive vocabulary scores and mean maternal ratings of childhood CP across 4–9 years of age in both the population-level analyses and in sibling comparisons. These associations also were significant in the analyses based on only full siblings (right-hand column of Table 2).

These results are from the same Model 2 reported in Table 3 for paths in which adolescent delinquency was the response variable.

Association of Receptive Vocabulary with Adolescent Delinquency—We first conducted a bivariate test of the association with no covariates in log-linear regression. Consistent with the Pearson correlation reported in Table 1, the PPVT z-score significantly predicted adolescent delinquency, $\beta = -0.08$, $z = -4.34$, $p < 0.001$. The β coefficients for predicting adolescent delinquency in log-linear regression models represent the effect on the log mean delinquency score of a 1 unit difference in the associated predictor (here, PPVT z-score). Exponentiating these coefficients and multiplying by 100 yields a percent difference in mean delinquency score. Thus, this effect represents an 8% decrease in mean delinquency scores corresponding to a 1 SD increase in PPVT, not adjusted for demographic covariates.

The results for the multivariate models in which adolescent delinquency was the response variable are reported in Table 3. The results of Model 1 revealed no significant association of PPVT scores with self-reported adolescent delinquency at either population level when demographic covariates were included or within-family (sibling comparison) levels. Model 2 is illustrated in Figure 1A. The results of this model revealed that childhood CP at 4–9 years predicted self-reported adolescent delinquency (path b), but PPVT scores did not directly predict delinquency (path c) in either population-level or within-family (sibling comparison) analyses. Nonetheless, Model 2 revealed a significant *indirect path* from PPVT through childhood CP to adolescent delinquency in population-level analyses ($\beta = -0.02$, $z = -5.72$, $p < 0.001$), in sibling-comparison models of all families with > 1 child ($\beta = -0.02$, $z = -3.39$, $p < 0.001$), and in sibling-comparison models of just families full siblings ($\beta = -0.02$, $z = -2.76$, $p < 0.01$).

Model 3 is illustrated in Figure 1B. The results of Model 3 revealed a significant interaction between childhood CP and receptive vocabulary in the prediction of adolescent delinquency (path d) that was significant at the population level and in comparisons of siblings, but not significant in sibling comparisons in families with only full siblings. Post hoc analyses are presented in Table 4 to facilitate interpretation of the interaction, which is illustrated at the population level in Figure 2. Among children with higher PPVT scores, there was a steeper decrease in delinquency associated with decreasing CP than among children with average or lower PPVT scores.

Estimates of the nonlinear direct and indirect effects of PPVT on adolescent delinquency when the interaction of PPVT and childhood CP is included (Model 3) are presented in Table 5. Because these effects of PPVT are not linear, they are presented at different levels of PPVT. The direct effects PPVT on adolescent delinquency are not significant at any level of PPVT, but the inverse *indirect effects* of PPVT on adolescent delinquency are significant at every level of PPVT in both the population level and within-family (sibling comparison) analyses.

DISCUSSION

The results in Table 1 revealed small, but statistically significant bivariate Pearson correlations between childhood PPVT receptive vocabulary scores measured in childhood and both mother-rated childhood CP and self-reported adolescent delinquency at the population level (i.e., across all children in the sample in different families, including singletons). Similarly, as reported in the text, when the association between PPVT and adolescent delinquency was tested in a bivariate log-linear regression among families with >1 child and no missing data, the association was significant.

In contrast, the results of Model 1 reported at the top of Table 3 did not identify a significant association in the population between receptive vocabulary in childhood and future self-reported adolescent delinquency. This was likely because measured demographic covariates were included in the model. When childhood CP was added as a simultaneous predictor of adolescent delinquency in *Model 2*, childhood CP was a significant predictor of delinquency (path b in Figure 1A), but PPVT was not (path c in Figure 1A). These results were the same in within-family analyses for both all families with siblings and families with only full siblings.

Nonetheless, separate tests of the direct and indirect predictive associations of PPVT with adolescent delinquency in Model 2 substantially modify these conclusions. As reported in the text above, although there was not a significant *direct* association between PPVT and adolescent delinquency, the *indirect path* from PPVT through childhood CP to adolescent delinquency was significant at $p < 0.001$ in population-level analyses with measured demographic covariates included and in both sets of sibling-comparison analyses that rule out family level environmental confounding. These findings indicate that each 1 SD difference in PPVT at 4–9 years reliably predicted a 2% smaller mean delinquency score at 14–17 years.

