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The Role of Heart Rate Levels in the Intergenerational Transmission of Crime

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Abstract: Several prospective multigenerational studies have shown that crime runs in the family, while empirical research on the biological causes of crime has also established that low heart rate is related to antisocial behavior. This study examines whether the intergenerational transmission of crime is moderated or mediated by a low heart rate of the son. Prospectively collected conviction data on 794 men from three consecutive generations of the Dutch Transfive dataset is used. Heart rates were measured around age 18, during the medical examination prior to the mandatory military service in the Dutch army. All analyses were conducted separately for violent and non-violent crime. Both paternal violence and low heart rate levels are associated with increased violent offending. Intergenerational transmission of violence was only found among families in which the son had a low heart rate, although the degree of transmission did not differ significantly from families in which the son had a high heart rate. No support was found for a mediating influence of low heart rates of criminals' offspring on the intergenerational transmission of crime and violence. The results from this study underline the importance to focus on the interaction between biological risk factors and psychosocial risk factors for criminal behavior.

Keywords: heart rate; intergenerational transmission; criminal behavior; violence; biosocial interaction

1. Introduction

Ever since the late 19th century and the early 20th century, when [1] and Henry H. Goddard [2] published their studies on the Jukes family and the Kallikak family, respectively, scientists have studied family influences on antisocial and criminal behavior. These studies, and the methods they used, are now outdated. Research methods improved considerably during the 20th century and several prospective multigenerational studies have shown that crime runs in the family (e.g., [3–5]). During the last decades, empirical research on the biological causes of crime has established that low heart rate is related to antisocial behavior [6]. An increasing body of research also shows that psychosocial (e.g., parental crime) and biological (e.g., low heart rate) risk factors interact in predisposing to criminal behavior (see e.g., [7]). In this study we will further explore such biosocial interactions by examining whether the intergenerational transmission of crime is moderated or mediated by a low heart rate.

These moderating and mediating influences will be compared for violent and non-violent crime. A recent study from the Netherlands, the country in which also the current study is conducted, showed that the intergenerational transmission of violent crimes is significantly larger than the intergenerational transmission of non-violent crimes [8]. Also, recent studies have found that a low heart rate was

more strongly associated with violent crime than with non-violent crime [9,10]. Therefore, we explore whether or not low heart rate levels play a larger mediating or moderating role in the intergenerational transmission of violent crime than in the intergenerational transmission of non-violent crime.

1.1. Crime Runs in the Family

Intergenerational transmission of crime can be assumed from several criminological perspectives. Farrington [11] described six, not mutually exclusive, mechanisms that might explain why crime is transmitted across generations. First, Farrington [11] argues that exposure to risk factors (e.g., disrupted families, living in deprived neighborhoods, teenage parenting) may be transmitted intergenerationally, which leads to offending behavior in each successive generation. Second, the intergenerational transmission of crime may be mediated by risk factors for criminal behavior. Delinquent parents tend to live and raise their children in bad neighborhoods, give birth to children at younger ages and use inadequate child-rearing methods. Consequently, their children are at increased risk for criminal development. A third explanation suggests that the intergenerational transmission of crime is the consequence of assortative mating. Studies have shown that female offenders tend to have relationships and children with male offenders (e.g., [12]). Children with two criminal parents may have a disproportionally higher risk of becoming criminal. The fourth mechanism suggested by Farrington [11], relates to theories about social learning (e.g., [13]). Children might imitate and learn criminal behavior from their parents. Fifth, the intergenerational transmission of crime might be attributable to genetic factors. Over the last decades, an increasing number of studies have shown that a large part of the variance in antisocial phenotypes can be attributed to genetic factors (see e.g., [14,15]). Farrington's [11] sixth explanation suggests that official bias towards known criminal families leads some criminal families to be monitored more intensively by law enforcement bodies, which increases the risk for convictions of children of known criminal parents.

In accordance with these mechanisms, earlier research from the Cambridge Study in Delinquent Development (CSDD) [4,16,17] and the Pittsburgh Youth Study (PYS) [18] showed that offending is transmitted between immediate and extended family members. Moreover, results from the Rochester Youth Development Study (RYDS) indicated that parental offending leads to early antisocial and externalizing behavior in their offspring, both directly [19] and indirectly, mediated by parents' depressive symptoms [20], parenting stress and parenting behaviors [21]. Two Dutch intergenerational studies, the Criminal Careers and Life-Course Study (CCLS) and the Transfive study, also provided evidence for the transmission of offending from parents to children [3,5,22] and between siblings [23,24]. Van de Weijer and colleagues [8] also showed that the intergenerational transmission of violent crimes was significantly stronger than the intergenerational transmission of non-violent crimes, within the families of the Transfive study. A strong transmission of violent offending between both nuclear and extended family members was found within a Swedish population study as well [25]. Based on Farrington's [11] mechanisms and these previous studies, we expect that:

