Chapter 3
Problem Behavior and Heart Rate Reactivity in Adopted Adolescents: Longitudinal and Concurrent Relations

Abstract

The present longitudinal study examined resting heart rate and heart rate variability and their reactivity to a stressful gambling task in adopted adolescents with aggressive, delinquent, or internalizing behavior problems and adopted adolescents without behavior problems (total $N = 151$). Early-onset delinquent adolescents showed heart rate hypo-reactivity to the stress-eliciting gambling task compared to late-onset delinquent adolescents and adolescents without behavior problems. Heart rate, heart rate variability, and reactivity to stress were not related to environmental factors such as early-childhood parental sensitivity, parental socioeconomic status, or children’s health status in the first year of life. The differentiation between delinquency and aggression, and between childhood-onset and adolescence-onset delinquency (Moffitt, 1993) was found to be important in investigating stress reactivity in adolescents.

Introduction

Genetic and biological processes have been found to play an etiological role in the development of aggressive and antisocial behavior (Eley, Lichenstein, & Stevenson, 1999; Ge et al., 1996; Raine, 1993; Slutske et al., 1997) and environmental processes may produce physiological changes in both the central nervous system (CNS) and the autonomic nervous system (ANS) functioning in a way that can predispose to aggressive and antisocial behavior (Suomi, 2000; Raine, 1997). The present longitudinal study examined resting heart rate and its reactivity to a stressful situation in adolescents with and without aggressive, delinquent, or internalizing behavior problems. This study is the first to assess these associations in adopted children, who are raised by their biologically unrelated adoptive parents. In adoptive families, genetic influences that predispose children for developing behavior problems are less likely to be intensified by a problematic rearing environment compared to non-adoptive families (Golombok, MacCallum, & Goodman, 2001; Golombok, MacCallum, Goodman, & Rutter, 2002).

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Psychophysiological correlates of antisocial behavior and other behavior problems

The psychophysiological correlates of aggressive, antisocial, and violent behavior are somewhat ambiguous, and there have been mixed results in studies relating tonic levels of autonomic activity to behavior problems (Dettling, Gunnar, & Donzella, 1999; Fishbein, Lozovosky, & Jaffe, 1989; Lahey, McBurnett, Loeber, & Hart, 1995; Patrick, Zempolich, & Levenston, 1997; Raine, 1993; Susman, Granger, Murowchick, Ponirakis, & Worrall, 1996; Volavka, 1995). In contrast to the inconsistent findings relating global arousal to aggressive and antisocial behavior, low resting heart rate is the best-replicated biological correlate of antisocial and aggressive behavior in child and adolescent populations (Raine, 2002). In a meta-analysis incorporating 29 independent samples, the average effect size was \( d = .56 \) (Raine, 1996). This combined effect size is robust in that it is found in both female (\( d = .63 \)) and male samples (\( d = .50 \)), and when heart rate is taken from a pulse reading (\( d = .49 \)) as well as when it is measured from a Grass polygraph (\( d = .53 \)). More recently, Ortiz and Raine (2004) conducted a meta-analysis on 45 independent effect sizes obtained from 40 studies on the association between heart rate and antisocial behavior in children and adolescents. A significant overall effect size was found for resting heart rate. Antisocial children had significantly lower resting heart rates (\( d = .44 \)). These findings suggest that antisocial and aggressive behavior may be associated with ANS underarousal in terms of low sympathetic and high parasympathetic nervous system activity. This pattern of underarousal may trigger individuals to seek out stimulation, for example by engaging in antisocial or criminal behaviors (Fox, Schmidt, & Henderson, 2000).

In addition to tonic levels of autonomic arousal, antisocial behaviors have been related to unique patterns of autonomic reactivity to various environmental stimuli or situations. Raine, Venables, and Williams (1990a) found that heart rate hyporeactivity to auditory stimuli in 15-year-old male subjects predicted criminal behavior at age 24. This pattern of hyporesponsivity was predictive over and above the predictive effects of tonic heart rate levels, suggesting that hyporesponsivity was not simply a function of overall physiological arousal but may be a risk factor for later criminal behavior (Fox, Schmidt, & Henderson, 2000). In their meta-analysis on heart rate and antisocial behavior in children and adolescents, Ortiz and Raine (2004) also found that antisocial behavior was negatively associated with heart rate in a stress condition (\( d = .76 \)). It was hypothesized that antisocial individuals are lacking in anxiety, are fearless, and are particularly unresponsive to aversive social contexts.

Even though low resting heart rate is the best-replicated biological correlate of antisocial and aggressive behavior and reduced heart rate reactivity predicts criminal behavior, some studies did not find such a relation between heart rate or heart rate reactivity on the one hand and aggressive or anti-social behavior problems on the other hand (for a recent example see Van Hulle, Corley, Zahn-Waxler, Kagan, & Hewitt, 2000). Different definitions and measurements of aggression and anti-social behavior may be responsible for
these diverging results. For example, most studies have assessed antisocial behavior in general without differentiating between aggressive and non-aggressive forms of antisocial behavior. Besides such different types of antisocial behavior, there are groups of individuals with different developmental courses of these problem behaviors (Caspi & Moffitt, 1995; Loeber, 1982; Loeber & Coie, 2001; Moffit, 1993; Moffitt & Caspi, 2001). Raine, Venables and Williams (1995) found a difference in heart rate and heart rate reactivity between adolescence-limited and life-course persistent antisocial individuals. Adolescent-limited antisocial individuals had higher resting heart rates and greater electrodermal orienting responses than their persistent antisocial peers. Adolescence-limited antisocial individuals had also higher heart rates and greater electrodermal orienting responses than non-antisocial adolescents, but these differences did not reach statistical significance. Adolescence-limited antisocial individuals may thus respond in the same way as their non-antisocial peers do, or their greater autonomic arousal may reflect a unique protective mechanism against committing crime (Fox et al., 2000). Life-course persistent offenders have been hypothesized as having early neurobiological deficits (Moffitt, 1993), and Moffit and Caspi (2001) recently reported that low resting heart rate assessed at ages 7, 9, and 11 years is particularly characteristic of life-course persistent offenders. Differences in heart rate and heart rate reactivity between adolescence-limited and life-course persistent antisocial individuals may be essential in studying stress reactivity in antisocial adolescents.