The results of Model 3 further amplify and modify conclusions regarding the predictive association between PPVT and adolescent delinquency. First, even when the PPVT-by-CP interaction term was in the model, the indirect effects of PPVT on later delinquency were significant in population-level and both sets of sibling comparisons. The direct and indirect associations between PPVT and adolescent delinquency are tested across the range of PPVT in Table 5 because the association is nonlinear, even though it is significant at all levels of PPVT. In addition, as illustrated in Figure 2, the results of Model 3 revealed a significant PPVT-by-CP interaction in Model 3, which suggests that PPVT also moderates the prediction of adolescent delinquency from childhood CP. As illustrated in Figure 2, this interaction reflects a stronger association between childhood CP and adolescent delinquency in children with *higher* PPVT receptive vocabulary scores. As shown in Table 3, this interaction was found in both population-level analyses with measured covariates and in sibling comparisons among all families with siblings, but was not found in families with only full siblings. This raises the possibility that differences in the genetic and environment influences on different half siblings (who have different biological fathers) may explain all or part of this interaction. On the other hand, because the parameter estimate is similar in

full siblings, the lack of statistical significance may only reflect the lower power in the smaller subset of full siblings.

Implications of Sibling Comparisons for Causal Inference

Although the predictive association of low levels of receptive vocabulary in childhood with later adolescent delinquency is complicated, it is statistically significant. PPVT was found to predict adolescent delinquency, even though the association is indirect through childhood CP, and PPVT also appears to moderate the prediction of adolescent delinquency from childhood CP. These conclusion are consistent with previous findings that children who engage in antisocial behavior tend to have deficits in language development (Brownlie, et al., 2004; Cantwell & Baker, 1987) and lower cognitive ability test scores (Kratzer & Hodgins, 1999; Lipsitt, et al., 1990; Loeber, et al., 2012; Lynam, et al., 1993; Moffitt, et al., 1981; Moffitt & Silva, 1988).

Sibling comparisons were conducted to begin to move our understanding of the association between childhood language skills and adolescent delinquency beyond the simple mapping of correlations to inferences that can support testable causal hypotheses. The within-family analyses differ from population-level analyses by automatically ruling out all confounding with environmental variables and some genetic factors that are shared by siblings, only differ between families, and are correlated with both PPVT and adolescent delinquency (Lahey & D'Onofrio, 2010). This substantial reduction in confounding adds weight to possibility of (indirect) causal links between early language deficits and the development of later delinquency.

One cannot conclude that there is a causal link between receptive vocabulary and adolescent delinquency on the basis of the present findings for two reasons. First, because PPVT and childhood CP were measured concurrently, there is ambiguity regarding the direction of effect between these variables. Second, some types of potential confounding are not ruled out by sibling comparisons. Although full siblings each randomly draw from the same gene pool, one sibling may receive alleles of variants associated with both PPVT and delinquency, creating a genetic link between the predictor and the outcome. The results of a previous twin study of intelligence and CP in young children were consistent with this possibility in finding complete sharing of genetic influences on concurrently measured intelligence and childhood CP (Koenen, et al., 2006). Whether the same is true for the predictive association of adolescent delinquency from receptive vocabulary is currently unknown, however. The present sibling-comparison analyses also do not rule out the possibility that environmental variables that are not shared by siblings, but influence both PPVT and adolescent delinquency, are responsible for what appears to be a causal link between PPVT and adolescent delinquency. No single type of quasi-experimental design can control all forms of confounding. Therefore, multiple different quasi-experimental study designs that rule out different confounds will be needed to determine if a causal sequence exists from childhood receptive vocabulary to adolescent delinquency.

Although the present findings cannot support *conclusions* regarding causal influences, they do suggest at least one *testable causal hypothesis* that may explain the present findings of an indirect association of receptive vocabulary on adolescent delinquency, including the

interaction between receptive vocabulary and childhood conduct problems. We hypothesize that (1) there are multiple causal influences on childhood CP, some of which are unrelated to receptive vocabulary, and (2) the causal influences on CP that are unrelated to receptive vocabulary give rise to adolescent delinquency in ways that remain to be defined. This hypothesis is consistent with the findings shown in Figure 2 that childhood CP predicts adolescent delinquency at all levels of receptive vocabulary. In addition, we hypothesize that better developed cognitive and/or communication skills indexed by the PPVT play one or more causal roles in influencing risk for adolescent delinquency, such as inhibiting the development of CP by facilitating socialization during childhood (Keenan & Shaw, 1997). The steeper slope for the association between childhood CP and adolescent delinquency among children with higher PPVT scores children shown in Figure 2 suggests that children with higher levels of CP have enough other causal influences for persisting antisocial behavior to override the inhibitory influences of well developed cognitive and language skills in predicting adolescent delinquency.

