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SELF-CONTROL AS AN EXECUTIVE FUNCTION

Reformulating Gottfredson and Hirschi's Parental Socialization Thesis

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According to Gottfredson and Hirschi (1990), levels of self-control are determined by parental management techniques, not by biological and genetic influences. Recent behavioral genetic and neuroscientific research challenges this view and reveals that biogenic factors are largely responsible for the development of self-control. The current article builds off this body of literature and argues that Gottfredson and Hirschi's parental socialization thesis should be reformulated to recognize that self-control is just one part of a larger constellation of executive functions that are modulated by the prefrontal cortex of the brain. Using a sample of about 3,000 children, this reformulated thesis was tested by examining whether neuropsychological deficits are predictive of parental and teacher reports of the child's level of self-control. Results revealed that measures of neuropsychological deficits were associated with variability in childhood self-control. Theoretical implications of the findings are discussed.

Keywords: biology; brain; executive functions; genetics; low self-control; parents

The predominant view in criminology is that levels of self-control are determined by social influences, such as family factors, neighborhood conditions, and the school context (Burt, Simons, & Simons, 2006; Gottfredson & Hirschi, 1990; Hay, 2001; Pratt, Turner, & Piquero, 2004; Turner, Piquero, & Pratt, 2005). According to these perspectives, environmental forces are the active agents that shape self-control in children. Although empirical research has revealed some support in favor of these views (Cochran, Wood, Sellers, Wilkerson, & Chamlin, 1998; Gibbs, Giever, & Martin, 1998; Hay, 2001; Pratt et al., 2004; Turner et al., 2005), there is reason to believe that self-control is also guided by biogenic factors (Barkley, 1997a; Beaver & Wright, 2005; Cauffman, Steinberg, & Piquero, 2005; DeLisi, 2005; Unnever, Cullen, & Pratt, 2003; Walsh, 2002; Wright & Beaver, 2005).

A largely unexplored possibility, and one driven by an emerging line of neuroscientific literature, is that the capacity for self-control resides in specific regions of the brain (Barkley,

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1997a, 1997b; Goldberg, 2001; Ishikawa & Raine, 2003; Moffitt, 1990). Findings from brain-imaging studies have revealed that behavioral inhibition, self-regulation, and the control of emotions—all of which are very closely related to self-control—are housed in the prefrontal cortex of the brain (Damasio, 1994; Goldberg, 2001; Ishikawa & Raine, 2003; Raine, 2002). Neuropsychologists and brain science researchers refer to the coordinated actions of the prefrontal cortex as "executive functions" (Damasio, 1994; Goldberg, 2001). From this view, self-control is just one part of a larger constellation of executive functions that is localized in the frontal lobes of the brain (Barkley, 1997a; Damasio, 1994).

GOTTFREDSON AND HIRSCHI'S PARENTAL MANAGEMENT THESIS

Gottfredson and Hirschi's (1990) theory of self-control has made a major contribution toward understanding the causes of crime and criminality (Pratt & Cullen, 2000). Research has consistently revealed that low self-control is a robust predictor of a wide range of delinquent and maladaptive behaviors (Cochran et al., 1998; Evans, Cullen, Burton, Dunaway, & Benson, 1997; Grasmick, Tittle, Bursik, & Arneklev, 1993; Pratt & Cullen, 2000; Wood, Pfefferbaum, & Arneklev, 1993). With evidence supporting the main hypothesis of Gottredson and Hirschi's theory (Pratt & Cullen, 2000), researchers have begun to examine the factors that are related to the development of self-control. According to Gottfredson and Hirschi's theory, levels of self-control are determined by three intertwined parental management techniques. Specifically, parents must monitor their child, they must recognize their child's wayward behavior, and they must correct their child's transgressions. Parents who engage in these techniques will tend to raise children with high levels of self-control. Those parents who fail to employ these three childrearing strategies will have children with lower levels of self-control.

An emerging body of literature has found some support for the role that parents play in the creation of self-control in their children (Burt et al., 2006; Cochran et al., 1998; Feldman & Weinberger, 1994; Gibbs et al., 1998; Gibbs, Giever, & Higgins, 2003; Hay, 2001; Polakowski, 1994; Unnever et al., 2003). Two qualifications to this statement need to be pointed out. First, parenting measures leave a substantial amount of variance in self-control unexplained (Unnever et al., 2003). Second, Gottfredson and Hirschi (1990) have dismissed the possibility that self-control has a biological or genetic component (Wright & Beaver, 2005).

Recent research, however, has revealed that biogenic factors have an important effect on self-control—perhaps even more important than social factors (Barkley, 1997a, 1997b, 2000; Beaver & Wright, 2005; Wright & Beaver, 2005). Twin studies, which allow for the dual estimation of environmental and genetic effects, have found that problems with impulse control and self-regulation are largely the result of genetic influences (Price, Simonoff, Waldman, Asherson, & Plomin, 2001; Rietveld, Hudziak, Bartels, van Beijsterveldt, & Boomsma, 2003). Heritability estimates for attention deficit hyperactivity disorder (ADHD) and other closely related disorders often range between .60 and .90 (Barkley, 1997a, 1997b, 2000; Price et al., 2001; Rietveld et al., 2003). Neuropsychologists have pointed to similar conclusions and have shown that self-control and self-regulation are controlled by the prefrontal cortex of the brain (Aron, Robbins, & Poldrack, 2004; Convit et al., 1996; Spencer, Biederman, Wilens, & Faraone, 2002). To take these findings into consideration, the explanation of self-control set forth by Gottfredson and Hirschi needs to be revised with an explicit focus on how the biological processes of the brain affect the development of self-control (Cauffman et al., 2005; Wright & Beaver, 2005).