Whereas aggressive and antisocial problem behaviors have been linked to low resting heart rate and hyporeactivity to stress, other problem behaviors have been linked to higher resting heart rates and/or hyperreactivity. These relations have been found particularly for behavior problems of an internalizing nature, such as anxiety (Mezzacappa et al., 1997; Rogeness, Cepeda, Macedo, Fisher, & Harris, 1990), inexpressive emotion regulation (Cole, Zahn-Waxler, Fox, Usher, & Welsh, 1996), behavioral inhibition (Garcia-Coll, Kagan, & Reznick, 1984; Kagan, 1989; Kagan, Reznick, & Snidman, 1987, 1988; Scarpa, Raine, Venables, & Mednick, 1997), and emotional disturbances (Garralda, Connell, & Taylor, 1991). Kagan et al. (1987, 1988) suggested that heightened physiological responsivity in inhibited individuals may reflect a tendency to respond to uncertainty and novel situations with stress which, in turn, may lead to future anxiety disorders.

Heart rate and heart rate reactivity in adolescents with and without behavior problems

The current study has some additional strength in comparison with previous studies on heart rate and behavior problems. We compared adolescents with behavior problems to adolescents without these problems, but we also distinguished between individuals with late-onset and individuals with early-onset delinquent and aggressive behavior problems. Both resting heart rate and heart rate reactivity during a stressor were examined. For example, antisocial and aggressive behavior may be associated with ANS underarousal in terms of low resting heart rate because it may cause individuals to seek out stimulation by
engaging in antisocial or criminal behaviors (Fox et al., 2000), but it has not been tested whether individuals with low resting heart rate are also unresponsive to aversive social contexts or stressful situations (Raine, 1993). If they are unresponsive to stress, heart rate reactivity during stress will be lower than heart rate reactivity in non-antisocial individuals.

A limitation of many studies on the relation between heart rate and antisocial behavior is that they do not distinguish between aggressive and non-aggressive forms of antisocial behavior (Ortiz & Raine, 2004). Therefore, it is unclear whether low heart rate is more specific to aggressive or non-aggressive forms of antisocial behavior. In the present study, a distinction was made between adolescents with aggressive behavior problems (for example, fighting, attacking others, teasing) and adolescents with delinquent behavior problems (for example, stealing, setting fire to something, vandalism). Moreover, only a few studies have investigated behavior problems of an internalizing nature (but see for example Cole et al., 1996; Scarpa et al., 1997) or compared internalizing and externalizing problems within the same sample (Mezzacappa et al., 1997). The present study investigated both internalizing and externalizing behavior problems within the same sample of adolescents. We investigated continuous and categorical measures of behavior problems. The continuous score represents behavior problem rate, and the categorical measure indicates the severity of a particular behavior problem, that is, whether the incidence of behavior problems of a particular individual exceeds a cutoff score and equals the incidence of behavior problems of children who have been referred to clinical settings (cutoff scores distinguishing deviant from non-deviant children). In previous studies the lack of differential reactivity for children with problem behaviors might be related to the use of continuous scores for behavior problems that mask differences between groups in the clinical range.

To date most studies on the phenomenon of life-course-persistent antisocial behavior included only males. Moffitt, Caspi, Rutter, and Silva (2001) argued that the biological mechanisms underlying antisocial behavior are the same in males and females, but Mednick, Kirkegaard-Sorensen, Hutchings, Knop, Rosenberg and Schulsinger (1977) hypothesized that biological correlates of antisocial behavior are stronger in females than in males. In the meta-analysis of Ortiz and Raine (2004) gender did not moderate the relation between heart rate and antisocial behavior. Because in our sample males and females were included in comparable proportions, we were able to investigate whether the relations between heart rate and different behavior problems hold for male and female adolescents.

Ortiz and Raine (2004) reported that in their meta-analysis on the association between heart rate and antisocial behavior only two out of 40 studies controlled for increased cigarette smoking in antisocial children, although smoking is associated with heart rate (Farrington, 1997). The present study not only examined the influence of cigarette smoking on heart rate, but also the potential influence of physical conditioning through sports participation (De Geus, Boomsma, & Snieder, 2003; Katona, Mc Lean, Dighton, & Guz, 1982;
Vander, Sherman, & Luciano, 2001) and associations with IQ (Farrington, 1997; Raine, Venables, & Williams, 1990b).

The current study is the first to assess the association between heart rate and behavior problems in adopted adolescents. All studies in the meta-analysis of Ortiz and Raine (2004) concerned non-adoptive families. The parents of these families may transmit a genetic predisposition for antisocial behavior to their children, and also provide a rearing environment that provokes antisocial behaviors. The adoptive parents in the current study are predominantly from middle-class or upper middle-class backgrounds and were screened for the absence of a criminal past before the adoption. The adopted children were neither selected by nor matched to the characteristics of their future adoptive parents.

