

PSYCHOLOGICAL, NEUROPSYCHOLOGICAL AND PHYSIOLOGICAL CORRELATES OF SERIOUS ANTISOCIAL BEHAVIOR IN ADOLESCENCE: THE ROLE OF SELF-CONTROL

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Gottfredson and Hirschi claim that self-control is the only enduring personal characteristic implicated in criminal activity. Other scholars, such as Moffitt and Rowe, claim that although self-control is important, so are neuropsychological and physiological factors. This study attempts to adjudicate between these two positions by examining the ways in which neuropsychological factors, especially those relevant to executive function, biological factors, especially those relevant to autonomic reactivity, and self-control interrelate to distinguish between offenders and nonoffenders. Data were obtained from adolescents attending public high schools in northern California and adolescents incarcerated in the California Youth Authority. Serious juvenile offenders evince lower resting heart rate, show poorer performance on

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tasks that activate cognitive functions mediated by the prefrontal cortex, especially those measuring spatial working memory, and score lower on measures of self-control. Regression analyses indicated that although variations in self-control distinguish between the two groups, so too do neuropsychological and biological factors, a result that both supports and refutes Gottfredson and Hirschi's contention. In contrast, variation in minor delinquency among high school students is unrelated to frontal lobe functioning and heart rate, but related to variations in self-control.

Criminologists have long been skeptical about the role that individual characteristics, particularly psychological and biological factors, play in the genesis of criminal activity. For example, Durkheim (1982:106) distinguished among social, biological and psychological factors and between crime and criminality: "from the fact that crime is a phenomenon of normal sociology, it does not follow that the criminal is an individual normally constituted from the biological and psychological points of view." Sutherland and Cressey (1974:170) similarly argued:

no consistent, statistically significant differences between personality traits of delinquents and personality traits of nondelinquents have been found. The explanation of criminal behavior, apparently, must be found in social interaction, in which both the behavior of a person and the overt or prospective behavior of other persons play their parts.

No less a view is popular among criminologists today, as two different surveys of criminologists indicate very little support for the relevance of psychological and biological factors as influences on criminal behavior (Walsh and Ellis, 1999).

Debates regarding the importance (or lack thereof) of psychological and biological factors have not been settled, however. Over the past dozen years, two criminological perspectives have dominated the theoretical and empirical landscape of criminology, but both make vastly different predictions about the role of psychology and biology in criminal activity. These are Gottfredson and Hirschi's general theory of crime and Moffitt's theory of life-course persistent and adolescence-limited offenders. The purpose of this paper is to examine how constructs drawn from each of these two perspectives distinguish between offender groups.¹

1. In this vein, we use the two perspectives as exemplars, Gottfredson and Hirschi of the importance of self-control and neglect of other personality, psychological, and biological factors above and beyond self-control, and Moffitt of the importance of personality, neuropsychological, and biological factors in addition to self-control. Although the paper is not meant as a formal test of these two theories against one

GOTTFREDSON AND HIRSCHI'S
GENERAL THEORY OF CRIME

At its core, the general theory of crime uses two key variables to explain criminal activity: low self-control and opportunity. For Gottfredson and Hirschi, low self-control is defined as the "tendency to pursue short-term, immediate pleasure" to the neglect of long-term consequences (p. 93). Persons with low self-control lack diligence, tenacity and persistence; find it difficult to delay gratification; have little tolerance for frustration and little ability to resolve problems through verbal rather than physical means; "need not possess or value cognitive or academic skills" or "manual skills that require training or apprenticeship" (p. 89); tend to be adventuresome, active and physical; lack interest in and preparation for long-term pursuits; and tend to be self-centered and either indifferent or insensitive to the suffering and needs of others (Gottfredson and Hirschi, 1990; Grasmick, Tittle, Bursik and Arneklev, 1993; Longshore, Turner and Stein, 1996; Nagin and Paternoster, 1993; Piquero and Tibbetts, 1996; Piquero and Rosay, 1998; Wiebe, 2003).² For Gottfredson and Hirschi (1990), self-control is, "for all intents and purposes, *the* individual-level cause of crime" (emphasis in original, p. 232), and is believed to relate to criminal and analogous acts throughout the life-course (Hirschi and Gottfredson, 1995). The notion that the difference between offenders and nonoffenders lies in their awareness of the concern for the long-term costs of their acts, or self-control, has been supported in extant research (see reviews in Pratt and Cullen, 2000), although self-control is not always the strongest or only-significant predictor of criminal activity (Pratt and Cullen, 2000).

Most relevant to present purposes, these scholars stand at the ready to discount any supposed biological and psychological (personality)

another, especially since we do not have measures of all key constructs found in Moffitt's theory, it is meant to distinguish perspectives that advance one view over the other generally, and more specifically to examine whether neuropsychological and biological correlates continue to predict crime after controlling for self-control.

2. According to Gottfredson and Hirschi, self-control is established early in childhood as a result of parental socialization efforts. Effective socialization (and the resultant self-control it engenders among children) arises from parents who monitor their child's behavior, recognize deviant behavior when it occurs, and punish such behavior. This social control/self-control process is believed to be dynamic during the first eight to ten years of a child's life, when by that time self-control becomes relatively stable, although it may change in absolute value (Turner and Piquero, 2002). Since this part of Gottfredson and Hirschi's theory is not central to this paper, we refer readers to their discussion of the topic (1990:ch.5) and relevant research (Feldman and Weinberger, 1994; Gibbs, Giever and Martin, 1998; Hay, 2001; Pratt, Turner and Piquero, 2004; Unnever, Cullen and Pratt, 2003).

influences on criminal behavior above and beyond self-control. With regard to biology, Gottfredson and Hirschi are clear in denying that biology exerts any direct effect on criminal behavior. In fact, their interpretation of the biological evidence could not be more clear:

Correlations between biology and crime... if statistically significant would be substantively trivial (p. 60).

[There is] strong evidence that the inheritance of criminality is minimal [and any] 'genetic effect' is near zero (p. 60).³

With regard to psychology, whom Gottfredson and Hirschi (1990:64) refer to as "biology's nearest neighbor in the study of crime," they outright reject any such effect on criminal activity (other than self-control) (p. 65, fn1) claiming that the search for personality characteristics has produced nothing "contrary to the use of low self-control as the primary individual characteristic causing criminal behavior" (p. 111). Juxtaposing a critique on sociological criminology, they then draw the sword up against psychological criminology and take the position that many personality traits have been shown to characterize criminals more than noncriminals (for example, Wilson and Herrnstein, 1985: ch.7). Gottfredson and Hirschi claim that both sociological and psychological criminology are wrong:

The level of self-control, it is believed, distinguishes offenders from nonoffenders, and the degree of its presence or absence can be established before (and after) criminal acts have been

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3. It is with regard to this point that there lies some discrepancy in the general theory. On one hand, biological (and psychological) factors independent of self-control are seen as irrelevant, having neither direct nor indirect (for example, operating through self-control) effects on criminal activity. Unlike other theories that have directly incorporated individual differences, Gottfredson and Hirschi fail to develop further the interplay between individual differences (that is, psychological or biological) and self-control (Unnever et al., 2003). On the other hand, Gottfredson and Hirschi do appear to leave the door cracked open, asserting that "the evidence suggests that the connection between these traits [low intelligence, high activity level, physical strength, and adventuresomeness] and commission of criminal acts ranges from weak to moderate... What we do suggest is that individual differences may have an impact on the prospects for effective socialization (or adequate control). Effective socialization is, however, always possible whatever the configuration of individual traits" (p. 96). As neither of their two most current efforts (Hirschi and Gottfredson, 2000, 2001) discuss these relationships further, we interpret their theory as suggesting that biology and personality may have a very small (if any) effect on self-control (with the lion's share resorting to parenting efforts) and absolutely no effect on criminal or analogous activity once self-control is taken into account. On this latter point, Gottfredson and Hirschi (1990:96) could not be clearer: "obviously, we do not suggest that people are born criminals, inherit a gene for criminality, or anything of that sort. In fact, we explicitly deny such notions." We return to this point throughout the manuscript.

committed. This enduring tendency is well within the meaning of "personality trait" and is thus contrary to the sociological view. Contrary to the psychological view, *the evidence for personality differences between offenders and nonoffenders beyond self-control is, at best, unimpressive* (p. 109, emphasis added).⁴

Their critique against psychological and personality correlates continues: "the search for personality correlates of crime other than self-control is unlikely to bear fruit" (p. 232). Additionally,

people who develop strong self-control are unlikely to commit criminal acts throughout their lives, regardless of their other personality characteristics. In this sense, *self-control is the only enduring personal characteristic predictive of criminal (and related) behavior* (p. 111, emphasis added).