THE PREFRONTAL CORTEX

With the advancement of neuroimaging techniques, such as magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), and positron emission tomography (PET), neuroscientists have learned a great deal about the workings of the brain and how different parts of the brain are responsible for different tasks. One of the more significant discoveries—and one that has direct application to the formation of self-control—is the functions and operations of the prefrontal cortex (Convit et al., 1996; Goldberg, 2001; Miller & Cohen, 2001). Anatomically, the prefrontal cortex is located directly behind the forehead in front of the motor and premotor regions of the brain.

Distinctions are made among three different areas within the prefrontal cortex to specify the location, direction, and function of each region (Ishikawa & Raine, 2003; Raine, 1993). The dorsolateral prefrontal cortex (DLPFC) is found in the lateral part of the prefrontal cortex and is connected with the orbitofrontal cortex. The DLPFC is thought to be responsible for behavioral inhibition, for cognitive control, for information-processing skills, and for working memory (Ishikawa & Raine, 2003; MacDonald, Cohen, Stenger, & Carter, 2000). The orbitofrontal cortex is found directly above the eyes and is interconnected with the amygdala and several other areas of the brain. The orbitofrontal cortex is believed to modulate emotions, to help maintain goal-oriented behaviors, and to regulate complex decision-making processes (Bechara, Damasio, & Damasio, 2000; Ishikawa & Raine, 2003; Schoenbaum, Chiba, & Gallagher, 1998). Finally, the medial prefrontal cortex (MPFC) is located deep within the brain and is connected with the DLPFC, with the hypothalamus, and with the amygdala (Ishikawa & Raine, 2003). The MPFC allows for the completion of tasks that demand a significant amount of attention (Ishikawa & Raine, 2003; Simpson, Snyder, Gusnard, & Raichle, 2001).

OVERLAP BETWEEN EXECUTIVE FUNCTIONS AND SELF-CONTROL

Together, the coordinated activities of the dorsolateral, orbitofrontal, and medial cortices of the prefrontal cortex are referred to as "executive functions" (Goldberg, 2001). "Executive functions," according to Ishikawa and Raine (2003), "refer to a cluster of higher order cognitive processes involving initiation, planning, cognitive flexibility, abstraction, and decision making that together allow the execution of contextually appropriate behavior" (p. 281). Moffitt (1990) described the day-to-day operations of the frontal lobes in a similar manner when she stated,

> The normal functions of the frontal lobes of the brain include *sustaining attention and concentration*, abstract reasoning and concept formation, goal formulation, *anticipation and planning*, programming and initiation of purposive sequences of motor behavior, effective *self-monitoring of behavior* and self-awareness, and *inhibition of unsuccessful, inappropriate, or impulsive behaviors*, with adaptive shifting to alternative behaviors. These functions are commonly referred to as "executive functions," and they hold consequent implications for social judgment, *self-control*, responsiveness to punishment, and ethical behavior. (p. 115; emphasis added)

Compare Moffitt's definition of executive functions with Gottfredson and Hirschi's (1990) conceptualization of low self-control. According to Gottfredson and Hirschi, there are six different elements that constitute the latent trait of low self-control. Specifically, people with low self-control are impulsive and lack the ability to delay gratification, prefer simple tasks that do not require persistence, are risk seekers, are self-centered, prefer physical activities to mental ones, and have a bad temper (Arneklev, Grasmick, Tittle, & Bursik, 1993; Gottfredson & Hirschi, 1990; Grasmick et al., 1993). Both concepts—executive functions and self-control—call attention to the importance of regulating impulsive tendencies and the ability to control emotions and sustain attention. Both recognize the salience of mental capabilities and cognitive functioning to anticipate and forecast behavioral consequences. Both are concerned with the ability to modulate tempers and to inhibit inappropriate conduct. Most important, both recognize that problems with executive functions or problems with self-control may lead to aberrant, delinquent, and violent behaviors (Damasio, 1994; Goldberg, 2001; Gottfredson & Hirschi, 1990; Moffitt, 1990).

There is reason to believe that the distinction between self-control and executive functions may be because of artificial disciplinary boundaries. The discipline of criminology—which traditionally has been dominated by sociologists—has been openly hostile to biological and genetic explanations of criminal behavior (Walsh, 2002; Walsh & Ellis, 2004). Criminologists working from a psychological perspective, or from an interdisciplinary perspective, tend to recognize the potential importance of biosocial criminology. Even so, most of the dominant theories of crime and criminality, including Gottfredson and Hirschi's (1990) theory, downplay the effects of biological and genetic factors.

Gottfredson and Hirschi's (1990) theory of low self-control is no exception; they argue that the "magnitude of the 'genetic effect' [on the development of self-control] . . . is near zero" (p. 60). A very different understanding of problems with self-regulation, however, has been set forth in the hard sciences. According to diverse lines of research, ranging from biology, genetics, and neuroscience, problems with behavioral and emotional regulation, including the capacity to exercise self-control, are the result of a deficiency in executive functions—functions that reside in the brain and are under genetic influence.