Decades of research have documented associations between antisocial behavior and adverse environments, both within the family and beyond. Antisocial behavior has been related, among others, to parental insensitivity or maltreatment, low socioeconomic status, and the child’s health (see Maughan, 2001, for a review of environmental influences and disruptive behavior problems). As the adolescents of the present study participated in a longitudinal study which began in infancy, information regarding pertinent characteristics of their rearing environments was available. It was thus possible to test empirically whether problem behaviors and resting heart rate or heart rate reactivity were related to environmental factors such as parental sensitivity, parental socioeconomic status or children’s health status in the first year of life.

In sum, the present study focused on the following questions: First, how are rates of aggressive, delinquent, and internalizing problem behaviors associated with resting heart rate? We expected to find positive correlations between resting heart rate and internalizing behavior problems (Kagan, Reznick, & Snidman, 1987). Because the continuous measures for aggression and delinquency may confound early- and late-onset of the behavior problems we did not expect to find a similarly clear-cut association between externalizing problems and resting heart rate. Second, do adolescents with aggressive, delinquent, and internalizing behavior problems (categorical syndromes) and adolescents without behavior problems show different resting heart rate? We expected to find lower resting heart rate in adolescents with early-onset persistent delinquent and aggressive behavior problems compared with all other groups and higher heart rate in adolescents with internalizing behavior problems. Third, do adolescents with aggressive, delinquent, and internalizing behavior problems and adolescents without behavior problems show different heart rate reactivity to a stress-eliciting task (change in heart rate from baseline to a stress-eliciting task)? We expected to find heart rate hyporeactivity in adolescents with early-onset persistent delinquent and aggressive behavior problems compared with all other groups and heart rate hyperreactivity in adolescents with internalizing behavior problems. Measures of heart rate reflect the contribution of parasympathetic and sympathetic nervous system influences.
to resting heart rate and heart rate reactivity. Parasympathetic influences to resting heart rate and heart rate reactivity can be easily obtained in a non-invasive design as used here, by time- or frequency domain based measures of heart rate \textit{variability} (Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology, 1996). With respect to heart rate \textit{variability}, we expected to find lower resting heart rate variability, i.e. lower parasympathetic tone, in adolescents with internalizing behavior problems (Porges, 1995, 2001) and higher resting heart rate variability, i.e. higher parasympathetic tone in adolescents with early-onset persistent delinquent and aggressive problem behaviors. We expected to find an increase in heart rate variability from baseline to a stress-eliciting task in adolescents with early-onset persistent delinquent and aggressive behavior problems compared with the other groups, and a decrease in heart rate variability in adolescents with internalizing behavior problems. A final question to be addressed is whether environmental factors such as parental sensitivity and parental socioeconomic status are related to behavior problems, to heart rate, heart rate variability and their reactivity to stress. We expected to find significant effects of these environmental factors on behavior problems, on heart rate, and on heart rate reactivity.

Method

Participants

Participants were 151 14-year-old internationally adopted children (67 boys and 84 girls), participating in a longitudinal study which began in infancy with 160 children (Juffer, Hoksbergen, Riksen-Walraven, & Kohnstamm, 1997; Juffer, Van IJzendoorn, & Bakermans-Kranenburg, in press; Stams, Juffer, Rispens, & Hoksbergen, 2000; Stams, Juffer, & Van IJzendoorn, 2002). All adoptive families were randomly recruited through Dutch adoption organizations. The children were adopted before the age of 6 months ($M = 9.9$ weeks; $SD = 5.33$) and they were adopted from Sri Lanka ($n = 93$), South Korea ($n = 38$), and Colombia ($n = 20$). The adoptive parents were Caucasian white and screened for the absence of a criminal past before the adoption. The adoptive families were predominantly from middle-class or upper middle-class (Stams et al., 2002). At the time of the birth of the children the mean age of the adoptive fathers was 35.0 ($SD = 3.26$) and of the adoptive mothers 32.9 ($SD = 3.06$).

Procedure

Families were visited at home at 5, 6, 9, and 12 months. Mothers and children came to the laboratory at 12, 18, and 30 months. At 7 years, families were visited at home to conduct an interview with the mother and to administer the Child Behavior Checklist (CBCL; Achenbach, 1991b). At 14 years, the families were visited at home again to measure heart rate of the adolescents during completion of a questionnaire in absence of the experimenter that served
Problem Behavior and Heart Rate Reactivity

as a baseline, and during a stressful gambling task with the experimenter present. The gambling task and the questionnaire were completed in the bedroom of the adolescent. The experimenter connected the adolescent to the ECG recording device (the Vrije Universiteit Ambulatory Monitoring System, VU-AMS; Klaver, De Geus, & De Vries, 1994) and explained each step of the process in nontechnical language. Participants were told that their heart rate would be monitored during the episodes in order to examine if a particular episode or situation was more exciting than other episodes. All teenagers were visited by the same experimenter. During the home visit the adoptive mother completed the CBCL.

Measures

Behavior problems. Mothers completed the Child Behavior Checklist (CBCL; Achenbach, 1991b) to assess the adolescent’s behavior problems. The CBCL has shown satisfactory reliability and good validity (Achenbach, 1991a, 1991b; Verhulst, Van der Ende, & Koot, 1996, 1997b). It consists of 118 items describing behavioral/emotional problems. The problem items are scored on similar 3-point scales: a 0 is given if the problem is not true for the child, a 1 if the item somewhat or sometimes true and a 2 if the item very true or often true. A total problem score is computed by summing all scores. The present paper examined the following syndromes: aggression and delinquency (being part of the broad-band syndrome externalizing behavior problems), and the broad-band syndrome internalizing behavior problems.