This discussion leads to the following hypothesis: once self-control is taken into consideration (after the age at which any parental socialization (direct social control) effort has concluded), there should be no independent effect of any other psychological or biological characteristic on criminal activity.⁵

Other criminologists have not held as strong a stance against the importance of psychologically and/or biologically based individual-level influences on criminal behavior. In fact, some criminological theories implicitly allow for biological and psychological factors to matter.

4. Thus, while self-control can be considered a personality trait, Gottfredson and Hirschi consider it to be the *only* personality trait that matters (that is, distinguishes offenders from nonoffenders).

5. Hirschi and Gottfredson (1995:140) have spoken on this issue:

Although we argue that self-control is a general cause of crime, we do not argue that it is the sole cause of crime. Indeed, our analysis of delinquent and criminal acts argues that 'lack of restraint' is only one of several conditions necessary, and collectively sufficient for such acts to occur. These other conditions are usually considered 'opportunity' factors.... On the other hand, self-control accounts for a good portion of the major, agreed-upon determinants of delinquency. As we have tried to show, self-control accounts for family factors... school-behavioral factors... peer factors... failure of efforts to treat delinquents or to deter them by the threat of punishment... and the apparent success of involvement in conventional institutions and relationships. Together, the concepts of opportunity and self-control provide a system for organizing the determinants of delinquency, and for approaching many of the traditional problems of the field.

It remains unclear whether self-control can account for any presumed biological and psychological correlates of crime. Still, as they discount these sets of causal influences on criminal activity (Gottfredson and Hirschi, 1990:60-65), we must believe that they would claim supremacy for self-control over any other correlates.

including social learning (Akers, 1985) and general strain theories (Agnew, Brezina, Wright and Cullen, 2002), and certain criminological theories are explicitly psychologically or biologically informed (Walsh, 2000), including those of Fishbein (1990), Raine (1993) and Farrington (1995), Moffitt's (1993) developmental taxonomy in particular is one such theory and has received a sustained amount of research attention among criminologists. We use her theory as an exemplar of the biological/neuropsychological perspective in criminology.

MOFFITT'S DEVELOPMENTAL TAXONOMY

Moffitt's taxonomy proposes two types of offenders, each of whom evinces a unique set of factors related to criminal and antisocial activity as well as a different patterning of criminal and antisocial activity over the life-course. (A third group, abstainers, is a small, select group of individuals who refrain from antisocial activity altogether.) Moffitt's taxonomy has received a sustained amount of research attention (see review in Moffitt, 2003) and has produced results that are both consistent (Bartusch, Lynam, Moffitt and Silva, 1997; Moffitt, Lynam and Silva, 1994, 1996; Tibbetts and Piquero, 1999) and inconsistent (Nagin, Farrington and Moffitt, 1995) with the theory. Still, the main hypothesis that offenders—especially serious offenders—suffer from neuropsychological and/or biological deficits has yet to be refuted (Moffitt et al., 1994, 1996; Piquero, 2001).

One group of offenders in Moffitt's theory, adolescence-limited offenders, constrain their offending activity to the adolescent time period. According to Moffitt, adolescence-limited delinquency is the result of developmental immaturity and peer influence. Developmental immaturity leads to youngsters' experience of dysphoria during the relatively roleless years between their biological maturation and their access to mature privileges and responsibilities, while the salience of the peer group influences similarly situated adolescents, who "grow-up" together biologically and socially, to look to each other for support. During adolescence, involvement in delinquency surfaces as a way to demonstrate autonomy from parents and teachers, win affiliation with peers and hasten social maturation. Because adolescence-limited delinquency is both normative and typically social in nature, this sort of offending is usually group-oriented and relatively minor. And because their pre-delinquent development is normal, most adolescence-limited delinquents are able to desist from crime when they age into satisfying adult roles, returning gradually to a more conventional lifestyle. For a select few adolescence-limited delinquents, their desistance from delinquent activity may be delayed because of experiences that can compromise the ability to make a successful transition to adulthood.

In contrast to adolescence-limited offenders, life-course-persistent offenders begin their antisocial activity early in the life-course, offend more while active, commit a variety of crimes, including violent crimes, and are unlikely to desist from criminal activity in adulthood. Importantly, according to Moffitt the risk for life-course-persistent offending emerges from inherited or acquired neuropsychological liabilities, initially manifested as subtle cognitive deficits, difficult temperament, or hyperactivity. The environment in which the child is reared is also an important contributory factor, as inadequate parenting, disrupted family bonds, poverty and other adversities tend to compromise effective parenting and in many cases exacerbate the effects of the child's liabilities. The environmental risk domain expands beyond the family as the child ages, to include poor relations with peers and teachers. Over the first two decades of development, transactions between individual and environment gradually construct a disordered personality characterized by physical aggression and antisocial behavior that persist well into mid-life. It has been shown that, among this small select group of offenders, cognitive factors produce patterns of deviant and criminal activity in a direct fashion (Moffitt, 1990), independent of other individual-level factors such as self-control (see Caspi et al., 1994; Moffitt et al., 1994).

Thus, contrary to Gottfredson and Hirschi, Moffitt, and numerous other writers (Farrington, Raine, Rowe, Walsh) claim that although self-control is an important individual-level characteristic which should be incorporated into models of criminal activity, it is not the only crime-generating factor (especially among serious offenders). More specifically, biological and psychological/personality factors should also be directly and independently related to offending, above and beyond the impact of poor self-control.

BIOLOGICAL AND PSYCHOLOGICAL CORRELATES OF OFFENDING

Recent advances in the study of the biological bases of behavior in fact suggest that antisocial behavior and the individual-level characteristics associated with it may have at least some biological underpinnings (Raine, Brennan, Farrington and Mednick, 1997). For example, anatomical, chemical and neurological abnormalities are more prevalent among chronic criminal offenders and those exhibiting recurrent antisocial behavior than among the general population (Brennan et al., 1997; Giancola and Zeichner, 1994; Gorenstein, 1982; Raine, Venables and Williams, 1990, 1996). These "abnormalities" or "deficits" may be caused by damage to a specific brain region (through injury) or due to a variety of other behavioral or environmental factors (for example, poor nutrition, exposure to violence, substance abuse). In addition, these deficits may also

become accentuated as a result of the neurobiological and endocrinological changes of adolescence. Previous research has shown that adolescence is a time of marked cellular differentiation in brain regions that subserve various aspects of self-control, and that this differentiation plays a role in emotional regulation (Kolb, 1998; 1999; Steinberg et al., in press). Given that changes in these brain regions occur during the adolescent years and that these brain regions may affect self-control, it is important to examine more closely the inter-relationships among biological and psychological factors and self-control as correlates of antisocial behavior during this period.

Among the most consistently observed biological correlates of conduct problems and criminal behavior are various indices of neurological functioning. Deficits in the prefrontal lobes, the area of the brain located in front of the cortex (the gray matter that subserves higher cognitive functioning), have been related to violence and behavioral problems (Elliott, 1992; Moffitt and Henry, 1989). For example, deficits in the medial and lateral areas of the prefrontal lobe are frequently observed among subjects with disruptive behavior disorders, such as conduct disorder and attention deficit/hyperactivity disorder (ADHD) (Anderson, Bechara, Damasio, Tranel and Damasio, 1999; Barratt, Stanford, Kent and Felthous, 1997; Henry and Moffitt, 1997; Kempton et al., 1999; Pennington and Bennetto, 1993; Raine, 1997b). In view of the fact that the frontal lobe is the primary modulator of executive functioning, including planning, impulse control, affect regulation and attention (Elliott, 1992; Golden, Jackson and Peterson-Rohne, 1996; Jones, 1992) and in light of the evidence linking problems in these domains with antisocial behavior, it is not surprising that poor performance on cognitive tasks involving the frontal lobe is also associated with externalizing problems. As a result, researchers have focused on one particular cognitive domain, executive function.

