THE RELATIONSHIP BETWEEN SELF-CONTROL AND LANGUAGE: EVIDENCE OF A SHARED ETIOLOGICAL PATHWAY*

KEVIN M. BEAVER
College of Criminology and Criminal Justice
Florida State University

MATT DELISI
Department of Sociology
Iowa State University

MICHAEL G. VAUGHN
School of Social Work and Departments of Public Policy and Epidemiology
Saint Louis University

JOHN PAUL WRIGHT
Division of Criminal Justice
University of Cincinnati

BRIAN B. BOUTWELL
College of Criminology and Criminal Justice
Florida State University

KEYWORDS: behavioral genetics, childhood, language, self-control, twin models

Converging lines of research suggest that self-control and language may be inextricably linked. No empirical research has ever examined this proposition, however. We address this gap in the literature by analyzing a sample of twin pairs from a nationally representative data set of children. The results revealed three broad findings. First, diminished

* We would like to thank the editor and the anonymous reviewers for their comments on an earlier draft of this article. Direct all correspondence to Kevin M. Beaver, College of Criminology and Criminal Justice, Florida State University, 634 West Call Street, Tallahassee, FL 32306-1127 (e-mail: kbeaver@fsu.edu).

© 2008 American Society of Criminology

language skills were predictive of low self-control both cross-sectionally and longitudinally. Second, the covariation between language and self-control was linked to both genetic and environmental factors. Third, after controlling for genetic influences on self-control, language skills were predictive of variation in individual levels of self-control. The theoretical implications of these findings are discussed.

An emerging body of research has examined the factors that are implicated in the development of self-control. Much of this work has tested Gottfredson and Hirschi's (1990) parental socialization thesis. According to this explanation, three interwoven parenting techniques determine levels of self-control in children. To inculcate self-control effectively, parents must supervise/monitor their children, recognize their child's misbehavior, and consistently punish their child for misbehaving. Parents who engage in these three parenting practices and who are attached to their children will, on average, produce children with high levels of self-control. In contrast, parents who fail to follow these three parenting techniques will, in general, raise children with lower levels of self-control.

Empirical research has found some support in favor of Gottfredson and Hirschi's (1990) parental socialization thesis (Cullen, et al., 2008; Gibbs, Giever, and Higgins, 2003; Gibbs, Giever, and Martin, 1998; Unnever, Cullen, and Pratt, 2003). It is important to point out, however, that parenting measures typically account for only a very small percentage of explained variance, much less than what Gottfredson and Hirschi's theory predicts (Wright and Beaver, 2005). These findings indicate that other factors that extend beyond the family are also implicated in the development of self-control. Although research has identified some of these extrafamilial factors (e.g., schools and neighborhoods) (Pratt, Turner, and Piquero, 2004; Turner, Piquero, and Pratt, 2005), a paucity of criminological studies examine whether *individual*-level characteristics may also be important in structuring levels of self-control.

One individual-level characteristic that may be particularly important to the emergence of self-control is language skills. Diminished language skills and verbal abilities have been linked to a range of antisocial phenotypes (Moffitt, 1990, 1993; Wilson and Herrnstein, 1985), and some scholars have theorized that reduced language skills may actually impede the development of self-control (Luria, 1961; Luria and Hamskaya, 1964). To our knowledge, however, no studies have examined the mutual unfolding of language and self-control. Whether the acquisition of language covaries with the development of self-control thus remains an open-empirical question, one that we address in the current study. In addition, we also test several competing hypotheses, each of which specifies slightly different

causal mechanisms that relate language skills to self-control. Before proceeding, we begin with an overview of the literature that ties language acquisition to behavioral development, followed by a discussion of the different explanations that have been advanced to account for the close nexus between language and self-control.

LANGUAGE ACQUISITION, BEHAVIORAL REGULATION, AND SELF-CONTROL

One hallmark of childhood is the acquisition of language. Although children are exposed to hundreds of thousands of words within their first year of life, most children do not speak their first words until around the ages of 12 to 15 months, after which their vocabulary grows at an exponential rate (Hart and Risley, 1995). By age 3, for example, children can have more than 1,000 words in their vocabulary (Hart and Risley, 1995), which allows them to communicate verbally with others. With newly acquired language skills, children can easily articulate their wants, needs, and feelings to others. Vocabulary development also facilitates other functions, especially behavioral regulation.

Children who fail to acquire language at a normal rate, or who are deficient verbally, are at risk for a range of maladaptive outcomes (Dionne, 2005). Language deficiencies often co-occur with a clinical diagnosis of Attention-Deficit/Hyperactivity Disorder (ADHD), (Cohen et al., 1998; Willcutt, Pennington, and DeFries, 2000), reading disabilities (Tomblin et al., 2000), problems decoding emotions accurately, and difficulties in social problem-solving skills (Cohen et al., 1998). Deficits in language abilities also are strongly associated with serious problem behavior phenotypes, which include early-life externalizing behaviors (Gallagher, 1999), physical aggression (Dionne et al., 2003), and adolescent delinquency (Davis, Sanger, and Morris-Friehe, 1991). These findings have been reinforced with clinically based samples in which research has shown that more than 50 percent of youthful psychiatric patients (Giddan, Milling, and Campbell, 1996) and about 80 percent of antisocial boys have language impairments (Warr-Leeper, Wright, and Mack, 1994).

Collectively, the results that flow from these studies indicate a high degree of comorbidity between language deficits and behavioral problems. Still, the question remains whether impaired language skills predict later life problems. It could simply be the case that all children—even those with early language problems—eventually develop the requisite language skills and are no longer at risk for displaying maladaptive outcomes in the future. Yet a line of research findings has converged to show that the long-term prognosis of children with language deficits is not promising. Language-impaired children are at risk for having reading and writing

problems later in life (Stevenson, 1996), and they are also at risk for school failure (Dworkin, 1989; Lloyd, 1978). Importantly, children with diminished language abilities are also prone to engaging in criminal behaviors as adults (Brownlie et al., 2004). Stattin and Klackenberg-Larsson (1993), for example, found that language assessments at ages 6, 18, and 24 *months* of age were significantly predictive of the number of arrests accrued in adulthood.

That an association exists between language/verbal skills and adverse behavioral outcomes is undeniable. What explains the linkages between the two, however, remains a matter of debate (Dionne, 2005). Based on the existing empirical and theoretical research, it seems that language skills do not cause misconduct directly, but instead some mediating factor or factors are involved. Precisely what the mediators are remains unclear, but some research suggests that language fosters emotional control, impulse regulation, and cognitive skills more generally. All of these tasks overlap considerably with the definition of self-control proffered by Gottfredson and Hirschi (1990). Moreover, the outcomes associated with impaired language skills (e.g., delinquency, school failure, and physical aggression) are many of the same outcomes associated with low levels of self-control. Therefore, the association between low language abilities and behavioral problems may be mediated, at least in part, by low self-control. This explanation is reinforced by research indicating that the development of language promotes the development of self-control and that deficiencies in language skills may actually stunt the emergence of self-control. Gallagher (1999: 5) underscored this viewpoint when she stated that:

> One of the most important functions of language is intrapersonal emotional and behavioral regulation. Children's language comprehension and expression skills are critical to their understanding, encoding, organization, and retrieval of rules that enable them to effect appropriate levels of self-control and emotional regulation. Language skills facilitate executive control and meta-cognitive processing by providing a means for self reflection, verbal mediation, response inhibition, and behavioral direction.

Similar conclusions have been reached by other researchers who explored the link between language skills and antisocial behaviors (Moffitt, 1993). Fujiki, Brinton, and Clarke (2002: 104), for example, argued that:

> [C]hildren develop the ability to regulate emotion within a context of external support from caregivers. Language plays an important role in these interactions . . . It seems clear that language ability is important to the development of emotion regulation . . . Given the relationship between emotion regulation and language ability, it might be expected that children who have difficulty with language would be at a disadvantage in developing appropriate emotion regulation skills.

EXPLANATIONS FOR THE COVARIATION BETWEEN LANGUAGE DEFICITS AND LOW SELF-CONTROL

The available evidence seems to point to the likelihood that the onset of language coincides with the ability to exercise self-control and to regulate behavior. Although important, these findings do not identify the precise causal mechanisms that link variations in language skills to variations in levels of self-control. A close reading of the literature that examines the language-antisocial behaviors link reveals two general perspectives that can be applied to, and potentially explain, the relationship between language and self-control. The two general perspectives described below are referred to as the s*hared etiology explanation* and the *causal effect explanation* (Dionne, 2005). Embedded within each of these two general perspectives are different theoretical variants (Stevenson, 1996); however, we focus only on those that are most applicable to the language–self-control connection.