Hypothesis 1. *Offspring of a criminal father have an increased risk to become criminal compared to offspring without a criminal father.*

1.2. Underarousal: Fearlessness and Stimulation-Seeking

The most influential psychophysiological theories of antisocial behavior assume that antisocial individuals are chronically underaroused. Psychophysiological indicators for underarousal include low heart rate, low skin conductance and more excessive slow-wave electroencephalogram [26]. In this study we will focus on low heart rate. According to fearlessness theory, underarousal, indicated by low heart rate levels, is a marker of low levels of fear [26,27]. This may lead to criminal and violent behavior because a lack of fear might be to some extent be required to commit (violent) crimes, while

fear on the other hand might inhibit crime. Moreover, a lack of fear, especially in childhood, reduces the effectiveness of social conditioning [26,27].

Stimulation-seeking theory explains the relationship between antisocial behavior and reduced arousal by arguing that low levels of arousal represent an aversive physiological state [28]. Underaroused individuals engage in antisocial, criminal, and violent behavior because they seek stimulation in order to increase their arousal levels to an optimal or normal level. Fearlessness theory and stimulation-seeking theory are complementary theories rather than competing ones because underarousal may lead to (violent) crime by generating both fearlessness and stimulation-seeking [26]. It is beyond the scope of this current study to test which of these two theories best explains the relationship between heart rate and antisocial behavior, but we will test whether the relationship is in the predicted direction.

In accordance with these theories, a meta-analysis by Ortiz and Raine [6], covering 40 studies from seven different countries in both hemispheres, showed a relationship between low resting heart rate and antisocial behavior in children and adolescents. Previous studies showed that this relationship could not be accounted for by potential confounders such as physical characteristics, intelligence, drug and alcohol use, physical exercise or disadvantageous social factors [29–32]. In addition, several prospective studies showed that this relationship is in the predicted direction by ruling out the possibility that an antisocial lifestyle decreases heart rate levels [29–33]. Based on these results, Ortiz and Raine ([6], p. 154) concluded that "low resting heart rate appears to be the best-replicated biological correlate to date of antisocial and aggressive behavior in children and adolescents". An effect of low heart rate on self-reported antisocial behavior [34] and criminal convictions [31,32,35] was also found among young adults. Lorber [36] further showed in a meta-analysis that low resting heart rate is correlated with aggression among adults as well. Whether or not the association between low resting heart rate and offending is stronger for violent offending than non-violent offending remained unclear from these meta-analyses. Ortiz and Raine [6] could not test this in their meta-study since too few studies compared between aggressive behavior and non-aggressive antisocial behavior. Lorber's [6] meta-study does not distinguish between aggressive and non-aggressive antisocial behavior for the adult population either. Wadsworth [32], however, found lower heart rates among sexual and violent offenders than among non-violent offenders and non-criminal controls. More recently, low resting heart rate was shown to be related to both all crime and violent crime at age 50 in the CSDD [37]. However, effect sizes could not be compared in this study since different types of regression analyses were used for all crime and violent crime. Using a large Swedish population study, Latvala and colleagues [9] did show a stronger association of low resting heart rate with violent crime (in particular serious violent crime) than with non-violent crime. Also Murray and colleagues [10] found that, among Brazilian males, a low resting heart rate at age 15 was more strongly associated with violent crime than with non-violent crime at age 18. Using prospective longitudinal data from the Mauritius Child Health Project, Choy and colleagues [38] further showed that resting heart rates measured at age 11 were the lowest for those participants involved in serious violent offending at age 23. In line with these studies, Portnoy and Farrington [39] found, in a recent meta-analysis, a larger effect size for the relationship between heart rate and violence than for all other forms of antisocial behavior (i.e., aggression, behavior problems, conduct disorder, offending, psychopathy). Based on fearlessness theory, stimulation-seeking theory and previous findings, we expect that:

Hypothesis 2. *Individuals with low resting heart rate levels are more likely to offend than individuals with high resting heart rate levels.*

In addition to those two main effects of parental crime and heart rate levels on criminal offending, heart rate levels may impact the intergenerational transmission of crime as a mediating or moderating factor.