In general, executive functions comprise those abilities implicated in goal-oriented processes such as initiating and maintaining efficient strategies (Lezak, 1983) and programming and planning motor behavioral skills. They also include learning and applying contingency rules, abstract reasoning, problem solving, sustained attention and concentration. According to Séguin and his colleagues (1999), executive functions: (1) require little effort and active "on-line" monitoring resources in contrast with automatic processing; are activated (2) particularly to process novel information or (3) when high demands for cognitive resources are solicited; and (4) operate in a limited-capacity system. Measures of executive functioning are typically derived from tests that assess programming and planning of goal-oriented motor behavior skills, modulation of behavior in light of expected future consequences, anticipation of events in regulating behavior, learning contingency rules

and using feedback cues, inhibition of response set and flexibility (vs. perseveration), abstract reasoning, problem solving, sustained attention and concentration. Executive functions are largely but not exclusively associated with the frontal lobes (Pennington and Ozonoff, 1996).

Deficiencies in executive functioning frequently have been found to distinguish between juvenile offenders and nonoffenders, and especially aggressive and nonaggressive children (Séguin, Pihl, Harden, Tremblay and Boulerice, 1995; Yeudall, Fromm-Auch and Davies, 1982), and the relationship between aspects of working memory and physical aggression has been found to exist regardless of attention deficit hyperactivity disorder and IQ (Séguin, Boulerice, Harden, Tremblay and Pihl, 1999). In fact, several specific deficits in cognitive and emotional functioning have been found among children and adolescents with conduct disorder, including deficits in concentration and attention, impulsivity, response perseveration, poor intellectual flexibility and difficulty with sequential behavior; response inhibition; establishing or changing a mental set; and creating, planning, organizing and executing goal-directed behavior (Giancola, Mezzich and Tarter, 1998; Golden, Jackson, Peterson-Rohne and Gontkovsky, 1996; Oosterlaan, Logan and Sergeant, 1998; Oosterlaan and Sergeant, 1998; Raine, 1997b; Stanford, Greve and Gerstle, 1997)."

A different set of biological factors associated with antisocial behavior includes indices of autonomic reactivity. The autonomic nervous system, which includes the sympathetic and parasympathetic branches of the nervous system, controls automatic functions and responses that do not require conscious attention. The parasympathetic branch controls the normal functioning of organs (for example, breathing, digestion, heart muscle contractions), while the sympathetic branch controls reflex responses to environmental stimuli (for example, elevations in heartbeat and perspiration in response to stressors, restriction of blood vessels in response to cold). Individual differences in autonomic reactivity have been

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6. Some research suggests that the association between executive functioning deficits and conduct disorder may be due to the high rate of comorbidity of CD and ADHD. ADHD has been linked repeatedly to numerous problems with executive functioning, including attention modulation, set shifting, spatial working memory, planning, anticipation of consequences, response inhibition, performance monitoring, and maintenance of appropriate response output for significant periods of time (Aronowitz et al., 1994; Clark, Prior and Kinsella, 2000; Grodzinsky and Barkley, 1999; Grodzinsky and Diamond, 1992; Kempton et al., 1999; McBurnett et al., 1993; Oosterlaan et al., 1998; Oosterlaan and Sergeant, 1998; Pennington and Ozonoff, 1996), and sometimes linked to problems with spatial recognition and visuospatial processing (Kempton et al., 1999; Pennington and Ozonoff, 1996). Some, but not all, studies that exclude conduct disordered individuals with ADHD fail to find executive functioning deficits among CD subjects (Clark et al., 2000; McBurnett et al., 1993; Pennington and Ozonoff, 1996).

associated with a variety of problems, including internalizing and externalizing psychopathology (Kagan, 1994; Raine, Venables and Mednick, 1997), psychological and physical symptomatology (Boyce et al., 1995; Gannon, Banks, Shelton and Luchetta, 1989), and risk-taking behavior (Liang et al., 1995). Most important, conduct disorder among children and adolescents and antisocial behavior among adults both have been associated with low autonomic reactivity.

Specifically, a low resting heart rate, reduced skin conductance and higher levels of slow-wave EEG theta activity are more commonly observed among adult criminals than noncriminals (Raine et al., 1990) and, among children as young as 3, low heart rate has been associated with aggression (Raine et al., 1997). In fact, one of the most replicable findings in the literature is that antisocial and violent youth tend to have low resting heart rates (Raine, 1993). A study by Boyce et al. (2001) suggests as well that autonomic reactivity discriminates significantly and strongly among children with internalizing behavior problems, children with externalizing behavior problems, and children with neither. Internalizers show high reactivity relative to children without symptoms, principally in the parasympathetic branch, while externalizers show low reactivity, in both the sympathetic and parasympathetic branches. Interestingly, physiological arousal is regulated by the frontal lobe (Hellige, 1993), deficits in which, as we noted earlier, have been implicated in the development of conduct problems and in the psychological correlates of antisocial behavior.

Taken together, then, there is both direct and indirect evidence that problematic frontal lobe functioning is linked to disruptive behavior disorders in childhood and delinquent and criminal behavior in adolescence and adulthood. Low autonomic reactivity, poor performance on tests of executive function, impulsive aggression and antisocial behavioral tendencies may, to some extent, be related consequences of common underlying neurological deficits. Although the weight of the evidence implicating frontal lobe deficiencies in antisocial behavior derives from studies of adults, there is growing evidence that similar links exist at younger ages.

CURRENT FOCUS

Gottfredson and Hirschi claim that a single factor, low self-control, when coupled with opportunity for antisocial activity, underlies antisocial behavior over the life-course. For these scholars, "the difference between offenders and nonoffenders is in their awareness of and concern for the long-term costs of crime.... They are, or tend to be, children of the moment. They have what we call low self-control" (Hirschi and Gottfredson, 2001:90). According to these theorists, low self-control is

presumed to be the main underlying personal characteristic of all criminal and analogous acts:

self-control theory takes the social and economic conditions of offenders as a reflection of their tendency to offend, not as a cause of their offending.... This concept, in our view, accounts for the important facts about crime. In our view, it also questions the meaning of the facts claimed by competing theories (Hirschi and Gottfredson, 2001:81–82).

Thus, we interpret Gottfredson and Hirschi to mean that no independent effect for biological/psychological variables should remain, once levels of self-control (thought to be the result of parenting practices) are taken into account. This is a straightforward mediational question, as self-control should eliminate (or render close to insignificance) any biological/psychological correlate of crime.

On the other hand, theorists like Rowe (2002) and Moffitt (1993) claim that by emphasizing this one characteristic to the neglect of other biological and/or psychological/personality factors, Gottfredson and Hirschi risk oversimplifying the heterogeneity of personality dispositions underlying criminal behavior. Thus, we interpret these scholars as suggesting that biological-psychological variables can independently add to the prediction of offending above and beyond measures of self-control.

METHODS

Data for this study were obtained from adolescents attending public high schools in northern California and adolescents incarcerated in the California Youth Authority (CYA). The high school sample ($N = 78$) ranges in age from 14 to 19 years ($M = 15.9$, $SD = 1.4$) and is fairly evenly split between males and females (45 percent males, 55 percent females). In addition, the sample was ethnically diverse: African American (22 percent), Asian (4 percent), Hispanic (35 percent), white (29 percent), and other (10 percent). Approximately 55 percent come from homes where their parents had not attended school beyond the twelfth grade.

The CYA primarily houses youths who have committed serious, typically violent, offenses or are repeat offenders, and thus provides an ideal sample within which to explore the biological and psychological correlates of serious antisocial behavior. The juvenile offender sample ($N = 105$) also ranges between 14 and 19 years of age ($M = 16.4$, $SD = 1.2$) and displays similar ethnic and socioeconomic diversity as the high school students. The juveniles (49 percent male, 51 percent female) were sentenced for a range of committing offenses: 63 percent for violent crimes against persons (such as murder, rape, robbery, assault), 30 percent for property crimes (such as burglary, auto theft, receiving stolen property), 2

percent for drug related crimes, and 5 percent for other crimes (such as violation of probation, evading an officer). The average length of incarceration at the CYA was 14 months ($SD = 10.2$), with a minimum of 1 month and a maximum of 36 months. As shown in previous research, the juveniles who participated in this study are representative of the general CYA population (Cauffman, Feldman, Waterman and Steiner, 1998; Steiner, Garcia and Matthews, 1997).

