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Cognitive impulsivity and the development of delinquency from late childhood to early adulthood: Moderating effects of parenting behavior and peer relationships

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Abstract

Cognitive impulsivity may increase children's risk of developing delinquent behavior. However, the influence of cognitive impulsivity may depend on social environmental risk factors. This study examined the moderating effect of late childhood parenting behaviors and peer relations on the influence of children's cognitive impulsivity on delinquency development across adolescence and early adulthood, while taking possible interactions with intelligence also into account. Delinquent behavior of 412 boys from the Pittsburgh Youth Study was measured annually from ages 13 to 29 years with official arrest records. Cognitive impulsivity (neurocognitive test scores) and intelligence were assessed at age 12–13. Parenting behaviors (persistence of discipline, positive reinforcement, and parental knowledge), peer delinquency, and peer conventional activities were assessed between ages 10 and 13 years. Results showed that, while controlling for intelligence, the influence of youths' cognitive impulsivity on delinquency depended on their parents' behaviors. An interaction was found among cognitive impulsivity, intelligence, and peer delinquency, but instead of cognitive impulsivity, the effect of intelligence on delinquency was particularly moderated. Overall, findings suggest that when there was moderation, high cognitive impulsivity and low intelligence were associated with an increased probability for engaging in delinquency predominantly among boys in a good social environment, but not in a poor social environment.

Delinquent behavior is most prevalent during adolescence, as depicted by the peak of the age–crime curve around age 17, followed by a decline in prevalence in adulthood (Blumstein, Cohen, Roth, & Visher, 1986; Farrington, 1986). This peak is accounted for by (a) youths who exhibit early conduct problems during childhood and then begin engaging in serious criminal behavior as they transition into adolescence (i.e., childhood-onset offenders); and (b) youths who begin offending from adolescence onward after exhibiting no/few behavior problems in childhood (i.e., adolescent-onset offenders; Moffitt, 1993). Although the number of childhood-onset offenders is smaller than the number of adolescent-onset offenders, these youth likely also show a peak in offending during adolescence (Wiesner, Capaldi, & Kim, 2007) and account for a disproportionally high percentage of offenses committed in adolescence and young adulthood (Moffitt, Caspi, Harrington, & Milne, 2002). Given the negative consequences of delinquency at the individual or societal level (Molero Samuelson, Hodgins, Larsson, Larm, & Tengström, 2010; Welsh et al., 2008), it is crucial to identify risk factors that predict the course of offending in adolescence and early adulthood, especially among childhood-onset offenders, who are at an increased risk of being more (persistently) delinquent across the life course (Moffitt, 1993).

Predictors of Delinquency Development

In the search for factors underlying the development of delinquency, emphasis has been put on neuropsychological deficits (Moffitt, 1993; Nigg & Huang-Pollock, 2003). Particular attention has been given to dysfunction within regions in the prefrontal and medial frontal cortex, which is thought to result in cognitively impulsive behavior (White et al., 1994), expressed in having problems with adaptively shifting between cognitive sets, disinhibition, acting without thinking/rapid cognitive tempo, and poor problem solving, working memory, self-control, and attention. Moffitt (1993) postulated that subtle neurological deficits in the brain regions underlying these cognitive functions are more often present among boys who show behavior problems early in their development, and especially affect their development of delinquent behavior. Deficits in such cognitive functions are suggested to hamper youth to control their behavior, to learn, recognize, and understand social norms and laws, and to foresee conse-

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quences of delinquent acts, thereby increasing the risk of showing delinquent behavior (Ishikawa & Raine, 2003; Moffitt, 1993; Nigg & Huang-Pollock, 2003). Consistent with this notion, measures of cognitive impulsivity (e.g., set shifting, inhibition, and cognitive tempo) have been found to be associated with delinquent behavior in adolescence and adulthood (Carroll et al., 2006; Morgan & Lilienfeld, 2000; Ogilvie, Stewart, Chan, & Sum, 2011), as well as the probability of being arrested across adolescence and early adulthood (Loeber et al., 2012).

In addition to neuropsychological deficits, a number of social environmental (risk) factors have been described to predict the development of delinquent behavior from late childhood/early adolescence onward, particularly inadequate parenting behaviors and deviant peer group affiliation (Dodge & Pettit, 2003; Loeber, 1990; Loeber & Hay, 1997; Moffitt, 1993; Rubin, Bukowski, & Parker, 2006; Rutter, 2003). Studies have consistently found that youths raised by parents who are inconsistent in discipline and exhibit low levels of supervision, support, and positive reinforcement are at increased risk of exhibiting (later) delinquent behavior (Hoeve et al., 2009; Loeber & Stouthamer-Loeber, 1986). Peer influences are postulated to become increasingly important during the transition into early adolescence (around ages 12–13), as youths begin establishing greater autonomy and begin spending more time with peers outside of home and school (Larson, Richards, Moneta, Holmbeck, & Duckett, 1996; Rubin et al., 2006). Those youths who affiliate with deviant/delinquent peers during this developmental period are more prone to exhibit delinquent behavior (Deater-Deckard, 2001; Matsueda & Anderson, 1998), because these behaviors are learned and reinforced within the context of social interactions in a process referred to as "deviancy training" (Dishion, Spracklen, Andrews, & Patterson, 1996). For this reason, parental supervision or knowledge of the child's whereabouts in unsupervised periods likely becomes increasingly important for preventing the development of delinquency during the transition from childhood into adolescence.

Moderation of the Influence of Cognitive Impulsivity on Delinquency by Parenting Behaviors and Peer Relations

Studies indicate that neurocognitive and social environmental risk factors both incrementally contribute to the development of early onset persistent delinquency. For instance, Moffitt et al. (2002) demonstrated that childhood-onset delinquents, who exhibited higher levels of both cognitive and environmental risk factors compared to adolescent-onset males, showed most delinquent behavior at age 26 (Moffitt et al., 2002). When examined simultaneously, cognitive and environmental factors were mostly considered as additive predictors, but their effect on delinquency may be interactive (Farrington & Ttofi, 2011; Moffitt, 1993). That is, the risk that boys with a higher cognitive impulsivity follow a delinquent developmental pathway might be disproportionally larger or exacerbated in an at-risk social environment. The early starter model poses that cognitive impulsivity expresses itself in the context of an at-risk social environment, resulting in more and persistent delinquent behavior (Moffitt, 1993). For example, an at-risk environment may fail to provide the external control these children likely need to compensate for their weaker internal regulatory competences (Henry, Caspi, Moffitt, & Silva, 1996; Lynam et al., 2000). In other words, when parenting is poor, the likelihood that cognitive impulsivity increases the probability of being arrested may become especially apparent, because there is no proper parental control to compensate for the increased cognitive risk. Children with poorer cognitive skills may also have difficulties learning from punishment cues to refrain from inappropriate behaviors, which could lead to problem development particularly when parents do not provide the environment to stimulate this learning process (e.g., when discipline is inconsistent; Matthys, Vanderschuren, Schutter, & Lochman, 2012). By being authoritative (i.e., warm but firm parenting, associated with a proper behavior development; see Steinberg, 2001, 2008), parents could provide the external control and/or appropriate models to learn to cope with self-control difficulties that cognitively vulnerable children may need to prevent the development of antisocial behavior (see Matthys et al., 2012). When authoritative behaviors such as persistence of discipline, supervision/parental knowledge, and positive reinforcement are absent, cognitive impulsivity may lead to higher levels of delinquency. Prosocial activities with mainstream peers may similarly provide the external social control that these vulnerable boys need (e.g., by reducing unstructured time; Booth, Farrell, & Varano, 2008) and opportunities for learning appropriate, prosocial behavior, which could prevent cognitively impulsive boys from engaging in delinquent behavior. By contrast, affiliations with delinquent peers may disproportionally increase their risk of being arrested, because their higher impulsivity may make them more susceptible to negative peer influences (Grosbras et al., 2007).

There is some empirical evidence supporting the theorized interaction between neurocognitive dysfunction and social environmental risk in predicting delinquent behavior. Impulsive boys (impulsivity measured with behavioral reports and cognitive tests) have been found to be most delinquent in disadvantaged neighborhoods, whereas impulsivity had little effect on delinquency in better neighborhoods (Lynam et al., 2000); similar findings were reported by Meier, Slutske, Arndt, and Cadoret (2008). Furthermore, boys with lower neuropsychological test scores who were raised in an adverse home environment were found to be disproportionally more likely to exhibit aggressive behavior than were boys with either of these risk factors in isolation (Moffitt, 1993). Moreover, the risk of adverse outcomes among children who have disorders characterized by impulsiveness and difficulties with information processing, such as attention-deficit/hyperactivity disorder, has been found to be disproportionally larger if they affiliated with more deviant friends, as compared to boys without attention-deficit/hyperactivity disorder

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(Marshal, Molina, & Pelham, 2003). Comparable results may be found when effects of cognitive impulsivity on delinquency are examined in the context of parenting behavior and peer relational variables.