1.3. Heart Rate Levels as a Mediator

First, the intergenerational transmission of crime might be mediated by low heart rate levels of offenders' offspring. A possible mechanism behind the intergenerational transmission of crime distinguished by Farrington [11] is that criminal behavior of parents is associated with risk factors for criminal development for their children. One of these risk factors could be a low resting heart rate, as children of offenders have been shown to have lower heart rate levels than controls [29,40]. It is suggested that this is the consequence of experiencing environmental stress in early childhood [26]. Young children from broken homes, for example, have lower resting heart rates [32], and experiencing stress such as maternal separation or physical abuse at young age could also make children more resistant to later life stress [26]. Further support for this position has been provided by Choy et al. [41] who documented in a mediation model that social adversity (including parental crime) predisposed to low heart rate which in turn was associated with delinquency. We therefore expect that:

Hypothesis 3. *The intergenerational transmission of crime is mediated by lower heart rate levels of offenders' offspring.*

1.4. Heart Rate Levels as a Moderator

Second, the intergenerational transmission of crime might be moderated by low heart rate levels of offspring. As it has been shown that low resting heart rate levels are associated with antisocial behavior (e.g., [6]), it can also be expected that high resting heart rate levels might play a protective role for the development of antisocial behavior. According to the compensatory model, protective factors help individuals to compensate for risk factors or high levels of stress [42]. Support for this model was found by Raine, Venables and Williams [31]. They matched 17 antisocial adolescents who desisted from crime as adults with 17 antisocial adolescents who were convicted at age 29 years and 17 non-antisocial controls. They showed that the desisters had significantly higher resting heart rate levels than their more persistent criminal counterparts. The non-antisocial controls' heart rates were intermediate between these two groups but did not differ significantly from either one. Farrington [29] also found some protective influences of high heart rate levels, among 389 British men. He showed that in many cases the effects of several risk factors (e.g., large family size, low job status, low nonverbal IQ) on violent behavior were smaller for men with high heart rates than for those with low heart rates. Moreover, the influence of having a convicted parent on violent behavior (both convictions and teacher-reported violence) was smaller when the son had a higher heart rate. De Vries-Bouw and colleagues [43], however, found less support for a compensating influence of high heart rate levels. Among a sample of 68 male adolescents who had committed a minor offense, they did not find significant differences in resting heart rate levels between those who reoffended during adolescence and those who did not. The evidence that high heart rate levels can protect individuals who are at high risk for criminal behavior (e.g., by having a criminal father or by behaving antisocially as adolescents) to become criminal is thus ambiguous. In order to further explore this possible protective influence of high heart rate levels we will test the hypothesis that:

Hypothesis 4. *The degree of intergenerational transmission of crime is larger for offspring with low heart rate levels than for offspring with high heart rate levels.*

1.5. The Current Study

In this study, the mediating and moderating influence of heart rate levels on the intergenerational transmission of criminal and violent offending among Dutch males is studied. Our research questions are fourfold. First, we study the associations of resting heart rate levels and parental criminality with the offspring's criminal behavior. Second, we examine whether low resting heart rate levels of criminals'

offspring mediate the intergenerational transmission of criminal offending. Third, we examine whether the intergenerational transmission of criminal offending is moderated by the offspring's heart rate levels. Fourth, we explore whether these associations are different for violent and non-violent crime.

2. Materials and Methods

2.1. Sample

A sample from the Transfive dataset, which contains data on five consecutive generations from 198 Dutch families, was used. The starting point of the Transfive dataset are the first 198 boys who were placed in a Dutch Catholic reform school between 1911 and 1914. Some boys were placed in this institution because of concern about their character and problem behavior, including minor delinquency. Others were in the reform school because their parents, according to guardian organizations, were not able to take proper care of them. Therefore, these 198 boys constitute a sample at high-risk for delinquency.

The parents and all descendants of these boys were traced in Dutch genealogical and municipal records, with a retrieval rate of 100 percent. Emigrated sample members and their descendants were not traced further. As the parents of the 198 boys are the oldest generation in the sample, they will be called 'Generation 1' (G1). The 198 boys are called G2, while their children, grandchildren and great-grandchildren are called G3, G4 and G5, respectively. The G3 to G5 are studied prospectively. On average, the G3 were born in 1932; the G4 in 1960; and the G5 in 1986.The surviving G3 were, on average, approximately 76 years old at the moment of data collection. The surviving G4 were about 48 years old and the G5 were approximately 22 years old. Information on any partners is also included to the dataset in order that transmission from both parents can be examined. More detailed information may be found in Bijleveld and Wijkman [3]. Figure 1 summarizes the study design. (Permission for the construction of the sample was granted by the Frentrop foundation (legal successor to the reform school) and Bureau Registratie Persoonsgegevens, responsible for the municipal records.)