Besides continuous scores for the different syndromes cutoff scores are available to distinguish deviant from non-deviant scoring children. On the basis of these criteria, it is possible to determine the percentage of adolescents falling in the borderline clinical and clinical range for each of the syndromes. The incidence of behavior problems in children exceeding the clinical cutoff criterion is likely to equal the incidence of behavior problems in children who have been referred to clinical settings. Children in the borderline clinical range also show substantial and serious behavior problems (Achenbach, 1991b, 1991c; Verhulst et al., 1996). We used cutoff points that were based on a sample of 2227 children and adolescents, drawn from the Dutch general population in 1993 (Verhulst et al., 1996). Achenbach (1991b) found that for the specific syndrome scales the 95th percentile and for the broad-band syndrome scales the 82nd percentile were the best cutoff points for the differentiation between children in the normal range on the one hand and children in the borderline clinical and clinical range on the other hand. These cutoffs reflect differences in scores between groups of children that were referred to mental health clinics and groups of children that were not referred (Achenbach, 1991b). Adolescents without behavior problems (hereafter: ‘normal adolescents’) were teenagers who did not exceed the cutoff point of any of the behavior problem syndromes (aggression, delinquency, and internalizing behavior problems). In the analyses, individuals who were deviant on a particular syndrome were compared with these adolescents without any behavior problems. Early-onset delinquents were also compared with late-onset
delinquents and early-onset aggressive adolescents were compared with late-onset aggressive adolescents. We did not compare adolescents with a particular syndrome with adolescents with another syndrome because of the high comorbidity of the syndromes and therefore the low sample sizes in case the comorbid adolescents were left out of those analyses. The comorbid adolescents were included in both syndrome groups in the comparisons with the adolescents without any behavior problems. In order to control for co-occurring symptoms of delinquency and aggression, the continuous scores for the syndrome scales were used as a covariate in the analyses (ANCOVAs), e.g., in the comparisons of early-onset and late-onset delinquents and normal adolescents, the continuous score of aggression was used as a covariate. Gender differences in the number of deviant adolescents were found for the syndromes delinquency and aggression: More boys than girls were deviant on these syndrome scales ($\chi^2(1, N = 148) = 6.67, p = .01$, and $\chi^2(1, N = 148) = 10.41, p < .01$, respectively). There were no differences between children from Sri Lanka, South Korea or Colombia ($p > .10$).

In order to distinguish between early-onset and late-onset delinquent and aggressive behavior problems, we examined the cutoff scores at 7 years and at 14 years. Moffitt and Caspi (2001) suggested that life-course-persistent antisocial behavior originates early in life (early-onset behavior problems) and that adolescence-limited antisocial behavior emerges alongside puberty (late-onset behavior problems). In the present study, the terms early- and late-onset delinquent or aggressive adolescents were used because delinquent and aggressive behavior was assessed at the age of 7 and 14 years and not after adolescence. Early-onset adolescents were individuals that were deviant on the syndrome delinquent or aggressive at both 7 and 14 years and late-onset adolescents were individuals that were deviant at 14 years but not at 7 years.

Heart rate. For the recording of heart rate by the VU-AMS device, three disposable ECG electrodes were placed on the adolescent’s chest. Before placing the electrodes, the skin was rubbed firmly with alcohol (by the adolescent her or himself). One electrode was placed at the jugular notch of the sternum between the collarbones, the other one below the left breast, 4 cm (1.5”) under the nipple (between two ribs), and the third at the right side of the chest, between the lower two ribs. After placing the electrodes the resulting signal quality and the electrode attachment were checked by online-monitoring of the HR. The VU-AMS was secured unobtrusively in a little carrying bag attached to a waist belt, allowing the participants to move about freely. Very little inconvenience is generally reported from wearing the device, even over prolonged periods of time (De Geus & van Doornen, 1996). Although changes in posture and physical activity are powerful determinants of ambulatory recorded physiological signals, the questionnaire and the gambling task were administered while the adolescents were seated, so their gross body movement was close to zero.

The device was programmed to continuously record all inter beat intervals. From the interbeat interval time series, an average HR was extracted each 10-second period and written to device memory. The experimenter recorded the time when the various experimental conditions were started or
stopped by pressing a key on the device that measured heart rate. Mean heart rates and heart rate variability (MSSD; mean square of standard differences in interbeat intervals) for resting and stress conditions were computed from all 10-sec periods falling between these condition start and stop times. This yielded the following heart rate measures: (1) resting heart rate defined as the mean heart rate and heart rate variability during completion of a questionnaire (nonstressful situation), (2) heart rate during stress defined as the mean heart rate and heart rate variability during the gambling task, and (3) heart rate reactivity defined as the change in heart rate from rest to stress. The registration of heart rate was successful in all adolescents. The correlation between mean heart rates and heart rate variability was -.56. The standard deviations for MSSD were large (a common phenomenon with MSSD, see also Vrijkotte, van Doornen, & De Geus, 2000). However, no extreme outliers (HR mean < 30 or > 200 and MSSD > 200) were found on inspection of the raw data. Also, no outlying means were identified on the basis of standardized scores (z-values) larger than 3.29 or smaller than -3.29 (p < .001; Tabachnick & Fidell, 2001).