SHARED ETIOLOGY EXPLANATIONS

The first perspective that can account for the covariation between language skills and self-control is the shared etiology explanation. According to this explanation, the development of language and the development of self-control are both caused by the same factors. The contributors to language are precisely the same contributors to self-control. Exactly what those antecedent causal factors are is not completely evident, but drawing from the self-control literature, it is possible to identify two broad groups of shared etiological factors: environmental factors and genetic factors.

The shared environmental etiology explanation is completely compatible with Gottfredson and Hirschi's (1990) parental management thesis. If, as Gottfredson and Hirschi claim, parents are the main cause of self-control, and if, as some research suggests, parents also influence the development of language (Hart and Risley, 1995; Lyytinen, Laasko, and Poikkeus, 1998; Storch and Whitehurst, 2001), then parents could be the source of the covariation between language and self-control. The shared environmental etiology explanation does not have to focus exclusively on parental effects. Nonfamilial environmental effects, such as the socialization processes that occur within peer groups, at schools, or in neighborhoods, could also potentially account for the covariation between language and self-control. The link between language and self-control could also be explained by multiple shared environmental influences, which include parents *and* peers *and* neighborhoods *and* schools. The important point to

bear in mind, however, is that according to the shared environmental etiology explanation, only environmental sources account for the covariation between language and self-control.

The shared genetic etiology explanation stands in stark contrast to the shared environmental etiology explanation. According to this explanation, the same genetic factors that explain variation in language also explain variation in self-control (Stevenson, 1996). Although Gottfredson and Hirschi (1990) argue that low self-control is not influenced by genetic factors, a small but growing pool of research suggests that this proposition may need to be revised (Beaver, Wright, and DeLisi, 2007; Wikström and Treiber, 2007; Wright and Beaver, 2005). Findings culled from these studies have produced empirical evidence to indicate that levels of self-control are determined in part by genetic and neuropsychological factors. At the same time, some scholars have argued that language is an innate instinct (Pinker, 1994), and a considerable amount of research has indicated that genetic and neurological factors are a source of variation in language skills (Bishop, 2003; Gopnik, 1997). The results showing that both language and self-control are genetically influenced leave open the possibility that shared genetic factors may explain the covariation between language and self-control.

The shared environmental etiology explanation and the shared genetic etiology explanation are somewhat exaggerated, and neither probably exists in its "pure" form. A wealth of behavioral genetic research has revealed, for example, that most behaviors and personality traits are caused by a complex arrangement of environmental and genetic interplay (Moffitt, 2005; Rutter, 2006; Walsh, 2002). In addition, research has also demonstrated that genetic factors often only have an effect when paired with high-risk environmental stimuli (Caspi et al., 2002). Against this backdrop, if the shared etiology explanation has merit, then it is probably due to a combination of environmental factors and genetic factors.

CAUSAL EFFECT EXPLANATIONS

The shared etiology explanation posits that language and self-control covary simply because the causes of each overlap considerably. The main drawback to this explanation is that it ignores the potential causal effects that language has on self-control and that self-control has on language. This oversight is addressed by the second perspective, which is called the causal effect explanation. Three main variants of the causal effect explanation exist. The first variant suggests that low levels of self-control cause language impairments. According to this model, children with low self-control may be less interested in learning, reading, and listening to their parents. This type of explanation is in line with Gottfredson and Hirschi's (1990) theory. After all, they argue that one of the six dimensions of self-

control is the preference for physical activities over mental ones, and they also maintain that a host of maladaptive outcomes, which include learning problems, would be more common among people with low levels of self-control.

The second variant to the causal effects explanation is that language skills have a causal effect on the development of self-control. This perspective is advocated by researchers who argue that language equips children with the "necessary skills" needed to evince self-control and to resist situational temptations (Wilson and Herrnstein, 1985). Necessary skills may take on a variety of different forms. For example, Gottfredson and Hirschi (1990) maintain that for self-control to develop in children, parents must correct their offspring's misbehavior. Presumably, parents explain to their child what they did wrong, why they should not do it again in the future, and the consequences of their actions. The effectiveness of these parental management techniques hinges on the child's capacity to understand their parents, which almost always requires the acquisition of language-processing skills (Moffitt, 1996).

But not all of these "necessary skills" need to be social. Luria (1961; Luria and Hamskaya, 1964) presented a theory that attempted to explain the close relationship between language and self-control in which he argued that for neuronal pathways in the frontal lobes to develop properly, children must learn to abide by verbal instructions and commands. Such tasks involve a complex chain of events that begin by decoding language, processing the verbiage embedded within the statements, and acting on the commands, all of which are contingent on a minimum level of language skills. Luria's theory is congruent with research indicating that self-control is an executive function housed in the prefrontal cortex of the brain (Beaver, Wright, and DeLisi, 2007; Wikström and Treiber, 2007).

The third and final variant of the causal effect explanation is a reciprocal effects model, in which variations in language cause variations in self-control, and variations in self-control cause variations in language. Reciprocal effects models necessarily escape the "chicken-or-the-egg" question because it does not have to provide an answer of whether language predates self-control or whether self-control predates language. With that said, the existing literature tentatively suggests that language is antecedent to antisocial phenotypes, such as self-control (Dionne, 2005).

THE CURRENT STUDY

The purpose of the current study is threefold. First, we examine whether language and self-control covary. Drawing from the language-antisocial behavior literature, we hypothesize that a moderate correlation will exist. Second, we examine the shared etiological explanations by decomposing

the covariation into an environmental component and a genetic component. We hypothesize that the covariation is caused by both the environmental and the genetic factors. Third, we examine the causal connections between language skills and self-control, controlling for shared genetic and shared environmental factors. We do so by examining whether the covariation between language skills and self-control is observed cross-sectionally and longitudinally. Using a longitudinal research design helps to establish temporal ordering. Even so, it is difficult to determine with any degree of certainty whether language should have causal effects on self-control or whether self-control should have causal effects on language. We follow the lead of the language-antisocial behavior research and assume that language predates self-control.

METHODS

DATA

This study uses data from the Early Childhood Longitudinal Survey, Kindergarten Class of 1998–1999 (ECLS-K). The ECLS-K is a nationally representative and longitudinal sample of children. Six waves of data have been collected thus far. The first wave of data was collected in the fall of 1998 at the beginning of the kindergarten year. The second round of interviews was conducted in the spring of 1999 when the children were approaching the end of their first year of formal education. The third and fourth waves of data were collected in the fall of first grade and the spring of first grade, respectively. However, only a small subsample of respondents was reinterviewed at wave 3. The last two interviews were completed in 3rd grade and in 5th grade. Response rates were over 90 percent for teacher interviews, parent interviews, and child assessments. Overall, more than 20,000 children participated in the ECLS-K, which makes it the largest prospective and nationally representative sample of children.

The ECLS-K also oversampled twins. If respondents indicated that they were part of a twin pair, then their co-twin was added to the sample. Overall, N = 310 twins (N = 155 twin pairs; n = 190 dizygotic [DZ] twins; n = 110 monozygotic [MZ] twins; n = 10 twins of unknown zygosity) were identified and selected for inclusion in the ECLS-K. Information about each child was collected from the respondent's parent (typically the mother) and the respondent's teacher. In addition, a series of standardized tests were administered to the children. The inclusion of twins and the use of a multirater measurement strategy make the ECLS-K a very rich and appealing data set to examine the development of self-control early in life. The full ECLS-K sample and the sample of twins have been used by previous researchers to explore the correlates of low self-control (Beaver and Wright, 2005; Beaver, Wright, and DeLisi, 2007; Wright and Beaver,

2005). For reasons to be discussed momentarily, we restricted our final analytical sample to the subsample of twins. Additionally, and in line with previous researchers, we only used data collected at wave 1 and at wave 4 (Beaver and Wright, 2005) because after wave 4, the low self-control measures were altered. To maintain consistency in measurement across waves, we opted not to extend the analyses using the newer self-control measures (Beaver, Wright, and DeLisi, 2007).