Clinical Implications

If a causal relation between early cognitive and language development and future delinquency is supported in future studies that rule out other confounds, it may be possible to reduce the risk of adolescent delinquency by fostering language development during childhood. Given that the present findings suggest that any such predictive association between receptive vocabulary and adolescent delinquency is modest in size, and the existence of a causal link is still in question, the present findings provide little support for tests of early language interventions to prevent delinquency at this time. Nonetheless, the significant interaction suggests that early interventions that *both* reduce childhood CP and foster language development might be beneficial.

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Figure 1.

Structural equation models of (A) the direct and indirect associations of Peabody Picture Vocabulary Test (PPVT) receptive vocabulary scores and childhood conduct problems with adolescent delinquency (del), and (B) the same model with a test of the interaction of PPVT receptive vocabulary scores and childhood conduct problems included.

Figure 2.

Association of mother-reported childhood conduct problems (CP) with self-reported adolescent delinquency at four levels of Peabody Receptive Vocabulary Test (PPVT) receptive vocabulary scores at the population level with no adjustment for covariates.

Table 1

Zero-order correlations among measures of receptive vocabulary at 4–9 years, mother-rated conduct problems at 4–9 years, and self-reported delinquency at 14–17 years in (A) all children in the population-level analyses including singletons (N = 5343; above the diagonal), and (B) among children in families with >1 child (N = 4211; below the diagonal).

	PPVT receptive vocabulary at 4–9 years	Conduct problems at 4–9 years	Self-reported delinquency At 14–17 years
PPVT receptive vocabulary at 4–9 years		–.18	–.08
Conduct problems at 4–9 years	–.18		.17
Self-reported delinquency at 14–17 years	–.10	.14	

PPVT = Peabody Picture Vocabulary Test.

Table 2

Estimates of linear associations between receptive vocabulary scores and childhood CP in the population (top) and in within-family sibling comparisons (below) conducted in the full sample and among full siblings only from the same path model illustrated in Figure 1A that is reported in Table 3 as Model 2.

Predictor variables	All Families with Siblings		Full Siblings Only	
	β (S.E.)	z	β (S.E.)	z
<i>Estimated associations in the population</i>				
PPVT (z)	-0.26 (0.04)	-6.65***		
Female	-0.53 (0.05)	-11.19***		
Birth order	-0.10 (0.03)	-3.96***		
Family income (log)	-0.23 (0.04)	-5.898***		
Maternal age/10 years	-0.40 (0.08)	-4.76***		
African-American	-0.05 (0.09)	-0.56		
Hispanic	-0.14 (0.09)	-1.58		
<i>Estimated within-family associations (sibling comparisons)</i>				
PPVT (z)	-0.24 (0.06)	-4.31***	-0.24 (0.07)	-3.35***
Female	-0.55 (0.06)	-9.18***	-0.51 (0.07)	-7.13***
Birth order	-0.14 (0.03)	-4.64***	-0.12 (0.04)	-3.46***

Note: CP = conduct problems; PPVT = Peabody Picture Vocabulary Test; maternal age/10 years = maternal age at first birth divided by 10. Childhood conduct problem scores range from 0 to 14; units given in text. All models include a random effect at the family level. Estimates are weighted to represent the offspring of the NLSY79 population; standard errors account for household clustering in the original NLSY79.

p < .001;

**
p < .01;

*
p .05.

Table 3

Estimates of log-linear associations of receptive vocabulary test scores and caretaker-rated childhood CP with self-reported adolescent delinquency during adolescence in the population (top) or in within-family sibling comparisons (bottom) conducted in the full sample and among full siblings only.