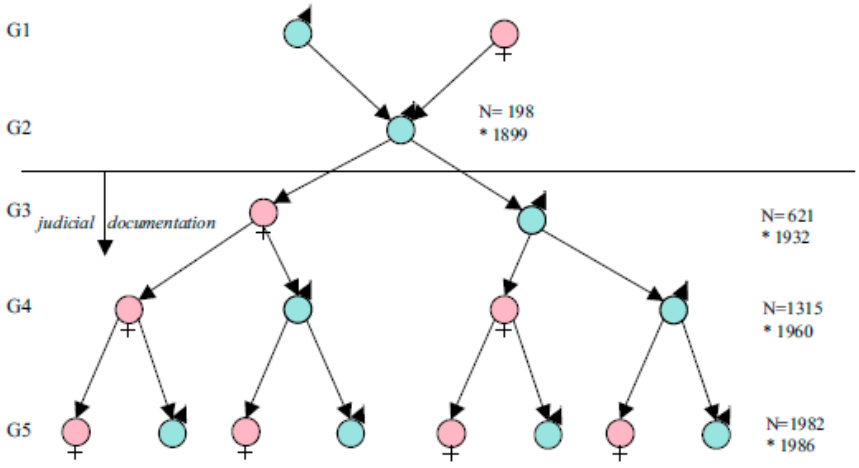

Figure 1. Study design of the Transfive study.

Sample members from G1 and G2 were excluded from analyses because their conviction data was collected from different (archival) sources and in all likelihood had worse coverage than the conviction data of the later generations. Moreover, only men from G3, G4 and G5 who underwent a medical examination prior to their mandatory military service were included to the sample, because heart rate levels were measured during this medical examination. In the Netherlands, every male citizen was eligible for conscription since 1898. Prior to the mandatory military service, men underwent medical examination around age 18. Women were excluded because they did not undergo this medical

examination as women were not conscripted in the Netherlands. In 1992 the Dutch government decided to suspend mandatory military service, and thus the medical examination, and four years later the last draft cohort ended their duty [44]. Persons who turned 17 after 1996 were therefore not medically examined by the Dutch army. Consequently, heart rate levels were not available for them and they were therefore not included in the sample. Information from the medical examination might also be missing for men from older cohorts for several reasons. If it was clear that someone would be exempt from military service, the medical examination could be cancelled. Men could be exempted if they were the main source of income in their family, were indispensable in their work (often in family businesses), or if they resided outside the European Community [45]. Moreover, men with extensive prior criminal behavior (i.e., more than six months imprisonment) were deemed ineligible. Also, not all brothers from large nuclear families had to serve [46]: until 1966 the three oldest brothers had to serve, and from that year on only the two oldest brothers were conscripted. Persons who did not undergo medical examination for these or other reasons were excluded from the sample as well. In total, data on heart rate levels from the medical examination was available for 828 of the 1229 G3, G4, and G5 men who turned 17 before 1996. In case men were not medically examined, it is unknown for which of the abovementioned reasons they were exempted from military service.

Participants who emigrated were excluded from the sample since the information on their offending behavior might be truncated. This resulted in a final sample of 794 men for whom judicial and medical data was available. This sample of 794 men was used to examine the associations of resting heart rate levels and parental criminality with criminal behavior (Hypotheses 1 and 2). Judicial information of the fathers was available for 557 of these men (Judicial information was not available for 237 fathers because the conviction data of fathers of the G3 (i.e., the G2 men) was collected from different sources (N = 186), because 31 fathers were born before 1916 (the Dutch judicial documentation did not contain data on individuals born before 1912 and may have missed people born between 1912 and 1916), because the fathers emigrated (N = 4) or because the biological father was not known (N = 16).). This sample of 557 men was used to examine the mediating and moderating influence of resting heart rate levels on the intergenerational transmission of crime (Hypotheses 3 and 4).

2.2. Measurements

Criminal Behavior: Information on offending was obtained from computerized, paper and microfilmed archives of the Dutch Criminal Records Documentation Service (judicial documentation), in December 2007. Offenses were classified based on the Statistics Netherlands standard classification for offenses [47]. The violent crimes in this classification included: all hands-on sex crimes (i.e., rape, sexual assault, sexual abuse), crimes against life (i.e., murder and manslaughter), threats, assaults, physical injury, robbery and extortion. All other crimes were considered as non-violent offenses. Only information on the registrations that resulted in a conviction or a policy dismissal (i.e., dismissal of a case because, although the prosecutor deemed the defendant guilty, it was considered undesirable to prosecute, for instance because the perpetrator had already paid damages) were used. Offenses followed by an acquittal or so-called 'technical' dismissal (i.e., dismissal of a case by the public prosecutor because of insufficient evidence and the case therefore expected to result in acquittal) were not included. Offenses were timed to the date the crimes were committed. If the commission date was unknown it was estimated as one year before the conviction date, since that is the average time period between conviction dates and known commission dates. If the conviction date was missing as well, the commission date was timed as July 1 of the year of registration. We only included offenses after the year in which the resting heart rate levels were measured during the medical examination, in order to test whether low heart rates lead to offending and not vice versa.

