Foreword

It is always very difficult to choose a subject for your thesis. If you already have a field of interest, it is hard to narrow this to a definition of the problem for a research project like a thesis. I was interested in criminology and my first idea was to research as much as an experienced researcher could do in 20 years. My first aim was something like researching why people become criminal.

Soon it became clear that I had to find something more realistic. I wanted to go abroad for a while and had read a lot about the Dunedin Multidisciplinary Health and Development Study in New Zealand. Not only the aim of this study, but also the country attracted me very much. After making known my interest in doing an internship and writing a thesis for the study, Richie Poulton (the director of the study) invited me to come over to New Zealand to realise all this.

The problem of not knowing what kind of subject to choose for my thesis was solved by this invitation. Richie Poulton suggested me to research the relation between heart rate and antisocial behaviour and to find out what influence socio-economic status has on this relation. This proposal sounded very attractive and a few months later my design was approved. After a lot of preparations in the Netherlands I was ready to leave to New Zealand.

In New Zealand I spend four months on my research project. I want to thank Richie Poulton for making it possible for me to come to New Zealand and to make use of a working place and a computer at the Unit. I also want to thank him that he could always make time in his busy schedule to discuss my progress. Furthermore I want to thank Barry Milne for being my minder during my time in Dunedin. I could always drop in when necessary and I learned many new things about data analyses. I also want to thank my other colleagues at the Unit for the great time I had. David Welch, thanks for reading my thesis and having good comments. Terrie Moffitt, thanks a lot for giving good advice on my analyses.

In the Netherlands I was very well supervised by René Veenstra. He is the one, who supervised me from the beginning till the end. René, thank you very much for your support and supervision. Furthermore I want to thank Siegwart Lindenberg for reviewing my thesis.

Besides the contents of my thesis, the lay-out is also important. Therefore I want to thank Roland Blokhuizen for placing his drawing at my disposal, so I could use it for the cover of my thesis. And last but not least, Dekkers' design, thank you very much for your effort in making my thesis orderly and good looking.

Finally, I can enumerate a catalogue of expressions of thanks to the people in my surrounding who supported me very well during the writing process, but this will take pages. All of you, thank you very much!

Saskia Dekkers

Summary

Several investigations have been done into the relation between heart rate and antisocial behaviour. Raine mentions several reasons to do so[1]. Firstly, he mentions that it is the best replicated correlate of antisocial behaviour in child and adolescent samples. Secondly, the relation between heart rate and antisocial behaviour is not artificial. Potential artifacts have been ruled out repeatedly in earlier research, as for example physiological confounds as height, weight and body bulk, but also social confounds as family size and divorce, and psychological confounds as low IQ. A next reason is that the relation is confirmed in prospective studies and in at least six countries. Further, low heart rate is diagnostically specific. Only antisocial behaviour has turned out to relate with lower heart rate, while for example depression, schizophrenia, and anxiety disorder have been linked to higher heart rates. The relation is furthermore consistent with gender differences in antisocial behaviour, which means that low heart rate characterises female as well as male antisocial individuals. Heart rate characterises life-course persistent antisocial individuals in particular. Finally, Raine mentions that heart rate interacts with psychosocial risk factors.

Most of the earlier findings into the relation between heart rate and antisocial behaviour have found lower heart rates in antisocials. This relation will be examined using for the first time the data of the Dunedin Multidisciplinary Health and Development Study (Dunedin study). The first research question is:

1 'Is there a relation between low heart rate and high antisocial behaviour?'

Furthermore, few investigations have been done into the influence of socio-economic status on this relation. The results are equivocal and limited. Raine and Venables found that the relation between heart rate and antisocial behaviour could only be applied to people from the high socio-economic status groups[2]. Raine, Reynolds, Venables & Mednick found the same result only for Creoles, but not for Indians[3]. Because of these limitations, the influence of socio-economic status will be examined using the data of the Dunedin Study to get a better understanding of it. The second research question is therefore the following:

2 'Does socio-economic status influence the relation between low heart rate and high antisocial behaviour?'

As said, findings showed lower heart rates in antisocials. A frequently used theory to give a possible explanation for this is the *arousal theory*. This theory postulates that antisocial behaviour in individuals is caused by the fact that those individuals have an ongoing low level of arousal (in this case measured with heart rate). The arousal theory can be divided into two parts, the fearlessness theory and the stimulation

[1] Raine, A. (2002). Annotation: The role of prefrontal deficits, low autonomic arousal, and early health factors in the development of antisocial and aggressive behaviour in children. *Journal of Child Psychology and Psychiatry, 43:4,* 417-434.

[2] Raine, A. & Venables, P.H. (1984). Tonic HR level, social class, and antisocial behaviour. *Biological Psychology, 18,* 123-132

[3] Raine, A., Reynolds, C., Venables, P.H. & S.A. Mednick (1997b). Biosocial bases of aggressive behaviour in childhood. Resting HR, skin conductance orienting, and physique. In: Raine, A., Brennan, P.A., Farrington, D.P. & Mednick, S.A., *Biosocial bases of violence* (pp. 107-126). New York: Plenum Press

seeking theory[4]. The *fearlessness theory* indicates that low levels of arousal are markers of low levels of fear. In turn, low fear may lead to an increased propensity to engage in antisocial behaviour. The theory maintains that those who are more fearful do not dare to engage in antisocial behaviour. Conversely, those who are not easily scared will have little fear of the consequences of their antisocial behaviour, such as punishment by parents or caretakers. If punishment does not work the socialising process is likely to be less effective. Norms and values might not be able to be passed on to these children very well. Because of this, there is a larger chance that children become antisocial.