MEASURES

Low Self-Control

An adapted version of Gresham and Elliott's (1990) Social Skills Rating Scale (SSRS) was included in the ECLS-K. The SSRS is a multirater, standardized assessment tool. Parents and teachers were asked a series of questions that pertained to multiple domains of the child's personality, development, and functioning. Of these items, eight different variables tapped the child's level of self-control.[1] For example, at wave 1, parents were asked about their child's impulsivity, self-control, whether their child had difficulty concentrating, and whether their child had difficulty interacting with peers. Similarly, teachers were asked about the child's ability to be attentive, self-control, externalizing problem behaviors, and ability to forge friendships. The responses to the items were then summed together to form the wave 1 self-control scale (α = .66). The exact same items were available to construct the wave 4 low self-control scale (α = .60). Prior researchers who analyzed the ECLS-K have used identical measures, and research has found the SSRS to be a valid and reliable way to measure self-control in children (Beaver and Wright, 2005; Beaver, Wright, and DeLisi, 2007; Benes, 1995; Gresham, 2001; Wright and Beaver, 2005). Higher scores on both of these scales indicated lower levels of self-control. Table 1 includes descriptive statistics about all of the scales used in the analyses.[2]

1. The eight items were actually eight preconstructed scales that were composed of multiple items. However, because of contractual agreements with the distributors of the SSRS, the individual items that composed each of the eight scales were not available for analysis. If they were available, then the number of items that composed both of the low self-control scales would be much higher. As a result, we would also expect the alpha values to be higher. More detailed information about the individual items that composed the preconstructed scales is available from the National Center for Education Statistics (NCES, 2001), and an assessment of the psychometric properties of these scales has also been published by the National Center for Education of Statistics (NCES, 2002).
2. We should note that the self-control scales contain a significant amount of missing data (15 percent at wave 1 and 20 percent at wave 4). We examined whether the data were missing at random or whether the data were missing systematically. To do so, we calculated binary logistic regression models, where 0 = no missing

Table 1. Descriptive Statistics for the ECLS-K Sample Variables (*N* = 310 Twins)

Variable	Mean	SD	Minimum–Maximum	Percentage Missing
Language skills scale	1.03	.85	0–2.98	9
Letter recognition	.63	.41	0–1.00	9
Beginning sounds	.27	.31	0–1.00	9
Ending sounds	.13	.22	0–.98	9
Low self-control at wave 1	16.39	3.09	10.27–26.56	15
Low self-control at wave 4	15.75	2.80	10.08–24.53	20
Parental involvement	24.72	4.60	13–36	2
Gender (1 = male)	.41	.49	0–1	0
Race (1 = nonwhite)	.36	.48	0–1	0

Language Skills

During wave 1 interviews, the child completed a direct cognitive assessment that measured their language skills. Specifically, each child was assessed along three different dimensions of language development.[3] The first dimension—letter recognition—evaluated the child's ability to recognize uppercase and lowercase letters. The second dimension—beginning sounds—assessed the child's ability to recognize the appropriate sound that a series of letters at the beginning of a word should make. The third and final dimension—ending sounds—assessed the child's ability to recognize the appropriate sound that a series of letters at the end of a word should make. Each of the three dimensions will be examined separately. In addition, and to gain a more global measure of language development, a composite language skills scale was also created by summing together

data on the low self-control scales and 1 = missing data on the low self-control scales. All other measures (i.e., the language skills scales, parental involvement, gender, and race) were entered into the equations as covariates. The results of these analyses revealed that none of the covariates were statistically significant predictors of whether the respondent had missing data on the low self-control scales. As a result, it seems that the data are not missing systematically, and thus, our results should not be biased by missing data for the low self-control scales.

3. The children were also assessed on two other items: sight words (i.e., the ability to recognize words by sight) and comprehension of words in context (i.e., reading). However, given that the wave 1 interviews were conducted in the fall of kindergarten, relatively few respondents received a score of above 0 on these items. For example, over 80 percent of all children received a proficiency probability score of "0" on the comprehension of words in context test. As a result, we excluded these two items from the analysis.

the scores for these three scales (α = .63). Higher scores on all variables/scales indicated increased language skills.

The ECLS-K provided five different scoring schemes for the language skills variables: 1) number right scores, 2) item-response theory (IRT) scores, 3) standardized scores (*t*-scores), 4) proficiency level scores (dichotomous), and 5) proficiency probability scores (continuous). We chose to use the proficiency probability scores for two main reasons. First, the cognitive assessment followed a two-stage design, in which children first completed a routing section. This routing section was the same for all children, but their performance on the routing section determined the difficulty of questions asked in the second-stage form. Thus, using "number-right scores" would be unadvisable because one student may have correctly answered 10 items for the low difficulty second-stage form, whereas another student may have correctly answered 9 items for the high difficulty second-stage form. A different scoring scheme, one that takes into account the dual-stage routing design, is needed to provide accurate appraisals of each child's language skills.

Second, the proficiency probability scores provided very detailed information about each child's language skills. The direct cognitive assessment of language skills contained clusters of questions that were of similar difficulty. The clusters were arranged in a standard Guttman fashion, where correctly answering a cluster of questions at one particular skill level indicated that the student was proficient at all of the lower skill levels. Conversely, failing a particular skill level indicated that they were not proficient at any of the higher skill levels. The proficiency level scoring system was available in two alternative forms in the ECLS-K: a dichotomous proficiency level score and a proficiency probability score. The dichotomous proficiency scale was coded such that if a respondent answered correctly at least two of four items in a cluster, then they received a score of "1"; otherwise, they were assigned a value of "0." The proficiency probability score, however, contained much more specific information about language skills. Proficiency probability scores were based on IRT analysis and were constructed from the child's overall test performance taking on any value from 0 to 1. Proficiency probability scores were estimated from an IRT model, and the specific value reflected the probability that the respondent had mastered that particular language skill. This more detailed approach could make much finer distinctions in language skills across all of the children in the sample. It is important to point out that the different scoring schemes available in the ECLS-K were all highly intercorrelated ($r \sim .90$), which suggests that they were all accurately measuring variation in language skills.

Control Variables

Three control variables were also included in the analyses to take into account extraneous influences. First, theoretical and empirical research suggests that parental socialization is important to the development of self-control and to the acquisition of language (Gottfredson and Hirschi, 1990; Hart and Risley, 1995). To take into account the effect that parents have on language and on self-control, we created a measure of parental involvement.[4] During wave 1 interviews, the mother was asked how often they had engaged in nine different activities with their child. For example, the parental involvement scale taps how often the parent reads to their child, tells their child stories, plays games with their child, and sings songs with their child, among others. Responses to the items were summed together to form the parental involvement scale ($\alpha = .74$). Higher scores reflected a greater degree of parental involvement.

The last two control variables—gender and race—were included in the statistical models as dichotomous variables. Gender was coded 0 = female and 1 = male; race was coded 0 = white and 1 = nonwhite.

PLAN OF ANALYSIS

The analysis for this article proceeded in three different stages. First, ordinary least-squares (OLS) regression models were calculated to examine the effects that the language skills measures had on the wave 1 and wave 4 low self-control scales. We included both a wave 1 self-control scale and a wave 4 self-control scale to examine the robustness of our measures over time and to examine the mutual unfolding of language skills and self-control during child development. In addition, according to Gottfredson and Hirschi (1990), levels of self-control do not become stable until around age 8. Thus, given that self-control was assessed during a time period when self-control might be variable, it was important to examine the models over time. The OLS equations were first calculated using the

4. Of course, we recognize that including only one parental socialization variable does not constitute a definitive test of Gottfredson and Hirschi's (1990) theory on the development of self-control. Unfortunately, the parental involvement scale was the only parental socialization variable available in the wave 1 data. Although other parenting variables were available at later waves, we opted not to include them for three reasons. First, they were not temporally ordered. Second, prior research that analyzed the ECLS-K has found that once genetic effects were held constant, the parenting measures were not significantly related to levels of low self-control (Wright and Beaver, 2005). And third, in some of our analyses, we used DF analysis, which held shared environmental effects (e.g., parental influences) constant. Model misspecification, therefore, does not seem to be problematic in the current analysis.

composite language skills measure as an independent variable. In subsequent models, the individual constituent variables (i.e., letter recognition, beginning sounds, and ending sounds) were entered into the equations separately. Using this process allowed us to determine whether each dimension of the language skills scale contributed equally to the OLS models. To ensure that the observations were independent of each other, one twin from each twin pair was randomly selected for inclusion in the analysis; the other twin was deleted.