It is important to note, however, that other types of interaction may be possible. For instance, in line with the social push hypothesis (Mednick, 1977; Raine, 2002), the presence or visibility of the effect of cognitive impulsivity may depend upon the social environment. According to the social push hypothesis, the impact of biological factors (e.g., cognitive impulsivity) could be especially visible in a positive social environment but found overshadowed in a poor social environment (Mednick, 1977; Raine, 2002), as was, for instance, found for genetic influences on antisocial behavior, which appeared to be more important in more advantaged neighborhoods (Tuvblad, Grann, & Lichtenstein, 2006).

Current Study

The current study builds on an earlier study in this sample in which it was found that cognitive impulsivity in early adolescence increased the probability that boys would be arrested from adolescence into early adulthood (Loeber et al., 2012). However, this earlier work, or to our knowledge any other previous studies, did not study the impact of cognitive impulsivity on delinquency in the context of parental and peer factors across a time period covering adolescence and early adulthood. Therefore, this study aimed at investigating the predictive value of cognitive impulsivity on the course of arrests, as an indicator of delinquency, over the period from ages 13 to 29, in the context of parenting behaviors and peer relationships. This was tested using an at-risk inner-city male sample in which children with signs of antisocial behavior at or around age 10 years were oversampled. We hypothesized that both parenting behavior and peer relational factors would moderate the association between cognitive impulsivity and the prevalence of delinquency from early adolescence into adulthood. More specifically, we hypothesized the risk of being arrested to be highest in boys exposed to both cognitive and social environmental risks.

Cognitive Impulsivity Versus General Intelligence

It is important to note that any possible direct or moderated by environmental factors effects of cognitive impulsivity on delinquency may depend on intelligence, an aspect of general cognitive functioning and found to be correlated with cognitive impulsivity (e.g., see Loeber et al., 2012; White et al., 1994). Lower intelligence was also found to be associated with higher delinquency in several studies (e.g., see Jolliffe & Farrington, 2010; Moffitt, Caspi, Silva, & Stouthamer-Loeber, 1995). The effect of intelligence on delinquency may, similar to cognitive impulsivity, be influenced by parenting behaviors and peer relationships. For that reason, interactions between intelligence and the social relational factors were also examined. Moreover, the effect of cognitive impulsivity might even depend on social relational factors and intelligence simultaneously (also following the interaction effects between cognitive impulsivity and intelligence in predicting arrest probability, found by Loeber et al., 2012). Therefore, when exploring the possible combined impact of cognitive impulsivity and environmental factors on our delinquency outcome, intelligence and possible moderating effects of intelligence were also taken into account.

Theft and Violence

In addition to testing the hypothesis for general delinquency, we explored whether the moderating effects on general delinquency applied similarly to subtypes of delinquency: theft and violence. It was found not only that the developmental trajectories of theft and violence were somewhat different (i.e., the prevalence of theft decreased earlier in the life course than violence; see Barker et al., 2007; Sampson & Laub, 2003) but also that neurocognitive and social relational risk factors may be somewhat differently related to theft and violence (Barker et al., 2007, 2011; Hoeve et al., 2009; Loeber et al., 2012). More important for the current study, the hypothesized moderating effects may perhaps also differ between subtypes of delinquency. For instance, the probability that a cognitively impulsive boy commits a property offense may be more reduced by good parenting behaviors, such as parental knowledge, compared to a violent offense, because violence (e.g., noninstrumental physical aggression) is more often an impulsive act than is theft (e.g., see Barker et al., 2011) and perhaps less influenced by parents' behaviors.

Methods

Participants

Participants were from the middle sample of the Pittsburgh Youth Study (for details see Loeber, Farrington, Stouthamer-Loeber, & Van Kammen, 1998). From a pool of all eligible fourth-grade boys in participating public elementary schools in 1987–1988, 1,146 were randomly selected for potential participation in the screening. A follow-up sample was selected using the screening risk score of the boys' antisocial behavior measured with parent, teacher, and self-report instruments. This risk score was created by indicating whether antisocial behaviors (e.g., attack, set fires, burglary, truancy, liquor use, and arrested) were present according to at least one of the informants (Loeber et al., 1998). A cutoff was made to identify the most antisocial third of the sample. Consequently, all boys within the upper 30% of risk scores were selected for follow-up ($n = 259$, ≈50%) along with a roughly equal number of boys selected from the lower 70% of the distribution ($n = 249$, ≈50%), resulting in a total sample of 508 boys. The mean age of the sample was 10.2 years ($SD = 0.76$) at screening, with a racial composition of 42.7% Caucasian, 52.4% African American, and 4.9% other (similar to the screening sample). Informed consent was obtained from all

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participants. Youths, their parents, and teachers received a monetary incentive for their participation in the study.

For 412 boys (81.1% of the total sample), scores were available on all three tests of cognitive impulsivity used in this study, intelligence, the control variables, and at least two arrest scores from ages 13 to 29 (one boy died at age 14). These 412 boys did not differ from the total 508 sample on race or screening risk status (*p*s > .05), but had higher mean socioeconomic status (SES) scores than the 96 boys who were not included in the study sample, F (1, 506) = 5.54, p = .02. Criminal record information was collected for all participants each year until age 29. Of these 412 participants, 12 died at some point during the follow-up (age range 14 to 29). These 12 participants did not differ on screening risk status, race, or SES. For all other 400 participants, arrest records were available at every age.

Measures

Official arrest records from ages 13 to 29 were obtained via local, state, and federal sources (Loeber, Farrington, Stouthamer-Loeber, & White, 2008). When participants were charged at least once at a particular age year for any type of offense (general delinquency, e.g., robbery, fraud, rape, theft, or drug possession), they received the score 1 for that particular age year, and participants without any charge in that age year received the score 0. Subtypes theft and violence (moderate and serious theft and violence) included charges for larceny, dealing in stolen property, burglary, and motor vehicle theft, and charges for simple/aggravated assault, robbery, rape, involuntary deviate sexual intercourse, aggravated indecent assault, spousal indecent assault, and homicide (coded the same as general delinquency; Loeber et al., 2008).

Measures of cognitive impulsivity

An overall index of cognitive impulsivity was constructed using scores on the Trail Making Test, the Stroop Color and Word Association Test, and time perception. These measures were administered at the university during the summer of 1990, when the boys were on average 12.73 years old (SD = 0.87, range = 10.75–16.08). Three full-time rigorously trained examiners, who were unaware of the boys' risk status and potential prior police contacts, conducted a 90-min laboratory session. Tasks were assessed in two blocks of 45 min and in the same order because a similar motivational set was required at the beginning of each task for each boy. For the cognitive impulsivity measure, the three tests with the highest factor loadings in the cognitive impulsivity construct described by White et al. (1994) were selected (see Loeber et al., 2012).

The Trail Making Test measures the ability to initiate, switch, and stop a sequence of complex purposive behaviors, requiring attention and concentration skills. After drawing lines between consecutively numbered circles (Form A), the participants had to draw lines between consecutive numbers and letters (Form B), switching between the two sequences (i.e., A to 1 to B to 2 to C). Scores used were the time needed for Form B minus the time needed for Form A (White et al., 1994), with M = 18.25, SD = 14.97, and a range from –36 to 87.

The Stroop Color and Word Association Test measures the ability to inhibit an automatic overlearned response and generate a competing new response instead (Dodrill, 1978; Stroop, 1935), requiring sustained attention and mental control. In the first trial, participants had to read color names, followed by the inhibition trial, where participants were asked not to read the name of the color, but instead name the different color of the ink in which the words were printed (suppressing reading the color names). The number of errors in the inhibition trial was used in this study, because the time needed to finish the card and the number of errors were highly correlated, and the error score was more normally distributed (White et al., 1994), with M = 9.18, SD = 5.72, and a range from 0 to 48.

