Online Supplement: Twin Research and Human Genetics

Proposing a Pedigree Risk Measurement Strategy: Capturing the Intergenerational Transmission of Antisocial Behavior in a Nationally Representative Sample of Adults

Joseph A. Schwartz, Eric J. Connolly, Kevin M. Beaver, Joseph L. Nedelec, and Michael G. Vaughn

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Items Included in the Antisocial Behavior Measures

Table S1 contains a list of all 33 items used to create the antisocial behavior (ASB) measures. For each item, respondents were asked: (1) whether they had ever engaged in the behavior; (2) whether they had engaged in each incident before they were 15 years old; and (3) whether they had engaged in each incident since they were 15 years old. Importantly, two items — ever cut class and ever stayed out late at night without permission — were presented using the same format, but the specified age was 13 instead of 15. All items were coded dichotomously, such that 0 = no and 1 = yes.

Table S1. Items Included in the Antisocial Behavior Measures

1. Often cut class, not go to class or got to school and leave without permission?
2. Ever stay out late at night even though parents told you to stay home?
3. Ever have a time when you bullied or pushed people around or tried to make them afraid of you?
4. Ever run away from home at least twice or run away and stay away for a longer time?
5. Ever have a time when you were often absent from school, other than when caring for someone who was sick?
6. Have you quit a job more than once without knowing where you would find another one?
7. Have you quit a school program more than once without knowing what you would do next?
8. Have you travelled from place to place for one or more months without advance plans or without knowing how long you would be gone or where you would work?
9. Have you ever had a time lasting more than one month when you had no regular place to live?
10. Have you ever had a time lasting one or more months when you lived with others because you did not have your own place to live?
11. Was there ever a time when you lied a lot, other than to avoid being hurt?
12. Have you ever used a false or made-up name or alias?
13. Have you ever scammed or conned someone for money, to avoid responsibility or just for fun?
14. Have you ever done things that could easily have hurt you or someone else, like speeding or driving after having too much to drink?
15. Have you ever gotten more than three tickets for reckless/careless driving, speeding, or causing an accident?
16. Have you ever had your driver's license suspended or revoked for moving violations?
17. Have you ever destroyed, broken, or vandalized someone else's property (car, home, etc.)?
18. Have you ever started a fire on purpose to destroy someone else's property or just to see it burn?
19. Have you ever failed to pay off debts — like moving to avoid rent, not making payments on a loan or mortgage, failing to pay alimony or child support, or filing bankruptcy?
20. Have you ever stolen something from someone or someplace when no one was around?
21. Have you ever forged someone else's signature, like on a legal document or a check?
22. Have you ever shoplifted?
23. Have you ever robbed, mugged, or snatched a purse from someone?
24. Have you ever made money illegally, like selling stolen property or drugs?
25. Have you ever done something you could have been arrested for, regardless of whether you were caught or not?
26. Have you ever had sex with someone against their will?
27. Have you gotten into a lot of fights that you started?
28. Have you ever gotten into a fight that came to swapping blows with someone like a husband, wife, boyfriend, or girlfriend?
29. Have you ever used a weapon like a stick, knife, or gun in a fight?
30. Have you ever hit someone so hard that you injured them or they had to see a doctor?
31. Have you ever harassed, threatened, or blackmailed someone?

32. Have you ever physically hurt another person in any way on purpose?
33. Have you ever hurt an animal or pet on purpose?

Note: All items were coded dichotomously such that 0 = no and 1 = yes.
For each question, respondents were asked whether the incident had occurred before they were 15 years old and since they were 15 years old. These supplemental questions were used to create the early onset and adult onset measures of antisocial behavior.

Results From Exploratory Factor Analysis Examining the Lifetime Antisocial Behavior Measure

Exploratory factor analysis (EFA) was used to identify the underlying factor structure of the lifetime ASB items. The results revealed a four-factor solution provided a close fit to the data (CFI = .982, TLI = .976, RMSEA = .038). The standardized factor loadings for the four-factor EFA model are presented in Table S2 (all loadings were significant at the $p < .01$ level). Bolded values indicate the item was included in subsequent confirmatory factor analysis (CFA) to create the corresponding ASB subfactor. Importantly, six items loaded strongly on multiple factors (these items are flagged in the Table with an asterisk). The majority of these items were somewhat vague and included lying a lot, doing something that could have resulted in an arrest, and bullying others. Based on these findings, the primary analyses were estimated a second time with all six items allowed to cross-load onto multiple factors. The results did not differ substantively from those presented in the current study.