A handful of researchers whose work cuts across different fields of inquiry has recognized the close correspondence between self-control and executive functions (Cauffman et al., 2005; Convit et al., 1996). In an exhaustive review of the literature examining the link between neuropsychological deficits and delinquent behavior, Moffitt (1990) frequently equated executive functions with self-control. She also made reference to the likelihood that self-control is one of myriad duties performed and carried out by the executive functions of the prefrontal cortex. In a similar vein, Barkley (1997a, 1997b, 2000), a leading ADHD expert, views ADHD as a disorder originating in the brain. Most recently, Cauffman and colleagues (2005) conducted a sophisticated analysis revealing that measures of brain functioning were predictive of levels of self-control. The findings from their study, along with those garnered by other researchers, seriously calls into question Gottfredson and Hirschi's (1990) claim that self-control is free from biological or genetic influences and points to the likelihood that self-control may be guided by the brain (Barkley, 1997a, 1997b, 2000; Beaver & Wright, 2005; Cauffman et al., 2005; Convit et al., 1996; Moffitt, 1990; Wright & Beaver, 2005).

VARIABILITY IN EXECUTIVE FUNCTIONS

If self-control is viewed as an executive function, then the important question that arises is: What factors account for variation in self-control? Neuroscience and brain science research indicates that self-regulation and levels of self-control are partially influenced by the functioning of the prefrontal cortex. Typically, the prefrontal cortex of the brain develops normally, and levels of self-control remain in the normal range of variation. However, sometimes something interferes with healthy brain development. When the prefrontal cortex is affected adversely, executive dysfunctions, including a reduction in self-control, may result.

At certain times during fetal development, it is roughly estimated that the brain is growing and forming at an astonishing rate of approximately 250,000 neurons per minute; it is largely complete by the early to mid-20s (Restak, 1986, 2001). Beginning in childhood and lasting through young adulthood, the brain continues to develop by adding new synapses and pruning unused ones (Restak, 2001; Thompson et al., 2001). Importantly, the prefrontal cortex is one of the last areas of the brain to develop (Thompson et al., 2001; Toga & Thompson, 2005). Anything that interferes with normal brain growth can cause abnormal functioning of the brain, especially in the prefrontal cortex. For example, neurotoxins and tetratoxins, such as lead, tobacco, alcohol, and other drugs, can cross the placenta and enter the developing fetus. These toxins act on the nervous system and can disrupt brain growth, they can cause a decrease in brain metabolic activity, and they can cause irreversible structural and functional damage to the prefrontal cortex—all of which can cause neuropsychological deficits and compromise the development of self-control (Bellinger, Leviton, Allred, & Rabinowitz, 1994; Chen, Maier, Parnell, & West, 2003; Karr-Morse & Wiley, 1997; Sadowski & Parish, 2005).

Not all deficits in executive functions are caused by environmentally introduced agents that disrupt brain growth (Restak, 2001). Brain growth and brain development also appear to be guided by genetic influences (Pfefferbaum, Sullivan, Swan, & Carmelli, 2000; Thompson et al., 2001; Toga & Thompson, 2005). Neuroimaging studies analyzing monozygotic (MZ) and dizygotic (DZ) twins have revealed almost identical cortical gray matter between twins of the same MZ dyad (Thompson et al., 2001). Indeed, Toga and Thompson (2005) reviewed a wealth of neuroscientific research examining the genetics of brain structure and concluded that "genetic influences on brain structure are pronounced in some frontal and temporal lobe regions, including the dorsolateral prefrontal cortex and temporal poles" (p. 9)—the same areas that are in charge of executive functions and the regulation of self-control (Barkley, 1997a, 1997b, 2000; Ishikawa & Raine, 2003; Goldberg, 2001; Moffitt, 1990).

THE CURRENT STUDY

Cauffman and colleagues (2005) have urged "proponents of Gottfredson and Hirschi's theory . . . to revisit the role of neurobiology in the determinants of self-control" (p. 159). We have followed their advice and have argued that variability in self-control is likely because of variation in the functioning of the prefrontal cortex of the brain. When the prefrontal cortex is operating properly, self-control should remain in the normal-to-high range; when there is an abnormality in the prefrontal cortex, levels of self-control should be relatively low. These hypotheses were tested by examining whether measures of neuropsychological deficits predicted levels of self-control in a sample of children. If the reformulated theory of self-control is correct, then there should be statistically significant relationships between the measures of neuropsychological deficits and self-control.

METHOD

PARTICIPANTS

Data for this study came from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-1999 (ECLS-K). The ECLS-K is the largest prospective and nationally representative sample of American children. The primary goal of the ECLS-K is to examine the effects that educational experiences have on the development of children. Toward this end, six waves of data have been collected thus far. The first wave of questionnaires was administered during the fall of 1998, when the children first entered kindergarten. Approximately 6 months later, in the spring of 1999, the second wave of data was collected. A third round of interviews was conducted on a small subsample of respondents in the fall of first grade. Three additional waves of data were collected in the fall of first grade, the spring of third grade, and, most recently, the spring of fifth grade. Detailed information was collected from parents and teachers to index the children's behaviors, their personalities, and their learning abilities. In addition, each child was subjected to a battery of tests that assessed cognitive capabilities and psychomotor abilities. Overall, 21,000 children participated in the first wave of data collection, with the vast majority of respondents being retained in subsequent waves.