Gambling task (cost benefit reasoning task). The ECG of the adolescents was recorded during a gambling task (Bechara, Damasio, Damasio, & Anderson, 1994). In this gambling task the subjects sat in front of four decks of cards and were given € 20 loan of play money (10 coins of € 1,-; 40 coins of € 0.20; and 40 coins of € 0.05). The subjects were told that they had to choose a number of cards, one card at a time, from any of the four decks, until they were told to stop. Turning each card carried an immediate reward (€ 1,- in decks A and B and € 0.50 in decks C and D). Unpredictably, however, the turning of some cards also carried a penalty (which was large in decks A and B and small in decks C and D). The subjects were free to switch from any deck to another, as often as they wished and at any time. They were told that they had to maximize profit on the loan of play money and that they were not told ahead of time how many cards they had to pick (the task was stopped after a series of 100 cards). The subjects had no way of predicting when a penalty would arise in a given deck and no way to calculate with precision the net gain or loss from each deck. Decks A and B were disadvantageous because they led to the largest losses in the long run (because of the higher penalties compared to the rewards) and decks C and D were advantageous because they resulted in an overall gain in the long run (because of the lower penalties compared to the rewards).

Intelligence. Because intelligence may affect heart rate (but see Farrington, 1997 and Raine, Venables, & Williams, 1990b for an exception), the adolescents completed the abbreviated Groningen Intelligence Test (GIT; Luteijn & van der Ploeg, 1983). We used the following subtests of the GIT: cipher, enumerate words, and word matrices.

Physical condition and smoking. Because physical condition and smoking affect heart rate (De Geus, Boomsma, & Snieder, 2003; Farrington, 1997; Katona, Mc Lean, Dighton, & Guz, 1982; Vander, Sherman, & Luciano, 2001), the adolescents were asked which sports they played during the previous year and how much time they had spent on each sport (less, the same or more compared
to peers). Participants were also asked if they smoked and if so, how much they smoked (1 = never, 2 = a few times, 3 = now and then, 4 = regularly, 5 = often). The same question was asked for smoking soft drugs.

**Health condition on arrival.** Health condition on arrival was an index of the infant’s health condition from the time of birth until arrival (Stams et al., 2002). The information was gathered in the first interview with the parents at the child’s age of 5 months. Health condition on arrival was computed by the standardized summation of three variables: birth weight, incidence of prematurity, and health problems on arrival (reversed). Health problems on arrival included variables such as symptoms of malnourishment, dehydration, anaemia or paratyphoid. A high score represents a good health condition.

**Early-childhood maternal sensitive responsiveness (12, 18, and 30 months).** Maternal sensitive responsiveness was assessed in early childhood by observations of videotaped free-play or task episodes of mother-child interaction at home and in the laboratory. At 12 and 30 months, maternal sensitive responsiveness consisted of seven variables (Stams et al., 2002). Sensitivity and cooperation were assessed during an 8-min free-play situation with the Ainsworth scales (Ainsworth, Bell, & Stayton, 1974). Emotional support, respect for the child’s autonomy, structure and limit setting, hostility, and quality of instruction were assessed in a task situation (e.g., making a simple puzzle) with the five Erickson scales (Egeland, Erickson, Clemenhagen-Moon, Hiester, & Korfmarher, 1990; Erickson, Sroufe, & Egeland, 1985). At 18 months, maternal sensitive responsiveness was measured in a task situation (e.g., building a tower of blocks) with the five Erickson scales (Erickson et al., 1985). The 12-, 18-, and 30-months scores were the standardized summation of all variables divided by their number. The correlation between the 12- and 18-months score was .45 ($p < .01$), between the 12- and 30-months score .27 ($p < .01$), and between the 18- and 30-months score .31 ($p < .01$). Principal-components analysis was performed on the three scores, which resulted in a one-dimensional solution. The explained variance was 58%. Cronbach’s standardized item alpha was satisfactory ($\alpha = .62$). The three scores were therefore combined into one overall score. The overall score of early-childhood sensitive responsiveness ranged from -2.06 to 1.41 ($M = .05$, $SD = 0.78$). Validity data on the sensitive responsiveness scores have been reported in previous studies (see Stams et al., 2002).

**Socioeconomic status.** At 7 years the socioeconomic status (SES) of the adoptive families was assessed. SES was a combination of the educational and vocational background of both parents and was computed on the basis of sample-specific factor loadings and standard deviations (Stams, et al., 2002). Mean scores correspond to socioeconomic strata in the following way: 3 to 9, lower class; 9 to 12, middle class; and 12 to 16, upper class (Bernstein & Brandis, 1970). The mean score of parental socioeconomic status was 10.03 ($SD = 2.68$, range = 2.99 to 14.73).
Problem Behavior and Heart Rate Reactivity

Results

Descriptive statistics and background variables and their relations with behavior problems and heart rate

Table 1 presents descriptive statistics and background variables for each of the syndromes and for the group of adolescents without behavior problems (‘normal’). There were no significant differences between adolescents with and without different behavior problems in age on arrival, health condition on arrival, number of card selections from advantageous/disadvantageous decks during the gambling task, number of sports, using soft drugs, and age of the adoptive fathers and mothers (see Table 1). With respect to age at study, adolescents without behavior problems were somewhat older than adolescents with early- and late-onset aggressive behavior problems (see Table 1). Early-onset aggressive adolescents were somewhat younger than adolescents with late-onset delinquent behavior problems. More boys than girls were deviant on early- and late-onset aggression and early-onset delinquency compared with the group of children without behavior problems (see Table 1). Early-onset aggressive and early-onset delinquent adolescents had lower IQ than children without behavior problems. Late-onset delinquents smoked more than all other groups (see Table 1).