Secondly, the *stimulation seeking theory* states that those with low levels of arousal are searching for activities to bring their arousal to a normal, or optimum, level. These people are searching for excitement and adventure. They will experience daily activities as routine and boring much sooner, and so will seek for stimulation more readily. In this sense antisocial behaviour is seen as a form of stimulation seeking.

The earlier findings and the above-described theory about the relation between heart rate and antisocial behaviour result in the following hypothesis, which is examined in this thesis:

Hypothesis I: *'People with low heart rates will be more likely to engage in high antisocial behaviour than people with high heart rates'*

As said, the research into the influence of socio-economic status on the relation between low heart rate and antisocial behaviour is more equivocal and limited. The Social Production Function Theory is used to try to give a possible explanation for the influence of socio-economic status on the relation between heart rate and antisocial behaviour[5]. In short, this is a theory about how people produce their well being, the appreciation of someone for his or her life in general. Well being can be produced by attaining two universal goals, namely *physical well being* (appreciation of someone for his or her life in physical aspects, as for example feeling healthy) and *social well being* (appreciation of someone for his or her life in social aspects, for example feeling appreciated and having friends). There are instrumental goals to reach these two universal goals. *Stimulation* (activities that produce arousal) and *comfort* (activities which reduce or remove thirst, hunger, fatigue, pain and fear, etc.) can produce physical well being. Similarly, *status* (possessing scarce resources or having a good position with regard to others), *behavioural confirmation* (approval and encouragement of behaviour by intimate family and friends and the like) and *affection* (love received from intimate family and friends and the like) can produce social well being.

According to Lindenberg, within each universal goal, the instrumental goals can be exchanged. If affection drops off by losing a good friend, people might go and search for status and behavioural confirmation to maintain the same level of social well being. This process is called substitution. However the process of substitution is limited, because everybody needs a certain level of each instrumental goal. For

[4] Raine, A. (1993) *The psychopathology of crime. Criminal behaviour as a clinical disorder*. London: Academic Press

[5] Lindenberg, S.M. (1996). Continuities in the theory of spf. In: Ganzeboom, M., *Verklarende sociologie: opstellen voor Reinhard Wippler*. Amsterdam: Thesis Publishers

example, people need to have food and drinks. Sport, as a form of stimulation can not be a substitution for a lack of food (comfort).

The Social Production Function Theory also postulates that when a good is scarcer, it is easier to provide status with it. For example, if you have an expensive car in front of your house, that will only provide status if no one else has such an expensive car. Suppose that in the high socio-economic status group the 'good' fearlessness (which is a cause of performing antisocial behaviour) is much scarcer than in the low socio-economic status group. This might be because: I) people from the high socio-economic status group have more skills to oversee the consequences of their behaviour and are therefore more afraid of the consequences. II) people from the high socio-economic status group do have more to lose and are therefore more afraid to lose; or because III) the environment, for example supervision of parents, plays a larger role for children from the high socio-economic status group and that is why these children may be more afraid of, for example, punishment.

Assuming fearlessness is scarcer in the high socio-economic status group, this means that someone being fearless in the high socio-economic status group can distinguish himself much better from other people than someone being fearless in the low socio-economic status group. Peers would admire such a person, which leads to behavioural confirmation and status, and may also lead to affection from admiring group members. Furthermore, the tension of exhibiting antisocial behaviour may produce stimulation (stimulation seeking theory). Some kinds of antisocial behaviour even produce comfort (e.g. stealing a car). So, exhibiting antisocial behaviour in a group where the members are in general less fearless is multifunctional for obtaining well being.

In summary, the afore-mentioned gives a possible explanation of why the relation between low heart rate and antisocial behaviour is stronger for people living in the high socio-economic status group than for people living in low socio-economic status group. If someone has a low heart rate it is more 'lucrative' for this person to behave antisocially if he or she is from the high socio-economic status group.

This theory leads to the following hypothesis, which will be examined in this thesis:

Hypothesis II: *'The relation between low heart rate and high antisocial behaviour will be stronger for people in the high socio-economic status group'.*

All this is examined using the data of the Dunedin Study, a study into the health and development in a birth cohort of New Zealanders (n=1037). Measures of heart rate were taken during childhood (ages 7, 9 and 11), adolescence (ages 13, 15 and 18) and adulthood (age 26). Self-reported, other reported and official reported antisocial behaviour was measured at ages 11, 13, 15, 18 and 26.

The results, considering hypothesis I, are that there is a small to moderate difference between the high and low heart rate groups in terms of antisocial behaviour, during adolescence. Significant effects were especially found in the self-reports, less for the official reports and nothing was found for the other reports. The differences between the low and high heart rate group on antisocial behaviour are very small considering the childhood heart rate and there is no difference at all between these two groups

when looking at the results with adult heart rate. Hypothesis one can therefore be partly confirmed. Concerning the interaction-effect of sex, the relation between adolescent heart rate and the DSM antisocial personality diagnosis at age 26 can only be applied to females and not to males. For all other results can be concluded that the differences between the low and high heart rate group are the same for both sexes.

The second hypothesis considered socio-economic status as an interaction-variable. Three out of the 25 results were significant. The relation between childhood heart rate and the CD symptom scale at age 13 was only found to be significant in the low socio-economic status group. The relation between adolescent heart rate and the ASPD symptom scale at age 26 was only found to be significant for the low and the high socio-economic status group (not for the medium socio-economic status group) and finally, the relation between adolescent heart rate and SRD at age 26 was only found to be significant for the middle and the high socio-economic status group (not for the low socio-economic status group). The second hypothesis has to be rejected since the results from this study do not show that the relation between heart rate and antisocial behaviour is stronger for those from the high socio-economic status group.