The analysis herein was restricted to data collected during the fall and spring of kindergarten (Waves 1 and 2) and the spring of first grade (Wave 4) because the items tapping low self-control were redesigned for the later waves of data. For example, the teacher reports of self-control were dropped from the questionnaires and self-reported measures of self-control were introduced. However, research has shown that the most accurate and valid way of measuring self-regulation in childhood is by using both parental and teacher reports (Mitsis, McKay, Schulz, Newcorn, & Halperin, 2000). When only one reporting source is employed, the scale may be unreliable and inaccurate. Therefore, we chose to use data that included both parental and teacher assessments of self-control.

In addition, since only a relatively small number of children were re-interviewed at Wave 3, the third wave of data was excluded from the analysis. We followed the lead of past research analyzing the ECLS-K and focused on data collected in kindergarten and first grade (Beaver & Wright, 2005; Wright & Beaver, 2005).[1] Given that the sample size was extremely large, 15% of the entire sample was selected at random. With these criteria in place and after deleting cases that had missing data, a final analytic sample of nearly 3,000 children was obtained.[2]

MEASURES

Low Self-Control

The ECLS-K data contain an adapted version of Gresham and Elliott's (1990) widely used Social Skills Rating Scale (SSRS). The SSRS is a norm-referenced, standardized assessment battery that includes a number of subscales tapping self-control. Psychometric examinations of the SSRS have found it to be a valid and reliable way to measure self-control (Benes, 1995; Gresham, 2001). Consistent with prior research (Wright & Beaver, 2005), a composite Low Self-Control scale was developed by using parental and teacher responses extracted from the SSRS.[3] Teachers provided details about the child's externalizing problem behaviors, about his or her levels of self-control, attentiveness/persistence, and ability to form and sustain friendships. Parents responded to a series of questions asking about their child's levels of self-control, about their impulsivity, their attentiveness/persistence, and about their ability to form and sustain friendships. Responses to each of these items were then added together to form the Low Self-Control scale. Higher scores indicate lower levels of self-control. The identical questions were used to create the Wave 1 (alpha = .77), Wave 2 (alpha = .77), and Wave 4 (alpha = .78) Low Self-Control scales.

Neuropsychological Measures

Measures of neuropsychological deficits are frequently used to test for abnormalities in the frontal lobes and prefrontal cortex (Ishikawa & Raine, 2003). In the ECLS-K, neuropsychological functioning was evaluated at Wave 1 using the Early Screening Inventory–Revised (ESI-R; Meisels, Marsden, Wiske, & Henderson, 1997). The ESI-R is a standardized screening instrument used to evaluate a child's ability to perform developmentally appropriate tasks. Research examining the psychometric properties of the ESI-R has found it to be a reliable and valid assessment tool (Meisels et al., 1997; Meisels, Henderson, Liaw, Browning, & Have, 1993).

Two different scales from the ESI-R were used to index neuropsychological deficits: a Fine Motor Skills scale and a Gross Motor Skills scale (Rock, Pollack, & Hausken, 2002). For the Fine Motor Skills scale, children were asked to build a gate, draw a person, and copy five simple figures. Children could receive a score of 0, 1, or 2 for each task. Scores for the seven tasks were then added together to form the Fine Motor Skills scale. For the Gross Motor Skills scale, children were evaluated on their ability to balance, hop, skip, and walk backward. The scoring scheme was the same as the one used for the fine motor skills assessment: Children could receive between 0 to 2 points for each activity. The scores for these five items were then added together to form the Gross Motor Skills scale. Higher scores on both scales indicate better motor skills. Analysis of the ECLS-K data has confirmed that the tasks load on two separate factors (Rock et al., 2002).

Prior research has employed motor skills scales and visual-motor scales to index neuropsychological deficits and neurological damage (Karniski, Levine, Clarke, Palfrey, & Meltzer, 1982; Moffitt, Lynam, & Silva, 1994; Moffitt & Silva, 1988; Schonfeld, Shaffer, & Barmack, 1989; Shafer et al., 1986). Motor skills are able to tap frontal lobe dysfunction partly because, as Miller and Cohen (2001) noted, the prefrontal cortex

> has preferential connections with motor system structures that may be central to how the PFC [prefrontal cortex] exerts control over behavior. The DL [dorsolateral] area . . . is interconnected (a) with motor areas in the medial frontal lobe such as the supplementary motor area, the pre-supplementary motor area, and the rostral cingulated, (b) with the premotor cortex on the lateral frontal lobe, and (c) with cerebellum and superior colliculus. . . . Also important are the dense interconnections between the PFC and basal ganglia, a structure that is likely to be crucial for automating behavior. (p. 175)

In a similar vein, Damasio (1994) pointed out that the frontal lobes are highly involved in motor functioning. The evidence thus suggests that fine and gross motor skills scales tap deficits in the regions of the brain that are most likely to be responsible for self-control, self-regulation, and behavioral inhibition.

Socialization Measures

Gottfredson and Hirschi (1990) argue that parents are the main contributor to the development of self-control. To take this perspective into account, and following prior research analyzing the ECLS-K (Beaver & Wright, 2005; Wright & Beaver, 2005), we develop six different socialization measures.