Time perception was measured with time estimation and time production tasks, measuring cognitive tempo (White et al., 1994). In time estimation, the stopwatch was run for six consecutive intervals of 2, 2, 4, 4, 12, and 25 s in this study. Participants had to estimate after each interval how many seconds had passed. Estimations that were too high indicate a too fast perception of time (i.e., risk). In time production, participants had to indicate when they thought 2, 2, 4, 4, 12, 25, and 60 s had passed. Too low time production scores indicate a fast time perception (or risk), which concurs with the negative correlation between time estimation and time production (r = –.54). To obtain scores in the same direction (where higher scores indicated higher risk), time production scores were inverted by reflecting the difference from the time they should have indicated (e.g., a score of 1.5 in the 2-s trial became score 2.5). Subsequently, the time estimation and inverted time production scores were summed (White et al., 1994). Scores ranged from 44 to 849.6 (M = 211.6, SD = 86.29). The three tests were significantly associated (*r*s = .14 to .28). To obtain a total cognitive impulsivity score, scores were standardized and summed (positive scores indicated higher cognitive impulsivity, and negative scores lower cognitive impulsivity), which was standardized once more within the sample of 412 boys.

Overall, boys who showed most behavioral problems at screening (i.e., at risk; half of the sample) had poorer scores on the cognitive impulsivity tests than did the boys who were not considered to be at increased risk, F (1, 410) = 14.53, p < .001.

Intelligence was measured in the same test session as the cognitive impulsivity tests. A short form of the Wechsler Intelligence Scale for Children—Revised was used (Wechsler, 1974). This form included all 12 subtests but shortened by including every other item. This procedure follows the one described by Yudin (1966), who reported a correlation of 0.97 between the short and full form of the Full Scale IQ scores (Yudin, 1966). Intelligence scores (M = 101.1, SD =

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15.40, range = 63–145) were standardized within the 412 sample of boys.

Parenting behavior variables

Three parenting behavior variables were used in this study, assessed with questionnaires, verbally administered to the primary caretaker (mostly the boys' mother [87.4%], then father [4.5%], grandmother [4.4%], or adult otherwise related to the child), and the boys every 6 months, for six consecutive assessment points after the screening (average age is 10.8 at first assessment and 13.3 years at last assessment; see Loeber et al., 2008). A multiple-informant score (parent and boy) over multiple assessments was used to make a more reliable and temporally stable score. Because not all items in each scale were in the same direction, the items where a higher score represented poor parenting behavior (or a higher risk) were reversed before being summed so that higher total scores represented better parenting behavior (lower risk). The scale range for parent and child was made equal by dividing the sum score by the number of items in the scale. Next, the mean of parent and child scores was calculated for each of the six assessment points. Scores were coded missing if parent and/or child data were not available at a particular assessment point. A mean score was then calculated for the parent/child combined scores across all available time points for each boy. These scores were standardized into z scores within the sample of boys included in the analyses ($M = 0$, $SD = 1$). Almost all boys had both a parent and child score at three or more assessment points for each parenting variable (99.3%–99.8% of the boys), and none of the boys had missing data on all occasions for any of the three variables.

Persistence of discipline consisted of four items for both parent and child, measuring the degree to which the parent persisted in disciplinary action toward the boy (e.g., parent: "Do you let your son get away with things?"; boy: "If your mother had planned some punishment for you, could you talk her out of it?"; Loeber et al., 1998), using a 3-point Likert scale (1 = *almost never*; 2 = *sometimes*; 3 = *almost always*). Some items were reversed so that high scores represented persistent parental discipline. Cronbach αs ranged from 0.49 to 0.66 for the parent and from 0.54 to 0.64 for the child scale across the six assessments. All correlations between the six assessments were significant for both informants (parent: rs = .42–.65; child: rs = .30–.51). The mean parent and child score across the six assessment points was also significantly correlated ($r = .23$, $p < .001$). Scores used in the analyses were calculated as described above (the multiple-informant, multiple time points mean, converted into a z score).

Positive reinforcement was measured with the child- and parent-reported Positive Parenting Scale (Loeber et al., 1998). Items ask about the parents' tendency to provide positive reinforcement when their child has done something well (e.g., "When your son/you did something that you/your mother liked or approved of, how often did you/does she give him/you a wink or smile?"), which are rated on a 3-point Likert scale (1 = *almost never*; 2 = *sometimes*; 3 = *often*). The scale consisted of eight items for the parent and seven for the boy. Cronbach αs ranged from 0.74 to 0.79 for the parent and 0.75 to 0.88 for the child across the six assessments. Correlations ranged from 0.39 to 0.64 between the six parent assessments, and 0.34 to 0.56 between the six child assessments. The parent and child score, both averaged across the assessments, correlated significantly ($r = .30$, $p < .001$). Scores were also calculated as described above.

Parental knowledge was measured with four items from the child- and parent-reported Supervision/Involvement measure (Loeber et al., 1998). Items include: "When your son is/you are out, do you/do your parent(s) know what time he/you will be home?" using a 3-point Likert scale (1 = *almost never*, 2 = *sometimes*, 3 = *almost always*). Cronbach αs were 0.50 to 0.64 for the parent and 0.53 to 0.70 for the child scale across the six assessments. Correlations ranged from 0.32 to 0.61 between the six parent assessments and 0.29 to 0.53 between the six child assessments. The correlation between the average parent and child score across the six assessments was 0.35 ($p < .001$). Scores were also calculated as described earlier.

Peer relational variables

The two peer relational variables used in this study were measured with questionnaires verbally administered to the boys only, every 6 months (peer delinquency; six assessments points, first on average at 10.8, last at 13.3 years) or every year (conventional activities with peers; three assessments points $M = 10.8$, 11.8, and 12.8 years). A mean score across all available time points was calculated for both peer relation variables (with peer delinquency scores available from at least three measurements for all boys, and conventional activities at least two out of three assessments for 99.3% of the boys), which was then converted to z scores for the boys included in the current study.

Peer delinquency was measured with nine items, asking how many of the boy's friends were delinquent (e.g., theft, violence, and property damage; see Loeber et al., 2008) in the past 6 months (*none* = 0, *all of them* = 4). Cronbach αs ranged from 0.82 to 0.90 across the six assessments. Correlations ranged from 0.33 to 0.61 between the six assessments. High scores indicate high peer delinquency.

Conventional activities of peers was measured with eight items, asking the boys how many of their friends have been involved in conventional activities, such as school athletics or family activities, or whether they are good students (Loeber et al., 1998). Cronbach alphas ranged from 0.71 to 0.80 across the three assessments. Correlations ranged from 0.22 to 0.41 between the three assessments. High scores represent having many friends involved in multiple conventional activities.

Study covariates

Screening risk status, race/ethnicity, SES, test age, and pubertal development were taken into account to control for sampling

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(i.e., an urban sample, with a disproportionally high number of high-risk boys), time of assessment, and level of physical development during assessment. Screening risk status was determined before initiation of the study around age 10. Parents were given the Child Behavior Checklist, teachers were given the Teacher Report Form, and the boys were given the Self-Reported Antisocial Behavior Questionnaire to measure early antisocial behavior (Loeber et al., 1998). As shortly described earlier, about half of the boys in the study sample scored high on antisocial behavior at screening (i.e., the upper 30% of the antisocial behavior scores in the initial screening sample). The rest of the boys had lower antisocial behavior scores (from the other 70% of the distribution). Boys identified as being high risk received the score 1 ($n = 214$), and boys without elevated risk of showing antisocial behavior had score 0 ($n = 198$). Because participants were primarily Caucasian or African American (95.4%), race/ethnicity was dichotomized into African American (score = 1) or Caucasian and other racial/ethnic backgrounds (score = 0; see Pardini, Fite, & Burke, 2008). SES was the mean of the available SES scores from seven semiannual assessments (screening, and the six consecutive assessment points), based on the Hollingshead Four Factor Index of Social Status (1975). Test age was participants' age at the time the cognitive tests were conducted (summer 1990). Pubertal development was assessed at age 13.3 years with a five-item self-report questionnaire, including questions about facial hair and voice change, with an answer range from 1 *no development* to 4 *development completed* (Petersen, Crockett, Richards, & Boxer, 1988). Test age, SES, and pubertal development were converted to z scores within the sample included in the current study.

Statistical analyses

Data were analyzed with logistic population-averaged generalized estimating equation models, using STATA version 11 (StataCorp, 2009). Generalized estimating equation models account for nonindependent observations on dependent variables, such as repeated measures over time. The association between the dependent variables over time was modeled using an autoregressive correlation structure (AR1). This model assumes that the association between arrest outcomes measured at different ages decreases as the temporal separation between the assessments increases in a systematic manner (Shults et al., 2009). Standard errors that are robust to potential misspecification of dependent variable correlation structure were used (Zeger, Liang, & Albert, 1988).