Resting heart rate and heart rate variability nor reactivity of heart rate and heart rate variability were associated with health condition on arrival, age on arrival, age at time of the present study, gender, number of card selections from advantageous/disadvantageous desks during the gambling task, IQ, number of sports, smoking behavior, and age of the adoptive fathers and mothers. Because age at study, gender, IQ, and smoking were associated with behavior problems, we used these variables as covariates in the analyses. None of the variables were significant covariates. P-values ranged from .07 (in the comparison of heart rate reactivity of early-onset aggressive versus normal adolescents with IQ as a covariate) to .99 (in the comparison of resting heart rate of internalizing versus normal adolescents with IQ as a covariate). These descriptive and background variables were not included, therefore, in further analyses.

How are aggressive, delinquent, and internalizing problem behaviors associated with resting heart rate?

There were no significant correlations between aggressive, delinquent, and internalizing problem behaviors on the one hand and resting heart rate and heart rate variability on the other hand. Table 2 presents resting heart rate and heart rate variability with standard deviations for adolescents with (early-onset and late-onset) aggressive, (early-onset and late-onset) delinquent, and internalizing problem behaviors and for adolescents without problem behaviors (categorical syndromes). There were no significant differences in resting heart rate and heart rate variability between the different behavior problem groups and the adolescents without behavior problems.
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<th></th>
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<th>Aggressive (n = 19)</th>
<th>Delinquent (n = 25)</th>
<th>Internalizing (n = 46)</th>
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<td>M</td>
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<td>Health condition on arrival</td>
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<td>7&lt;sup&gt;-&lt;/sup&gt;</td>
<td>77.8</td>
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<td>22.2</td>
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</table>

Note. Different superscripts indicate significant differences between means for different behavior problems at p < .05. For example: age at time of study of adolescents without behavior problems (‘normals’) deviates significantly from age at time of the study of early-onset and late-onset aggressive adolescents, but not from age at time of the study of adolescents with early-onset and late-onset delinquent adolescents.

<sup>1</sup>Total sample size is 151; because of comorbidity the summation of all n’s is larger than 151.

<sup>2</sup>Smoking: 1 = never, 2 = a few times, 3 = now and then, 4 = regularly, 5 = often.
Do adolescents with aggressive, delinquent, and internalizing behavior problems and adolescents without behavior problems show different heart rate reactivity to a stress-eliciting task?

Table 2 also presents reactivity of heart rate and heart rate variability: the changes from baseline level to the stressful situation (gambling task). The early-onset delinquents showed large differences in both heart rate and heart rate variability when compared to both the adolescents without behavior problems and the late-onset delinquents. With respect to heart rate, early-onset delinquents showed a decrease in heart rate from baseline to the gambling task, whereas adolescents without behavior problems and late-onset delinquents showed an increase in heart rate ($F(1, 111) = 7.17, p < .01, d = 0.51$ and $F(1, 21) = 11.72, p < .01, d = 1.49$, respectively). In both comparisons, aggression was not a significant covariate ($F(1, 111) = .67, p > .10$ and $F(1, 21) = .49, p > .10$, respectively). The decrease in heart rate in the early-onset delinquents was associated with an increase in the measure of parasympathetic tone. Their heart rate variability showed an increase from baseline to the gambling task, whereas in adolescents without behavior problems and late-onset delinquents a decrease in heart rate variability was seen, although the difference was significant only for the late-onset delinquency group ($F(1, 21) = 5.68, p < .05, d = 1.04$). Aggression was a significant covariate ($F(1, 21) = 4.92, p < .05$). Figure 1 and 2 graphically present the changes in heart rate (Figure 1) and heart rate variability (Figure 2) for normal adolescents, for the combined delinquent group, and for the early-onset and late-onset delinquent groups.

Table 2

| Behavior Problems, Resting Levels of Heart Rate and Heart Rate Variability, and Their Reactivity to a Stress-Eliciting Task (N = 151) |
|---|---|---|---|---|---|---|---|---|
| | Normal | Aggressive | Early-onset | Late-onset | Delinquent | Early-onset | Late-onset | Internalizing |
| N | 92 | 19 | 10 | 9 | 25 | 10 | 15 | 46 |
| Heart rate | 77.74 | 80.94 | 80.38 | 81.56 | 78.67 | 77.42 | 79.43 | 79.15 |
| SD | 8.68 | 8.27 | 8.60 | 8.36 | 8.44 | 7.00 | 9.35 | 8.68 |
| Heart rate variability | 55.75 | 52.70 | 50.01 | 55.69 | 56.83 | 41.59 | 65.97 | 54.74 |
| SD | 27.97 | 29.27 | 26.46 | 33.48 | 33.12 | 11.78 | 38.53 | 32.37 |
| Reactivity | | | | | | | | |
| Heart rate | 1.84 | 1.26 | 1.21 | 1.31 | 1.17 | 1.70 | 2.86 | 1.50 |
| SD | 3.60 | 2.90 | 2.66 | 3.30 | 3.77 | 3.03 | 3.15 | 3.94 |
| Heart rate variability | 4.70 | -1.71 | -2.90 | -0.38 | -5.56 | -10.37 | -10.37 | -6.10 |
| SD | 20.31 | 11.44 | 14.93 | 6.31 | 15.38 | 17.14 | 17.14 | 24.08 |

1 Total sample size is 151; because of comorbidity the summation of all n’s is larger than 151.
2 Early-onset delinquent adolescents differ significantly from late-onset delinquent and normal adolescents.
3 Early-onset delinquent adolescents differ significantly from from late-onset delinquent adolescents.
Chapter 3

Figure 1. Heart rate in different forms of delinquency.