The results in this thesis concerning the first hypothesis are less strong (lower effect sizes) than the results in earlier findings. These results are in consistency with predictions of the arousal theory.

Furthermore, the results concerning the second hypothesis do differ from earlier research, because it turns out that socio-economic status in most cases does not have a large influence. In those cases it has an influence, it is not found for people from the high socio-economic classes only. The results are therefore not in consistency with one prediction of the Social Production Function theory, namely that the relation between low heart rates and high antisocial behaviour can only be applied to people from the high socio-economic group.

Two reasons for this can be that the items of antisocial behaviour, as analysed in this thesis, are not divided into status-providing and non-status-providing antisocial behaviour. If this was done, the theory might have been a better predictor for the influence of socio-economic status on the relation between heart rate and antisocial behaviour. Secondly, the theory assumed that antisocial behaviour could provide status to people of the high socio-economic groups if they participate in stable peergroups. However, also the stability of the peer groups is not examined in the analyses. These two aspects may be researched in the future.

Another recommendation for further research is examining the influence of other social factors on the relation between heart rate and antisocial behaviour. Socio-economic status turned out to have no large influence, but maybe other social factors do.

Table of contents

Chapter 1

Introduction

Criminality and antisocial behaviour are considered serious problems worldwide. Much research has been done in these fields from disciplines as diverse as education, sociology, psychology and biology. There are many points of view, explanations, and solutions for the problems of criminality and antisocial behaviour.

A lot of research has been done into family, situational, and societal factors leading to antisocial behaviour (Rutter, Giller & Hagell, 1998). There is clear evidence that these factors have an important influence on this kind of behaviour. There is however, increasing evidence that also biological or physiological processes are important in examining antisocial behaviour (Raine, 1997). Furthermore it has been found that non-genetic, environmental processes produce physiological changes which in their turn can lead to antisocial behaviour (Raine, 2002). These biological and physiological processes therefore play a key role and need further examination.

Many researchers, like Buikhuisen and Mednick (1987) and Farrington (1987), plead for more integrated research. They want to see a further integration of sociological and biological aspects. Farrington even says that more research is needed to discover the precise relation between biological and non-biological aspects.

This thesis will take a multidisciplinary point of view. This research will contain sociological and biological aspects. The relation between heart rate (HR) and antisocial behaviour and the influence of socio-economic status (SES) on this relation will be researched. These subjects have been studied several times before, but this field of research still needs addition. It is for example not clear yet what the exact influence of SES is on the relation. A rational for choosing these variables to examine will follow in the second chapter.

Aim and research questions

The aim of this thesis is to obtain insight in the relation between HR and antisocial behaviour and to research if socio-economic status influences this relation.

There have been several investigations into the relation between HR and antisocial behaviour. This thesis contains another investigation into this relation and what the nature is of this relation. All this is done while using data of the Dunedin Multidisciplinary Health and Development Study (hereafter the Dunedin Study). The first research question is therefore the following:

1 'Is there a relation between low HR and high antisocial behaviour?'

Furthermore, the research into the influence of SES on the relation between HR and antisocial behaviour is equivocal and limited, as will be discussed in chapter two. Therefore further research is necessary. The second research questions is the following:

2 'Does SES influence the relation between low HR and high antisocial behaviour?'

Structure of this thesis

This thesis contains five chapters. After this introduction, chapter two follows with the theory and earlier research. Chapter two is divided into six sections. After the introduction in section 2.1, the second section provides a discussion about physiology. It will be discussed how physiology leads to behaviour (section 2.2.1), and more specifically how it leads to antisocial behaviour (section 2.2.2), whereafter a rationale is given to use HR - as one aspect of physiology - as a predictor for antisocial behaviour (section 2.2.3). The third section provides a sociological point of view. First of all will it be discussed how aspects of sociology lead to behaviour (section 2.3.1), and more specifically how it leads to antisocial behaviour (section 2.3.2), and finally one aspect of sociology, namely SES, is chosen and discussed as a predictor for antisocial behaviour (section 2.3.3). In section 2.4, the two disciplines (physiology and sociology) will be brought together to discuss the influence of SES on the relation between HR and antisocial behaviour. Earlier research into this subject (section 2.4.1) and a theoretical approach (section 2.4.2) will follow in this section. In section 2.5 the two hypotheses will be stated and finally in section 2.6, the reasons for using the data from the Dunedin Study will be discussed.

Chapter three contains the methodological part of this thesis. In the first section (3.1) the Dunedin Study will be discussed, as well as the data of this study (section 3.2). The data is discussed in three parts, the HR data (section 3.2.1), the antisocial behaviour data (section 3.2.2) and the SES data (section 3.2.3). Finally the analytical approach will be discussed (section 3.3).

The results of these analyses will be presented in chapter four. In section 4.1 the relation between childhood HR and antisocial behaviour will be discussed, whereafter in section 4.2 the relation between the adolescent HR's and antisocial behaviour will be presented and finally in section 4.3 the relation between the adult HR's and antisocial behaviour will be discussed.

Finally a discussion and conclusion will follow in chapter five. In that chapter the results will be summarized. Also will be discussed how these results differ from earlier findings and if these results are in line with the theory. Furthermore, how the results differ between the different developmental stages of HR and between the different measures of antisocial behaviour will be discussed. Also a discussion about the validity of the measures and the strengths and limitations of the study will be included.