Comparisons of these two samples allow for an exploration of the relation between frontal lobe functioning, heart rate, self-control and offending because individuals incarcerated in the CYA represent serious juvenile offenders, whereas high school students are unlikely to have a serious offense history. While it is likely that the high school sample includes individuals who have engaged in minor forms of delinquency, it is unlikely that these individuals have engaged in the serious violent and property offenses that reflect the committed offenses of those in the CYA sample; moreover, the high rate of dropping out and truancy among serious adolescent offenders even makes it more unlikely that a large number of these youth would be found in a sample of adolescents who are still enrolled in school.⁷ As such, a binary variable reflecting whether or not a given respondent is in the CYA should be a reasonable proxy for serious offending.

PROCEDURE

This study was approved by both the CYA and the Institutional Review Board at Stanford University. To recruit high school students, fliers describing the study were posted throughout the school with a phone number for youths to respond to. Teachers also allowed our research team to come into classrooms and briefly describe the study to students. Youths who were interested in participating were required to obtain written consent from their parents. Teachers agreed to give students extra credit for returning signed consent forms, regardless of whether the signature indicated parental permission or denial of parental permission for participation in the study. In addition to written parental consent,

7. We recognize that the distinction between the CYA sample and the high school sample may not perfectly reflect the offending-nonoffending distinction we are attributing to it. Nonetheless, the severity of the offenses necessary to warrant admission to the CYA clearly designate the CYA sample as unquestionably seriously delinquent, whereas studies of high school samples indicate that incidences of serious delinquent involvement are limited to a very small percentage of high school students. As such, we would argue that a comparison of juveniles in the CYA and those in high school provides a reasonable basis for an initial test of the relation between frontal lobe functioning, heart rate, self-control and offending.

informed consent was obtained from all eligible students, who were informed about the purpose of the study. Participants were informed that their participation was voluntary and that they could withdraw from the study at any time without penalty. Each participating high school student was paid \$10 for taking part in the study.

After receiving approval from the CYA, the investigators approached juveniles within the institution and invited their participation in the study. Members of the research team described the nature of the study in group presentations to the juveniles' units and invited interested youths to participate. Since more youths volunteered to participate than could be accommodated by the study, we randomly selected youths from the pool of potential participants. Once selected, juveniles were provided oral and written explanations of the study, their confidentiality was ensured and their informed consent was obtained. Prospective participants were told that the information provided would not be shared with the staff at the CYA. In addition, participants were told that their participation in the study would not affect their treatment at the CYA or their evaluation for parole. Subjects were assured that their participation was voluntary and that they could withdraw at any time without penalty. Due to CYA regulations, which prohibit offenders from receiving money while in the institution, juvenile offenders were offered a snack in appreciation for their participation.

Self-report questionnaires and the CANTAB, a computerized neuropsychological assessment tool, were administered in individual sessions at both the high school and the CYA in a private room, with only the administrator and the subject present. This is an important feature of our study because although this tool has been used previously in studies of adults, and to a lesser extent children and adolescents, to the best of our knowledge this is the first study to use the CANTAB in the assessment of serious juvenile offenders, a group long hypothesized to have impaired neuropsychological functioning. During the administration of the measures, the participant was instructed to obtain clarification from the research assistant regarding any items of which he or she was unsure. In some cases, the research assistant read the questionnaire to the participant, who privately recorded his or her answers. Following the completion of the measures, participants were escorted back to their appropriate class or program.

MEASURES

Demographic variables. Participants were asked to report their age, sex (1=Male, 2=Female), ethnicity (0=Nonwhite, 1=White), and parent's level of education. Parents' educational status was used as a proxy for

socioeconomic status, as research has indicated that parental education may be the most stable component of an adolescent's family's social class (Steinberg, Mounts, Lamborn and Dornbusch, 1991).

Intelligence. Intelligence was assessed in order to examine the comparability of the offender and nonoffender groups before testing hypotheses concerning group differences in neuropsychological functioning. The Kaufman Brief Intelligence Test (K-BIT) was used to assess IQ. This measure comprises two subtests to assess vocabulary and skill with analogies (Kaufman and Kaufman, 1990). The vocabulary subtest includes forty-five items in which subjects are asked to name pictured objects, and thirty-seven items requiring subjects to complete partial words in response to written clues. The second K-BIT subtest consists of forty-five multiple-choice matrix analogies. Standardized scores on the vocabulary and matrices subtests can be combined to yield a total IQ composite ($M = 100$, $SD = 15$). The K-BIT has been found to have an internal consistency of .92 as well as test-retest reliability greater than .90. The IQ composite has been found to be correlated with the WISC-R and the WAIS-R. In addition, the IQ composite has been found to be a reliable measure of intelligence among incarcerated youth (Prewett, 1992).

Heart rate. Resting heart rate (tonic heart rate) was recorded using an oscillometric measurement method via a wrist pressure cuff that was manufactured to meet specifications set by the Association for the Advancement of Medical Instruments. As demonstrated in previous research, pressure cuffs are a reliable way to assess heart rate (Raine, 1997a). Per the manufacturer's instructions, it was recommended that at least two readings be taken to reduce measurement error. While we experienced very few errors (< 5 percent), we devised a standardized protocol so that all interviewers performed the assessment in the same fashion. In order to maximize measurement accuracy (pulse within 5 percent of reading), heart rate was assessed four times throughout the interview. At no time during the interview was the subject stressed or put through physical exertion. All subjects were sitting and no questions were asked or answered during the assessment. The first two heart rate assessments were taken 10 minutes apart at the beginning of the interview to ensure that the initial reading was reliable. If the two initial readings were vastly discrepant, another reading was taken 20 minutes later and the outlier reading was discarded. The remaining two assessments were done at the halfway and end point of the interview. These time points were chosen based on the natural transition and break points in the interview process so that the participant would not be focused on an alternate task. To provide the most accurate assessment, the heart rate reported is the average beats/minute of these four assessments. The reliability of these four heart rate assessments was high ($\alpha = .90$) as were

the inter-correlations between each of the heart rate assessments ($r = .68$ to $.81$; $p < .01$).

Neuropsychological functioning. Four tasks representing functions mediated by the prefrontal cortex were administered, using the Cambridge Neuropsychological Test Automated Batteries (CANTAB) (Elliott et al., 1996; Luciana and Nelson, 1998). The CANTAB is a computerized battery of neuropsychological tests that have been found to be highly sensitive to a variety of psychiatric and neurological disorders (Elliott et al., 1996). Although performance on the CANTAB is, not surprisingly, correlated with performance on standard IQ tests, the use of the CANTAB in research aimed at understanding the neuropsychological underpinnings of behavior offers several advantages over conventional intelligence testing. Most important, the individual CANTAB subtasks have been studied extensively to identify and confirm their neural correlates (Joyce and Robbins, 1991; Owen, Downes, Sahakian, Polkey and Robbins, 1990; Owen, Evans and Petrides, 1996; Owen, Morris, Sahakian, Polkey and Robbins, 1996; Owen, Roberts, Polkey, Sahakian and Robbins, 1991; Owen, Sahakian, Semple, Polkey and Robbins, 1995). Accordingly, the CANTAB provides much more specific information about an individual's pattern of cognitive functioning than is obtained through a standardized intelligence test. In addition, as all of the subtasks require nonverbal responses, performance is not confounded with subjects' verbal skills. The CANTAB has been standardized on a large group of normal adolescent and adult subjects (Robbins et al., 1994) and a group of normal children between 4 and 12 years of age (Luciana and Nelson, 1998).⁸

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8. Our conclusion that the intellectual differences between offenders and nonoffenders are not simply due to gross differences in intelligence is supported by post-hoc analyses we conducted that compared the CANTAB performance of the offenders in our study to that of two other samples of adolescent nonoffenders. The first comparison group was composed of healthy adolescents ($N=16$) studied by Luciana, Sullivan and Nelson (2001), in their investigation of neuropsychological functioning among individuals with and without Phenylketonuria (PKU). The adolescents in the study were white teenagers who were approximately the same age as the participants in the present study, but who were from more advantaged socioeconomic backgrounds. The average IQ of this group was not reported, but given their social background, it is likely that the group's average IQ well exceeded that of the present sample ($M=87.97$). Although the high school students in our sample (who, like the offenders, were of below-average intelligence) did not differ from the Luciana, Sullivan and Nelson adolescents on any of the four CANTAB tests, the sample of offenders scored significantly lower than the Luciana sample specifically on the test of spatial working memory. The second comparison group was composed of about forty British 12- to 15-year-olds (N s varied slightly from test to test), whose data were provided to us by the developers of the CANTAB. Demographic information on these individuals was not available, but information on the distribution of IQ scores in these groups indicated that the individuals were

All tasks were administered through the use of a touch-screen computer (Fray, Robbins and Sahakian, 1996). For each task, we computed an index of performance identical to that used by Luciana, Sullivan and Nelson in their previous study of adolescents. The following description of the four tasks is taken from Bosquet, Nelson, Essex and Quas (2002).