Parental Involvement. A 9-item Parental Involvement Scale was developed to assess the amount of time that the parent and child spent playing together (Beaver & Wright, 2005; Wright & Beaver, 2005). At Wave 1, parents were asked to indicate how many times each week they read to their child, sang songs with their child, played games with their child, told stories to their child, helped their child with art activities, helped their child with chores, taught their child about nature, helped their child build things, and played sports with their child. The response set for these questions was 1 = *not at all*, 2 = *once or twice*, 3 = *3 to 6 times*, and 4 = *every day*. Scores for each item were summed together to form the Parental Involvement Scale (alpha = .75).

Parental Withdrawal. A Parental Withdrawal Scale was created to index whether the parent was detached from the child's life. At Wave 2, parents were asked nine different questions about their feelings toward being a parent. For example, they were asked whether they felt trapped as a parent, whether they often felt angry with their child, and whether being a parent was more work than pleasure. Higher scores on this scale reflect greater levels of parental withdrawal (alpha = .68).

Parental Affection. A 4-item Parental Affection Scale was developed from parental interviews conducted at Wave 2. Parents were asked whether they enjoyed spending warm, close time with their child, whether their child liked them, whether they always showed love for their child, and whether they expressed affection to their child. Responses to these items were added together, with higher scores indicating more parental affection (alpha = .60).

Family Rules. A Family Rules Scale was also available in the ECLS-K data. This scale was composed of 3 questions posed to the parent (at Wave 2) about family rules governing television viewing. Specifically, parents were asked whether there were family rules for which television programs their child could watch, for the number of hours their child could watch television, and for how early or how late the child could watch television. Each item was coded dichotomously (0 = *no*, 1 = *yes*). The items were then added together to form the Family Rules Scale (alpha = .58).

Physical Punishment. At Wave 2, parents were presented with a hypothetical scenario depicting their child hitting them. They were then given a list of potential retaliations and asked to indicate the most appropriate way to punish their child. Two different retaliations—hit the child back and spank the child—were identified as forms of physical punishment. Other responses included explaining to the child what he or she did wrong or giving a time out. The two physical punishments were assigned a score of 1, and all of the other responses were coded with a value of 0. The items were then added together to form the Physical Punishment Index, whereby higher scores indicate that the parent is more likely to use physical punishment when disciplining their child.

Neighborhood Disadvantage. Recent research has revealed that community characteristics may affect the development of self-control (Pratt et al., 2004). To take this finding into account, we employ a six-item measure of neighborhood disadvantage. At Wave 2, parents were asked how safe it was for their child to play outside, whether there was garbage and litter on the street, whether there were problems with drugs in their neighborhood, whether there were problems with burglaries or robberies in their neighborhood, whether there were problems with violent crime in their neighborhood, and whether there were vacant houses in their neighborhood. These six items were then added together, with higher scores indicating more signs of neighborhood disadvantage (alpha = .72).

Statistical controls. Gender (1 = *male*, 2 = *female*) and race (0 = *White*, 1 = *non-White*) were included as dichotomous variables to help control for the possibility that any significant findings were caused by a third confounding influence.

ANALYSIS

The analysis began by examining whether neuropsychological deficits were associated with kindergarten levels of low self-control. To test this possibility, we calculated ordinary least squares (OLS) regression equations for the full sample and separately for males and for females. In subsequent models, a measure of prior low self-control was introduced to help control for unmeasured influences that may affect the development of self-control. It is important to keep in mind, however, that in the models that incorporate a measure of prior low self-control, no longer are we predicting low self-control, but rather we are predicting change in self-control between the measurement waves. This procedure provides a very conservative estimate of the effects of the predictor variables. The same analytical plan was followed when the Wave 4 Low Self-Control scale (that was measured during the spring of first grade) was included as the dependent variable.[4]

RESULTS

Table 1 presents the results of the OLS models predicting kindergarten levels of self-control (measured at Wave 2). Model 1 shows that the two measures of neuropsychological deficits—fine motor skills and gross motor skills—exerted a significant negative effect on the Low Self-Control scale for the full sample of respondents. Specifically, respondents scoring high on the motor skills scales had higher levels of self-control. These significant findings were observed even when partitioning out the effects of six different parental and neighborhood scales. In Model 2, we examined whether the neuropsychological measures retained significance when controlling for prior levels of low self-control (measured at Wave 1). The results revealed that both fine motor skills and gross motor skills remained significant predictors of the Low Self-Control scale, but the effects were attenuated substantially.[5]

We next examined whether the neuropsychological measures were predictive of low self-control for males. As shown in Model 3, both of the motor skills measures were related to levels of self-control for male children. These findings were in the predicted direction, where higher motor skills corresponded to lower levels of self-control. In addition, four of the socialization variables were significant. However, in Model 4, when the measure of prior low self-control was introduced, the Gross Motor Skills scale dropped from statistical significance, but the Fine Motor Skills scale remained significant.