Chapter 2

Theory and earlier research

§2.1 INTRODUCTION

This chapter contains six sections. Section two will explain the physiological part of this thesis. The third section explains the sociological part of the thesis. The two disciplines will be brought together in section four, in which the influence of SES on the relation between HR and antisocial behaviour will be scrutinised. The hypotheses, which will be investigated in this thesis, will be stated in section five. Finally, in section six will be explained why the research questions will be answered using the data of the Dunedin Study.

§2.2 PHYSIOLOGY

§2.2.1 Physiology and behaviour

Behaviour is a very general term and contains many aspects. 'Almost every writer on the subject has his own definition, his own point of view, his own method of procedure, and his own views as to what the aim of behaviour research should be' (Eysenck, 1964, p. 1). There are a lot of possible explanations for different types of behaviour and one type of explanation is the physiological one.

An example of physiological research is research into genetic influences. A good deal of evidence suggests that much human behaviour, which we regard as reflecting important personality characteristics, has strong genetic components. There is good evidence for a genetic component in sociability, or affiliativeness. There is less clear evidence for a genetic contribution to anxiety or neuroticism. There appears to be a significant genetic contribution to psychoticism (Mangan, 1982).

This is a very global example of physiological research leading to behaviour, but besides genetic influences there are many other factors leading to very different types of behaviour. Section 2.2.2 will discuss the ways in which physiology has been linked to antisocial behaviour.

§2.2.2 Physiology and antisocial behaviour

There are many points of view, explanations, and solutions for the problems of criminality and antisocial behaviour. There have been many studies into physiological factors leading to antisocial behaviour. It would be impossible to discuss all previous research in this field, and therefore a selection is made to demonstrate the type of physiological explanations for antisocial behaviour.

Genetic influences
The first type of physiological research into antisocial behaviour discussed here is genetic influences. Hollin (1992) says that the overall conclusion can be that heritable factors appear to increase the likelihood of criminal behaviour. Certain genetic and environmental antecedents can heighten the risk of criminal behaviour. Carey and Goldman (1997) carried out a meta-analysis showing that many studies have shown

that there is some genetic involvement in antisocial behaviour. It appears, for example, that both a long arm on the Y chromosome and an extra Y chromosome probably do cause an increased risk of behaviour problems, such as conduct disorder (Rutter et al., 1998). However, this meta-analysis showed that the heritability of violent behaviour is much less consistent than the evidence for heritability of general antisocial behaviour. Exactly how a genetic factor works is still unclear.

Central Nervous System (CNS)
The CNS includes the brain and the spinal cord. Therefore, studies of the CNS are concerned with brain functioning and the transmission of information through the CNS. One of the traditional ways to assess brain functioning is through the use of electroencephalograms (EEG). A large number of studies implicate EEG abnormalities in violent recidivistic offending (Raine, 1997). However, Hollin (1992) says that the pattern that emerges from recent research is somewhat equivocal. Some studies have suggested links between EEG abnormalities and violent behaviour, while others did not.

A fundamental way of transmission of information through the CNS is by chemical neurotransmission (Hollin, 1992). There has been a lot of research into the relation between neurotransmitter function and aggressive and violent behaviour. Frequently researched neurotransmitters are serotonin and noradrenaline (Berman, Kavoussi & Coccaro, 1997). For example, from the findings of both animal and human studies, it seems that serotonin exhibits inhibitory control over aggression (Hollin, 1992; Volovka, 1995). Lower levels of serotonin have been found in violent individuals (Hollin, 1992).

Hormonal physiology
Another example of physiological factors leading to antisocial behaviour is hormonal physiology. An example of research in this field is investigations into the relation between testosterone and violent behaviour. For both adolescents and adults there may be a relation between higher testosterone levels and violence (Hollin, 1992). However, this relation is not invariable; high testosterone levels have also been found in men who were not criminal (Hollin, 1992).

Another aspect of hormonal physiology is cortisol. Cortisol is released in the body during stressed or agitated states, and is the so-called ‘stress hormone’. But this hormone is also necessary for the functioning of almost every part of the body. Low cortisol is in general associated with more antisocial behaviour (Brain & Susman, 1997). Low cortisol levels are associated with aggressive behaviour in children and adults in several studies (Virkkunen, Rawlings, Tokola, Poland, Guidotti, Nemeroff, Bisette, Kalogeras, Karonen & Linnoila, 1994; Bergman & Brismar, 1994).

Autonomic Nervous System (ANS)
The ANS is concerned with the internal running of the body, connecting the CNS with various organs. This system plays a large role in, for example, the regulation of breathing, HR and blood flow. It is increasingly argued that these variables are related to criminal behaviour. It has been suggested that ANS arousal is lower in criminals (Raine, Venables & Williams, 1990). However, the pathway to criminal behaviour is not exactly understood (Hollin, 1992). This relation is central to the present research, and will be discussed fully later.

Further research
The above-mentioned research into physiological factors leading to antisocial behaviour still needs a lot of additional research to draw conclusions about the relation between physiology and antisocial behaviour. Importantly, it is often still unclear what the direction of the relation between a physiological factor and antisocial behaviour is. The research is also, in many ways, equivocal and the working of many mechanisms needs further attention.

In this thesis attention will be paid to one physiological measure leading to antisocial behaviour, namely HR. In the next section, it will be explained why HR is chosen as a subject for further research. Also the earlier research in this field and the theoretical approach for the relation between HR and antisocial behaviour will be discussed.