Second, after establishing a statistically significant association between the language skills scale and the low self-control scales, we estimated bivariate Cholesky decomposition models (Neale and Cardon, 1992). These models provide detailed information about whether the correlation between language and self-control was caused by genetic factors, environmental factors, or both. Both twins from each twin pair were included in these analyses, and the models were estimated using the statistical software package, Mx (Neale et al., 2002). More detail about this modeling strategy is provided below.

Finally, we employed DeFries-Fulker (DF) analysis (DeFries and Fulker, 1985) to examine the potential causal connections between language skills and self-control. For these models, genetic and shared environmental effects were held constant, and the effect of language skills on self-control was estimated. In the DF equations, the language skills variables/scales were modeled as nonshared (unique) environmental differences. This test is very conservative, and it helps to establish an empirical linkage between language acquisition and levels of self-control. More information about DF analysis is provided below. All the OLS and DF models were calculated with AMOS, which makes use of a full-information maximum likelihood imputation algorithm to estimate missing values. As a result, these analyses were based on a sample of $N = 310$ twins.

RESULTS

The analysis began by estimating a series of OLS regression equations where the wave 1 low self-control scale was the dependent variable and the language skills measures were independent variables. Control variables for parental involvement, gender, and race also were included in the models. Table 2 contains the results. As can be observed in model 1, the composite language skills scale had a statistically significant and negative effect on the low self-control scale, which means that greater language skills were associated with more self-control. In addition, the parental involvement scale was inversely related to the low self-control scale, in which higher parental involvement corresponded to greater levels of self-control in children.

Table 2. OLS Regression Equations Predicting Low Self-Control at Wave 1 (*n* = 155 Twins)

	Model 1		Model 2		Model 3		Model 4	
	b	SE	*b*	SE	*b*	SE	*b*	SE
Language Development								
Language skills	–.43*	.29						
Letter recognition			–.39*	.59				
Beginning sounds					–.38*	.82		
Ending sounds							–.35*	.95
Control Variables								
Parental involvement	–.30*	.06	–.31*	.06	–.29*	.06	–.28*	.06
Gender (1 = male)	–.08	.48	–.08	.49	–.10	.49	–.10	.50
Race (1 = nonwhite)	.04	.49	.04	.50	.06	.51	.06	.51

NOTES: Standardized coefficients presented.
*$p < .05$, two-tailed tests.

Models 2 through 4 are duplicates of model 1 except that the individual language skills items were entered into the equations in place of the composite measure. As revealed in table 2, all individual language skills variables (i.e., letter recognition, beginning sounds, and ending sounds) had statistically significant effects on low self-control. In line with expectations, children with more language skills also had more self-control. The parental involvement scale retained statistical significance in all models.

The next set of OLS regression models employed the wave 4 low self-control scale as the dependent variable. These models thus estimated whether language skills (measured at wave 1) predicted levels of low self-control 1.5 years into the future. As shown in table 3, and strikingly similar to the results presented in table 2, the composite language skills scale, letter recognition variable, beginning sounds variable, and ending sounds variable were all statistically significant predictors of self-control. The parental involvement scale, however, failed to reach statistical significance in any of the four models presented in table 3.

The results thus far suggest that a strong and consistent association exists between language skills and low self-control. The question that remains, however, is what factor or factors are responsible for driving the covariation between language and self-control? Recall that one explanation for the language-self-control nexus is that they are both the result of shared etiological causes. These common causes could include environmental forces, genetic forces, or some combination of the two. To shed light on this issue, we next calculated univariate variance components twin models to estimate the environmental and genetic effects on the language

Table 3. OLS Regression Equations Predicting Low Self-Control at Wave 4 (*n* = 155 Twins)

	Model 1		Model 2		Model 3		Model 4	
	b	SE	*b*	SE	*b*	SE	*b*	SE
Language Development								
Language skills	–.35*	.28						
Letter recognition			–.41*	.55				
Beginning sounds					–.27*	.78		
Ending sounds							–.20*	1.12
Control Variables								
Parental involvement	–.08	.05	–.09	.05	–.08	.06	–.08	.06
Gender (1 = male)	–.14	.47	–.13	.46	–.15	.48	–.16	.49
Race (1 = nonwhite)	.18*	.48	.17*	.47	.19*	.49	.20*	.50

NOTES: Standardized coefficients presented.
*$p < .05$, two-tailed tests.

skills scale and on the two low self-control scales. Univariate twin models are widely used in behavioral genetic research, and they compare the resemblance of MZ twins with DZ twins on a particular measure. MZ twins share 100 percent of their DNA, whereas DZ twins share 50 percent of their genetic material; the environments, however, are the same between MZ twins and DZ twins. Thus, the only reason that MZ twins should be more similar to each other than DZ twins is because they share more genetic material. Specific estimates of genetic influences can be calculated by calculating a cross-twin correlation for MZ twins and a cross-twin correlation for DZ twins. Then, the DZ cross-twin correlation is subtracted from the MZ twin correlation and the difference is doubled (to take into account that MZ twins share twice as much genetic material as DZ twins). This value indexes the proportion of variance accounted for by genetic factors—that is, heritability. The heritability estimate is then subtracted from 1.0 to arrive at an estimate of environmental influences. These ways of estimating heritability and environmental influences, although useful, are somewhat antiquated with the development of statistical software programs. These statistical programs provide even more reliable and more valid estimates than those described above.

The most widely used statistical package in the calculation of twin models is Mx. Mx is a structural equation modeling program that was designed specifically to be used for behavior genetic research (Neale et al., 2002). Appendix A shows the basic univariate twin model that was estimated in Mx. The traditional twin model decomposes the variance in a measure into three different components: a shared environmental component (C), a

nonshared environmental component (E), and a heritability component (A). For the purposes of this article, however, we pool together the shared environmental effects with the nonshared environmental effects. All models were fit to variance-covariance matrices that had been estimated using AMOS.

After calculating the univariate twin models, we then proceeded to estimate the proportion of the correlation (between language and self-control) that is linked to environmental factors and the proportion that is linked to genetic factors (see Carey, 2003; Neale and Cardon, 1992). It is not possible to calculate these estimates using the traditional univariate twin model. Instead, we needed to estimate a bivariate twin model that can estimate the covariation between the two measures and simultaneously can estimate the proportion of the covariation linked to genetic and environmental influences. One such model that has been used relatively frequently in the behavior genetic literature is the bivariate Cholesky decomposition model (Neale and Cardon, 1992). Appendix B presents the bivariate Cholesky decomposition model that was estimated in the current study. Again, Mx was used to calculate these models.

Table 4. Results of the Univariate Twin Models and the Bivariate Cholesky Decomposition Models (N = 155 Twin Pairs)

Model	Genetic Effects	Environmental Effects
Univariate Results		
Language skills	.41	.59
	(.26–.66)	(.34–.74)
Low self-control at wave 1	.72	.28
	(.58–.86)	(.14–.42)
Low self-control at wave 4	.46	.54
	(.20–.73)	(.27–.80)
Bivariate Results		
Cross-sectional model	.61	.39
Longitudinal model	.76	.24

NOTES: 90 percent confidence intervals included in parentheses.

Table 4 presents the results of the univariate and bivariate Cholesky models. For the univariate models, 90 percent confidence intervals were also included because heritability estimates can become somewhat unstable with small sample sizes. As observed in the top row, genetic effects

accounted for 41 percent of the variance in the language skills scale, whereas the remaining 59 percent was attributable to environmental effects. For the wave 1 low self-control scale, genetic factors accounted for 72 percent of the variance, whereas the environment accounted for the remaining 28 percent. Last, 46 percent of the variance in the wave 4 low self-control scale was linked to genetic factors and 54 percent was linked to environmental effects. Of particular interest, however, are the results from the bivariate Cholesky models. For the cross-sectional models that examined the association between the wave 1 language skills scale and the wave 1 low self-control scale, 61 percent of the covariation between these two measures was linked to genetic factors, whereas 39 percent of the covariation was linked to environmental factors. In the longitudinal model that examined the association between the wave 1 language skills scale and the wave 4 low self-control scale, 76 percent of the covariation between these two measures was linked to genetic factors, and 24 percent of the covariation was linked to environmental effects.

Analysis of the ECLS-K data has revealed two broad findings. First, language skills are strongly associated with self-control. Second, the covariation between language skills and self-control is linked to genetic factors and, to a lesser extent, environmental factors. In the last set of analyses, we hold genetic effects and shared environmental effects constant and estimate whether differences in the acquisition of the language skills (between siblings from the same twin dyad) can explain differences in levels of self-control (between siblings from the same twin dyad). We used DF analysis to explore these issues.