Before testing the effects of cognitive impulsivity, intelligence, and the social contextual factors on the delinquency outcome, the course of delinquency between ages 13 and 29 years was modeled by adding a linear, quadratic, and cubic age term, as described in an earlier study in this sample by Loeber et al. (2012). The main analysis was conducted in four steps (e.g., for a similar analyses strategy, see Benoit, Lacourse, & Claes, 2013). In the first model, control variables as well as the three age terms were added as predictors of the probability of being arrested from ages 13 to 29. In the second model, both cognitive impulsivity and intelligence were added to the model from the previous step. In the third model, all five social contextual factors were added to the previous model as main effects. In the subsequent models, interaction effects between cognitive impulsivity/intelligence and the parenting/peer relational variables were tested to examine possible moderation of parenting and peer variables on the impact of cognitive impulsivity/intelligence on delinquency (in separate models to avoid problems of multicollinearity; see Benoit et al., 2013). Two-way interactions between cognitive impulsivity and each of the parenting/peer factors, as well as between intelligence and each of the parenting/peer factors, were examined (and the two-way interaction between cognitive impulsivity and intelligence). Then three-way interactions among cognitive impulsivity, intelligence, and each of parenting/peer factors were tested. Only significant interactions are presented in the results. To explore whether interaction effects applied similarly to subtypes of delinquency, these steps were repeated for theft and violence.

Results

Descriptives

Seventy percent of the participants were arrested at least once between ages 13 and 29 (median = 6 arrests). The proportion of participants who were charged for any offense, theft, and violence at least once for each study year is presented in Figure 1. The age–crime curve shows increases during adolescence, followed by a decrease in early adulthood. The correlations among cognitive impulsivity (CI), intelligence (IQ), and parenting behavior and peer relational variables are presented in Table 1. There were significant correlations between CI and IQ, and between CI and parental knowledge and peer delinquency; the correlations between CI and persistence of discipline, positive reinforcement, and conventional activities with peers were nonsignificant. For IQ, correlations with persistence of discipline, parental knowledge, and peer delinquency were significant. Correlations between the parenting behavior and peer relational variables were in the expected direction.

Cognitive impulsivity, intelligence, parenting, and peers, and the estimated probability of being arrested for any offense across adolescence and adulthood

Before interactions were tested between CI, IQ, and the parenting and peer relational variables, linear (age), quadratic (age^2), and cubic (age^3) terms were added to the generalized estimating equation model as predictors of the probability of being arrested, together with the control variables (see Table 2, Step 1). The three age variables were significant, which mirrored the observed age–arrest curve in Figure 1 (increases in arrests in early to middle adolescence, followed by a decrease in late adolescence/early adulthood, and stabilization in adulthood).

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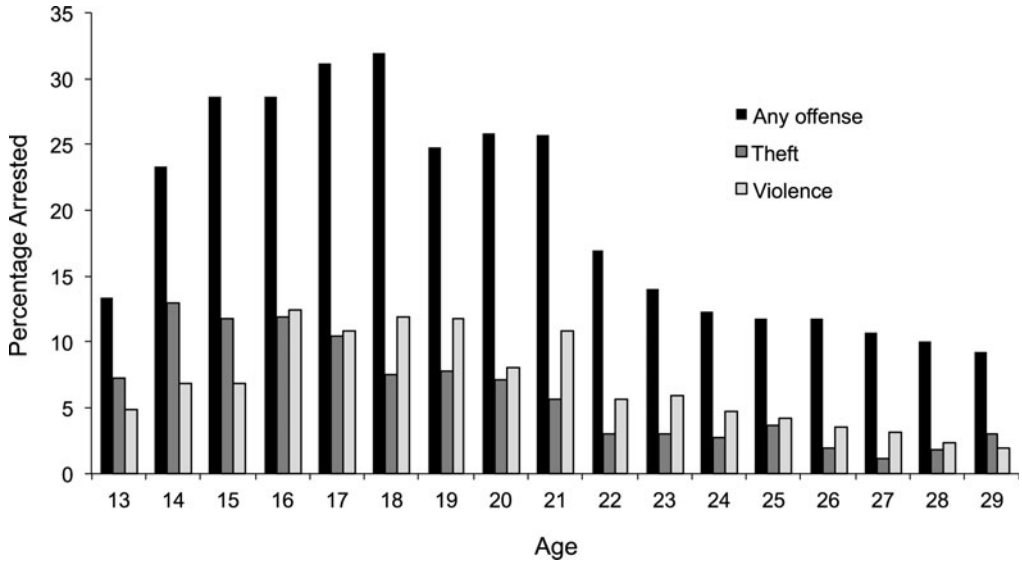

Figure 1. Observed percentages of participants arrested for any offense, theft, and violence at least once in each age year (ages 13–29), following the shape of the age–crime curve.

After adding the main effects of CI and IQ (see Table 2, Step 2), the three parenting behavior variables (persistence of discipline, positive reinforcement, and parental knowledge) and two peer relational variables (peer delinquency and conventional activities of peers) were added (see Table 2, Step 3). This was followed by testing the two-way interaction terms, first between CI and the parenting and peer relational variables, and followed by interaction terms between IQ and the parenting and peer relational variables. Only models with significant interaction terms are shown in Table 2. None of the two-way interactions of IQ with the parenting/peer relational variables were significant (nor was the interaction between CI and IQ). However, two-way interactions between CI and persistence of discipline (Table 2, Step 4a), between CI and positive reinforcement (Table 2, Step 4b), and between CI and parental knowledge (Table 2, Step 4c) were significant. None of the three-way interactions among CI, IQ, and the parenting behaviors were significant ($ps > .05$). For conventional activities of peers, no main effect or interaction effect with CI was found. However, a significant three-way interaction among CI, IQ, and peer delinquency was found (see Table 2, Step 4d).

Cognitive impulsivity and parenting behaviors

To decompose the direction of the moderation between CI and parenting behaviors, the significant two-way interaction terms were probed by estimating the effects of CI at high (1 *SD* above the mean) and low (1 *SD* below the mean) levels of parent variables (see Holmbeck, 2002). Results are graphically presented in Figure 2. The results showed a number of findings. First, CI only significantly predicted the probability of being arrested in the *absence* of social–environmental risk (comparing curves 3 and 4 in Figure 2). Specifically, when positive reinforcement ($B = 0.23$, $SE = 0.09$, $p < .05$, odds ratio [OR] = 1.26) and parental knowledge ($B = 0.29$, $SE = 0.11$, $p < .01$; $OR = 1.34$) were high (i.e., low-risk parenting behavior), CI significantly increased the probability of being arrested across ages 13 to 29 years. For high persistence of discipline, despite the significant interaction term, CI did

Table 1. *Correlations among cognitive impulsivity, intelligence, and parenting behavior and peer relational variables*

Variable	1	2	3	4	5	6
1. Cognitive impulsivity	—					
2. Intelligence	−.50**	—				
3. Persistence of discipline	−.08	.15**	—			
4. Positive reinforcement	−.08	.05	.10*	—		
5. Parental knowledge	−.22**	.34**	.30**	.41**	—	
6. Peer delinquency	.16**	−.32**	−.15**	−.05	−.44**	
7. Conventional activities of peers	−.00	.05	.10*	.30**	.30**	−.19**

*$p < .05$. **$p < .01$.

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Table 2. *Main and moderating effects of cognitive impulsivity, intelligence, parenting behaviors and peer relationships on the probability of being arrested from age 13 to 29 (n = 412)*

	Model 1		Model 2		Model 3	
	B (*SE*)	*OR*	*B* (*SE*)	*OR*	*B* (*SE*)	*OR*
Step 1						
Age	4.196 (0.476)***	66.42	4.241 (0.483)***	69.49	4.327 (0.488)***	75.72
Age^2	−0.198 (0.023)***	0.820	−0.201 (0.024)***	0.818	−0.205 (0.024)***	0.815
Age^3	0.003 (0.000)***	1.003	0.003 (0.000)***	1.003	0.003 (0.000)***	1.003
Risk status	0.750 (0.136)***	2.118	0.678 (0.135)***	1.969	0.429 (0.141)**	1.536
Race/ethnicity	0.801 (0.136)***	2.229	0.621 (0.138)***	1.860	0.450 (0.141)**	1.569
Test age	0.205 (0.064)**	1.228	0.092 (0.069)	1.097	0.074 (0.066)	1.077
SES	−0.174 (0.063)**	0.841	−0.108 (0.063)	0.898	−0.103 (0.065)	0.902
Pubertal development	0.094 (0.066)	1.098	0.100 (0.066)	1.106	0.080 (0.067)	1.084
Step 2						
CI			0.012 (0.066)	1.012	0.031 (0.071)	1.031
IQ			−0.349 (0.092)***	0.705	−0.280 (0.094)**	0.756
Step 3						
Disc					0.041 (0.071)	1.042
PosRein					0.023 (0.072)	1.023
ParKnow					−0.236 (0.079)**	0.790
PeerDel					0.202 (0.053)***	1.224
ConvPeerA					0.101 (0.067)	1.106