§2.2.3 HR and antisocial behaviour

As discussed in the previous section, in this thesis attention will be paid to HR. Raine (2002) mentions several reasons to do so. Firstly, he mentions that it is the best-replicated correlate of antisocial behaviour in child and adolescent samples (Rutter et al., 1998). Secondly, Raine mentions that the relation between HR and antisocial behaviour is not artificial (Wadsworth, 1976; Raine, Venables & Mednick, 1997). Potential artifacts have been ruled out repeatedly in earlier research, as for example physiological confounds as height, weight and body bulk, but also social confounds as family size and divorce, and psychological confounds as low IQ. Third, Raine mentions that the relation is confirmed in prospective studies (Wadsworth. 1976; Farrington, 1987; Raine et al., 1990, 1997a). Fourth, low HR is diagnostically specific (Raine, 2002). Only antisocial behaviour has turned out to relate with lower HR, while for example depression, schizophrenia, and anxiety disorder have been linked to higher HR's. Fifth, the findings have been replicated in at least six countries (Raine, 2002). Sixth, the relation is consistent with gender differences in antisocial behaviour (Moffitt, Caspi, Rutter & Silva, 2001). That is, low HR characterises female as well as male antisocial individuals (Moffitt & Caspi, 2001). Seventh, HR characterises life-course persistent antisocial individuals in particular (Moffitt, 1993; Moffitt et al., 2001). Finally, Raine mentions that HR interacts with psychosocial risk factors (Farrington, 1997).

All these aspects are studied before. So why researching it again? This will be discussed in section 2.6. First, in section 2.2.3.1 earlier research into the relation between HR and antisocial behaviour will be scrutinised.

Earlier findings

To get an overview of the relation between HR and behaviour, a couple of resources have been used. Raine (1993) has done a meta-analysis of the studies into the relation between HR and antisocial behaviour thus far. He used the studies with resting HR. Where possible in this thesis, the original source has been used. For an indication of the researches after 1993 several databases are used, all volumes of the Biological Abstracts, Medline, PsychINFO and Sociological Abstracts after the year 1993. In the volumes of these three databases is searched for a combination of the words HR and conduct disorder and for a combination of the words pulse rate and conduct disorder, both in the title of the article, as well as in the abstracts. If an article dealt about the

relation between HR and antisocial behaviour or conduct disorder this article was sought. Probably this overview is not complete. Some research is not available or never published, because it was only presented at a conference. The aim of this overview is however not to give a complete review, but to provide an impression of the research investigating the relation between HR and antisocial behaviour.

Below will follow a summary of the main findings in the research field of the HR – behaviour relation. The discussion of the research into the relation between low HR and antisocial behaviour will be divided into research on boys, girls, and mixed groups. Within each of these sections, the description is in order of the ages of the study members.

Boys

Maliphant, Watson & Daniels (1990) researched 50 boys of age seven to nine, attending two primary schools. They used three groups, a disruptive group (i.e. low levels of motivation and concern, unresponsive and difficult to handle), an intermediate group and a well-behaved group. The result was that the disruptive group had significantly lower HR's than the other two groups. The same result was found in the research of Kindlon, Tremblay, Mezzacappa, Earls, Laurent & Schall (1995). They examined 138 boys at age nine to twelve from the lower classes of Montreal. The study members had been rated as having disruptive behaviour problems in kindergarten.

Raine and Jones (1987) examined 40 Caucasian boys from one special school and one hospital for behavioural maladjusted children in Nottingham. The boys who visited the hospital were of age seven to eleven and the children visiting the special school were of age eleven to fifteen. The two groups were combined to get a more acceptable sample size. They used two scales, the conduct disorder scale and the socialised aggression scale of the Revised Behaviour Problem Checklist (RBPC; Quay and Peterson, 1987). They found a correlation in which low HR was associated with antisocial behaviour. Wadsworth (1976) researched boys at the age of eleven. He examined 1813 male English, Scottish and Welsh schoolchildren. The result was that official delinquents had significant lower HR's than non-delinquents did. Delinquency was measured by court appearances and police contacts between the ages 8 and 21.

The first research in the field of the HR – behaviour relation was done by Davies and Maliphant (1971). They examined 68 schoolboys from England at the ages of thirteen to sixteen years old. The result was that the refractory boys (i.e., those who scored highly on measures of deviant behaviour) had significant lower HR's than the control group. Pitts (1997) has done research of 103 male study members from third to sixth grade classrooms from a lower status school in the district near Los Angeles. A consistent finding was that the HR's of the aggressive subjects were significantly lower than the HR's of the non-aggressive subjects.

Raine and Venables (1984) researched 101 fifteen-year-old schoolboys from England. They measured antisocial behaviour using the Behaviour Problem Checklist from Quay and Parsons (1970) and using self-reports of delinquent behaviour. The result was that antisocial adolescents (i.e., those who are unsocialised, psychopathic or who break the law) were characterised by lower HR's. Raine et al. (1990) used the same data a few years later to research the behaviour of the study members at the age of

twenty-four. The criminal group at the age twenty-four had significant lower HR's at age fifteen than had the non-criminal group.

Lösel and Bender (1997) researched boys of the age of sixteen to eighteen. They examined 37 adolescents and found no significant correlation between low HR and antisocial behaviour. They give a possible explanation for a non-significant effect, namely that the study members were from institutions and they all had disturbed backgrounds. They suggest that intensive supervision of high-risk juveniles may stimulate their HR and increase their sensitivity for social stimuli like punishments or delayed rewards.