In order to test whether the intergenerational transmission of crime was mediated by lower heart rate levels of offenders' offspring, variables were constructed that indicated whether or not fathers committed any offenses and violent offenses during the child's youth. Results are presented for paternal crime and violence committed during the pre-school years of the child (i.e., 0–5 years).

However, these variables were also constructed for different age ranges in order to test whether the results are robust when other age ranges are used.

Heart Rate Levels: Heart rate levels were obtained from the data of medical examinations of conscripts at the "Defensie Archieven-Registratie-en Informatiecentrum" (DARIC) (Permission for the collection of these data was granted by the Ministry of Justice and the Ministry of Defence.). During this examination the resting heart rate of the conscripts was measured. The heart rates ranged between 48 and 120 beats per minute (bpm), with an average of 74.18 bpm (S.D.: 9.11). In line with previous studies on this topic, heart rate levels were recoded into categories (see e.g., [9,10]). The heart rates in this study were divided into three groups, of approximately equal size. Heart rates between 48 and 71 bpm were considered as low resting heart rates; heart rates between 72 and 75 bpm were considered as medium resting heart rates; and heart rates between 76 and 120 bpm were considered as high resting heart rates. All analyses were also repeated using the heart rates as an interval variable, to test the robustness of the analyses.

2.3. Analyses

In most analyses, the criminal behavior of the sample members was the dependent variable. This variable was highly right-skewed since most of the participants were either not convicted for an offense or were only convicted for a small number of offenses. We therefore chose to recode the offending variable into several dichotomous variables, indicating whether or not a participant was convicted for any crime, a non-violent crime or a violent crime after his medical examination. Logistic regression analyses, in which offspring offending was predicted by parental offending, were used to test whether violent and non-violent offending is transmitted from father to son. Moreover, logistic regression analyses were used to test whether low heart rates are related to (violent) offending. Next, a multinomial logistic regression analysis was performed to test whether paternal crime and violence during the youth of the child predicted low heart rates, and consequently mediated the intergenerational transmission of crime. Finally, in order to test the moderating influence of heart rate levels on the intergenerational transmission of (violent) crime, separate logistic regression models were estimated for sons with low heart rates, medium heart rates and high heart rates. Additionally, interaction terms between heart rate levels and parental offending were included to the logistic regression models in order to test whether the degree of intergenerational transmission of criminal offending differed significantly between offspring with different heart rate levels.

Because participants were born in different years and not all participants were medically examined at the same age, the odds ratios in all analyses were controlled for exposure. Exposure was measured as the number of years between the medical examination and the moment of data collection (or the year of death, in case of deceased participants).

The odds ratios in the logistic regression analyses are simple to interpret and widely used measures in intergenerational studies to assess the transmission of offending. However, odds ratios do not control for the fact that multiple sons are clustered within the same father. As a consequence, the assumption of independent observations in the regression analyses is violated, which without an appropriate correction would result in underestimated standard errors. Therefore, robust standard errors were computed to correct for this clustering within families.

All analyses were carried out using Stata version 14.

3. Results

3.1. Descriptive Statistics

Table 1 shows the descriptive statistics of all the variables that were used in the analyses. These statistics show that 53 percent of the participants had criminally offended after the medical examination, 50 percent with at least one non-violent crime and 15 percent with at least one violent crime. The offending rates for paternal crime were approximately the same. Table 1 further shows that

13 percent of the participants had a father who committed a crime during the first five years of their lives, while only two percent of them had a father who committed a violent crime during this period. Finally, 32 percent of the sample members had a low heart rate, 31 percent had a medium heart rate and the remaining 37 percent had a high heart rate.

Table 1. Descriptive statistics of all variables used in the analyses.

Variable	N	Percentage	Total N
Any crime	417	53%	794
Non-violent crime	396	50%	794
Violent crime	121	15%	794
Any crime father	300	54%	557
Non-violent crime father	282	51%	557
Violent crime father	70	13%	557
Paternal crime during childhood	72	12%	557
Paternal violence during childhood	10	2%	557
Heart rate: low (48–71 bpm)	251	32%	794
Heart rate: medium (72–75 bpm)	246	31%	794
Heart rate: high (76–120 bpm)	297	37%	794

3.2. Intergenerational Transmission of Crime

We started our analyses by testing to what extent crime is transmitted between generations. Table 2 shows the odds ratios for the intergenerational transmission of all crime, violent crime, and non-violent crime. In line with our first hypothesis, all three odds ratios are significantly higher than 1. This indicates that all crime, non-violent crime, and violent crime are transmitted between generations. The odds ratio of violent crime (2.192) is larger than the odds ratio of non-violent crime (1.512) which suggests that the intergenerational transmission of violent crime is larger than the intergenerational transmission of non-violent crime.