DF analysis is a regression-based statistical technique that can be used with samples of twins to estimate genetic and environmental effects on a phenotypic measure (DeFries and Fulker, 1985). The baseline DF equation is

$$K_1 = b_0 + b_1K_2 + b_2R + b_3(R \times K_2) + e \tag{1}$$

where K_1 is the phenotypic score for one twin, K_2 is the co-twin's phenotypic score, R measures genetic relatedness (R = 1.0 for MZ twins and R = .5 for DZ twins), and $R \times K_2$ is a multiplicative interaction between R and K_2. In the DF equation, b_0 = the constant, b_1 = the proportion of variance in K_1 that is attributable to shared environmental factors, b_2 is not usually interpreted in DF analysis, b_3 = the proportion of variance in K_1 that is attributable to genetic factors, and e = nonshared environmental effects plus measurement error.

Recently, Rodgers and Kohler (2005) reformulated and simplified the baseline DF model presented in equation 1. The new DF equation is

$$K_1 = b_0 + b_1(K_2 - K_m) + b_2(R * (K_2 - K_m)) + e \tag{2}$$

where K_1 remains the phenotypic score for one twin, K_2 remains the co-twin's phenotypic score, and R remains the measure of genetic relatedness. In comparison with equation 1, equation 2 includes a new term, K_m. K_m is equal to the mean of the phenotypic measure for K_2. So now, K_2 is being centered around the mean, whereas in equation 1, K_2 was left untransformed. Additionally, the main effect of R has also been removed from the equation. The interpretation and substantive meaning of the slopes remains the same: b_1 is equal to the proportion of variance in K_1 accounted for by shared environmental effects, and b_2 is equal to the proportion of variance in K_1 accounted for by genetic effects.

The DF model presented in equation 2 thus estimates genetic and environmental effects on a particular phenotype. However, Rodgers, Rowe, and Li (1994) have expanded equation 1 to include nonshared environmental effects. This newly amended DF equation can be used in conjunction with equation 2 to arrive at the following equation:

$$K_1 = b_0 + b_1(K_2 - K_m) + b_2(R * (K_2 - K_m)) + b_4(ENVDIF) + e \quad (3)$$

The only difference between this equation and equation 2 is the introduction of one additional term, *ENVDIF*. *ENVDIF* captures the difference between one twin and their co-twin on a particular measure. For example, one twin's score on the language skills scale can be subtracted from their co-twin's scores on the language skills scale. The resulting value would index the difference between the two twins in their language development. This difference score can then be introduced as *ENVDIF* into equation 3, which provides an estimate of whether differences in language development (i.e., a nonshared environmental effect) may begin to explain differences in low self-control. We used equation 3 to estimate a series of DF equations.

Table 5 presents the results of the DF models that predict wave 1 low self-control. For ease of presentation, in table 5, b_1 and b_3 have been labeled as "shared environment" and "heritability," respectively. Model 1 estimated the heritability of low self-control and shared environmental effects on low self-control. In addition, the composite language skills scale was included in the equation as a difference score, and parental involvement was also included in the equation as a difference score. Remember that these difference scores are tapping the nonshared environment and are estimated only after the effects of genes and the shared environment are held constant. Three findings emerged from model 1. First, the wave 1 low self-control scale was under substantial genetic influence; 78 percent of the variance in low self-control was linked to genetic factors. Second, the shared environment had no effect on the development of self-control.

The remaining 22 percent of variance was thus attributable to the nonshared environment and to measurement error. Third, differences in language skills between twins had a negative and statistically significant effect on low self-control, which means that the twin with fewer language skills had lower levels of self-control. The parental involvement difference score was not related to low self-control.

Table 5. DF Analysis of Low Self-Control at Wave 1 (*N* = 155 Twin Pairs)

	Model 1		Model 2		Model 3		Model 4	
	b	**SE**	***b***	**SE**	***b***	**SE**	***b***	**SE**
DF Analysis Components								
Heritability	.78*	.07	.79*	.07	.77*	.07	.78*	.07
Shared environment	–.01	.06	–.01	.06	–.02	.06	–.02	.06
Developmental Differences								
Language skills	–.64*	.27						
Letter recognition			–1.42*	.54				
Beginning sounds					–1.38*	.66		
Ending sounds							–1.45	.95
Control Variables								
Parental involvement	–.09	.06	–.09	.07	–.09	.07	–.10	.07
Gender (1 = male)	–.43	.33	–.44	.33	–.42	.33	–.43	.34
Race (1 = nonwhite)	–.58	.34	.57	.34	.56	.34	.57	.34

NOTES: Unstandardized coefficients presented.
*$p < .05$, two-tailed tests.

Models 2 through 4 introduced the difference scores for each individual item that comprised the language skills composite measure. In model 2, the difference in letter recognition was inversely associated with the wave 1 low self-control scale; in model 3, the difference in beginning sounds was negatively related with the wave 1 low self-control scale. As shown in model 4, the difference in ending sounds was not a statistically significant predictor of low self-control. Across all of these models, however, the heritability estimate for low self-control was around .78, whereas the shared environmental estimate was 0.

The DF equations presented in table 5 revealed that differences in language skills were associated with the development of self-control, net of genetic and shared environmental effects. The equations, however, were based on cross-sectional data. We next turn our attention to the DF models that were estimated with longitudinal data, whereby the wave 1 language skills were used to predict the wave 4 low self-control scale. The

results of these models are presented in table 6. Across all four models, three findings are strikingly obvious. First, the heritability estimates for the wave 4 low self-control scale hovered around .50 and were statistically significant in all equations. In substantive terms, this finding means that about 50 percent of the variance in the wave 4 low self-control scale was accounted for by genetic factors. Second, shared environmental effects accounted for about 20 percent of the variance in self-control. Third, differences in language skills, which include the composite measure and the individual items, were all statistically significant predictors of self-control. Consistent with expectations, the twin with more language skills had greater levels of self-control.

Table 6. DF Analysis of Low Self-Control at Wave 4 (*N* = 155 Twin Pairs)

	Model 1		Model 2		Model 3		Model 4	
	b	**SE**	***b***	**SE**	***b***	**SE**	***b***	**SE**
DF Analysis Components								
Heritability	.50*	.09	.52*	.09	.49*	.09	.51*	.09
Shared environment	.20*	.06	.18*	.06	.19*	.06	.20*	.06
Developmental Differences								
Language skills	–.71*	.25						
Letter recognition			–1.13*	.50				
Beginning sounds					–1.28*	.61		
Ending sounds							–1.89*	.88
Control Variables								
Parental involvement	.04	.06	.04	.07	.04	.07	.03	.07
Gender (1 = male)	–.56	.31	–.56	.32	–.56	.32	–.57	.32
Race (1 = nonwhite)	.66*	.32	.69*	.32	.68*	.32	.67*	.32

NOTES: Unstandardized coefficients presented.
*$p < .05$, two-tailed tests.

DISCUSSION

Prior research has established a link between language deficits and involvement in antisocial behaviors (Dionne, 2005), but to our knowledge, no study has ever empirically examined the extent to which language and self-control are intertwined. We addressed this gap in the literature, and analysis of twins from the ECLS-K revealed a moderately strong and robust relationship between language skills and levels of self-control. This covariation was observed when analyzing the data both cross-sectionally and longitudinally. Specifically, children who scored low on language

assessments during wave 1 interviews were more likely to have low levels of self-control at wave 1 and at wave 4. These findings add to research that underscores the deleterious effects that flow from language impairments (Dionne, 2005; Gallagher, 1999).

The underlying causal mechanisms that related language skills to self-control were also explored. Based on the extant research, we investigated two different perspectives: a shared etiology explanation and a causal effect explanation. The results revealed support in favor of both perspectives. In regard to the shared etiology explanation, we found that 61 percent of the covariation between language assessments at wave 1 and the wave 1 low self-control scale was accounted for by genetic factors, and 39 percent was the result of environmental factors. In longitudinal analyses, in which the wave 1 language scores were used to predict the wave 4 low self-control scores, 76 percent of the covariation was linked to genetic factors, and the remaining 24 percent was attributable to environmental factors. The findings reported here reinforce those from prior research showing that genetic factors and environmental factors explain some covariation between maladaptive phenotypes (Silberg et al., 1996; Stevenson et al., 1993).