	Model 4		Model 5		Model 6		Model 7	
	B (*SE*)	*OR*	*B* (*SE*)	*OR*	*B* (*SE*)	*OR*	*B* (*SE*)	*OR*
Step 1								
Age	4.337 (0.490)***	76.48	4.345 (0.492)***	77.12	4.338 (0.490)***	76.59	4.325 (0.488)***	75.53
Age^2	−0.205 (0.024)***	0.815	−0.206 (0.024)***	0.814	−0.205 (0.024)***	0.814	−0.205 (0.024)***	0.815
Age^3	0.003 (0.000)***	1.003	0.003 (0.000)***	1.003	0.003 (0.000)***	1.003	0.003 (0.000)***	1.003
Risk status	0.427 (0.140)**	1.533	0.401 (0.142)**	1.494	0.403 (0.143)**	1.496	0.436 (0.142)**	1.546
Race/ethnicity	0.440 (0.139)**	1.553	0.449 (0.140)**	1.567	0.451 (0.140)**	1.570	0.432 (0.141)**	1.541
Test age	0.070 (0.066)	1.072	0.059 (0.068)	1.061	0.083 (0.066)	1.087	0.077 (0.068)	1.080
SES	−0.098 (0.064)	0.907	−0.122 (0.066)	0.885	−0.122 (0.064)	0.885	−0.099 (0.066)	0.906
Puberty status	0.081 (0.066)	1.085	0.080 (0.067)	1.083	0.084 (0.066)	1.088	0.074 (0.067)	1.077
Step 2								
CI	0.041 (0.075)	1.042	0.067 (0.064)	1.069	0.118 (0.070)	1.126	0.079 (0.088)	1.082
IQ	−0.280 (0.095)**	0.756	−0.263 (0.091)**	0.769	−0.217 (0.094)*	0.805	−0.272 (0.100)**	0.761
Step 3								
Disc	0.017 (0.071)	1.017	0.037 (0.070)	1.037	0.040 (0.071)	1.041	0.045 (0.070)	1.046
PosRein	0.019 (0.073)	1.019	−0.003 (0.072)	0.997	0.024 (0.071)	1.025	0.033 (0.074)	1.034
ParKnow	−0.240 (0.080)**	0.786	−0.250 (0.079)**	0.779	−0.271 (0.079)**	0.763	−0.215 (0.080)**	0.807
PeerDel	0.197 (0.052)***	1.218	0.195 (0.052)***	1.215	0.199 (0.052)***	1.220	0.238 (0.070)**	1.268
ConvPeerA	0.106 (0.067)	1.112	0.107 (0.066)	1.113	0.091 (0.067)	1.095	0.100 (0.067)	1.105

Step 4a										
CI × Disc	0.137 (0.065)*	1.147								
Step 4b										
CI × PosRein			0.163 (0.060)**	1.177						
Step 4c										
CI × ParKnow					0.176 (0.048)***	1.193				
Step 4d										
CI × IQ							−0.057 (0.075)	0.945		
CI × PeerDel							0.098 (0.062)	1.103		
IQ × PeerDel							0.077 (0.075)	1.080		
CI × IQ × PeerDel							−0.084 (0.039)*	0.920		

Note: Step 1: age variables and controls; Step 2: CI and IQ added to Step 1 model; Step 3: three parenting behavior and two peer relationship variables added to Step 2 model; Step 4a–d: significant interactions between CI and parenting/peer variables and among CI, IQ, and parenting/peer variables (interactions tested separately). SES, Socioeconomic status; CI, cognitive impulsivity; IQ, intelligence; Disc, persistence of discipline; PosRein, positive reinforcement; ParKnow, parental knowledge; PeerDel, peer delinquency; ConvPeerA, conventional activities of peers.
*$p < .05$. **$p < .01$. ***$p < .001$.

not reach significance when probing the interaction (B = 0.18, SE = 0.11, p = .10, OR = 1.19).

Second, in the *presence* of social–environmental risk (i.e., low protective parenting behavior), CI was unrelated to arrest, however (comparing curves 1 and 2 in Figure 2). That is, for low persistence of discipline (B = –0.10, SE = 0.09, p = .30, OR = 0.91), low positive reinforcement (B = –0.10, SE = 0.08, p = .24, OR = 0.91), and low parental knowledge (B = –0.06, SE = 0.06, p = .33, OR = 0.94), we did not find a significant effect of CI on arrest probability.

Because two-way interactions can be probed at varying levels of either variable, we next examined the association between parenting behaviors and the probability of being arrested at high and low levels of CI. The results from this analysis indicated that in the *absence* of *cognitive risk* (i.e., low CI; comparing curves 2 and 4 in Figure 2), only parental knowledge significantly predicted the probability of being arrested (parental knowledge: B = –0.45, SE = 0.10, $p < .001$, OR = 0.64). This indicates that boys with low CI were less likely to be arrested when their parents had high levels of knowledge regarding their whereabouts. However, the other two parenting behaviors were nonsignificant when CI was low (persistence of discipline: B = –0.12, SE = 0.10, p = .23, OR = 0.89; positive reinforcement: B = –0.17, SE = 0.10, p = .09, OR = 0.85). In the *presence* of the *cognitive risk* (i.e., high CI), parental knowledge did not predict the probability of being arrested (B = –0.09, SE = 0.09, p = .27, OR = 0.91), nor did the other parenting variables (persistence of discipline: B = 0.15, SE = 0.09, p = .10, OR = 1.17; positive reinforcement: B = 0.16, SE = 0.09, p = .07, OR = 1.17).

Cognitive impulsivity, intelligence, and peer delinquency

The results for the three-way interaction among CI, IQ, and peer delinquency (PD) are graphically shown in Figure 3. The direction of the interaction was further examined by using a method to test differences in effects of one variable under different conditions of the other two variables, described by Dawson and Richter (2006) as an accurate and useful method to probe three-way interactions (CI and IQ probed with M + 1 SD/M – 1 SD; PD probed with M + 0.8 SD/M – 0.8 SD to better match the range of PD scores). More specifically, with respect to the findings for CI, for each of the six pairs of lines in Figure 3a (representing effects of CI on arrest probability) under the four IQ/PD conditions (1: high IQ, high PD; 2: high IQ, low PD; 3: low IQ, high PD; and 4: low IQ, low PD) the difference was examined by performing six t tests. None of the lines/effects of CI under the different conditions of IQ and PD significantly differed from one another. Testing the effect of CI on arrest in the different combinations of high/low IQ and PD also showed that CI did not significantly predict arrest probability in any of the high/low IQ and PD combinations. These results indicate that the effect of CI on the probability of being arrested did not significantly differ under the different IQ and PD conditions.