Table 2. Logistic regression models predicting offspring criminal behavior.

	Non-Violent Crime OR (95%-CI)	Violent Crime OR (95%-CI)	All Crime OR (95%-CI)
Paternal non-violent crime	1.512 (1.054–2.169) *		
Paternal violent crime		2.192 (1.229–3.907) **	
All paternal crime			1.512 (1.057–2.161) *
Exposure	1.011 (0.990–1.033)	0.995 (0.970–1.021)	1.015 (0.994–1.036)
N	557	557	557

Note: * $p < 0.05$; ** $p < 0.01$ (one-sided).

3.3. Heart Rate Levels

In order to test our second hypothesis, we examined the association between heart rate levels and offending behavior, in which a high heart rate is used as a reference category. The odds ratios from these logistic regression analyses are shown in Table 3. In line with Hypothesis 2, all odds ratios for low heart rates were above one. However, only the odds ratio predicting violent crime was significant, indicating that persons with low heart rates were significantly more likely to be convicted for a violent crime than persons with a high heart rate. None of the odds ratios for medium heart rates were significant, which indicates that sample members with a medium heart rate level did not have a significantly larger risk to commit offences than those with high heart rates.

Table 3. Logistic regression analyses predicting offspring criminal behavior.

Heart Rate	Non-Violent Crime OR (95%-CI)	Violent Crime OR (95%-CI)	All Crime OR (95%-CI)
Heart rate:			
High (76–120 bpm)	Ref.	Ref.	Ref.
Medium (72–75 bpm)	1.124 (0.829–1.523)	1.508 (0.977–2.327) **	1.108 (0.792–1.551)
Low (41–71 bpm)	1.172 (0.849–1.618)	1.648 (1.099–2.470) *	1.212 (0.878–1.674)
Exposure	1.006 (0.998–1.015)	1.002 (0.992–1.011	1.010 (1.000–1.019) *
N	794	794	794

Note: * $p < 0.05$; ** $p < 0.01$ (one-sided).

3.4. Heart Rate Levels as a Mediator

Next, it was examined whether the intergenerational transmission of crime was mediated by low heart rate levels of criminals' offspring (Hypothesis 3). First, the influence of experiencing paternal crime or violence during early childhood (0–5 years) on participants' heart rate levels was examined. The results of these multinomial logistic regression analyses are shown in Table 4. Having a high heart rate is used as the reference category, and the odds ratios indicate the risk to have a medium or low heart rate, respectively, rather than a high heart rate. Model 1 shows that those participants whose fathers committed crimes during early childhood did not have a significantly lower heart rate than those whose fathers did not commit crimes during early childhood. Moreover, Model 2 shows that paternal violence during early childhood was not related to lower heart rates either. These insignificant odds ratios are not the consequence of the age range (0–5 years) we used: additional analyses showed that the odds ratios were similar if other age ranges were used (e.g., paternal crime when offspring was 0–3, 0–7, 0–10, 0–12, 0–18 years old). Since childhood exposure to paternal crime was not associated with offspring's low heart rates, the intergenerational transmission of criminal offending is not mediated by the low heart rate of offenders' offspring. Hypothesis 3 could therefore not be confirmed.

Table 4. Multinomial logistic regression analyses predicting offspring's heart rate levels.

	Model 1		Model 2	
	Medium vs. High	Low vs. High	Medium vs. High	Low vs. High
Paternal crime during childhood	0.823 (0.446–1.519)	0.666 (0.339–1.308)		
Paternal violence during childhood			0.963 (0.192–4.836)	1.354 (0.392–4.673)
Exposure	0.957 (0.931–0.983) **	0.938 (0.911–0.965) ***	0.957 (0.932–0.984) **	0.940 (0.913–0.967) ***
N				

Note: ** $p < 0.01$; *** $p < 0.001$ (one-sided).

3.5. Heart Rate Levels as a Moderator

Finally, we ended the analyses by testing whether the negative effect of having a criminal or violent father was moderated by having a high resting heart rate. In order to test this, we examined whether the intergenerational transmission of (violent) crime is different for participants with a low, medium or high heart rate. The odds ratios are shown in Table 5. In line with the compensatory model and our fourth hypothesis, a large and significant odds ratio was found for the intergenerational transmission of violent crimes among those with a low heart rate (3.434), but not among those with a high heart rate (OR = 1.573; $p = 0.43$). However, in contrast with Hypothesis 4, a significant odds ratio for the intergenerational transmission of all crime (2.201) and non-violent crime (1.917) was found among those with a high heart rate but not among those with a low heart rate ($p = 0.48$ and $p = 0.32$, respectively). None of the odds ratios were significant among the sample members with a medium heart rate.