Spatial span. This task is based on the Corsi block task (Milner, 1971). It measures memory for a figural sequence and is believed to activate the right ventrolateral prefrontal cortex (Robbins et al., 1994). The subject watches ten white boxes on the screen. At the start of the first trial, two boxes change color, one at a time. The subject is then asked to reproduce the sequence. One more box is added to the sequence at each trial level. The spatial memory span score is the maximum sequence length the subject was able to reproduce with higher scores indicating better performance.

Spatial working memory. This self-ordered searching task measures working memory for spatial stimuli. It requires the subject to use mnemonic information to work toward a goal. It is believed to activate the dorsal and ventral prefrontal cortex and the ascending catecholamine systems (Owen, Doyon, Petrides and Evans, 1996; Owen, Evans and Petrides, 1996). The subject is asked to search through a spatial array of colored boxes for "tokens" to fill an empty column at the right of the screen. Within each trial, the subject is told not to return to any box in which s/he has already found a token. The number of boxes in the array is increased from two to three to four to six. As shown in Table 1, a "strategy score," reflecting the subject's overall performance, is computed, with

clearly of above-average intelligence, with one third of the group having an IQ of 110 or higher. Despite their substantially lower IQ, however, the high school students in the present sample did not differ from the British group on any test other than spatial span, where they *outperformed* the British youngsters. Yet, the offenders in the present investigation scored lower than the younger British group specifically on the test of spatial working memory. The poor performance of the juvenile offenders in the present study relative to adolescents from the Luciana, Sullivan and Nelson and CANTAB norming samples on the spatial working memory task in particular parallels results from our comparison of offenders and nonoffenders. As an additional check to ensure that the spatial working memory deficit of the offenders was not simply a reflection of their lower intelligence, the comparison of the CANTAB performance of the offenders and adolescents in the CANTAB norming sample was repeated, with the comparison restricted to the small number of individuals ($N=15$) in the norming sample with an IQ of less than 100, the norming sample's lowest IQ group. As was the case in the full comparison, the juvenile offenders in the present study performed significantly worse on the test of spatial working memory than did the lower-IQ British 12- to 15-year-olds. The high school students in the present study did not differ in spatial working memory from lower-IQ British adolescents.

lower scores indicating better performance. For purposes of multivariate analyses in this paper, we reverse coded SWM so that higher values indicate better performance so that they would be similar to the other CANTAB variables.

Tower of London. This task measures spatial planning and behavioral inhibition. It is believed to activate the parietal lobe bilaterally and the left dorsolateral prefrontal cortex and left caudate nucleus in the dorsal striatum (Baker et al., 1996; Morris, Ahmed, Syed and Toone, 1993; Owen, Doyon, et al., 1996). Two sets of three colored balls are presented in three hanging pockets. The subject moves the balls in one of the arrangements, according to specified rules, to match the other arrangement. Each problem can be solved in a certain number of minimum moves (two, three, four or five moves). The subject's score on this task is the total number of problems perfectly completed in the minimum number of moves. Higher scores indicate better performance.

Intradimensional/Extradimensional Set-Shifting. This task measures discrimination and reversal learning under conditions that require the subject to shift attention to changing patterns of visual stimuli. It is presumed to activate the dorsolateral prefrontal cortex and orbitofrontal cortex (Dias, Robbins and Roberts, 1996). Briefly, this task progresses along a series of nine stages of increasing difficulty. The first two stages involve simple discrimination and reversal learning. The next three stages involve extending the discrimination and reversal learning to instances where a distractor stimulus is present. The sixth stage demands an attentional shift. Termed the intradimensional (ID) shiftstage, novel or never-seen exemplars of each of the two prior dimensions are introduced, and the subject is required to generalize the rule from previous learning in order to achieve correct responses. Subsequently, another "extradimensional" attentional shift is required. Novel exemplars of each stimulus dimension are presented, and the subject must shift response set from the previously relevant dimension to the previously irrelevant dimension. Of interest in the present analysis is the highest (that is, most difficult) stage reached by the adolescent. Higher scores indicate better performance.

Self-Control. It is frequently the case that scholars from different disciplines concern themselves with similar constructs that have different labels. Developmental psychologists, for example, have also been interested in "self-control" during adolescence but the construct typically has been labeled "emotion regulation" or "response inhibition" (Steinberg et al., in press) or as "psychosocial maturity" (Caffman and Steinberg, 2000; Steinberg and Caffman, 1996). Indeed, the construct of self-control as operationalized by Gottfredson and Hirschi bears striking resemblance to the operationalization of psychosocial maturity recently advanced by

two of the present study's authors as a major contributor to antisocial activity in adolescence. In several studies, for example, it has been shown that adolescents who score lower on measures of psychosocial maturity are relatively more likely to evince antisocial tendencies (Cauuffman and Steinberg, 2000) and to commit more serious delinquency (Cauuffman, 2002). Two components of these authors' model of psychosocial maturity are especially relevant to the present discussion, because they map so closely onto elements of "self-control" described by Gottfredson and Hirschi: "temperance," which concerns the capacity for the regulation of emotional and behavioral impulses, and "perspective," which concerns the capacity to orient to the future, rather than immediate, consequences of one's actions and to consider the viewpoint of other individuals.

Accordingly, participants completed several measures of psychosocial maturity that correspond to aspects of Gottfredson and Hirschi's definition of self-control: these questions form four separate constructs: future orientation, impulse control, consideration of others, and suppression of aggression.⁹ High scores on each of these reflect higher self-control. Future orientation, an index of the extent to which one thinks about and considers the future consequences of one's actions, was assessed via the Consideration of Future Consequences scale (Strathman, Gleicher, Boninger and Edwards, 1994; 12 items, $\alpha=.68$, sample item= "I often do things that don't pay off right away but will help in the long run"). The CFC is highly correlated with other measures of future orientation, such as the Stanford Time Perspective Inventory (Zimbardo, 1990). Because the CFC scale was originally designed for use with college students, we simplified the wording of the items so that participants ranging in age from early adolescence to young adulthood could complete the scale. Three other aspects of self-control were assessed using subscales from the restraint scale of the Weinberger Adjustment Inventory (WAI; Weinberger and Schwartz, 1990). The WAI restraint scale has been found to display convergent, discriminant, and predictive validity among both delinquent and nondelinquent adolescents (Feldman and Weinberger, 1994). These subscales measure impulse control, the extent to which an

9. We recognize that Hirschi and Gottfredson (1993) prefer behavioral measures of self-control, but such measures were not available. On this point, several researchers have provided useful commentary. Pratt and Cullen's (2000) meta-analysis showed that research using attitudinal and behavioral measures of self-control have obtained similar results. Tittle, Ward and Grasmick (2003) recently undertook an in-depth comparison of cognitive and behavioral indicators of self-control to predict eight measures of crime/deviance and found that both types of self-control measures produced supportive evidence for the theory, and that the behavioral measures produced no better prediction than did the cognitive measures. We return to this point later.

adolescent moderates his or her impulses before acting (eight items, $\alpha=.80$, sample item [reverse scored]= "I do things without giving them enough thought"); consideration of others, the extent to which the adolescent thinks about the feelings of others before acting (seven items, $\alpha=.72$, sample item= "Before I do something, I think about how it will affect the people around me"); and suppression of aggression, the extent to which the adolescent restrains aggressive impulses (seven items, $\alpha=.87$, sample item [reverse scored] = "I lose my temper and 'let people have it' when I'm angry"). In view of the high correlation between scores on the measure of suppression of aggression and the measure of impulse control ($r=.60$), we combined these scales into a measure of temperance (see Cauffman and Steinberg, 2000) by averaging the two scores. One of the advantages of this multifaceted measurement of self-control is that it permits us to ask whether certain aspects of self-control (for example, suppression of aggression) are more predictive of antisocial behavior than others (for example, future orientation).