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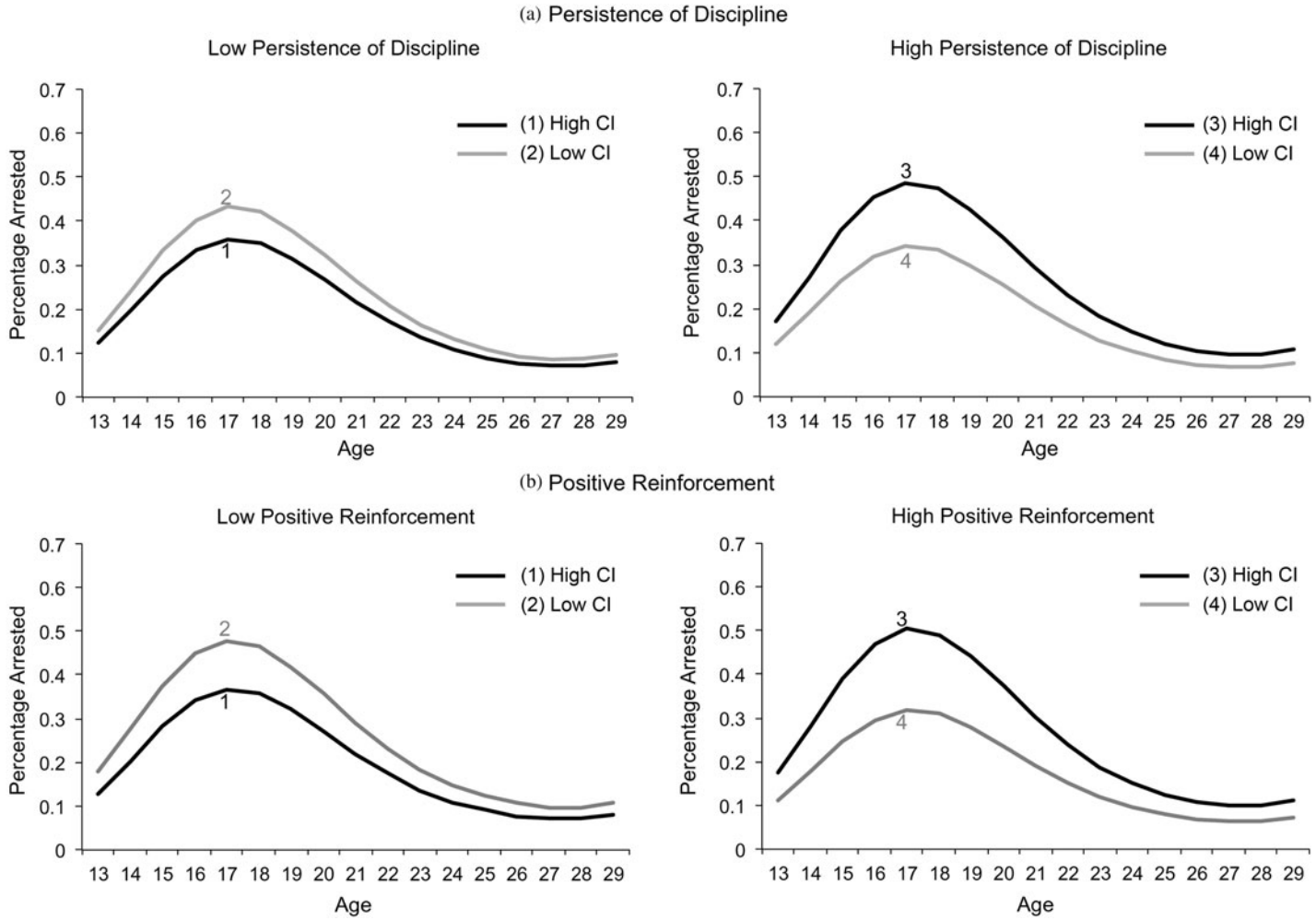

Figure 2. Estimated age–arrest curves for high ($M + SD$) versus low ($M - SD$) cognitive impulsivity in boys with (a) low ($M - SD$; left graph) and high persistence of discipline ($M + SD$; right graph); (b) low ($M - SD$; left) and high positive reinforcement of parents ($M + SD$; right); and (c) low ($M - SD$; left) and high parental knowledge ($M + SD$; right).

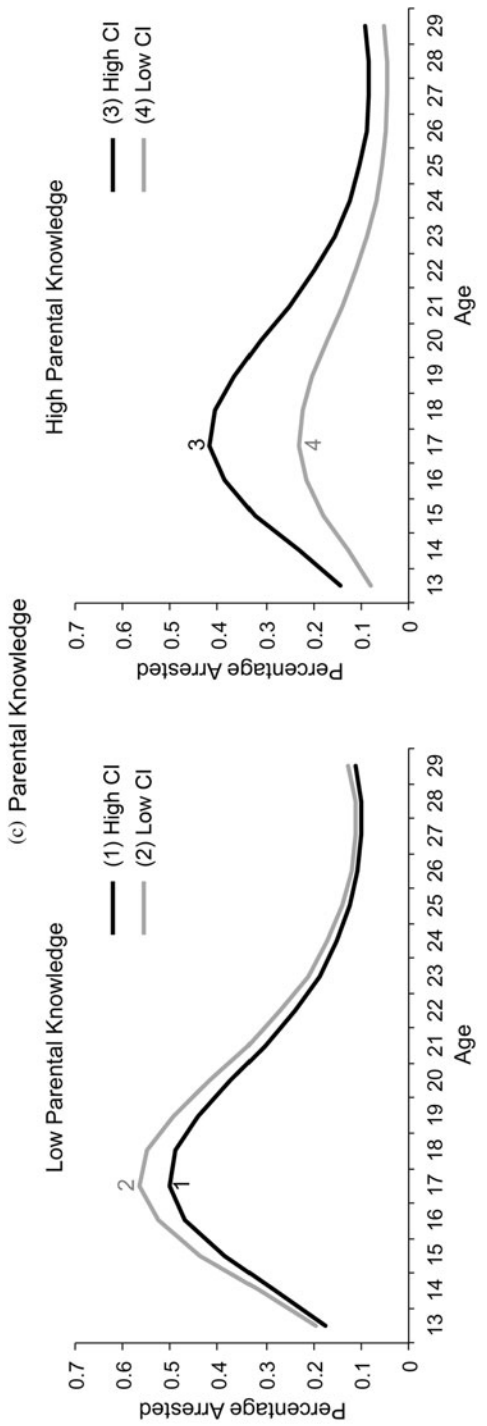

Figure 2 (*cont.*)

The difference between the effects of IQ under the different CI/PD conditions (1: high CI, high PD; 2: high CI, low PD; 3: low CI, high PD; and 4: low CI, low PD) was similarly tested. Results are shown in Figure 3b. One of the six pairs of IQ lines significantly differed: the effect of IQ under the low CI, low PD condition differed from the low CI, high PD condition ($t = 2.27$, $p < .05$). This indicated that the influence of IQ on the probability of arrest in low CI, low PD boys (no CI/PD risk) was significantly stronger than in boys with low CI and high PD. Examination of the effects of IQ under the different conditions indicated that IQ was only significant and negative when both CI and PD were low (low CI, low PD condition: $B = –0.49$, $SE = 0.14$, $p < .01$, $OR = 0.61$). The findings suggest that higher IQ particularly reduced the risk of being arrested when both CI and PD were low, as compared to when CI was low and PD was high.

Third, the difference between the effects of PD under the different CI/IQ conditions (1: high CI, high IQ; 2: high CI, low IQ; 3: low CI, high IQ; and 4: low CI, low IQ) was similarly tested. The results are depicted in Figure 3c. Significant differences were found between two of the six pairs of PD lines: the PD effect under the low CI, high IQ condition differed from the high CI, low IQ condition ($t = –2.06$, $p < .05$) and the low CI, low IQ condition ($t = 2.27$, $p < .05$). The influence of PD on arrest probability was significant and positive when CI was low and IQ high ($B = 0.48$, $SE = 0.13$, $p < .001$, $OR = 1.61$), and this effect was significantly stronger in low CI/high IQ boys as compared to boys with high/low CI and low IQ. These findings suggest that higher PD particularly increased the probability of arrest when CI was low and IQ was high (no cognitive risk), as compared to when IQ was low. The influence of PD did not differ when IQ was low.

Theft and violence

We explored whether the findings applied similarly to being arrested for theft and violence. As done when using the overall arrests rate as outcome, we tested for two-way interactions between CI and the parenting/peer variables, IQ and the parenting/peer variables, and possible three-way interactions among CI, IQ, and the parenting/peer variables for theft and violence. To test for possible differences in the size of the interaction term between the models with theft and in the models with violence as an outcome, we examined overlap in the 95% confidence intervals of the odds ratios of the interaction terms for both outcomes. Findings showed that all 95% confidence intervals overlapped between theft and violence, suggesting no different prediction patterns between theft and violence.