The last two models in Table 1—Models 5 and 6—present the results for the models calculated for the female sample. In Model 5, the two motor skills measures were significant predictors of low self-control for females. When the Wave 1 Low Self-Control scale was entered

TABLE 1: OLS Regression Models Predicting Levels of Low Self-Control in Kindergarten for the Full Sample, the Male Sample, and the Female Sample

	Full Sample		*Male Sample*		*Female Sample*	
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Neuropsychological measures						
Fine Motor Skills scale	–.17*	–.05*	–.19*	–.07*	–.16*	–.02
SE	.03	.02	.04	.03	.04	.03
Gross Motor Skills scale	–.11*	–.03*	–.11*	–.02	–.11*	–.04*
SE	.03	.02	.04	.03	.04	.03
Socialization variables						
Parental involvement	–.08*	.02	–.09*	.00	–.06*	.03
SE	.01	.01	.02	.02	.02	.01
Parental withdrawal	.21*	.08*	.24*	.09*	.17*	.07*
SE	.02	.01	.03	.02	.02	.02
Parental affection	–.07*	–.03*	–.05*	–.01	–.08*	–.05*
SE	.04	.03	.05	.04	.05	.04
Family rules	–.01	–.02	–.01	–.02	–.02	–.02
SE	.06	.05	.09	.07	.08	.06
Physical punishment	.06*	.05*	.05*	.05*	.07*	.05*
SE	.12	.09	.18	.14	.17	.13
Neighborhood disadvantage	.04*	.00	.03	–.01	.04	.01
SE	.04	.03	.06	.04	.05	.04
Control variables						
Gender	.19*	.04*				
SE	.10	.08				
Race	.08*	.03	.03	.01	.13*	.04*
SE	.11	.08	.16	.13	.15	.11
Prior self-control		.70*		.69*		.70*
SE		.01		.02		.02
R^2	.20	.58	.17	.56	.14	.56

Note. OLS = ordinary least squares. Standardized regression coefficients presented in first row, with standard errors (*SE*) in second row for each measure or variable.
$*p < .05$.

as a predictor variable (in Model 6), the Fine Motor Skills scale dissipated from statistical significance, whereas the Gross Motor Skills scale maintained a significant association.

The findings thus far reveal that the neuropsychological measures have a relatively consistent effect on the Low Self-Control scale for the full sample, for males, and for females. However, when the dependent variable was residualized by controlling for prior levels of self-control, the effects of the motor skills scales were reduced—sometimes to statistical insignificance. To test the ability of the neuropsychological measures to predict levels of self-control later in childhood, we next examined whether the motor skills measures were related to the Low Self-Control scale that was measured in the spring of first grade (Wave 4).

Model 1 of Table 2 shows that both the Fine Motor Skills scale and the Gross Motor Skills scale were significant predictors of first-grade levels of self-control. In addition, four of the socialization measures are also related to the Low Self-Control scale. In Model 2, when the Wave 2 Low Self-Control scale was introduced into the equation, the two motor skill scales and two of the parenting variables remained significant.

The results of the multivariate equations for the male sample are presented in Models 3 and 4. In both models, the two motor skills scales are significantly related to levels of low

TABLE 2: OLS Regression Models Predicting Levels of Low Self-Control in First Grade for the Full Sample, the Male Sample, and the Female Sample

	Full Sample		*Male Sample*		*Female Sample*	
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Neuropsychological measures						
Fine Motor Skills scale	–.16*	–.06*	–.17*	–.05*	–.17*	–.07*
SE	.03	.03	.04	.04	.04	.04
Gross Motor Skills scale	–.13*	–.07*	–.13*	–.06*	–.13*	–.08*
SE	.03	.03	.04	.04	.04	.04
Socialization variables						
Parental involvement	–.08*	–.03*	–.08*	–.04	–.07*	–.03
SE	.01	.01	.02	.02	.02	.02
Parental withdrawal	.16*	.06*	.19*	.08*	.14*	.04
SE	.02	.02	.03	.02	.03	.03
Parental affection	–.05*	–.00	–.03	.00	–.07*	–.01
SE	.04	.04	.06	.05	.06	.05
Family rules	–.03	–.02	–.04	–.04	–.02	–.01
SE	.07	.06	.10	.09	.09	.08
Physical punishment	.06*	.03	.06*	.03	.08*	.03
SE	.14	.12	.19	.17	.19	.17
Neighborhood disadvantage	.03	.01	.05	.05	.01	.03
SE	.04	.04	.07	.06	.06	.05
Control variables						
Gender	.20*	.10*				
SE	.11	.10				
Race	.08*	.04	.06*	.03	.12*	.06*
SE	.12	.11	.17	.16	.17	.15
Prior self-control		.54*		.54*		.55*
SE		.02		.03		.03
R^2	.19	.42	.14	.38	.13	.39

Note. OLS = ordinary least squares. Standardized regression coefficients presented in first row, with standard errors (*SE*) in second row for each measure or variable.
$^*p < .05$.

self-control. In Model 4, however, parental withdrawal is the only significant socialization variable. Similar results are garnered in Models 5 and 6 when the female sample is analyzed: The neuropsychological measures are significant in both models, but none of the socialization variables are significant in Model 6.

CONCLUSION

When Gottfredson and Hirschi (1990) set forth their general theory of crime, they argued that self-control, in combination with criminal opportunity, was the main cause of crime. In addition, they also presented a theory on the factors that are related to the development of self-control. In this part of their theory, they borrowed heavily from Patterson's (1982) coercive family processes model and maintained that self-control was the result of parental socialization techniques. However, Gottfredson and Hirschi were very vague in specifying where self-control is stored once it is fully developed. The present research built on and extended Gottfredson and Hirschi's work and provided evidence that self-control should be viewed as an executive function that is housed in the prefrontal cortex of the brain.

We tested this newly formulated thesis about the origins of self-control using the largest nationally representative sample of children. Analysis of the ECLS-K data revealed that deficits to neuropsychological functioning are related to levels of self-control in kindergarten and first-grade students. These results held for both genders, even after partitioning out the effects of parental and neighborhood influences and even after controlling for prior levels of low self-control. In addition, the effects that six different socialization measures had on self-control were assessed. The results revealed that most of the parenting measures had relatively small and inconsistent effects on self-control. Overall, the neuropsychological measures were among the most consistent predictors of childhood levels of self-control.