Antisocial behavior. To examine predictors of less serious antisocial behavior within the nonoffender sample, a fourteen-item ($\alpha=.93$) self-report measure of antisocial behavior was included in the instrument battery. This measure assesses the frequency of such behaviors as carrying a weapon, theft, drug and alcohol use, school misconduct and so forth (Gold, 1970). Youths were asked how often they engaged in deviant behavior in the past year and responses ranged from never, to once or twice, to several times, to often. Although self-reports of deviant behavior are subject to both under- and over-reporting, most researchers agree that these provide a closer approximation of youngsters' true involvement in deviant activity than do "official" reports (for example, police records), and the practice of using self-report data in the study of adolescent deviance is widely established.

Means and standard deviations of all variables used in the analyses are presented in Table 1, separately for the offender and nonoffender samples.

PLAN OF ANALYSIS

Our analyses proceeded in several steps. First, we tested for any differences between the offender and nonoffender groups on the demographic measures and IQ scales, in order to determine which, if any, of these potentially confounding variables needed to be controlled in subsequent analyses. Second, using either ANCOVA (in the case of heart rate) or MANCOVA (in the case of the neuropsychological and self-control variables), we examined differences between offenders and nonoffenders on the four neuropsychological variables, considered as a

group; heart rate; and the three self-control variables, considered as a group, all after controlling for any significant demographic or intellectual differences between the groups. Third, in order to look for patterns of mediated effects, we conducted a series of logistic regressions to determine whether the significance of particular predictors of group membership was attenuated when other predictors were introduced into the equation, which would suggest that the effects of the former predictors are mediated by the latter. Specifically, we tested Gottfredson and Hirschi's prediction

Table 1. Descriptive Statistics for Study Variables

<i>Variable</i>	<i>N</i>	<i>Mean</i>	<i>s.d.</i>	<i>Range</i>
IQ Vocabulary				
CYA	105	82.50	15.09	40-124
High School	75	91.60	19.31	40-132
IQ Matrices				
CYA	104	89.25	15.23	50-112
High School	75	95.33	16.32	54-124
Heart Rate				
CYA	105	67.85	9.78	43-95
High School	78	71.71	9.91	53-111
Spatial Working Memory ^a				
CYA	105	36.20	3.69	23-46
High School	78	34.56	4.61	19-44
Tower of London ^b				
CYA	105	8.51	1.57	5-12
High School	78	8.46	1.85	5-12
ID/ED ^b				
CYA	105	8.10	1.41	3-9
High School	74	8.07	1.91	0-9
Spatial Span ^b				
CYA	105	6.34	1.42	3-9
High School	78	7.01	1.54	3-9
Future Orientation				
CYA	105	3.14	.58	1-4
High School	77	3.30	.52	2-5
Suppression of Aggression				
CYA	104	3.16	1.0	1-5
High School	78	3.78	.84	1-5
Impulse Control				
CYA	104	3.07	.85	1-5
High School	78	3.56	.84	2-5
Consideration of Others				
CYA	104	3.26	.78	2-5
High School	78	3.54	.66	2-5
Antisocial Behavior				
CYA	105	2.54	.64	1-4
High School	78	1.41	.36	1-4

^aNote: Higher scores reflect poorer performance.

^bNote: Lower scores reflect poorer performance.

that self-control would mediate any and all neuropsychological and biological effects vis-à-vis Moffitt's prediction that such variables would, in addition to self-control, still matter in predicting offender status.¹⁰ Finally, we repeated the analyses described above using our antisocial behavior scale among high school students, rather than group membership (CYA versus high school), as the criterion variable. Here we hypothesized that the measures of heart rate and neuropsychological functioning would not predict scores on the deviance scale, but that the self-control would.

RESULTS

COMPARISON: DEMOGRAPHIC VARIABLES AND IQ

The two offender groups differed with respect to age and parental education (the juvenile offenders are slightly older and from less educated households) but not with respect to ethnicity or gender. Although the groups differ with respect to verbal and performance IQ (see Table 1), these differences disappear once group differences in age and parental education are controlled. As a consequence, comparisons between offenders and nonoffenders on the measures of heart rate, neuropsychological functioning and self-control were conducted controlling for age and parental education, but not for ethnicity, gender or IQ.¹¹

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10. Again, we remind readers that we are not adjudicating between the Gottfredson and Hirschi and Moffitt perspectives *per se*. Instead, we use these two theories as exemplars making different predictions regarding self-control, biological, and neuropsychological factors. Additionally, since we do not have all of the necessary measures to assess Moffitt's theory, we do not propose our effort as a test of it. That said, neuropsychological status is a key component of her theory that is believed to distinguish across offender types (Moffitt et al., 1994).
 11. Our decision to conduct comparisons between the offender and nonoffender groups without controlling for IQ is based not only on the comparability of the two groups with respect to the verbal and performance IQ tests, but on concerns about the potential impact of this procedure on our interpretation of the neuropsychological findings. In this sample, and in others, scores on the CANTAB are modestly, albeit significantly, correlated with IQ. This is not surprising, since many of the skills that are employed when taking the CANTAB (for example, memory) are also used when taking an IQ test, and because recent research has indicated that measures of IQ, working memory (on which the CANTAB draws heavily), and brain volume share common genetic variance (Posthuma et al., 2002). As a consequence, controlling for IQ in analyses involving the CANTAB will likely attenuate any observed relation between performance on specific CANTAB tests and other variables of interest (for example, offending). This potential attenuation is problematic, because using a very general measure of cognitive performance, like IQ, as a covariate may obscure patterns of findings involving some CANTAB tests but not others.

COMPARISON: NEUROPSYCHOLOGICAL FUNCTIONING,
HEART RATE AND SELF-CONTROL

A multivariate analysis of covariance (MANCOVA) was conducted to examine differences between the offender and nonoffender groups on the four measures of neuropsychological functioning (spatial working memory, spatial span, Tower of London and ID/ED shift). As noted above, because the groups differed with respect to age and parental education, it was necessary to control for these variables in these analyses. The groups do differ with respect to scores on the measures of neuropsychological functioning (Multivariate $F(4,153)=3.47$, $p < .05$). The univariate analyses revealed that the juvenile offenders performed more poorly than the nonoffenders on both spatial working memory ($F(1,153)=4.64$, $p < .05$) and spatial span ($F(1,153)=11.16$, $p < .01$). There were no differences with respect to performance on the Tower of London or the ID/ED shift task. Analyses also indicated significant sex differences (Multivariate $F(4,153)=5.86$, $p < .01$) in performance on the spatial working memory ($F(1,153)=9.10$; $p < .01$), spatial span ($F(1,153)=18.43$, $p < .01$), and Tower of London ($F(1,153)=5.33$, $p < .05$) tasks (but not on the ID/ED task), with males outperforming females on all three tasks. There were no sex by group (that is, offender versus nonoffender) interactions on any of these variables.

With regard to heart rate, as hypothesized, the offenders averaged significantly lower resting heart rate than nonoffenders, even after controlling for age and parental education (offenders $M=67.5$, nonoffenders $M=71.5$, $F(1,162)=8.03$, $p < .005$, $d=.40$). Although there were sex differences in heart rate (with males demonstrating a lower heart rate than females), there was no group by sex interaction. Overall, the findings regarding the ability of heart rate to distinguish between offenders and nonoffenders accord well with prior research on criminals (Raine, 1993).

A MANCOVA examining group differences in self-control after controlling for age and parental education revealed a significant multivariate effect ($F(3,157)=4.96$, $p < .01$), with significant univariate effects of group membership on temperance ($F(1,157)=14.11$, $p < .001$) and consideration of others ($F(1,157)=5.05$, $p < .05$) and a near-significant effect on future orientation ($F(1,157)=2.83$, $p=.10$). As expected, compared to nonoffenders, serious juvenile offenders are less able to control impulses and suppress aggression, less considerate of others and less future oriented. There were no significant univariate sex differences on any of these variables, however, there was a borderline sex by group interaction (Multivariate $F(3,157)=2.40$, $p=.07$). Specifically, the univariate analyses revealed that the difference between the female offenders and female nonoffenders in temperance was stronger in magnitude than the difference between the male offenders and male nonoffenders ($F(1,157)=6.26$, $p < .05$).