Table S2. Factor Loadings for the Lifetime Antisocial Behavior Measure

	Factor 1 (School)	Factor 2 (Nonviolent)	Factor 3 (Financial)	Factor 4 (Violent)
Cut Class	**.841**	.554	.423	.434
Stay out Late	**.678**	.551	.353	.443
Bullied/Pushed People Around*	.608	.623	.384	**.687**
Run Away from Home	**.644**	.516	.587	.449
Absent from School	**.802**	.569	.509	.443
Quit Job without Another	.568	.518	**.574**	.433
Quit School Program	**.626**	.473	.533	.379
Travel without Advance Plans	.482	.547	**.795**	.451
1+ Month with Nowhere to Live	.467	.572	**.956**	.448
1+ Month Lived with Others	.444	.510	**.804**	.432
Lied A Lot*	**.658**	.677	.590	.538
Use Alias	.528	**.625**	.492	.534
Scam Someone	.648	**.794**	.599	.660
Hurt You/Someone Else	.469	**.734**	.360	.549
3+ Traffic Tickets	.370	**.525**	.184	.481
Driver's License Revoked	.402	**.527**	.274	.515
Destroy Property	.554	**.801**	.493	.639
Start Fire on Purpose	.484	**.677**	.417	.520
Fail to Pay Off Debts*	.471	.576	**.573**	.490
Steal Something	.521	**.847**	.484	.488
Forge Signature	.468	**.659**	.422	.456
Shoplift	.558	**.827**	.505	.440
Rob/Mug/Snatch a Purse	.513	**.752**	.529	.677
Make Money Illegally	.562	**.865**	.591	.647
Could be Arrested*	.535	**.895**	.499	.632
Rape*	.336	.481	.393	**.477**
Get into A Lot of Fights	.611	.632	.456	**.787**
Domestic Violence	.433	.526	.526	**.578**
Used a Weapon in a Fight	.463	.638	.523	**.821**
Injured Someone in Fight	.475	.658	.487	**.815**
Harass/Threaten/Blackmail*	.570	.718	.483	**.734**
Hurt Someone	.469	.686	.455	**.722**
Hurt an Animal or Pet	.342	**.606**	.305	.466

Note: Bolded values indicate the item was included in subsequent confirmatory factor analysis (CFA) to create the corresponding ASB subfactor.

*Indicates item was allowed to cross-load onto other subfactors in supplemental analyses. The results are not reported but did not differ in any substantive way from the results reported in the current study.

Results From Supplemental Analyses

Results From a Two-Factor Model of Pedigree Risk

In an effort to assess the robustness of the findings reported in the primary analysis, two additional sets of supplementary analyses were performed. The results of both sets of supplemental analyses are presented in Table S3. The first set of analyses attempted to better specify the individual contributions of the first- and second-degree relative risk indicators. The primary purpose of this stage of the analysis was to more thoroughly investigate the predictive ability of the proposed pedigree risk approach when fewer family risk indicators are available. In line with these objectives, pedigree risk was measured using a series of two-factor CFA models. Directly in line with the primary analyses, the first model allowed the two first-degree family risk indicators (parent and sibling risk) to freely load on one factor and allowed the second-degree family risk indicators (grandparent, aunt, and uncle risk) to freely load on a second factor. Only two first-degree relative indicators were available in the NESARC. While it is customary to measure latent variables using three or more indicators, previous simulation studies have supported the use of two indicators when analyzing a large sample (e.g., $n < 200$; Anderson & Gerbing, 1984). Based on these results, the first-degree pedigree risk factor was created using only two indicators. The second two-factor measurement strategy was identical to the first, except that the factor loadings for first- and second-degree relative risk indicators were fixed to equality. Finally, the third measurement strategy fixed the factor loadings for first-degree family risk indicators to .50 and the factor loadings for second-degree family risk indicators to .25 in an effort to reflect levels of genetic relatedness. The measurement model is displayed in the top portion of Figure S1.