With these findings in mind, it is important to point out the main limitations of the research. First, the ECLS-K data only contain information about relatively young children. Therefore, we were unable to determine whether neuropsychological deficits were related to levels of self-control in adolescents and young adults. It is important to note that a link between aberrant conduct and neuropsychological damage has been observed in samples of adolescents and adults (Damasio, 1994; Ishikawa & Raine, 2003; Moffitt, 1990; Raine et al., 2005). Our research adds to this growing line of literature and shows that neuropsychological deficits are predictive of self-control very early in life.

Second, only two neuropsychological tests—for fine motor skills and gross motor skills—were available in the ECLS-K. A more complete test of our reformulated theory would include a broader range of tests that tap into the functioning of specific areas of the prefrontal cortex. Ideally, neuroimaging procedures would be used to examine whether activity in certain regions of the brain covary with levels of self-control. There is reason to believe, however, that the neuropsychological measures used in the analysis may have actually underestimated the effect that brain dysfunction had on the development of self-control. Without being able to measure precisely where the neuropsychological deficits were occurring, the motor skills scales may have been detecting dysfunctions in parts of the brain that were not related to self-control and self-regulation. If so, the coefficients for the neuropsychological measures would have underestimated the true effect that deficits to the prefrontal cortex have on the development of self-control. Future research needs to examine whether other neuropsychological measures are related to levels of self-control.

Finally, because of data limitations, the interrelationships among neuropsychological deficits, low self-control, and criminal behaviors could not be examined (Cauffman et al., 2005). Extant research has linked brain activity and brain structure to pathological lying, psychopathy, and murder (Blair, Mitchell, & Blair, 2005; Gatzke-Kopp, Raine, Buchsbaum, & LaCasse, 2001; Raine et al., 2003; Yang et al., 2005a, 2005b). It would be interesting to examine whether self-control has a causal effect on delinquent and criminal behaviors once neuropsychological deficits are taken into account. Recent work by Cauffman and colleagues (2005) provides initial evidence revealing that both self-control and neuropsychological deficits are important in the etiology of delinquency, but more research needs to be conducted in this area.

IMPLICATIONS FOR CRIMINOLOGY

If self-control is an executive function housed in the prefrontal cortex of the brain, what does this mean for criminology? Although not exhaustive, there are at least four different ways that a neuroscience explanation of self-control can be integrated into the criminological literature. First, a long line of research has revealed a connection between poverty or low socioeconomic status (SES) and criminal involvement. Children and adolescents growing up in poor, urban communities, for example, are at great risk for becoming delinquent

(Anderson, 1999; W. J. Wilson, 1987). Although different theories have been advanced to account for this SES-crime relationship, the common theme cutting across most of these perspectives is that community structural characteristics and the transmission of criminal subcultures are responsible for socializing children and adolescents to become criminal (Anderson, 1999; J. Q. Wilson & Herrnstein, 1985).

Although useful, these theories in general fail to recognize that growing up in poverty or in a disadvantaged environment has a negative effect on healthy human development (Brooks-Gunn, Duncan, Klebanov, & Sealand, 1993; Morenoff, 2003; Strathearn, Gray, O'Callaghan, & Wood, 2001). Low birth weight, reduced IQ, and other problems in infancy and childhood have been found to be related to low SES. Even biochemical differences have been observed between children of low SES and children of high SES. For example, research has revealed that children living in poverty have increased levels of the stress hormone cortisol (Lupien, King, Meaney, & McEwen, 2001). Most important to the current article, however, poverty can also affect the developing brain. In a recent study, Noble, Norman, and Farah (2005) administered tests that tapped prefrontal and executive system functioning in a sample of children. Their analyses revealed that children from low-SES families scored two thirds of a standard deviation below children from middle-SES families. The effects of living in poverty, therefore, might not only have distal effects (e.g., subculture values) but also salient proximal effects that disrupt normal fetal and childhood development.

Second, the age-crime curve is one of the most consistent yet least understood findings within criminology (Farrington, 1986). However, there is some evidence to suggest that the development of the brain parallels closely the ebb and flow of criminal involvement during the life course (Benson, 2002; Ishikawa & Raine, 2003). For example, although the limbic system is completely formed by adolescence, the prefrontal cortex—an area of the brain that can modulate the emotions generated in the limbic system—is not finished developing until the mid-20s. Adolescents thus have the biological machinery to generate emotions, but they lack the mental hardware to control these emotions adequately. Thus, it should not be too much of a surprise that, as the prefrontal cortex begins to take its final shape, delinquent involvement drops sharply. Benson (2002) also recognized the close connection between brain development and delinquency when arguing that

> the teenage brain has a lot to do with teenage delinquency. When it comes to managing their behaviors, teenagers lack more than just experience and education; they also lack some of the mental equipment necessary to make sound judgments and to act responsibly. At the outset of the teenage years, our emotional inner life takes on a vividness that we have never experienced before and that our brain is not yet fully ready to handle. From a developmental perspective, the misperceptions, bad decisions, and emotional overreactions of teenagers are to a certain degree biologically programmed. Conformity is simply more difficult for teenagers than adults. (p. 70)