Figure 2. Heart rate variability for different forms of delinquency.
Are environmental factors related to behavior problems, to heart rate, heart rate variability, and their reactivity to stress?

There were no significant correlations between early-childhood maternal sensitive responsiveness and parental socioeconomic status on the one hand and heart rate, heart rate variability, and their reactivity to stress on the other hand. Early-childhood sensitive responsiveness did not differ between the different groups of behavior problems. Parental socioeconomic status, however, differed significantly: Parents of late-onset delinquent adolescents had a lower SES than parents of adolescents with early-onset delinquent (t (20) = -2.31, p < .05) and late-onset aggressive (t (10) = 2.04, p < .01) problems (see Table 1). Parents of early-onset delinquent adolescents had a higher SES than parents of adolescents without behavior problems (t (85) = -1.28, p < .05) and parents of adolescents with late-onset delinquent (t (20) = -2.31, p < .05) and early-onset aggressive (t (8) = 2.55, p < .05) problems.

Discussion

Resting heart rate and heart rate reactivity to a stressful situation were assessed in adolescents with and without aggressive, delinquent, and internalizing behavior problems. Although there were no significant differences between the groups in resting heart rate, heart rate reactivity to a stressful situation showed rather strong differences. Early-onset delinquents showed heart rate hyporeactivity to a stress-eliciting task compared with late-onset delinquent adolescents and adolescents without behavior problems. According to Cohen’s criteria for weak (d = 0.20), medium (d = 0.50), and strong (d = 0.80) effects (Cohen, 1988), the effect size for the comparison of early-onset with late-onset delinquent adolescents was large and the effect size for the comparison with adolescents without behavior problems was medium. In their meta-analysis on heart rate and antisocial behavior in children and adolescents, Ortiz and Raine (2004) found a comparable effect size (d = 0.76) for heart rate reactivity during a stressor.

Heart rate variability suggested that these differences were in part mediated by differential responses of the parasympathetic nervous system. Heart rate variability showed an increase from baseline to the gambling task in the early-onset delinquents, whereas all other groups showed a decrease in heart rate variability. The early-onset delinquents differed strongly from late-onset delinquents. The difference with adolescents without behavior problems was not significant, but pointed to the same direction.

Our results show that the differentiation between early-onset and late-onset delinquency (Moffitt, 1993) is important in studying stress reactivity in adolescents. Without this differentiation, delinquents did not show a deviant stress reactivity pattern (see Figures 1 and 2). Early-onset delinquents appeared to be less aroused by stress. Ortiz and Raine (2004) suggested that antisocial individuals are lacking in anxiety, are fearless, and are particularly unresponsive
to aversive social contexts. Quay (1993) suggested that subjects with undersocialized conduct disorder are less anxious or inhibited in the presence of cues for rewards and also less sensitive to cues for punishment. They display deviant sympathetic nervous system activity, with lower levels of noradrenergic function and electrodermal responsiveness. Here we extend these findings by showing similar deviation in the responsiveness of the parasympathetic system during a stress-eliciting gambling task, which also dealt with rewards and punishments. All group differences in heart rate responses to this task were paralleled by reciprocal differences in our measure of heart rate variability, which is known to reflect cardiac parasympathetic tone (Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology, 1996).

We found no indications for less adequate child rearing or socialization practices (although our measure was restricted to maternal parenting) in the delinquent adolescents, at least not in early childhood, pointing to possible neurobiological or genetic biases towards hyporeactivity in these individuals (Bock & Goode, 1996; Carey, 1994). The differences in heart rate reactivity between the late-onset delinquents and adolescents without behavior problems were not significant, which is in line with the results found by Raine et al. (1995). Early-onset delinquent adolescents also differed from late-onset delinquents and individuals without behavior problems with respect to IQ: early-onset delinquents had a lower IQ (see also Aguilar, Sroufe, Egeland, & Carlson, 2000; Moffitt, 1993; and Moffitt & Caspi, 2001), but IQ was not associated with the various heart rate measures. Moffitt (1993) hypothesized that life-course persistent antisocial behavior is embedded in neuropsychological deficiencies (such as heart rate and cognitive abilities). Adolescence-onset delinquents may develop in the same way as their non-antisocial peers (Fox et al., 2000), except for a period in which they are more affected by the typical exploratory and limit-testing behavior of puberty, for example delinquent or antisocial behavior (Caspi & Moffitt, 1995; Moffitt, 1993; Moffitt & Caspi, 2001). Caspi and Moffitt (1995) hypothesized that adolescence-limited antisocial behavior can be seen as a normative attempt by these adolescents to gain independence and autonomy by displaying “mature” behaviors. Note that in our study late-onset delinquents smoked more compared with all other groups, which may also be considered indicative of exploratory or risk-taking behavior characteristic for puberty. These adolescents may mimic the antisocial behavior of deviant peers because they believe they acquire a mature status this way (Aguilar, Sroufe, Egeland, & Carlson, 2000). After puberty these behaviors may decrease to normative levels of behavior problems (Moffitt, 1993; Moffitt & Caspi, 2001). Early-onset delinquent behavior may point to a neurobiological or genetic risk for antisocial behavior in children, whereas late-onset delinquent behavior may be more strongly related to environmental risk factors. Several studies have shown that the genetic component is greater in the case of antisocial behavior that persist into adult life than in antisocial behavior confined to the teenage period (DiLalla & Gottesman, 1989; Lyons et al., 1995; Rutter et al., 1997).
Problem Behavior and Heart Rate Reactivity