SELF-CONTROL, NEUROPSYCHOLOGICAL FUNCTIONING AND HEART RATE

Here, we estimate a series of logistic regressions aimed at understanding how self-control, neuropsychological functioning, and heart rate are related to offender status (see Table 2). We begin by examining whether neuropsychological and biological correlates can distinguish between offenders (CYA sample, coded 1) and nonoffenders (High School sample, coded 2). As can be seen, two of these variables, spatial span and heart rate are related positively (and as expected) to offender status, indicating that the nonoffender (high school) sample evidences higher spatial span performance and heart rate, while the offender sample evidences lower spatial span performance and heart rate.

In the next set of estimates, we remove the neuropsychological and biological correlates and insert the self-control measures. One of these measures, future orientation, is positively and significantly related to offender status, indicating that the nonoffender (high school) sample reports greater future orientation, indicative of greater self-control. Neither of the other two self-control measures is significantly related to offender status. This was true regardless of whether we used the combined temperance scale or the impulse control and suppression of aggression subscales separately.

Next, we estimate a model where we include all of the predictors noted above in order to determine if self-control mediates the effects of neuropsychological and biological variables on offender status. In this model, one component of self-control, future orientation, relates positively to offender status, indicating that the nonoffenders are more likely than the offenders to consider long-term consequences. Also, nonoffenders score higher than offenders on spatial span and heart rate. In sum, while one component of self-control, future orientation, remains significant in this full model, it does not render insignificant the effects of neuropsychological functioning (in the form of spatial span scores) and biological factors (in the form of heart rate). Thus, while certain components of self-control are important in distinguishing the two groups, it does not eliminate other factors that Gottfredson and Hirschi would expect to be eliminated. These results, then, support the contentions of those scholars attributing importance to neuropsychological and biological factors in addition to self-control (Moffitt, 1993; Rowe, 2002).¹²

12. Moffitt does note that serious offenders (as well as those with neuropsychological deficits) exhibit "impulsive self-control problems" (Moffitt and Harrington, 1996; see also Moffitt, Caspi, Rutter and Silva, 2001).

Table 2. Logistic Regression Analyses Prediction Offender Status

Variable	<i>Neuropsychological/ Biological Only</i>		<i>Self-Control Only</i>		<i>Full Model</i>	
	B/SE(B)	Exp(B)	B/SE(B)	Exp(B)	B/SE(B)	Exp(B)
Parent's Education	.211/.114	1.235	.180/.106	1.198	.200/.117	1.221
Age	-.377/.144	0.686	-.363/.134	0.696*	-.403/.149	0.668*
Race	.134/.426	1.143	-.023/.396	0.978	.117/.437	1.124
Sex	.255/.400	1.291	.045/.347	1.046	.428/.420	1.534
ID/ED	-.134/.172	0.875			-.124/.175	0.884
Tower of London	-.102/.185	0.903			-.147/.193	0.863
Spatial Span	.615/.208	1.849*			.671/.221	1.956*
Spatial Working Memory	.265/.210	1.304			.182/.214	1.200
Heart Rate	.046/.019	1.047*			.045/.020	1.046*
Future Orientation			.412/.197	1.510*	.455/.227	1.576*
Consideration of Others			-.019/.185	0.981	.010/.204	1.010
Temperance			-.343/.222	0.710	-.304/.252	0.738
Constant	1.504/2.660		4.979/2.154		1.749/2.743	
Model Chi-Square/df	34.485/9		17.025/7		38.143/12	
Nagelkerke R-Square	.258		.132		.284	

*, $p < .05$

ACCOUNTING FOR SAMPLE DIFFERENCES

Based on Moffitt's (and other's) theory, we hypothesized that measures of heart rate and neuropsychological functioning should distinguish between serious and nonserious offenders, but that these measures would not be related to less serious antisocial behavior. In order to test this notion, we estimated an OLS regression model predicting the deviant behavior scale among nonoffenders only. These results may be found in Table 3. Here, none of the neuropsychological nor biological correlates is a significant predictor of deviant behavior. However, one of the three self-control measures, temperance, is significantly related to deviant behavior. Specifically, those individuals who score higher on temperance (that is, who can suppress aggression and who have relatively better impulse control) are less likely to be involved in deviant behavior than their counterparts. Thus, it seems that neuropsychological and biological factors are only related to a certain kind of offending, much as Moffitt (and others) would predict.

Table 3. Results of OLS Regression Predicting Deviant Behavior (Nonoffenders Only)

<i>Variable</i>	<i>B</i>	<i>SE(B)</i>	<i>beta</i>
Parent's Education	.170	.065	.323*
Age	.056	.077	.073
Gender	.112	.245	.054
Race	-.215	.247	-.097
Heart Rate	.005	.011	.048
ID/ED	-.107	.087	-.124
Tower of London	.130	.101	.140
Spatial Span	-.097	.116	-.094
Spatial Working Memory	.075	.108	.083
Future Orientation	-.074	.129	-.067
Consideration of Others	-.169	.114	-.156
Temperance	-.681	.146	-.576*
Constant	-1.946	1.584	
R-Square	.479		

* $p < .05$

DISCUSSION

In this study, we tested Gottfredson and Hirschi's (1990) hypothesis that self-control is believed to be the only enduring personal characteristic predictive of criminal (and related) behavior (p. 111). If they are correct, no independent effect for biological and psychological factors should remain once self-control is taken into consideration. The counter-

argument, arising from theories espousing the biological/psychological perspectives, such as Moffitt's developmental taxonomy among others, suggests that biological and psychological factors independently add to the prediction of offending above and beyond measures of self-control. To adjudicate between these two hypotheses, we analyzed data from two comparable samples of adolescents, one from a high school and the other from the California Youth Authority.

Our results indicate three main findings. First, as Gottfredson and Hirschi hypothesize, self-control is indeed a significant predictor of offending. Specifically, the element of future orientation, which may be at the heart of self-control, was a discriminator of offender status: the nonoffender (high school) sample reported more future orientation (higher self-control) than the offender sample. Also, when studying the determinants of deviant behavior among the nonoffender sample, we found that although one element of self-control (temperance) was related to deviant behavior, none of the neuropsychological/biological factors were significant. Second, heart rate (a biological factor) and spatial span (a neuropsychological factor) were able to distinguish a group of serious offenders from a comparison group of adolescents. This finding supports theoretical approaches (Moffitt, Lynam) that indicate that there is a subset of biologically and neuropsychologically based, serious offenders whose offending relates to their biological and psychological characteristics and whose offending, contrary to Gottfredson and Hirschi's hypothesis, cannot be explained simply from their levels of self-control. Finally, and most important, we tested Gottfredson and Hirschi's hypothesis that once self-control, believed to be the only relevant personal characteristic, is taken into consideration, no other factors (especially neuropsychological nor biological) should discriminate between offenders and nonoffenders. Our results showed that although one element of self-control, future orientation, was related to offender status as expected by Gottfredson and Hirschi, one neuropsychological (spatial span) and one biological (heart rate) factor continued to discriminate between offenders and nonoffenders even after the effects of self-control are considered.

In a supplemental analysis, we tested the inferred hypothesis emanating from Gottfredson and Hirschi's discussion of the determinants of self-control that biological and psychological factors may influence self-control. With respect to this hypothesis, we found that one neuropsychological factor, spatial working memory, was a significant predictor of one component of self-control, future orientation. Specifically, those individuals scoring high on spatial working memory also scored high on future orientation (reported more self-control). In contrast, no other neuropsychological variables were predictive of aspects of self-control measures in this study. One possible explanation for this is that the

paper-and-pencil measures of impulse control and suppression of aggression employed here do not tap the same aspects of these constructs as those measured in previous studies, many of which employed behavioral rather than self-report measures of temperance. Another possibility is that the CANTAB tasks employed in the present investigation did not activate all of the neural systems relevant to these traits, most notably, those that involve the ventromedial cortex, a brain region thought to be important for risk assessment, deliberation and decision making (Manes et al., 2002). In any event, because we did not have measures of parental socialization efforts in our data, we could not control for them, and as such the notion that poor future orientation has specific neurobiological underpinnings remains speculative. Still, this is one of the first results to link a neuropsychological deficit to an element of self-control. This is more than a passing matter. For example, research has pointed to a possible connection between the rate at which the brain produces certain neurotransmitters and dimensions of personality (Cloninger, 1987), and it has been argued that changes in brain serotonin in particular may produce both impulsivity and negative affect (Caspi et al., 1994). Research has also shown that individuals who perform poorly on tests of self-control also exhibit abnormalities in electroencephalographic recordings from electrode sites at the front of the head (Raine, 1988), and show poor blood flow to the frontal lobes of the brain (Lou, Henriksen and Bruhn, 1984). When these findings are taken in concert with the findings from a study of twins reared together versus apart where it was found that more than 50 percent of the observed variance in both negative emotionality and constraints could be attributed to genetic factors (Tellegen et al., 1988), the take-home message is that proponents of Gottfredson and Hirschi's theory may wish to revisit the role of neurobiology in the determinants of self-control.