West and Farrington (1977) examined 387 eighteen and nineteen years old English men. Those who were convicted of adult or adolescent offences were significantly over-represented in the low HR category and underrepresented in the high HR category. Ten years later Farrington (1987) reported research about the same population. He found the same result as before. Low HR's were significantly related to offending up to the age 25.

The last research discussed here, concerning boys only, was done by Zahn & Kruesi (1993). They examined 34 boys of age six to seventeen years old. They found higher HR's in boys rated as oppositional defiant disordered. This is very remarkable, given the results of the studies described above. The researchers commented that the findings could be caused by the selection of the study members. The boys were from a clinic-referred sample and all were children with an attention deficit hyperactivity disorder (ADHD). They were brought to a clinic by their parents, which may have biased the sample towards having anxious parents, and so may contribute to a higher HR.

Girls

The research concerning the relation between HR and behaviour concerning girls only is rarer. The first research was done by Maliphant, Hume & Furnham (1990). They examined 44 girls between twelve and thirteen years old. They all came from the middle or high social classes. Girls rated as disruptive had significant lower HR's than girls who were rated as well behaving or who were in an intermediate group.

The second research concerning girls only is by Bullock (1988). He researched 51 fifteen years old schoolgirls. The result was that antisocials had on average significantly lower HR's than prosocials.

Mixed groups

The remaining research of the relation between low HR and antisocial behaviour is done on mixed groups, containing boys and girls. El-Sheikh, Ballard & Cummings (1994) researched 34 four and five years old boys and girls. The result was that boys as well as girls having lower HR's had significantly more externalising behaviour (e.g., overactivity, defiance, non-compliance, aggression) problems than the high HR group. Furthermore, Van Hulle, Corley, Zahn-Waxler, Kagan & Hewitt (2000) researched 647 twins at the ages 14, 20 and 36 months and seven years. In spite of the results of the research mentioned above, Van Hulle et al. found no relation between HR and antisocial behaviour. In this case the null findings may have been due to the

very early age at which HR was measured, since HR's tend to be higher in infants (www.nlm.nih.gov/medlineplus).

Little reported in 1978 about a research of English male and female schoolchildren (Raine and Venables, 1984) at the ages seven, nine and eleven. These children showed significant lower HR's in antisocials in comparison with well behaving children at the ages nine and eleven. Antisocial behaviour was measured with the Rutter teacher rating scale (Rutter, Tizard & Whitmore, 1970). The relation was not found for the age of seven. This may signify a developmental trend in the relation between HR and behaviour.

A large investigation into the relation between HR and antisocial behaviour was conducted on the island of Mauritius, where 1795 girls and boys were examined (Raine et al., 1997a; Raine, Reynolds, Venables & Mednick, 1997b). The two main ethnic groups were Creoles and Indians. Raine et al. (1997a, 1997b) studied the relation between HR, measured at age 3, and antisocial behaviour, measured at age 11 using the Child Behaviour Checklist (Achenbach and Edelbrock, 1983). They made a distinction between aggressive and non-aggressive antisocial behaving children. Highly aggressive children had significantly lower HR's than non-aggressive children did. The non-aggressive antisocial children did not differ significantly from the children who scored low on non-aggressive antisocial behaviour. Raine et al. (1997a) also examined the low HR group versus the high HR group. The low HR group had higher aggression scores than the high HR group. The low HR group also had higher scores on non-aggressive antisocial behaviour than the high HR group. Furthermore, the low HR group had significantly higher scores on total antisocial behaviour than the high HR group.

Many studies are discussed in this section. These are therefore summarised in table 1.

Effect sizes

In table 1 also the effect sizes are given. Not all effect sizes could be presented, because some important information was missing in several papers to calculate these effect sizes. Effect sizes were calculated by subtracting the means from each other and dividing this number by the standard deviation. Except the equivocal or null findings of Lösel and Bender (1997), Zahn and Kruesi (1993) and Van Hulle et al. (2000) the findings of the earlier studies are rather consistent. Lower HR's are found in disruptive boys, official delinquents, refractory boys, aggressive subjects and in antisocial adolescents. Besides these differences between the antisocials and the non-antisocials, also correlations between low HR and antisocial behaviour turned out to be significant. The effect sizes of the studies however, were ranging from low (Wadsworth, 1976; Kindlon et al., 1995; Raine et al., 1997a, 1997b) to very high (Bullock, 1988; Maliphant et al., 1990b).