Discussion

The present study examined in an at-risk community sample whether the association between cognitive impulsivity and delinquency between ages 13 and 29 years would be moderated by parenting behaviors and peer relationships, whether a

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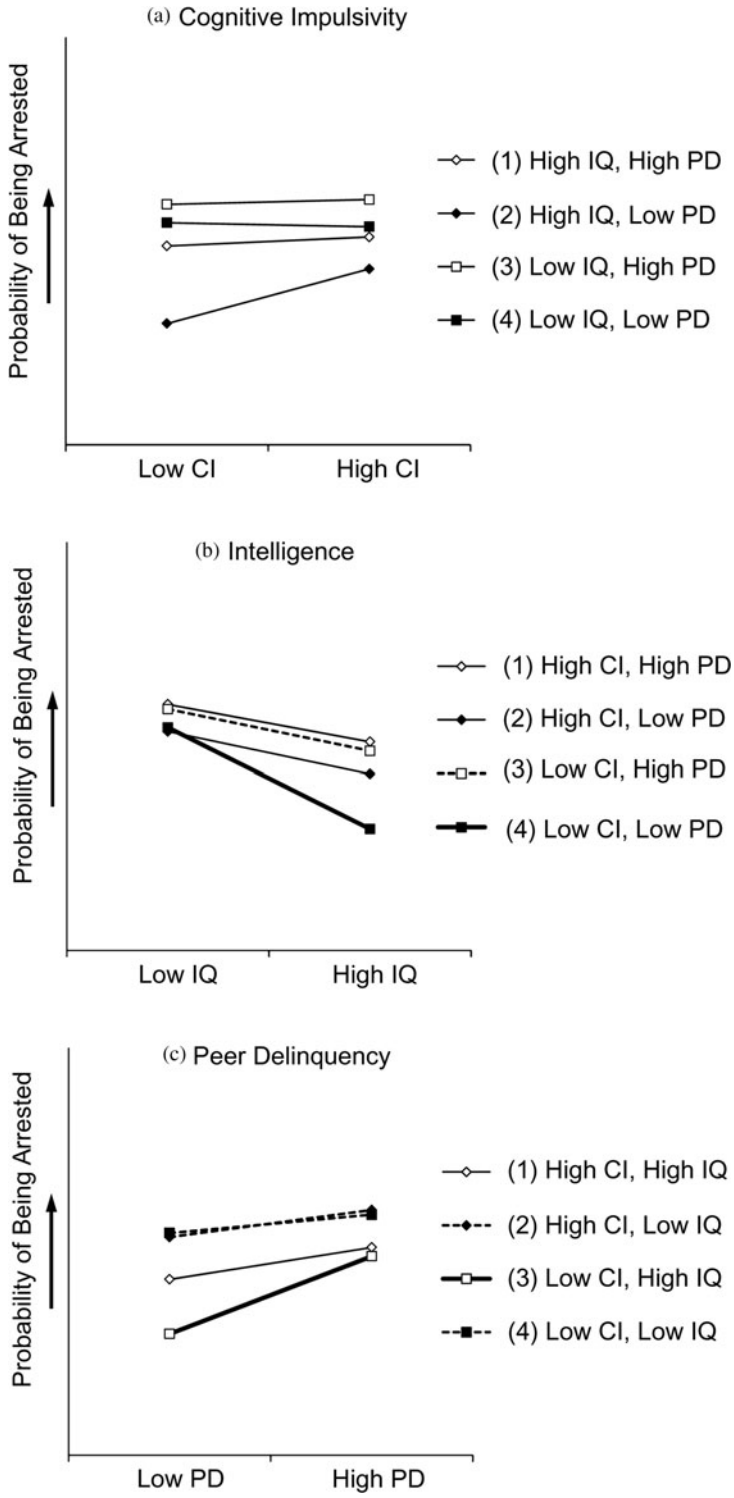

Figure 3. Probing the significant three-way interaction (following Dawson & Richter, 2006). The effects of (a) cognitive impulsivity (CI), (b) intelligence (IQ), and (c) peer delinquency (PD) on the probability of being arrested as a function of high/low (for CI and IQ: $M + 1\ SD/M - 1\ SD$; for PD, results were probed with $M + 0.8\ SD/M - 0.8\ SD$ to better match the range of PD scores) levels of the other two variables in the three-way interaction. In (b) line 4 (bold) differed significantly from line 3 (dotted), but not lines 1 and 2. In (c) line 3 (bold) differed from lines 2 and 4 (dotted), but not line 1.

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similar moderating role of parenting behaviors/peer relationships applied to intelligence (a broader measure of cognitive functioning), and whether the effect of cognitive impulsivity was moderated by parenting and peer relational factors and intelligence. We hypothesized that cognitive risk would be more strongly associated with an increased risk for arrest among boys living in poorer social environments relative to those living in better environments (Lynam et al., 2000; Moffitt, 1993).

In this study, the overall arrest rate mirrored the age–crime curve found in previous studies, with the peaked proportion of youth being arrested occurring around age 17 (Farrington, 1986). In accordance with our hypothesis, our results showed that the impact of cognitive impulsivity (but not intelligence) on delinquency from ages 13 to 29 was moderated by parenting behaviors. However, the nature of this moderation effect was different from our expectations, with higher levels of cognitive impulsivity being associated with an increased risk for later arrest for boys who were exposed to good parenting behaviors (i.e., the *absence* of social environmental risk). In contrast, for boys living in a poor parenting environment (i.e., the *presence* of social environmental risk), their level of cognitive impulsivity did not influence their probability of being arrested. These effects were found even after controlling for the presence of early antisocial behavior and intelligence.

For peer relationships, findings were more complex. No effects of conventional activities with peers on arrest rates were found. However, there was a complex interaction among peer delinquency, cognitive impulsivity, and intelligence. The results showed that the influence of cognitive impulsivity on delinquency did not significantly differ between the combinations of high/low intelligence and peer delinquency. Thus, in contrast to our hypothesis, the effect of cognitive impulsivity was not significantly affected by the boys' level of intelligence or peer delinquency. It appeared, however, that the association between intelligence and arrest from adolescence into adulthood was significantly influenced by peer delinquency and cognitive impulsivity. That is, lower intelligence was found to be a significant predictor of arrests when both cognitive impulsivity and peer delinquency were low (low risk), and a significantly stronger predictor relative to when cognitive impulsivity was low and peer delinquency was high.

Although we expected to find that boys with high levels of cognitive impulsivity would be particularly prone to be arrested when living in a risky social environment (comparable to the dual-risk type; see Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2007), we found something else. This could perhaps be due to the longer age range of arrest scores, the developmental period in which cognitive and social environmental factors were assessed, the different and combined (neuro)cognitive factors, and/or social environmental factors included in this study, as compared to studies for instance by Lynam et al. (2000) and Moffitt (1993). The current findings for cognitive impulsivity and the parenting behaviors are actually more in line with the social push hypothesis, which suggests that biological factors such as cognitive impulsivity increase antisocial outcomes when there is no predisposing social risk, but that any impact of cognitive impulsivity may be overshadowed by social risks in an at-risk environment (see Mednick, 1977; Raine, 2002). Regarding the interaction among cognitive impulsivity, intelligence, and peer delinquency, our findings also differed from the initial dual-risk type hypothesis (Belsky et al., 2007; Moffitt, 1993). The type of interaction found for peer delinquency was also supportive of the social push hypothesis (Raine, 2002). However, this seemed to apply more to the more general aspect of cognitive functioning intelligence (although intelligence was not the primary focus of this study) instead of cognitive impulsivity. The effect of cognitive impulsivity was not significantly influenced by intelligence and peer delinquency, but the effect of intelligence on delinquency was found to be only (and significantly stronger) related to future arrest for boys in a low-risk versus high-risk peer environment. This difference in effect of intelligence in the different peer delinquency conditions was only found when cognitive impulsivity was low, suggesting that cognitive impulsivity did play a moderating role (note also that the two-way interaction between intelligence and peer delinquency was nonsignificant; i.e., without taking cognitive impulsivity into account as a moderator, the influence of intelligence and peer delinquency on arrest did not depend on each other).

Our findings supported the importance of some of the social environmental factors in the development of delinquency suggested by the social push hypothesis under certain conditions. More specifically, this study showed that good parental knowledge reduced the probability of being arrested when cognitive impulsivity was low to average (absence of cognitive risk), but not when cognitive impulsivity was high. Similarly, affiliating with delinquent peers increased the probability of later arrest predominantly for boys with higher cognitive abilities (high intelligence and low cognitive impulsivity). Although not the main focus of this study, it is also worth mentioning that main effects of parental knowledge and peer delinquency were significantly associated with arrest probability (in line with Deater-Deckard, 2001; Loeber et al., 1986), indicating the robustness of these factors. Persistence of discipline and positive reinforcement, however, were not associated with future arrest regardless of the level of cognitive risk, at least not in late childhood/early adolescence. It is possible that these factors may influence the development of deviant behavior earlier in childhood. This study's findings suggest that is it particularly important to focus on increasing parental knowledge and reducing peer delinquency among late childhood/early adolescent boys who exhibit relatively high cognitive functioning in order to reduce the risk of future arrest. Parenting training programs that improve parental monitoring and enhance parents' knowledge of their youths' whereabouts could help reduce the risk of being arrested. Because child disclosure may also contribute to this (Kerr, Stattin, & Burk, 2010), interventions should also focus on improving the relationship and trust between parents and youths (see Hoeve et al., 2009). Parenting training programs

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with such components have been found to reduce behavior problems and delinquency, not only in younger children (Mulford & Redding, 2008). Regarding peer relationships, interventions should prevent at-risk youth from affiliating with delinquent peers. For example, youths with an increased risk of developing problems may be better off at regular schools where their special needs are met with innovative strategies, instead of going to special education; disciplinary suspension and expulsion should be avoided because they increase the chance of spending more unsupervised time with delinquent peers (Gifford-Smith, Dodge, Dishion, & McCord, 2005). Our findings indicate that, at least in youth with lower cognitive risk, interventions focusing on training parents to monitor and reduce their youths' affiliation with delinquent peers could particularly help in preventing delinquency (Gifford-Smith et al., 2005; Henggeler, Cunningham, Pickrel, Schoenwald, & Brondino, 1996).