It would be a mistake, however, to argue that genetic factors are more important than environmental factors in the explanation of the covariation between language and self-control. Now a solid knowledge base exists to show that genetic factors and environmental factors work interactively, not independently (Caspi et al., 2002). It is likely that gene–environment interactions also play an important role in the language–self-control nexus. Although we could not test this possibility directly, we should note that the heritability estimates garnered from the twin models absorb the effects of some gene–environment interactions. This finding could begin to explain why genetic factors had relatively stronger effects than environmental factors. Future research should explore the gene–environment basis to self-control, language, and the covariation between the two.

The causal effect explanation was also supported in the DF models. By using DF analysis, we could explore the effects that differences in language skills (between twins from the same dyad) had on differences in their levels of self-control. DF analysis of the ECLS-K data revealed that once genetic effects and shared environmental effects were held constant, wave 1 language skills were a statistically significant predictor of self-control at wave 1 and at wave 4. These findings are especially noteworthy because they revealed that the twin who had higher language skills also had higher levels of self-control, which underscores the mutual unfolding of language acquisition and self-control. We should note, however, that although the statistical models were constructed such that language predated self-control, it is possible that the direction of the effect is reversed

and that self-control actually predates language. This possibility needs to be explored more fully in the future with samples that include multiple waves of data collected early in childhood.

In light of these findings and those reported in other studies (Beaver, Wright, and DeLisi, 2007; Wikström and Treiber, 2007; Wright and Beaver, 2005), Gottfredson and Hirschi's (1990) theory on the development of self-control needs to be revised in at least two ways. First, to pretend that biological and genetic factors have absolutely no effect on self-control is at odds with a rich line of behavioral genetic research that shows otherwise. This statement is not to say that biogenetic factors are the only cause of self-control, but they are important causes that need to be addressed. Second, Gottfredson and Hirschi's (1990) theory needs to emphasize the important role that the brain—especially the prefrontal cortex—plays in structuring levels of self-control. A range of different disciplines recognizes that behavioral regulation, emotional control, the ability to delay gratification, and impulsivity—which are collectively known as the executive functions—are all controlled by the prefrontal cortex of the brain (Moffitt, 1990). To keep pace with these disciplines, self-control theory also needs to explicate the ways in which levels of self-control are tied to brain structure and brain functioning. As our findings revealed, some of the same genetic factors that are responsible for language acquisition are the same genetic factors that are responsible for the development of self-control. And given that language centers are housed in specific areas of the brain, particularly Broca's area and Wernicke's area, it is likely that some of the same genetic factors that are responsible for these regions of the brain are also responsible for self-control. Broca's area, moreover, is found in the frontal lobes of the brain, which is the general region of the brain that controls the "executive functions." This factor is particularly important because language can be thought of a liaison that connects the social world to the biological workings of the brain. When this liaison (i.e., language) does not develop properly, or is impaired in some way, the link between the social world and the biological world becomes muddied. Cues, directions, commands, and statements that flow from the social world may not be processed or may be processed inaccurately by the brain (Moffitt, 1996). When this occurs, parents and other social institutions may not be able to instill self-control in their children because the mental hardware needed to process these social cues is not functioning at full capacity.

Overlooking the potentially powerful effect that language deficits have on low self-control is particularly problematic because unrecognized language impairments cannot be targeted by intervention programs. When language-impaired children do not receive assistance for these deficits, their behaviors become even worse. For example, in a study of psychiatrically disturbed children, over one third had unrecognized language

problems (Cohen et al., 1993). In comparison with children who had been diagnosed with a language deficit, the undiagnosed children evinced more serious externalizing problem behaviors. What this finding may mean is that children with unrecognized language problems will be less likely to develop self-control effectively. On a positive note, however, levels of self-control may be increased in children with language deficits as long as they are receiving assistance for their verbal impairments.

Before concluding, we should note that our study had at least two different limitations that should be addressed in future research. First, we employed a sample of twins, which necessarily raises the question that the findings may not be generalizable to nontwins. Unfortunately, the only way to test the hypotheses that link language to self-control is to use samples of genetically related siblings (e.g., twins) or to use adoption-based research designs. We addressed the question of whether the covariation between language skills and self-control was observed in nontwins from the ECLS-K. To do this, we calculated OLS regression models predicting low self-control with the language skills scales/variables. The pattern of results was identical, which lends credence to the likelihood that the findings may be generalizable to the larger population of nontwin children.

The second limitation that might be pointed out is that perhaps the measures of low self-control and the measures of language were indicators of one factor. If this was the case, then we would be setting up the analyses to find evidence to support the shared etiological explanation; this result could begin to explain why genetic factors explain much covariation between the two. We examined this possibility by factor analyzing all of the language skills items and all of the low self-control items. The results of the analysis revealed the presence of two factors, in which all the low self-control variables loaded on one factor and all the language skills variables loaded on another factor. These findings are in alignment with other research revealing that attention deficits and reading/learning disabilities are separate entities (Felton and Wood, 1989; Silver, 1990).

The association between language skills and levels of self-control underscores the complex and dynamic contributors to individual differences in self-control. Most research that examines the antecedents to self-control has taken a monolithic approach that has exclusively focused on the effects of social/environmental factors. But more and more evidence is accumulating, which shows that self-control is a multifactorial trait that is constructed from environmental, genetic, and biological factors working independently and interactively (Beaver, 2008; Wikström and Treiber, 2007). The current results support this view by indicating that language is just one of many different biosocial variables that ultimately influence variations in self-control.

REFERENCES

Beaver, Kevin M. 2008. Nonshared environmental influences on adolescent delinquent involvement and adult criminal behavior. *Criminology* 46:341–70.

Beaver, Kevin M., and John Paul Wright. 2005. Evaluating the effects of birth complications on low self-control in a sample of twins. *International Journal of Offender Therapy and Comparative Criminology* 49:450–71.

Beaver, Kevin M., John Paul Wright, and Matt DeLisi. 2007. Self-control as an executive function: Reformulating Gottfredson and Hirschi's parental socialization thesis. *Criminal Justice and Behavior* 34:1345–61.

Benes, Kathryn. 1995. Review of the social skills rating system. In *Twelfth Mental Measurements Yearbook*, eds. Jane Close Conoley and James C. Impara. Lincoln, NE: Buros Institute of Mental Measurement.

Bishop, Dorothy V. M. 2003. Genetic and environmental risks for specific language impairment in children. *International Journal of Pediatric Otorhinolaryngology* 67S1:S143–57.

Brownlie, E. B., Joseph H. Beitchman, Michael Escobar, Arlene Young, Leslie Atkinson, Carla Johnson, Beth Wilson, and Lori Douglas. 2004. Early language impairment and young adult delinquent and aggressive behavior. *Journal of Abnormal Child Psychology* 32:453–67.

Carey, Gregory. 2003. *Human Genetics for the Social Sciences*. Thousand Oaks, CA: Sage.

Caspi, Avshalom, Joseph McClay, Terrie E. Moffitt, Jonathan Mill, Judy Martin, Ian W. Craig, Alan Taylor, and Richie Poulton. 2002. Role of genotype in the cycle of violence in maltreated children. *Science* 297:851–4.

Cohen, Nancy J., Melvyn Davine, Naomi Horodezky, Lisa Lipsett, and Lila Isaacson. 1993. Unsuspected language impairment in psychiatrically disturbed children: Prevalence and language and behavioral characteristics. *Journal of the American Academy of Child & Adolescent Psychiatry* 32:595–603.

Cohen Nancy, J., Rosanne Menna, Denise D. Vallance, Melanie A. Barwick, Nancie Im, and Naomi B. Horodezky. 1998. Language, social cognitive processing, and behavioral characteristics of psychiatrically disturbed children with previously identified and unsuspected language impairments. *Journal of Child Psychology and Psychiatry* 39:853–64.

Cullen, Francis T., James D. Unnever, John Paul Wright, and Kevin M. Beaver. 2008. Parenting and self-control. In *Out of Control: Assessing the General Theory of Crime*, ed. Erich Goode. Stanford, CA: Stanford University Press.

Davis, Abbe D., Dixie D. Sanger, and Mary Morris-Friehe. 1991. Language skills of delinquent and nondelinquent adolescent males. *Journal of Communication Disorders* 24:251–66.