Table 1 *Studies into the relation between heart rate and antisocial behaviour*

SEX	*AUTHOR*	*SAMPLE SIZE*	*HEART RATE AGE*	*ANTISOCIAL AGE*	*RESULT*	*SES AS A MEDIATOR*	*EFFECT SIZES*
MALE	Maliphant et al. (1990b)	50	7-9	7-9	Lower HR's in disruptive boys	-	1.91
	Kindlon et al. (1995)	138	9-12	9-12	Lower HR's in disruptive boys	-	0.28
	Raine and Jones (1987)	40	7-15	7-15	Correlation between low HR and antisocial behaviour	-	0.63
	Wadsworth (1976)	1813	11	8-21	Lower HR's in official delinquents	-	0.39
	Davies and Maliphant (1971)	68	13-16	13-16	Lower HR's in refractory boys	-	1.44
	Pitts (1997)	103	7-11	7-11	Lower HR's in aggressive subjects	-	-
	Raine and Venables (1984)	101	15	15	Lower HR's in antisocial adolescents	Only for adolescents in the high SES group	0.58
	Raine et al. (1990)	101	15	24	Lower HR's at age 15 in the criminal group at age 24	-	0.63
	Lösel and Bender (1997)	37	16-18	16-18	Non-significant correlation between HR and antisocial behaviour	-	0.20
	West and Farrington (1977)	387	18-19	18-19	Overrepresentation in the low HR group of people who were convicted of adult or adolescence offences	-	-
	Farrington (1987)	387	18-19	25	Low HR's were significant related to offending up to age 25	-	0.40
	Zahn and Kruesi (1993)	34	7-17	7-17	Higher HR's in disruptive boys	-	0.61
FEMALE	Maliphant et al. (1990a)	44	12-13	12-13	Lower HR's in girls rated as disruptive	-	1.28
	Bullock (1988)	51	15	15	Lower HR's in antisocials	-	1.60
MIXED GROUPS	El Sheikh et al. (1994)	34	4-5	4-5	More externalising behaviour problems in boys and girls with lower HR's	-	0.50
	Van Hulle et al. (2000)	647	14, 20, 36 months, 7 years	7	No relation between HR and antisocial behaviour		0.06-0.26
	Little (1978)	-	7, 9, 11	7, 9, 11	Lower HR's in antisocials at ages 9 and 11	-	-
	Raine et al. (1997a, 1997b)	1795	3	11	Lower HR's in highly aggressive children/ Higher aggression in the low HR group/ Higher scores on non-aggressive behaviour in low HR groups/ Higher scores on total antisocial behaviour in the low HR group	The low HR group was more antisocial than the high HR group in those from the high SES group. This could only be applied to Creoles, not to Indians (Raine et al., 1997b)	0.33/0.32

Theoretical approach

Arousal theory

One theory offered for the relation between low HR and antisocial behaviour is the *arousal theory*. This theory postulates that antisocial behaviour in individuals is caused by the fact that those individuals have an ongoing low level of arousal. Arousal levels can be measured by frequency and amplitude of EEG waves (high frequency, low amplitude waves indicating increased arousal), through motor and sensory effects (greater restlessness, increased receptor sensitivity) and through autonomic effects, which includes sympathetic mobilisation of increased blood pressure and HR (Mangan, 1982). Resting HR is often used, because it is relatively easy to record. The arousal theory can be divided into two parts, the fearlessness theory and the stimulation seeking theory (Raine, 1993, 1997).

The *fearlessness theory* posits that low levels of arousal are markers of low levels of fear. This assumption is made because subjects are not actually at 'rest' but that instead the rest period of psychophysiological testing represents a mildly stressful paradigm and that low arousal during this period indicates lack of anxiety and fear. People with low HR's, or arousal, are not frightened or scared easily. Evidence for this comes from the work of Cox, Hallam, O'Connor & Rachman (1983) who showed that people working as bomb disposal experts (a job requiring a low level of fear) have on average particular low HR's. The fearlessness theory states that low fear leads to an increased propensity to engage in antisocial behaviour. The theory maintains that those who are more fearful do not dare to engage in antisocial behaviour.

Finally, there is another factor playing a part. Those who are not easily scared will have little fear of the consequences of their antisocial behaviour, such as punishment by parents or caretakers. If punishment does not work, the socialising process is likely to be less effective. Norms and values might not be able to be passed on to these children very well. Because of this there is a larger chance that low HR children become antisocial (Raine, 1993).

The *stimulation seeking theory* states that those with low levels of arousal (HR in this case) are searching for activities to bring their arousal at a normal or an optimum level (Raine, 1993). These people are searching for excitement and adventure. They will experience daily activities as routinely and boring much sooner and so will seek for stimulation more readily. In this sense antisocial behaviour is seen as a form of stimulation seeking. Zuckerman, Simons & Como (1988) state that novelty and complexity are characteristics that can raise arousal and stimulation.

Quay (1965, p. 181) states that: 'In a highly organised environment such as that in which modern man resides this seeking of either added intensity or added variability of stimulation may on occasion involve transgressions of both law and moral code'.

Other explanations

Besides the arousal theory there are some other explanations for reduced HR in antisocials. One suggestion is reduced right hemisphere functioning. The right hemisphere is dominant for the control of autonomic functions, including HR (Raine, 2002). Also, poor right hemisphere functioning has been associated with deficits in

the withdrawal system, which make people retreat from aversive and dangerous situations. Reduced right hemisphere functioning and a weaker withdrawal system could make children less averse to dangerous, risky situations, which increase the risk of behaving antisocial (Raine, 2002). The result can be lower HR's in antisocial people.

A possible fourth explanation for low HR's in antisocials is the physical compensation for frequently heightened levels of HR. If a person behaves antisocially, HR will increase. If the body is exposed to frequent increases in HR it is possible that the body compensates for this by lowering the resting HR. This is a similar process to that in athletes, who have low resting HR's caused by frequently heightened levels of HR when they exercise (www.nlm.nih.gov/medlineplus).

§2.3 SOCIOLOGY

In this section, a theory will be discussed which links sociology to behaviour (section 2.3.1), after which this will be narrowed to antisocial behaviour (section 2.3.2). Finally, one aspect of sociology will be discussed in section 2.3.3. Because this is a thesis in sociology, this section will be a little bit more theoretical than the previous section.

§2.3.1 Sociology and behaviour

A lot of sociological theories about behaviour have been developed over time. It would be too comprehensive to go into detail, but to get an idea of a sociological theory explaining behaviour, the *Social Production Function theory* (SPF-theory) of Lindenberg (1996) will be discussed in this section. This theory integrates psychological theories (Diener, 1984) and economic consumer/household production theories (e.g. Becker, 1996). Furthermore there is considerable overlap with Maslow's renowned need hierarchy (Maslow, 1970).