The regression models estimated in the primary analysis were estimated a second time using the alternative two-factor pedigree risk measurement strategy. The results of the regression models are presented in Table S3. Importantly, each of the two latent pedigree risk measures was included in the estimated equations separately in an effort to assess the independent association (and corresponding proportion of variance explained) between each measure and the examined ASB outcomes. The first set of models regressed the three ASB measures on the freely estimated pedigree risk factors. The results are presented in the first set of columns and include unstandardized and standardized path coefficients, accompanying standard errors, and the

proportion of ASB variance explained for each examined outcome. The results indicated that the freely estimated first-degree pedigree risk measure explained between 43 and 46% of the variance in each of the examined ASB measures, compared to the second-degree pedigree risk measure, which explained between 30 and 32% of the variance in the same measures. Such a discrepancy in explained variance was expected since first-degree relatives share a greater proportion of genetic material and are also more likely to share environmental influences with one another compared to second-degree relatives.

In an effort to better reflect levels of genetic relatedness, the models were estimated a second time using measures of pedigree risk in which the indicators for the first- and second-degree latent factors were constrained to equality. This modification in the measurement model resulted in virtually identical results to those reported in the previous step in the analysis. The final step in the analysis involved estimating the same regression models a third time, with the most restrictive measurement strategy for the latent pedigree risk measures in which first-degree factor loadings were fixed to .50 and second-degree loadings were fixed to .25. Similar to the pattern of findings reported in the primary analysis, this measurement strategy resulted in an overall attenuation in the proportion of variance explained in each of the ASB measures with the first-degree pedigree risk measure explaining between 36 and 38% of the overall variance in the three ASB measures, and the second-degree pedigree risk measure explaining between 28 and 30% of the overall variance.

Collectively, these findings reveal that a more comprehensive measure of pedigree risk containing information from both first- and second-degree relatives should be favored. In situations in which less information is available, more restrictive measurement strategies (e.g., fixing factor loadings to reflect levels of genetic relatedness) involving first-degree relatives should be favored. These recommendations are largely based on the overall similarity between the results from Model 3 in the supplementary analysis and the results from Models 2 and 3 in the primary analysis.

Results From Multiple Indicator Multiple Causes (MIMIC) Models

The proposed pedigree risk approach takes into account the intergenerational transmission of antisocial behavior across family members sharing varying degrees of genetic relatedness in an effort to estimate properly specified statistical models and minimize genetic

confounding. However, and as mentioned in the primary analysis, due to a lack of twins, siblings, adoptees, or genome-wide data, this particular measurement strategy does not allow for the direct estimation of genetic and shared environmental influences. Rather, the resulting pedigree risk measure likely encapsulates both sets of influences. While measures were taken to minimize the overall amount of variance within the pedigree risk factor explained by sources of the shared environment, it is quite likely that the remaining variance is not comprised of purely genetic influences. In an effort to further address this limitation, a second set of supplemental analyses was performed using a series of Multiple Indicator Multiple Causes (MIMIC) models. MIMIC models typically consist of two simultaneously estimated equations within a structural equation modeling (SEM) framework (Jöreskog & Goldberger, 1975; Muthén, 1989). The first model typically defines one or more latent constructs and is analogous to a traditional CFA model. The second equation consists of a regression model in which the latent factor (or factors) defined in the previous step is regressed on a series of covariates. This second equation effectively removes any variance from the latent factor(s) that can be explained by the included covariates, with the residual variance providing a more precise measure of the intended concept(s).

The MIMIC models estimated at this stage of the analysis consisted of the same three single-factor latent measures of pedigree risk estimated in the primary analyses, but also included a total of 23 adverse family environmental measures tapping three domains: parental maltreatment, sexual abuse, and family support. The parental maltreatment category was comprised of 14 measures and included items that asked respondents to indicate how often their parents physically abused them, verbally abused them, and forced them to go without essential items such as food. The sexual abuse category was comprised of four items which asked respondents to report how frequently they were touched inappropriately, how frequently they were forced to touch an adult or other person in a sexual way, how often someone attempted to have sex with them, and how often someone actually did have sex with them. All of the parental maltreatment and sexual abuse measures were coded categorically such that 1 = *never*, 2 = *almost never*, 3 = *sometimes*, 4 = *fairly often*, 5 = *very often*. The family support category consisted of five items that asked respondents whether they felt their family was a source of strength, whether their family made them feel important or special, whether their family believed in them, and whether their family wanted them to be a success. All of the family support

measures were coded as follows: 1 = *never true*, 2 = *rarely true*, 3 = *sometimes true*, 4 = *often true*, 5 = *very often true*. All 23 adverse family environment measures (along with the accompanying coding schemes) are listed in Table S4. The pedigree risk measures were regressed on all 23 adverse family environment measures[1] prior to the estimation of the regression models estimating the proportion of variance explained in each of the three ASB measures. The MIMIC model is displayed in the upper portion of Figure S2 and effectively removes any variance in the estimated pedigree risk measures explained by the adverse family environment measures.