DeFries, John C., and David W. Fulker. 1985. Multiple regression analysis of twin data. *Behavior Genetics* 15:467–73.

Dionne, Ginette. 2005. Language development and aggressive behavior. In *Developmental Origins of Aggression*, eds. Richard E. Tremblay, Willard W. Hartup, and John Archer. New York: Guilford.

Dionne, Ginette, Richard Tremblay, Michel Boiven, David Laplante, and Daniel Perusse. 2003. Physical aggression and expressive vocabulary in 19-month-old twins. *Developmental Psychology* 39:261–73.

Dworkin, Paul H. 1989. School failure. *Pediatrics in Review* 10:301–12.

Felton, Rebecca H., and Frank B. Wood. 1989. Cognitive deficits in reading disability and attention deficit disorder. *Journal of Learning Disabilities* 22:3–13.

Fujiki, Martin, Bonnie Brinton, and Diane Clarke. 2002. Emotion regulation in children with specific language impairment. *Language, Speech, and Hearing Services in School* 33:102–11.

Gallagher, Tanya M. 1999. Interrelationships among children's language, behavior, and emotional problems. *Topics in Language Disorders* 19:1–15.

Gibbs, John J., Dennis Giever, and George E. Higgins. 2003. A test of Gottfredson and Hirschi's general theory using structural equation modeling. *Criminal Justice and Behavior* 30:441–58.

Gibbs, John J., Dennis Giever, and Jamie S. Martin. 1998. Parental management and self-control: An empirical test of Gottfredson and Hirschi's general theory. *Journal of Research in Crime and Delinquency* 35:40–70.

Giddan, Jane J., Leonard Milling, and Nancy B. Campbell. 1996. Unrecognized language and speech deficits in preadolescent psychiatric inpatients. *American Journal of Orthopsychiatry* 66:85–92.

Gopnik, M. 1997. Language deficits and genetic factors. *Trends in Cognitive Sciences* 1:5–9.

Gottfredson, Michael, and Travis Hirschi. 1990. *A General Theory of Crime*. Stanford, CA: Stanford University Press.

Gresham, Frank M. 2001. Assessment of social skills in children and adolescents. In *Handbook of Psychoeducational Assessment: Ability, Achievement, and Behavior in Children*, eds. Jac J. W. Andrews, Donald H. Saklofske, and Henry L. Janzen. New York: Academic Press.

Gresham, Frank M., and Stephen N. Elliott. 1990. *The Social Skills Rating System*. Circle Pines, MN: American Guidance Services.

Hart, Betty, and Todd R. Risley. 1995. *Meaningful Differences in the Everyday Experiences of Young American Children*. Baltimore, MD: Paul H. Brookes.

Lloyd, Dee Norman. 1978. Prediction of school failure from third-grade data. *Educational and Psychological Measurement* 38:1193–200.

Luria, Aleksandr R. 1961. *The Role of Speech in the Regulation of Normal and Abnormal Behavior*. New York: Basic Books.

Luria, Aleksandr R., and Evgenia D. Hamskaya. 1964. Disturbance in the regulative role of speech with frontal lobe lesions. In *The Frontal Granular Cortex and Behavior,* eds. John M. Warren and Konrad Akert. New York: McGraw-Hill.

Lyytinen, Paula, Marja-Leena Laasko, and Anna-Maiji Poikkeus. 1998. Parental contribution to child's early language and interest in books. *European Journal of Psychology of Education* 13:297–308.

Moffitt, Terrie E. 1990. The neuropsychology of juvenile delinquency: A critical review. In *Crime and Justice: An Annual Review of Research*, vol. 12, eds. Michael H. Tonry and Norval Morris. Chicago, IL: University of Chicago Press.

Moffitt, Terrie E. 1993. The neuropsychology of conduct disorder. *Development and Psychopathology* 5:135–51.

Moffitt, Terrie E. 1996. The neuropsychology of conduct disorder. In *Readings in Contemporary Criminology,* eds. Peter Cordella and Larry Siegel. Boston, MA: Northeastern University Press.

Moffitt, Terrie E. 2005. The new look of behavioral genetics in developmental psychopathology: Gene-environment interplay in antisocial behaviors. *Psychological Bulletin* 131:533–54.

National Center for Education Statistics (NCES). 2001. *ECLS-K Base Year Public-Use Data Files and Electronic Codebook.* Washington, DC:

U.S. Department of Education. http://nces.ed.gov/pubs2001/2001029rev_1_4.pdf.

National Center for Education Statistics (NCES). 2002. *Early-Childhood Longitudinal Study-Kindergarten Class of 1998-99 (ECLS-K), Psychometric Report for Kindergarten through First Grade* (Working Paper No. 2002-05). Washington, DC: U.S. Department of Education. http://nces.ed.gov/pubs2002/200205.pdf.

Neale, Michael C., Steven M. Boker, Gary Xie, and Hermine H. Maes. 2002. *Mx: Statistical Modeling*, 6th ed. Richmond: Department of Psychiatry, Virginia Commonwealth University.

Neale, Michael C., and Lon R. Cardon. 1992. *Methodology for Genetic Studies of Twins and Families*. Dordecht, the Netherlands: Kluwer.

Pinker, Steven. 1994. *The Language Instinct: How the Mind Creates Language*. New York: William Morrow and Company.

Pratt, Travis C., Michael G. Turner, and Alex R. Piquero. 2004. Parental socialization and community context: A longitudinal analysis of the structural sources of low self-control. *Journal of Research in Crime and Delinquency* 41:219–43.

Rodgers, Joseph Lee, and Hans-Peter Kohler. 2005. Reformulating and simplifying the DF analysis model. *Behavior Genetics* 35:211–17.

Rodgers, Joseph Lee, David C. Rowe, and Chengchang Li. 1994. Beyond nature versus nurture: DF analysis of nonshared influences on problem behaviors. *Developmental Psychology* 30:374–84.

Rutter, Michael. 2006. *Genes and Behavior: Nature-Nurture Interplay Explained*. Malden, MA: Blackwell.

Silberg, Judy, Michael Rutter, Joanne Meyer, Hermine Maes, John Hewitt, Emily Simonoff, Andrew Pickles, and Rolf Loeber. 1996. Genetic and environmental influences on the covariation between hyperactivity and conduct disturbance in juvenile twins. *Journal of Child Psychology and Psychiatry* 37:803–16.

Silver, Larry B. 1990. Attention deficit-hyperactivity disorder: Is it a learning disability or a related disorder? *Journal of Learning Disabilities* 23:394–7.

Stattin, Håkan, and Ingrid Klackenberg-Larsson. 1993. Early language and intelligence development and their relationship to future criminal behavior. *Journal of Abnormal Psychology* 102:369–78.

Stevenson, Jim. 1996. Developmental changes in the mechanisms linking language disabilities and behavior disorders. In *Language, Learning, and Behavior Disorders: Developmental, Biological, and Clinical Perspectives*, eds. Joseph H. Beitchman, Nancy J. Cohen, M. Mary Konstantareas, and Rosemary Tannock. New York: Cambridge University Press.

Stevenson, Jim, Bruce F. Pennington, Jeffrey W. Gilger, John C. DeFries, and Jacquelyn J. Gillis. 1993. Hyperactivity and spelling disability: Testing for shared genetic aetiology. *Journal of Child Psychology and Psychiatry* 34:1137-52.

Storch, Stacey A., and Grover J. Whitehurst. 2001. The role of family and home in the literacy development of children from low-income backgrounds. In *The Role of Family Literacy Environments in Promoting Young Children's Emerging Literacy Skills: New Directions for Child and Adolescent Development*, eds. Pia R. Britto and Jeanne Brooks-Gunn. San Francisco, CA: Jossey-Bass.

Tomblin, J. Bruce, Xuyang Zhang, Paula Buckwalter, and Hugh Catts. 2000. The association of reading disability, behavioral disorders, and language impairment among second-grade children. *Journal of Child Psychology and Psychiatry* 41:473–82.

Turner, Michael G., Alex R. Piquero, and Travis C. Pratt. 2005. The school context as a source of self-control. *Journal of Criminal Justice* 33:327–39.

Unnever, James D., Francis T. Cullen, and Travis C. Pratt. 2003. Parental involvement, ADHD, and delinquent involvement: Reassessing Gottfredson and Hirschi's general theory. *Justice Quarterly* 20:471–500.

Walsh, Anthony. 2002. *Biosocial Criminology: Introduction and Integration*. Cincinnati, OH: Anderson.