Continuous measures of behavior problems showed disappointingly weak associations with heart rate or heart rate reactivity. Heart rate reactivity appears to differ for behavior problems only when categorical classifications are used. Reactivity differences may surface only in those individuals who belong to the extreme end of the continuum of problem behaviours. The categorical approach may therefore show larger effect sizes than are usually found in correlational designs. A limitation of the categorical approach is, however, the rather low number of participants in the various problem behaviour groups, which in itself decreases the power for finding significant effects.

One could argue that the associations between problem behaviors and resting heart rate or heart rate reactivity might be related (also) to adoption-specific aspects or the rearing environment of the adoptive parents. In our study adoption-specific aspects (country of origin, health condition on arrival, age on arrival) did not differentiate between the groups and were not related to heart rate, heart rate variability, and their reactivity to stress. Early-childhood maternal sensitive responsiveness and parental socioeconomic status were not related either to heart rate, heart rate variability, and their reactivity to stress. The comparison between early- and late-onset delinquency did, however, show an environmental risk factor for the late-onset delinquents: the families of these adolescents had a lower socioeconomic status. In contrast, the socioeconomic status of the families of the early-onset delinquents was higher than the socioeconomic status of the families of either late-onset delinquents or adolescents without behavior problems. High socioeconomic status is generally considered a protective factor (Rutter, 1990). However, risk and protective factors are not static but depend on when they occur in a person’s development, in what social context, and under what circumstances (Rutter, 1989). In the case of adopted adolescents the discrepancy between the adoptive parents’ socioeconomic status and the background of the adoptees may be larger and more difficult to process for both parents and adolescents when the parents belong to a higher social stratum than the child’s original background, and the children are old enough to realize this discrepancy (see also Bohman, 1970; Tieman, Van der Ende, & Verhulst, 2004; Verhulst, Althaus, & Versluis-Den Bieman, 1989).

Research with adoptive families has many strengths (Rutter et al., 1990) but inevitably some limitations, too. It is often claimed that adoptees are broadly comparable with the general population, but this is not the case (Rutter, Silberg, O’Connor, & Simonoff, 1999). First, adoptees differ with respect to adoption-specific aspects. However, in our study adoption-specific aspects (e.g., age at adoption placement) did not differentiate between the groups. Second, adoptive parents differ from other parents in being better educated and more socially advantaged, as was the case in our sample. The birth parents and the adoptive parents may also differ with respect to particular forms of psychopathology (Rutter et al., 1999), that are more common in birth parents of adopted children (Bohman, 1996; Brennan, Mednick, & Jacobsen, 1996; O’Connor et al., 1998). The findings of adoption studies are likely to be affected by the fact that the
biological pairs include a disproportionately high percentage of individuals with genetic risk characteristics, and that the adoptive parents under-represent the proportion of high-risk environments found in the general population (Rutter et al., 1999). To the extent that the adoptive families provide an under-representation of high-risk environments, the consequence will be to underestimate the strength of environmental effects, which may be the reason that we hardly found any environmental risk factors in our sample (except for a lower socioeconomic status in the families of the late-onset delinquents and a higher socioeconomic status in the families of the late-onset delinquents). Interactions between genetic vulnerability and parental maltreatment in the development of antisocial behavior problems, such as reported by Caspi et al. (2002), may be difficult to replicate in a homogeneously high-functioning sample of adoptive parents.

The different forms of aggression (early-onset and late-onset aggression) did not show any significant differences in heart rate reactivity. The aggression and delinquency syndromes of the CBCL appear to refer to divergent patterns of problem behavior. The antisocial behavior assessed in the Raine et al. (1995) and Moffit and Caspi (2001) studies, with different results for early- and late-onset antisocial individuals, may be more similar to the CBCL delinquency syndrome than to the aggression syndrome. CBCL delinquency is also more similar to antisocial behavior as studied by Moffit and Caspi (2001) with respect to sex ratio. In our study, the male-to-female ratio was 4:1 for early-onset delinquency and only 1.5:1 for late-onset delinquency. For aggression a male-to-female ratio of 4:1 was found for early-onset aggression and a similar sex ratio of 3.5:1 for late-onset aggression. Moffit and Caspi (2001) reported a male-female ratio for childhood-onset antisocial behavior of 10:1, and for adolescent-onset antisocial behavior a ratio of 1.5:1. The male-female ratio of the aggression syndrome may show stability over the life-span, whereas the male-female ratio of antisocial behavior or CBCL delinquency decreases in adolescence-limited delinquency, maybe because in adolescence boys as well as girls are provoked by their peers to mimic their daring behaviors in order to acquire more status in the peer group. The divergent definitions and measurements of aggression and anti-social or delinquent behavior complicate the interpretation of findings from different studies in this research area.

Taken together, our findings show that delinquency and aggression may follow different developmental trajectories, and that early-onset delinquency –but not aggression– is characterized by stress hyporeactivity. The differentiation between delinquency and aggression, and between childhood-onset and adolescence-onset delinquency is crucial for our understanding of the development of externalizing problem behaviors.
References


Chapter 3


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