Each of the ASB measures were then regressed on the adjusted pedigree risk measures. The results of the regression models are presented in Table S3. The first set of models regressed each of the ASB measures on the adjusted pedigree risk measure in which the family risk indicator loadings were freed. As expected, the adjusted pedigree risk measures explained overall lower levels of variance in each of the ASB measures (estimates ranging between 31 and 37%) relative to the models presented in the primary analysis. The second set of models regressed the ASB measures on the adjusted pedigree risk measure in which first- and second-degree family risk indicators were fixed to equality. The results were virtually identical to the previous set of models. Finally, the third set of models regressed the ASB measures on an adjusted pedigree risk measure in which the factor loadings for the first-degree family risk indicators were fixed at .50 and the factor loadings for the second-degree family risk indicators were fixed at .25. The overall pattern of results indicated a further attenuation of the overall variance explained in ASB, with estimates ranging between 26 and 31%.

Taken together, the overall pattern of results flowing from this stage of the supplementary analyses suggest that accounting for observed aspects of environmental influence significantly reduces the overall proportion of variance in ASB explained by the pedigree risk measure (regardless of the measurement strategy). While such attenuated effects may be interpreted as a further isolation of genetic (as opposed to environmental) influences, this pattern of findings may also reflect other, unwarranted processes. More specifically, the employed MIMIC models likely remove variance explained by both environmental *and* genetic influences. Since at least some of the employed family risk measures are influenced by both genetic and environmental factors (Kendler & Baker, 2007), removing all of the variance explained by these measures likely artificially deflates the influence of genetic risk. In addition, as with any quasi-experimental

research design, it remains possible that additional covariates should be included in the MIMIC models to more effectively isolate genetic influences and remove environmental influences. However, this process is not as straightforward as it may seem and would almost certainly artificially attenuate the overall levels of genetic influence even further. Covariates used to adjust the proposed genetic risk measure should be selected using strict theoretical and methodological criteria directly related to the empirical question examined. Model comprehensiveness must be balanced against model parsimony. Based on these concerns, and the overall convergence in findings between the primary and supplemental analyses, it appears that the measurement models presented in the primary analysis should be favored unless there is sufficient theoretical reasoning to employ a MIMIC approach.

Endnote

1 Supplementary analyses included the adverse family environment measures as three latent factors. A series of EFA and CFA models were estimated to elucidate the underlying factor structure of the adverse family environment measures. An EFA model revealed that a three-factor model fit the data (CFI = .963, TLI = .950, RMSEA = .081), and a three-factor CFA model also resulted in a close fit to the data (CFI = .966, TLI = .962, RMSEA = .050). Based on these findings, a second set of MIMIC models regressed the pedigree risk factor on the three latent adverse family environment measures and the subsequent regression models were estimated a second time. The overall pattern of findings from the models employing latent adverse family measures did not differ in any substantive way from those reported in the current study.

References

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Kendler, K. S., & Baker, J. H. (2007). Genetic influences on measures of the environment: A systematic review. *Psychological Medicine, 37*, 615–626.

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Table S3. Results From Supplemental Analyses

	Model 1[a]				Model 2[b]				Model 3[c]			
	b	SE	Beta	R^2	*b*	SE	Beta	R^2	*b*	SE	Beta	R^2
Early Onset												
1st Degree	.86**	.04	.65	.43	.87**	.04	.66	.43	.33**	.02	.62	.38
2nd Degree	.65**	.03	.55	.30	.65**	.03	.55	.30	.11**	.01	.53	.28
						(42,134)						
MIMIC	.61**	.03	.56	.31	.61**	.03	.56	.31	.13**	.01	.51	.26
						(33,174)						
Adult Onset												
1st Degree	.87**	.03	.66	.43	.88**	.03	.66	.44	.26**	.01	.60	.36
2nd Degree	.67**	.03	.56	.31	.67**	.03	.56	.32	.12**	.01	.54	.29
						(42,137)						
MIMIC	.67**	.02	.60	.36	.67**	.02	.60	.36	.14**	.01	.55	.30
						(33,176)						
Lifetime												
1st Degree	.92**	.03	.68	.46	.92**	.03	.68	.46	.26**	.02	.61	.38
2nd Degree	.85**	.03	.56	.32	.67**	.03	.57	.32	.12**	.01	.54	.30
						(42,139)						
MIMIC	.68**	.02	.61	.37	.68**	.02	.61	.37	.15**	.01	.56	.31
						(33,176)						