Warr-Leeper, Genese, Nancy A. Wright, and Alison Mack. 1994. Language disabilities of antisocial boys in residential treatment. *Behavioral Disorders* 19:159–69.

Wikström, Per-Olof H., and Kyle Treiber. 2007. The role of self-control in crime causation. Beyond Gottfredson and Hirschi's General Theory of Crime. *European Journal of Criminology* 4:237–64.

Willcutt, Erik G., Bruce F. Pennington, and John C. DeFries. 2000. Twin study of the etiology of comorbidity between reading disability and attention-deficit/ hyperactivity disorder. *American Journal of Medical Genetics* 96:293–301.

Wilson, James Q., and Richard J. Herrnstein. 1985. *Crime and Human Nature: The Definitive Study of the Causes of Crime*. New York: Simon & Schuster.

Wright, John Paul, and Kevin M. Beaver. 2005. Do parents matter in creating self-control in their children? A genetically informed test of Gottfredson and Hirschi's theory of low self-control. *Criminology* 43:1169–202.

Kevin M. Beaver earned his PhD from the University of Cincinnati in 2006 and was awarded the Graduate Research Fellowship from the National Institute of Justice. He is currently an assistant professor in the College of Criminology and Criminal Justice at Florida State University. His research examines the ways in which the environment intersects with biological and genetic factors to produce delinquent and criminal behaviors. Recent publications have appeared in *American Journal of Public Health*, *Behavioral and Brain Functions*, *Criminal Justice and Behavior*, *Criminology*, *Journal of Adolescent Research*, *Journal of Quantitative Criminology*, and *Social Biology*, among others. He is also co-editor (with Anthony Walsh) of *Biosocial Criminology: New Directions in Theory and Research* (Routledge, 2009).

Matt DeLisi (PhD, University of Colorado, 2000) is an associate professor in the Department of Sociology and coordinator of the Criminal Justice Studies Program at Iowa State University. His recent books include *Career Criminals in Society* (Sage, 2005), *Criminal Justice: Balancing Crime Control and Due Process*, 2nd edition (Kendall/Hunt, 2008); *Delinquency in Society*, 7th edition (with Robert Regoli and John Hewitt, McGraw-Hill, 2008); and *Violent Offenders: Theory, Research, Public Policy, and Practice* (with Pete Conis, Jones & Bartlett, 2008). Professor DeLisi has published nearly 85 scholarly works on career criminals, self-control theory, psychopathy, and behavioral and molecular genetics.

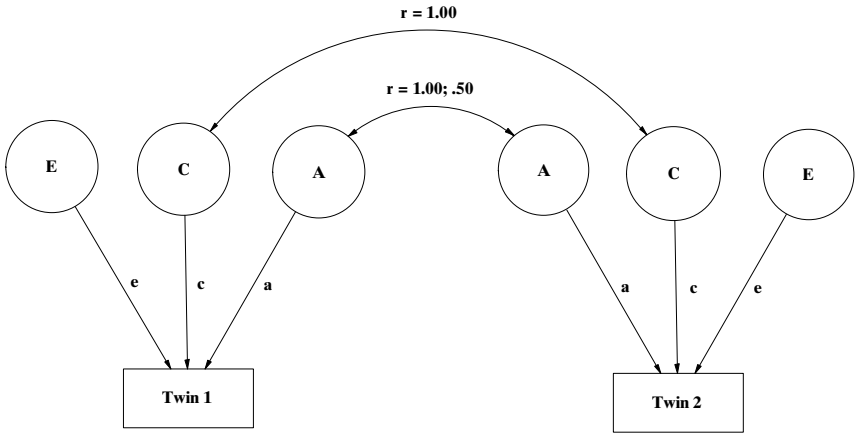
Michael G. Vaughn received his doctoral degree from Washington University in St. Louis and is currently an assistant professor in the School of Social Work and Departments of Public Policy and Epidemiology, Saint Louis University. His interdisciplinary research has appeared in such journals as *Addictive Behaviors*, *American Journal of Psychiatry*, *American Journal of Public Health*, *Behavioral and Brain Functions*, *Drug and Alcohol Dependence*, *Criminal Justice and Behavior*, *Behavioral Sciences & the Law*, *Youth Violence and Juvenile Justice*, *Journal of Emotional and Behavioral Disorders*, *Journal of Criminal Justice*, and *Social Work Research*. In

addition to several projects examining adolescent substance abuse, juvenile psychopathy, self-regulation, and violence, he is developing and testing a general biosocial theoretical model for research and intervention applications.

John Paul Wright received his PhD from the University of Cincinnati in 1996. He has published widely on the development of criminal behavior with an emphasis on genetic and biological factors associated with violent conduct. His work spans several disciplines, which include criminology, molecular and behavioral genetics, and evolutionary theory. He seeks to unite these disciplines under a broad biosocial criminology framework.

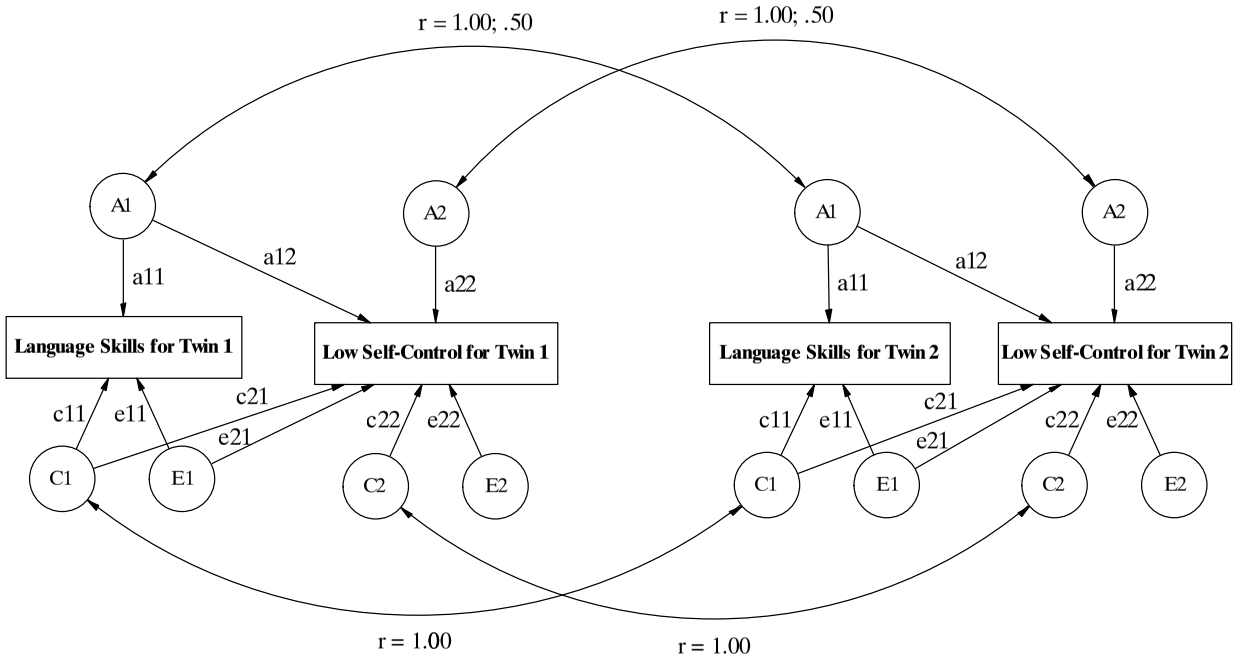
Brian B. Boutwell is a doctoral student in the College of Criminology and Criminal Justice at Florida State University. He received his B.S. in criminology and psychology and his M.S. in criminology from Florida State University. His research and teaching interests include life-course and biosocial criminology, including the gene-environment basis to antisocial behaviors. His most recent article appeared in *Criminal Behaviour and Mental Health*.

Appendix A. Basic Univariate Variance Components Models for the Language Skills Scale and for the Low Self-Control Scales



NOTES: r = 1.00 for MZ twins and r = .50 for DZ twins.
ABBREVIATIONS: A = genetic factors, C = shared environmental factors, and E = nonshared environmental factors.

Appendix B. Bivariate Cholesky Decomposition Model for Language Skills and Low Self-Control



NOTES: r = 1.00 for MZ twins and r = .50 for DZ twins.
ABBREVIATIONS: A = genetic factors, C = shared environmental factors, and E = nonshared environmental factors.