Our findings also indicate the relevance of targeting cognitive impulsivity to reduce the likelihood that youth will be arrested over adolescence and into the young adult period. It seems particularly important to address children's problems with cognitive impulsivity when they are being raised in good parenting environments (i.e., high positive reinforcement and high parental knowledge). Thus, in a good social environment, it is important to assess boys' cognitive impulsivity, and when cognitive impulsivity is high, improving cognitive control could reduce the risk of becoming arrested. Moreover, the findings suggest that improving parenting behaviors may not influence boys' risk of exhibiting later criminal behavior unless their high level of cognitive risk is reduced at the same time. Similarly, reducing peer delinquency would also have most effect when intelligence is high and cognitive impulsivity low. Because intelligence, and particularly crystallized intelligence, which is measured with vocabulary and general information tests, has been found to be relatively fixed (see Sternberg, 2008), cognitive impulsivity might be more malleable than intelligence. Interventions designed to foster the development of cognitive/executive functioning, such as computerized working memory training and martial arts, are described to have promising results in improving children's cognitive/executive functioning, particularly in children who scored poorly initially (Diamond & Lee, 2011). Training more specific cognitive functions such as working memory may also be effective in improving other domains of cognitive functioning (Klingberg, 2010). However, the development of empirically validated interventions that lead to meaningful and persisting effects on cognitive impulsivity is still in its infancy, so more research is necessary to study existing and newly developed programs and their effects. It is also interesting to test these programs when other domains, including social development, are simultaneously addressed, because combined interventions may be more effective (Diamond & Lee, 2011).

This study also explored whether the moderation effects found for general delinquency applied differently to theft and violence, because previous studies found different predictors of both types of delinquency (Barker et al., 2007, 2011; Hoeve et al., 2009; Loeber et al., 2012). Our findings suggest that the moderation effects found for general delinquency did not differ substantively for the subtypes theft and violence. To our knowledge, no other studies have examined such moderation effects on different types of delinquency, so it would be important to replicate these findings in future studies.

It is important to interpret the current findings in the context of several limitations. First, the study used an urban male sample that included a disproportionate number of boys with conduct problems. For this reason, it is unclear whether our findings can be generalized to the broader population of males, and females. In addition to sex differences in the prevalence of delinquency, there are some indications that social environmental factors could have a different impact on delinquency in girls (Hoeve et al., 2009; Wong et al., 2013).

Second, delinquency was measured with official arrest data. Despite the advantages of official arrests in longitudinal research, such as continuous recording at fixed time points and no recall errors, arrest data often underestimate actual delinquency because many offenses go undetected by law enforcement. This may apply particularly to younger children bcause the peak of the arrest curve was found to be later for official data compared with self-reported delinquency (Kirk, 2006), and it likely also applies more to less visible/severe offenses. In addition, impulsive children may be more likely to be arrested because they are less skillful in committing crimes without being caught. When using self-report data as opposed to arrest data, the difference between impulsive and nonimpulsive youth may be smaller, and the association between impulsivity and delinquency may also be affected differently by the social environment. Furthermore, dichotomized scores were used for arrests (any offense, theft, and violence) within each age year across a time span of 17 years. However, by doing this, the differences in frequency within each age year as well as the variety of different offense types within 1 year were not accounted for. Therefore, it is important for future studies to examine the moderation hypothesis within the context of a longitudinal study that used self-reports as well as information on the frequency and variety of delinquent acts committed within each time unit from adolescence to adulthood.

Third, the measure of parental knowledge used is likely partially confounded with the boys' behavior. The extent to which parents are aware of their child's whereabouts may depend on individual characteristics of the child, such as the extent to which they disclose information about their activities (Kerr et al., 2010). It is important to note that the correlation between some of the social environmental risk variables and cognitive impulsivity/intelligence were significant, albeit small/moderate in magnitude. This suggests that boys with a higher cognitive risk may have influenced their at-risk social environment to a modest degree. If these correlations were very high, this would have suggested that a higher social risk could have resulted from the boys' expression of high

cognitive risk, which then may result in an overshadowing of the impact of cognitive functioning in the prediction of delinquency. Our results suggested that this was not the case.

Fourth, cognitive impulsivity was assessed with a limited set of cognitive tests, not with direct measures of brain functioning such as functional magnetic resonance imaging. Moreover, even though the three tests used to construct the broader cognitive impulsivity measure included multiple aspects relevant for delinquency, the correlations between the tests were modest. This may have affected our findings. For example, not all test scores may have equally contributed to the interaction effects found in this study. Future studies should focus on more specific effects of different measures tapping into different domains of cognitive functioning. The same could be said for the combined parent–child parenting measures, with modest correlations between informants on the same construct.

Fifth, cognitive impulsivity was assessed only once in early adolescence, making it impossible to test changes in cognitive impulsivity across development and possible effects of these changes on the course of offending. Although individual differences in cognitive functioning deficits tend to be rather stable over time (Biederman et al., 2007), it would be important to retest our hypothesis with measures of cognitive functioning assessed repeatedly, in order to examine possible temporal interrelations between cognitive functions and delinquency, and to take into account that frontal brain areas associated with impulsivity and self-control develop across adolescence (see Silveri et al., 2013; Steinberg, 2010). Similarly, parenting behaviors and peer relationships were measured in late childhood and early adolescence only. High-risk environments in childhood may be a harbinger of high-risk environments in adolescence and adulthood. If both cognitive/brain functioning and social relational processes were repeatedly assessed over a longer period, it would be possible to further examine the mutual influences between these two factors across time (e.g., a good, authoritative parenting environment could also facilitate the development of self-regulation; Steinberg, 2001).

Sixth, this study focused only on boys from late childhood onward, making it impossible to say anything about the role of parenting/peer relations at earlier ages. As theorized by Moffitt (1993), cognitive vulnerabilities are likely exacerbated by social environmental risks at very young ages, thereby increasing the chance of antisocial development. This dual-risk type of interaction may apply more to earlier developmental periods and the development of behavior problems as a precursor of delinquency, as compared to risk factors in late childhood/early adolescence as predictors of delinquency into adulthood. Moreover, the role of parenting and peer relational factors may be different in earlier developmental periods. For instance, positive parenting may be influential during earlier stages of development, but may become less influential in adolescence when peers may become more prominent in affecting youth's behavior (Steinberg & Monahan, 2007). Consequently, we do not know whether poor parenting and peer delinquency during late childhood modify the impact of cognitive impulsivity on delinquency development, whether earlier social environmental factors already account for these effects, or whether they have additive effects. Future studies are needed to examine this.

Seventh and finally, although interaction analyses are an obvious and commonly used method to test moderation, interaction effects may be harder to replicate and tend to have smaller effect sizes. Therefore, this study's interesting and initially less expected interaction findings should be interpreted with some caution, and it is important to further replicate them in future research.

In summary, the findings from this study indicate that the effect of cognitive impulsivity, and in one occasion also intelligence, on the probability of offending depends on social–contextual factors. This implies that both individual cognitive and social environmental risks need to be taken into account when investigating offending, and not only as additive main effects. When taking social environmental factors into account as possible moderators, researchers may find (stronger) effects of cognitive variables on offending, particularly for those young males in a good social environment (cf. Raine, 2002). Similarly, the importance of cognitive skills in the prediction of delinquency may be underestimated in the presence of environmental risks when such risks are not taken into account. Moreover, these findings indicate that screening for the presence of social and cognitive risks in late childhood/early adolescence may help to promote more individualized and effective delinquency prevention programs. For boys who exhibit relatively intact cognitive (control) abilities, it appears particularly important to improve the social environment by increasing parental knowledge and reducing peer delinquency. In contrast, programs for boys exhibiting high levels of cognitive impulsivity should work toward enhancing their cognitive control abilities (e.g., by improving inhibition and working memory skills), although it is unclear whether and to what extent existing cognitive training programs can accomplish this task. Thus, our findings suggest that efforts to prevent children from being delinquent will likely be most effective when targeting cognitive and social environmental risks simultaneously.

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