In order to test whether the degree of intergenerational transmission of crime differed significantly between sons with different heart rate levels, additional analyses were performed that included an interaction variable between parental offending and heart rate levels. None of these interaction effects were significant. Thus, although different degrees of intergenerational transmission of crime were found between offspring with low, medium and high heart rates, these degrees of transmission did not differ significantly from each other.

Finally, additional analyses were performed in which heart rate levels were measured as a continuous variable rather than a categorical variable, in order to test whether this results in the same conclusions. Similar to the results shown in Table 3, the continuous heart rate variable is significantly associated with violent crime (OR: 0.974; $p < 0.05$), but not with non-violent or all criminal behavior. Moreover, the conclusion with respect to the mediating and moderating influence of heart rate levels on the intergenerational transmission of crime did not change either when the continuous measurement of heart rate levels was used.

Table 5. Logistic regression analyses predicting offspring criminal behavior, separately for sons with low, medium and high heart rate.

Intergenerational Transmission of:	Low Heart Rate Son OR (95%-CI)	Medium Heart Rate Son OR (95%-CI)	High Heart Rate Son OR (95%-CI)
Non-violent crime	1.369 (0.735–2.550)	1.458 (0.804–2.643)	1.917 (1.036–3.546) *
Violent crime	3.434 (1.197–9.853) *	2.168 (0.818–5.750)	1.573 (0.509–4.862)
All crime	1.249 (0.674–2.316)	1.407 (0.774–2.558)	2.201 (1.202–4.032) *
N	180	188	189

Note: * $p < 0.05$ (one-sided); all odds ratios are obtained from separate logistic regression analyses and reflect the effect of paternal offending on offspring offending, controlled for exposure.

4. Discussion

In this study, data on 794 Dutch conscripts were used to examine the associations of paternal crime and low resting heart rates with criminal behavior of Dutch adults. A possible mediating and moderating influence of low resting heart rates on the intergenerational transmission of criminal offending was examined as well. All this was analyzed separately for violent and non-violent crimes.

The results show support for intergenerational transmission of crime: if the father was ever convicted, his son was at increased risk to be convicted as well. As expected, the intergenerational transmission of violent crime is larger than the intergenerational transmission of non-violent crime. The odds ratio for the intergenerational transmission of violence, however, was smaller in this subsample than the previously found odds ratio among the complete sample of the Transfive study [8]. This might be the consequence of the policy of the Dutch army to exclude persons with an extensive criminal record from military service. Consequently, these men were not medically examined prior to the military service and, thus, excluded from this sample. Possibly, these persons who already had an extensive criminal record at young age were already convicted for violent crimes or are more likely to become violent offenders at older age. Due to the fact that these persons are excluded from the sample, the intergenerational transmission of violence might have been underestimated here. Moreover, we only took into account offspring offending after the medical examination. If children of violent parents commit violent crimes at younger age than children of non-violent parents, the intergenerational transmission of violence is again underestimated.

Previous research showed that a low resting heart rate is related to antisocial and criminal behavior among children, adolescents, and young adults [6,36]. In the current study, we showed that a low resting heart rate was related to violent offending but not to non-violent offending among Dutch adults. This finding is in line with previous studies that found that a low heart rate was more strongly associated with violent crime than with non-violent crime [9,10]. However, possible confounding variables that may influence both the heart rate levels at early age and adult offending should not be ruled out. Watching violent films, for example, has been shown to reduce heart rate by as much as 10

to 15 beats per minute [48], and may be associated with violent behavior through learning mechanisms. On the other hand, it could be argued that the effect of heart rate on offending is underestimated due to confounders. Alcohol intake and cigarette smoking, for example, increase heart rate levels and are more frequent among antisocial individuals [27]. Since we only measured heart rate at age 18 years our results should be interpreted with some caution.

We furthermore tested whether resting heart rate levels mediate the intergenerational transmission of crime. Children of criminal and violent parents were expected to have lower heart rate levels since previous research showed that stress during early childhood can lead to a low heart rate [29,40]. This finding was, however, not replicated in the current study. This might possibly be the consequence of the fact that we only took paternal crimes in children's early lives into account as stressors. Other possible stressors for young children, such as parental divorce [32], were not taken into account and could therefore distort the relationship between experiencing parental crime and heart rate level. In addition, the use of conviction data might influence the relationship between experiencing parental crime and heart rate levels as well. Possibly, many more participants were exposed to the criminal or violent behavior of their fathers than is displayed by the conviction data.