Predictor variables	All Families			Full Siblings Only		
	Model 1	Model 2	Model 3	Model 2	Model 3	z
	β (S.E.)	β (S.E.)	β (S.E.)	β (S.E.)	β (S.E.)	z
<i>Estimated associations in the population</i>						
PPVT (z)	-0.01 (0.02)	0.02 (0.02)	-0.08 (0.03)	0.68	-2.40*	
CP		0.08 (0.01)	0.08 (0.01)	8.40***	8.85***	
PPVT $\times$ CP			0.04 (0.01)		3.90***	
Female	-0.24 (0.03)	-0.19 (0.03)	-0.18 (0.03)	-5.77***	-5.67***	
Birth order	0.00 (0.02)	0.01 (0.02)	0.01 (0.02)	0.50	0.48	
Family income (log)	-0.06 (0.02)	-0.04 (0.02)	-0.04 (0.02)	-1.82	-1.88	
Maternal age/10 years	-0.26 (0.05)	-0.22 (0.05)	-0.21 (0.05)	-4.08***	-3.94***	
African-American	0.11 (0.04)	0.12 (0.04)	0.11 (0.04)	2.72**	2.67**	
Hispanic	0.22 (0.05)	0.23 (0.05)	0.23 (0.05)	4.96***	4.82***	
<i>Estimated within-family associations (sibling comparisons)</i>						
PPVT (z)	0.03 (0.03)	0.04 (0.03)	-0.02 (0.05)	1.37	-0.43	0.18
CP		0.07 (0.02)	0.08 (0.02)	4.80***	4.98***	4.04***
PPVT $\times$ CP			0.02 (0.01)		1.93*	1.12
Female	-0.25 (0.04)	-0.21 (0.04)	-0.20 (0.04)	-4.97***	-4.88***	-4.54***
Birth order	0.04 (0.02)	0.05 (0.02)	0.05 (0.02)	2.12*	2.08*	2.40*

Note: CP = conduct problems; PPVT = Peabody Picture Vocabulary Test; maternal age/10 years = maternal age at first birth divided by 10. Conduct problems range from 0 to 14; units given in text. Model 2 is illustrated in Figure 1A and Model 3 is illustrated in Figure 1B. All models include a random effect at the family level. Delinquency (DEL) score ranges from 0 to 7 and is modeled as a negative binomial distribution. Beta coefficients represent differences in log mean DEL per predictor unit. Estimates are weighted to represent the offspring of the NLSY79 population; standard errors account for household clustering in the original NLSY79.

p < .001;

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p < .01;

*
p .05.

Table 4

Post hoc analyses to facilitate interpretation of the interaction of PPVT receptive vocabulary scores and childhood CP in predicting adolescent delinquency in Model 3 analyses by testing the association of childhood CP with adolescent delinquency at reference points of -1 and $+1$ standard deviations from the mean of PPVT scores.

	β	z
<i>Population-level associations</i>		
At PPVT = -1	0.04	3.59***
At PPVPT = $+1$	0.123	7.93***
<i>Sibling comparisons in all families with siblings</i>		
At PPVT = -1	0.051	2.94**
At PPVPT = $+1$	0.100	4.58***
<i>Sibling comparisons in families with only full siblings</i>		
At PPVT = -1	0.061	2.31*
At PPVPT = $+1$	0.101	3.77***

Note: CP = Childhood CP; PPVT = Peabody Picture Vocabulary Test.

 $p < .001$;

**
 $p < .01$;

*
 $p < .05$.

Table 5

Direct and indirect associations of PPVT on adolescent delinquency at different values of PPVT to show the nonlinear indirect effect of PPVT on adolescent delinquency at reference points of -1 and $+1$ standard deviations from the mean of PPVT scores when the interaction of PPVT and childhood CP is in the model.

	β	z
<i>Population-level associations</i>		
<u>Direct effect</u>		
At PPVT = -1	0.02	0.64
At PPVT = 0	0.00	0.20
At PPVT = $+1$	-0.01	-0.24
<u>Indirect effect</u>		
At PPVT = -1	-0.01	-3.19^{***}
At PPVT = 0	-0.02	-5.55^{***}
At PPVPT = $+1$	-0.03	-5.32^{***}
<i>Sibling comparisons in all families with siblings</i>		
<u>Direct effect</u>		
At PPVT = -1	0.04	1.26
At PPVT = 0	0.04	1.06
At PPVT = $+1$	0.03	0.88
<u>Indirect effect</u>		
At PPVT = -1	-0.01	-2.58^{**}
At PPVT = 0	-0.02	-3.35^{***}
At PPVPT = $+1$	-0.02	-3.10^{**}
<i>Sibling comparisons in families with only full siblings</i>		
<u>Direct effect</u>		
At PPVT = -1	0.06	1.36
At PPVT = 0	0.05	1.23
At PPVT = $+1$	0.04	1.09
<u>Indirect effect</u>		
At PPVT = -1	-0.02	-2.13^*
At PPVT = 0	-0.02	-2.73^{**}
At PPVPT = $+1$	-0.02	-2.44^*

Note: CP = conduct problems; PPVT = Peabody Picture Vocabulary Test

p < .001;

**
p < .01;

*
p .05.