The findings concerning the differential autonomic and neuropsychological functioning of the juvenile offenders studied here are consistent with numerous studies of serious adult offenders and with many current theories about the antecedents of criminal activity, which point to neuropsychological and biological differences between individuals who become involved in serious or repetitive criminal activity and those who do not. Interestingly, and also consistent with current theories about juvenile crime and delinquency, the biological measures studied here do not predict involvement in minor delinquency among high school students. Although variations in minor antisocial activity have self-control correlates among high school students, such variations appear unrelated to autonomic or neuropsychological functioning. This is consistent with the notion that the importance of neuropsychological and biological factors may be in distinguishing the most serious antisocial individuals from their

peers, and that variations in antisocial behavior that are within the normal range (among nonserious offenders) may be best explained by self-control.¹³ Confirmation of this suggestion awaits further and more detailed analyses across distinct types of offending.

Although several studies of adults have pointed to the relatively lower autonomic arousal of serious criminals, few studies have examined this notion in younger populations. The fact that the serious offenders in this study showed a significantly lower average resting heart rate than nonoffenders is consistent both with previous studies of adults and with a recent report by Boyce et al. (2001) suggesting that low autonomic arousal is relatively more characteristic of young children with symptoms of externalizing problems. Few studies examine autonomic and neuropsychological functioning simultaneously, but the results of the present investigation suggest that doing so may be worthwhile.

The present results both support and refute Gottfredson and Hirschi's theory in that both minor delinquency and more serious offending are linked to deficiencies in self-control; however, the overall pattern of findings suggests some possible differences between the correlates of serious offending (which are neuropsychological, autonomic and self-control) versus minor delinquency (which are self-control, but not neuropsychological or autonomic) (see also Bartusch et al., 1997). Specifically, deficits in future orientation, which are predicted in part by deficits in spatial working memory, are correlated with serious offending but not with minor delinquency, as is the case with low autonomic activity. In other words, whereas problems in self-control may be a general risk factor for antisocial behavior, it is the additive effects of neuropsychological deficits, short-sightedness (which may be related to deficits in executive functioning), and low arousability that may be especially

13. A major strength of the present investigation was the use of the CANTAB, a highly sophisticated means of assessing neuropsychological functioning that allows a more fine-grained assessment of cognitive functioning than that obtained from a standardized intelligence test. It is therefore of special interest to note that, of the neuropsychological tasks employed in the present study, only the tests of spatial working memory and spatial span, thought to activate the ventral as well as dorsal regions of the prefrontal cortex, differentiated serious offenders from other adolescents. Interestingly, the offenders and nonoffenders did not differ on either the Tower of London or the ID/ED shift tasks, both of which are thought to activate primarily the dorsolateral prefrontal cortex, an area of the brain that has been found to be related to the regulation of aggression. Although the notion that the neuropsychological deficits associated with serious juvenile offending are those that are specifically revealed on spatial tasks or localized in a specific region of the brain necessarily remains speculative, it is a speculation that warrants further systematic study.

important in distinguishing between serious juvenile offenders and adolescents who engage in more minor delinquency.

What do these results imply for Gottfredson and Hirschi's theory? On the one hand, self-control was found to discriminate between offender and nonoffender samples as well as relate to the delinquency within the nonoffender sample. On the other hand, much like Caspi et al. (1994), our results show that, unlike Gottfredson and Hirschi's view that crime-proneness can be viewed as a single tendency (such as self-control), crime-proneness may be defined by multiple measures, including self-control but also neuropsychological and biological factors, among a subset of more serious offenders. It is clear that Gottfredson and Hirschi chose not to include individual differences (apart from self-control) in their formulation of the general theory (which has not changed much since its inception). Instead, they preferred to see self-control as overwhelmingly the result of parental socialization (or management practices), and then to see self-control—once inculcated—as the dominant individual difference that directed people toward crime. Because Gottfredson and Hirschi clearly developed a theory in which they chose to treat psychological and biological individual differences as unimportant, their work implies that any effects of these factors should be viewed not as intractable but as easily reversed by socialization practices and/or of minor causal importance once self-control is considered. If they were writing today—after nearly a decade and a half of criminological research demonstrating the importance of individual differences (other than self-control)—they might have developed a more nuanced treatment of these variables. At this stage, it is clear that a reasonable way to extend their work is to examine how individual differences are implicated with self-control in the causation of crime. Our results show that this would be a fruitful direction to take.

To be sure, due to several data constraints, ours is not the last word, and as such, care should be taken when interpreting the results of this study. First, our measure of self-control was attitudinal in nature. We recognize that Hirschi and Gottfredson (1993) prefer behavioral measures, but such measures were unavailable. And while several researchers have shown that the use of attitudinal or behavioral measures do little to change substantive conclusions (Pratt and Cullen, 2000; Tittle, Ward and Grasmick, 2003), future research should carefully consider the merits of using both attitudinal and behavioral measures of self-control. Second, our effort was cross-sectional in nature. Although such a design is consistent with Gottfredson and Hirschi's framework (after all, self-control was assessed after age 12 for our respondents—well after supposed parental socialization efforts have already taken place), future efforts should attempt to replicate our results prospectively. This is especially important

as some recent evidence suggests that self-control improves over time (Turner and Piquero, 2002). Relatedly, although the CANTAB was designed specifically to target tasks whose performance is associated with deficits in particular brain regions, what one can learn from neuropsychological testing is not the same as what one can learn from actual neuroimaging. Most executive functions are subserved simultaneously by multiple brain regions and systems, and it is unlikely that criminal activity maps onto brain anatomy or function in any simple one-to-one fashion. A fuller understanding of whether and through what processes biological functioning contributes to the development of serious criminal behavior will require longitudinal research that combines physiological, neuropsychological and psychological methods. Finally, that serious offending has physiological and neuropsychological correlates observable in adolescence does not mean that it is biologically determined. Indeed, the cross-sectional nature of the present study makes it impossible to determine whether the low resting heart rate and deficits in executive functioning observed among the juvenile offenders preceded, much less caused, these adolescents' involvement in criminal behavior. It is important to note, as well, that biological correlates are not the same as genetic correlates, and that the autonomic and neuropsychological correlates of offending observed here, even if they were antecedent to criminal activity, could well be the result of brain injury, prematurity, illness, exposure to violence, early social deprivation or any number of stressful experiences that can permanently affect brain functioning (Nelson and Carver, 1998).

The results reported here probably have more implications for policy-related research and debate about the appropriate treatment of serious juvenile offenders than they do for social policy per se. Much of this debate is polarized, characterized by intense disagreement between those who portray serious offenders as individuals whose antisocial behavior is "hard-wired" and who should be viewed as fledgling or budding "psychopaths" and those who believe that the potential plasticity of serious offenders is virtually limitless. Those in the former camp are inappropriately eager to label many serious offenders as biologically incorrigible, whereas those in the latter camp are inappropriately resistant to acknowledge that some offenders' behavior is very much biologically driven. The results of this study require further exploration before the direct implications for policy and practice can be drawn, but at the very least they suggest that a more complete understanding of the causes and treatment of serious juvenile crime is unlikely to be found at either extreme of the "hard-wired" versus "unlimited plasticity" continuum. Like depression, antisocial behavior likely has both biological and psychological

underpinnings, and its appropriate treatment depends on proper identification of contributing factors in each individual case.

In closing we note that several criminologists have attested to the importance of integrating more biological and neuropsychological perspectives into their theories and research (Walsh, 2000; Zahn, 1999). Our results show that some subset of these characteristics is indeed important to consider in differentiating between offenders. Specifically, both heart rate and spatial span directly differentiate between offenders, while spatial working memory does so indirectly—largely through its effects on future orientation (one element of self-control). The criminological community would therefore do well to pay close attention to these findings, which clearly demonstrate the potential of biological and neuropsychological characteristics to improve and extend existing models of criminal behavior.

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