Finally, the degree of intergenerational transmission of crime was shown to differ between offspring with different heart rate levels. Intergenerational transmission of violence was only found among participants with a low heart rate and not among those with a medium or high heart rate. A high heart rate thus seems to compensate for the increased risk that children of violent offenders have to become violent offenders themselves. On the other hand, the results could also be interpreted as a cumulative effect. Since we have shown that paternal violence and low resting heart rate levels are both associated with the risk to become a violent offender, children of violent fathers with a low heart rate have at least two risk factors for violent offending. As a consequence, those risk factors may cumulate and further increase the risk to become violent. The compensatory model was, however, not found for non-violent offending. In contrast, a significant degree of intergenerational transmission of non-violent offending was only found among sons with a high heart rate and not among those with a low heart rate. However, the interaction effects between paternal crime and heart rate levels were not significant, indicating that the degree of intergenerational transmission of crime and violence did not significantly differ between offspring with low and high heart rates. The results should therefore be interpreted with some caution.

4.1. Strengths and Limitations

This study contributes to the existing literature on the intergenerational transmission of offending as well as to the existing literature on effects of resting heart rate levels. It does so in several ways. First of all, we are the first to examine the effects of low resting heart rate levels on the criminal behavior among adults in The Netherlands. We are also among the first who prospectively examine the influence of heart rate levels on convictions during adulthood, with many other studies focusing only on children, adolescents or young adults. In addition, we examined the influence of low heart rate levels on both non-violent and violent crimes, which turned out to be an important distinction since most results were only significant for violent crimes. Finally, we are among the first to study the biosocial interaction between the effects of low resting heart rate and parental crime.

Besides these strengths, this study is also limited in several ways. First of all, the use of conviction data as a measure of offending behavior is a limitation, since much actual (violent) crime is not captured by these official data. This might have influenced our findings. We did, for example, not find a significant association between experiencing paternal crime as a young child and resting heart rate levels. Possibly many more participants experienced paternal crime during early childhood than is displayed by the conviction data, which might have led to an underestimation of the effect.

Another limitation is the measurement of the resting heart rate levels. First, confounding factors at a young age that are related to both heart rate levels and offending behavior, cannot be ruled out since heart rate levels are measured during the medical examination prior to military service,

usually at the age of 18. Since measurements of potential confounders were missing in the dataset they could not be included in the analyses and only the exposure time (i.e., number of years after medical examination and the moment of data collection) is controlled for. Second, one might question whether a heart rate measured during a medical examination is truly at rest. The medical examination might be experienced as stressful for some participants because the important decision whether or not they had to serve in the Dutch army was (partly) determined by this medical examination. Therefore, some participants might be nervous and have a higher heart rate. Moreover, some participants might have intentionally tried to sabotage the medical examination as they did not want to serve in the army. Third, a disproportionally large number of the measured heart rates were divisible by four. This suggests that in some cases the heart rates were only measured for fifteen seconds and multiplied by a factor 4 to yield a beats-per-minute figure. In these cases, the measured heart rates should be considered as a noisy approximation of the actual heart rate levels. However, the drawback of this might be limited, considering our use of three heart rate groups rather than the exact heart rates. Nonetheless, the results should therefore be interpreted with some caution.

A final limitation concerns the generalizability of our results. First of all, we use a sample that is at risk for criminal and violent behavior because they are all descendants of men who were placed in a Dutch Catholic reform school because of concern about their character, problem behavior, or family circumstances. Second, persons who were not medically examined for military service were excluded from the sample. Due to the policy of the Dutch army, individuals with certain characteristics (e.g., extensive delinquency during adolescence, having a large family) were less likely to be medically examined and thus less likely to be in our sample. Finally, only males were included in our sample. It would be an interesting topic for future research to test whether our results could be replicated among a sample of females.

4.2. Implications

The results from this study underline the importance of research that focuses on the interaction between biological risk factors and psychosocial risk factors for criminal behavior, since we showed that the intergenerational transmission of violence is only large and significant among men with low heart rates. It would be an interesting topic for future research to study whether other biological risk factors (e.g., low skin conductance) have an influence on the intergenerational transmission of violent crime as well, in order that interventions can be aimed at those with the highest risk to inherit their father's criminal behavior.

Moreover, it would be an important topic for further research to study what the exact mechanism is that leads to the association between low heart rate and criminal behavior, in order that suitable interventions for antisocial persons with low heart rates could be developed. If, for example, this effect is the consequence of stimulation-seeking, antisocial people with low heart rates could be stimulated to find stimulation in other activities, such as sports or academic achievements.

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