Note: MIMIC = multiple indicator multiple causes. All models were estimated using sample weights and cluster variables. MIMIC models adjust the pedigree risk measure for 23 family risk measures tapping three domains: (1) parental maltreatment (14 items); (2) sexual abuse (4 items); and (3) family support (5 items).

[a]Family risk indicators allowed to freely load on pedigree risk factor.

[b]Family risk indicator loadings for first- and second-degree relatives constrained to equality.

[c]First-degree family risk indicators constrained to .50 and second-degree family risk indicators constrained to .25.

Sample sizes presented in parentheses.

$^{\dagger}p < .10$; $*p < .05$; $**p < .01$

Table S4. Covariates Included in Multiple Indicator Multiple Causes (MIMIC) Models

Physical Maltreatment

1. Before you were 18 years old how often did your parent or caregiver make you do chores that were too difficult or dangerous for someone your age?
2. How often did your parent or caregiver leave you alone or unsupervised before you were 10 years old?
3. Before you were 18 years old how often did you go without things you needed because a parent or caregiver spent the money on themselves?
4. Before you were 18 years old how often did your parent or caregiver make you go hungry or not prepare regular meals?
5. Before you were 18 years old how often did your parent or caregiver ignore or fail to get you treatment when you were sick?
6. Before you were 18 years old how often did your parent or caregiver swear, insult, or say hurtful things to you?
7. Before you were 18 years old how often did your parent or caregiver threaten to hit or throw something at you?
8. Before you were 18 years old how often did your parent or caregiver make you fear that you would be physically hurt or injured?
9. Before you were 18 years old how often did your parent or caregiver push, grab, shove, slap, or hit you?
10. Before you were 18 years old how often did your parent or caregiver hit you so hard that you had marks or bruises or were injured?
11. Before you were 18 years old how often did your father or other adult male push, grab, slap, or throw something at your mother?
12. Before you were 18 years old how often did your father or other adult male hit your mother with a fist or something hard?
13. Before you were 18 years old how often did your father or other adult male repeatedly hit your mother for at least a few minutes?
14. Before you were 18 years old how often did your father or other adult male threaten your mother with a knife/gun or use a knife/gun to hurt her?

Sexual Abuse

15. Before you were 18 years old, how often did an adult or other person fondle/touch you in a sexual way when you did want this or were too young to know what was happening?
16. Before you were 18 years old, how often did an adult or other person have you touch them in a sexual way when you didn't want this or were too young to know what was happening?
17. Before you were 18 years old, how often did an adult or other person attempt sexual intercourse with you when you didn't want this or were too young to know what was happening?
18. Before you were 18 years old, how often did an adult or other person have sexual intercourse with you when you didn't want this or were too young to know what was happening?