Third, a large body of criminological research has shown that behaviors and personalities are relatively stable during long periods of time (Gottfredson & Hirschi, 1990; Loeber, 1982; Olweus, 1979). A number of perspectives have been advanced to explain stability in behavior, and even though they all emphasize slightly different processes, none of them identify adolescent and adult brain development as potential reasons (Gottfredson & Hirschi, 1990; Moffitt, 1993; Raine et al., 2005; Sampson & Laub, 1993). There is some evidence to suggest, however, that the brain may be partially responsible for behavioral stability (Tancredi, 2005). According to Ishikawa and Raine (2003), "Under circumstances where the individual is repetitively engaging in antisocial behavior with little consequence, the postadolescent decrease in gray matter and increase in white matter may actually facilitate the persistence of antisocial behavior into adulthood by strengthening the neural connections subserving such behavior" (p. 294). In short, brain structure and brain activity may actually change to support the maintenance of antisocial behaviors and the stability of some criminal traits.

Fourth, some opponents of biogenic explanations of crime and criminality may be quick to point out that if self-control is housed in the brain, then it would be impossible—or nearly impossible—to rehabilitate offenders. Yet research evaluating the efficacy of different types of depression treatment has shown otherwise (Brody et al., 2001; Martin, Martin, Rai, Richardson, & Royall, 2001; Thase, 2001). Brody and his colleagues (2001), for example, examined pre- and posttreatment brain activity in patients with major depressive disorder. Before treatment, many depressed subjects had higher normalized metabolism in the prefrontal cortex than did control subjects. After receiving interpersonal therapy, however, the activity of the prefrontal cortex was significantly reduced. Similar results were garnered by Martin et al. (2001) when they found that brain blood flow in depressed patients tended to normalize once they received interpersonal therapy. In both studies, changes in brain activity levels corresponded to a reduction in depressive symptoms.

The results from these studies suggest that certain types of rehabilitative programs—especially those that target cognitive functioning—may help to reduce antisocial behaviors and tendencies. Perhaps part of the reason that cognitive behavioral therapies are among the most effective programs at reducing recidivism is because they may alter brain activity (Tancredi, 2005; Thase, 2001). Future research needs to use advanced neuroimaging techniques to explore this possibility.

With the recent mapping of the human genome and with complex imaging machines that are able to capture even the most subtle brain abnormalities, there can be little doubt that a more detailed understanding of how the brain impacts behavior will be realized. There is now a wealth of empirical evidence linking deficits of the brain to various emotional problems, to behavioral disorders, and to certain personality traits (Blair et al., 2005; Damasio, 1994; Ishikawa & Raine, 2003; Moffitt, 1990; Raine, 1993, 2002; Raine et al., 2005). One of the keys for advancing the state of our discipline is for criminologists to accept findings from neuroscience and from brain science research and integrate them into existing theories of crime causation (Walsh, 2002). Such an interdisciplinary approach is likely to provide a much richer explanation of criminal behavior (Ellis, 2005; Walsh, 2002).

NOTES

1. According to Gottfredson and Hirschi (1990), self-control emerges in childhood and remains relatively stable throughout the remainder of life. If Gottfredson and Hirschi are correct, then studies seeking to uncover the origins of self-control need to focus on early childhood. Therefore, using data from kindergarten and first grade would provide the most appropriate way of detecting the antecedent causes of self-control.

2. We chose $N = 3{,}000$ respondents for three main reasons. First, many large, nationally representative samples contain between 1,000 and 5,000 participants. A sample size of 3,000 permitted us to calculate models separately for males and for females without losing statistical power. Second, if we had employed the entire sample, the sample size would have been driving many of the significant findings that we detected. Third, the pattern of results were the same when using sample sizes of $n = 1{,}000$, $n = 1{,}500$, $n = 2{,}000$, and $n = 2{,}500$. In some cases, the coefficients were not significant when using smaller sample sizes but were significant in our models using $N = 3{,}000$. We note any divergences in significant findings that were observed among the different sample sizes.

3. Because of a contractual agreement between the ECLS-K and the developers of the Social Skills Rating Scale (SSRS), only the subscales were available in the publicly available data set; responses to each of the items making up the subscales were not disclosed. Thus, the items that make up the Low Self-Control subscales in our analyses are really created from subscales and within each of those subscales are a number of questions. For example, one of the parental response items deals

with the child's impulsiveness. This is actually a scale composed of a number of items. Essentially, then, the Low Self-Control scales are created by adding together eight different subscales. Although we were unable to examine the psychometric properties of these scales with the ECLS-K data, the ECLS-K team has confirmed that the SSRS subscales are valid and reliable.

4. We explored the possibility that the neuropsychological measures would interact with the socialization variables to predict levels of low self-control. The analyses did not reveal any significant interactions beyond those that would occur by chance alone. Similarly, we also examined whether the parenting measures had a significant effect on the two motor skills measures. Again, the neuropsychological measures and the socialization measures were not related.

5. We realize that the standardized coefficients (i.e., betas) for the motor skills measures are relatively small but still significant. As a result, we also calculated these same models for sample sizes that were smaller than $N = 3{,}000$ to see whether the effects would remain significant. Across all of the models, betas equal to .04 or less dropped from statistical significance when analyzing a sample size of $N = 1{,}000$. In some instances, the betas that were equal to .05 also failed to reach statistical significance. However, across all of the models, the general pattern of findings remained the same.

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