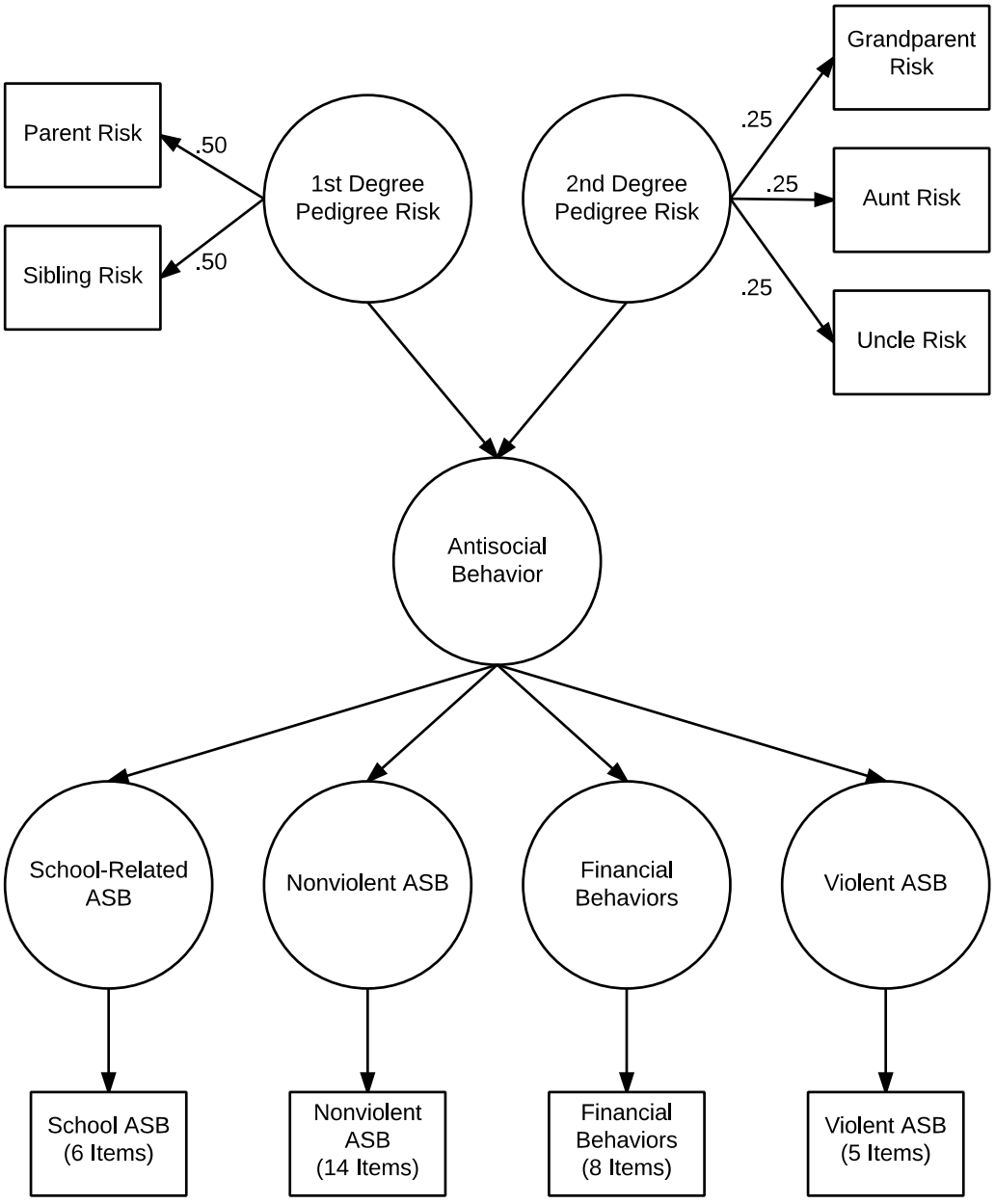
Family Support

19. Before you were 18 years old, you felt that there was someone in your family that wanted you to be a success.

20. Before you were 18 years old, you felt that there was someone in your family that helped you feel that you were important or special.
21. Before you were 18 years old, you felt that your family was a source of strength and support.
22. Before you were 18 years old, you felt that you were part of a close-knit family.
23. Before you were 18 years old, you felt that someone in your family believed in you.

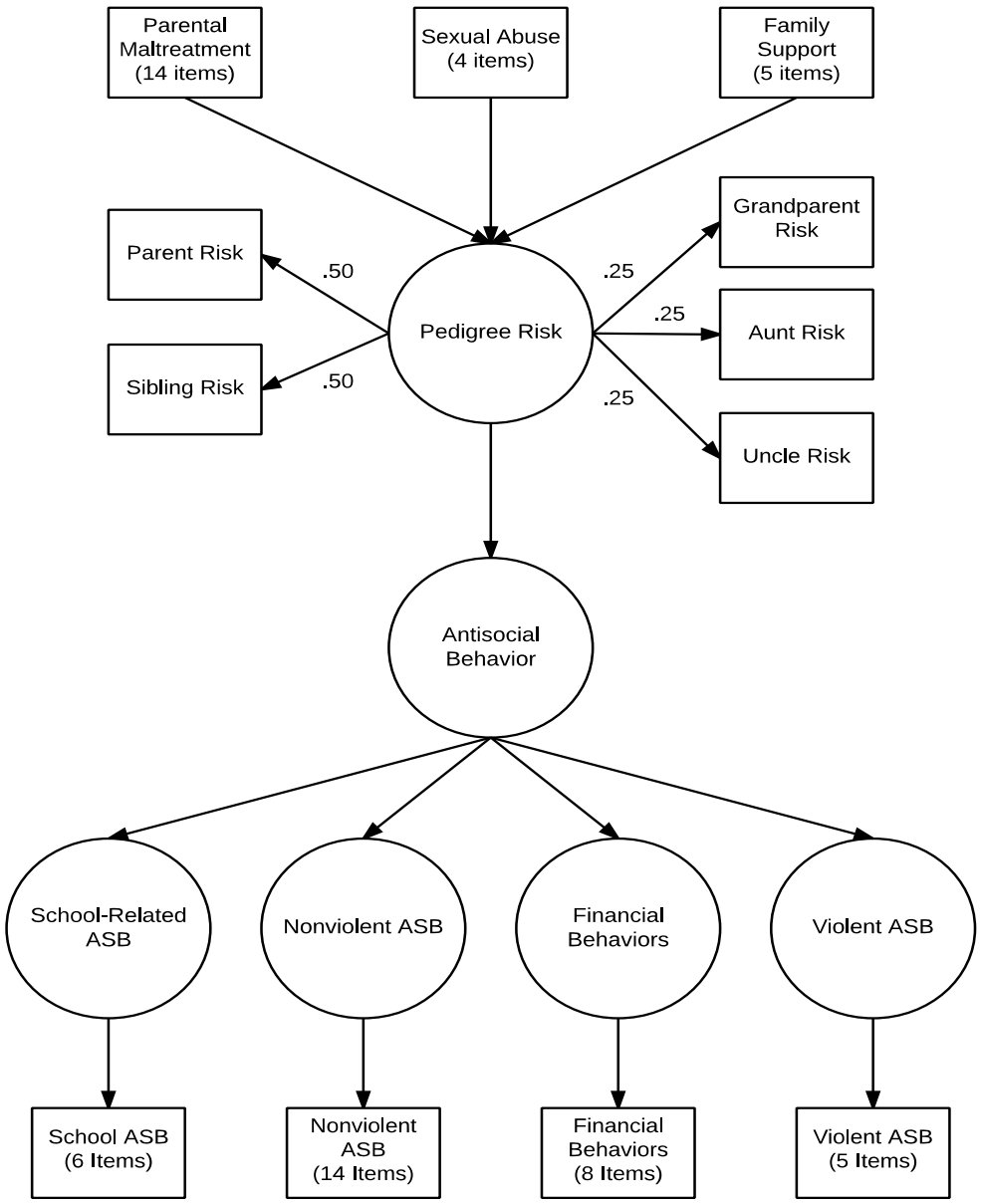
Note: Physical maltreatment and sexual abuse items were coded as follows: 1 = *never*; 2 = *almost never*; 3 = *sometimes*; 4 = *fairly often*; 5 = *very often.*
Family support measures were coded as follows: 1 = *never true*; 2 = *rarely true*; 3 = *sometimes true*; 4 = *often true*; 5 = *very often true.*

Figure S1. Structural Equation Model for Two-Factor Pedigree Risk Measure



Note: The top half of the path diagram displays the measurement model used to create the pedigree risk factors. The path estimates included in the figure indicate that the factor loadings for first-degree relatives were fixed to .50 and the loadings for second-degree relatives were fixed to .25. The bottom half of the model displays the measurement model used to create the antisocial behavior model. In an effort to more clearly display the model, the individual indicators used to create the ASB measures are represented with a single rectangle.

Figure S2. Structural Equation Model for Multiple Indicator Multiple Causes (MIMIC) Model



Note: The top half of the path diagram displays the multiple indicator multiple causes (MIMIC) model. The path estimates included in the figure indicate that the factor loadings for first-degree relatives were fixed to .50 and the loadings for second-degree relatives were fixed to .25. The pedigree risk measure was regressed on the covariates included in the top portion of the figure in an effort to remove any variance explained by adverse family environments. The bottom half of the model displays the measurement model used to create the antisocial behavior model. In an effort to more clearly display the model, the individual indicators used to create the ASB measures are represented with a single rectangle.