Lindenberg (1996) has developed a theory about how people produce their well being. The theory is based on the assumption of the rational acting human being. People use profitable sources to create well being. The well being can be produced by two universal goals, namely *physical well being* (appreciation of someone for his or her life in physical aspects, as for example feeling healthy) and *social well being* (appreciation of someone for his or her life in social aspects, for example feeling appreciated and having friends). And there are instrumental goals to reach these two universal goals. These are *stimulation* and *comfort* for physical well being. Comfort is the absence of for example pain, thirst, hunger, fatigue and fear. Stimulation implies that performed activities produce arousal. This rising level of arousal is experienced as pleasant. Too high and too long lasting levels of arousal however, can be experienced as less pleasant. Stimulation in this theory is meaning the same as stimulation is meaning in the arousal theory. The arousal theory consequently forms a part of the SPF-theory.

Besides the above-mentioned physical well being, social well being is the second universal goal. Social well being can be obtained by three instrumental goals. These are *status, behavioural confirmation* and *affectio*n. Status means possessing scarce resources or having a good position with regard to others. People can obtain status by

holding a leading position, having a lot of money or following good education. Behavioural confirmation can be received from intimate family and friends. People will confirm behaviour when this is exhibited in accordance with the existing norms and values in a group. Finally affection means the love people receive from these same intimate friends and family. Affection can be received from a partner, parents, relatives and friends.

Comfort, stimulation, status, behavioural confirmation and affection are called first-order instrumental goals, instruments to produce general well being. But these first-order goals have to be produced as well. Means to produce these first-order goals are activities and gifts. For example, stimulation can be obtained by physical and mental activities, which produces arousal. Comfort is produced by for example the absence of pain, hunger and thirst, good accommodation, possessing household appliances and good furniture. Status can be reached by for example having a good job. And an activity to obtain behavioural confirmation is confirming to norms and values in a group. Finally, affection can be produced by intimate relationships with a partner, parents, relatives and friends. All these activities and gifts are the so-called second-order instrumental goals.

In their turn resources can produce second-order instrumental goals. For example, physical and mental effort is needed to produce arousal (which produces stimulation). Food, health care and money are needed for the absence of pain, thirst and hunger. Furthermore, education and labour is needed for the production of the second-order goal having a good job, social skills are needed to know how to conform to the norms and values of a group. And finally for example having a partner or having good friends can produce intimate relationships. These resources are the so-called third-order instrumental goals.[1]

The above-mentioned can be summarised in table 2.

Table 2 *SPF-theory*

Highest level	*General well being*				
Universal goals	*Physical well being*		*Social well being*		
First-order instrumental goals	*Stimulation*	*Comfort*	*Status*	*Behavioural confirmation*	*Affection*
Activities and gifts, for example:	Physical and mental activities producing arousal	Absence of pain, hunger and thirst, having good accommodation	Profession, good job, possess much money	Confirm to the norms and values in a group	Intimate relationships with people
Resources, for example:	Physical and mental efforts	Food, health care and money	Education and labour	Social skills	Partner and good friends

Source*: Ormel, Lindenberg, Steverink & Verbrugge (1996)*

The instrumental goals can be exchanged. If affection drops off by losing a good friend, people will go and search for status and behavioural confirmation to maintain the same level of social well being. Another possibility to produce more affection is

[1] Besides the first-order, second-order and third-order instrumental goals or means for producing well being, there are fourth-order means for production. These are the so-called 'latent' means, or reserves. These reserves can be used when the means of the other orders are not sufficient to produce general well being. Examples are savings, friends with whom you have not much contact or non-utilised talents.

searching for contact with other people. A sufficient level of one resource can fill the lack of another. This process is called substitution.

Furthermore, some means are multifunctional: they produce more than one goal. For example, a friendship produces behavioural confirmation and affection, but it can also contribute to the production of stimulation if doing exiting things with a friend. However these multifunctional sources can cause a large problem if they drop off. If somebody's partner dies, the loss of behavioural confirmation and affection is huge and can not be filled up easily.

As just mentioned, goals can be exchanged. Substitution is taking place between the one and the other mean. However, this substitution is limited. Everybody needs a certain level of each instrumental goal. For example, comfort can not be fully replaced by stimulation, because people can not live without any food or drinks.

§2.3.2 Sociology and antisocial behaviour

Again sociology will be linked to antisocial behaviour by the SPF-theory to get an idea about a sociological point of view of antisocial behaviour. Children and youth, as well as adults, are looking for general well being. This can be done in several ways. Antisocial behaviour is one of these ways to do so. Antisocial behaviour can be a multifunctional mean to produce well being (Ormel, in press), which means that antisocial behaviour can fulfil several goals in once. How you can produce status by being antisocial will be discussed extensively in section 2.4.2. In summary, you can obtain status, because you dare to exhibit behaviour which others do not dare. You are a tough acting person and are therefore admired by peers, which leads to behavioural confirmation and status. And because you are participating in a group, you will receive affection from the group members. Furthermore it can be said that the tension of exhibiting antisocial behaviour produces stimulation (stimulation seeking theory). Some kind of antisocial behaviour even produces comfort, for example stealing a car. Exhibiting antisocial behaviour in a group where the members are in general less fearless, is multifunctional for obtaining well being.

Besides the fact that antisocial behaviour can be multifunctional, antisocial behaviour can also contribute negatively to general well being. Besides behavioural confirmation of the peergroup, people can also receive disapproval from parents or family members or from society in general if one behaves antisocial. That is how a person can get punished in stead of getting affection and how status is not obtained. Furthermore, the antisocial behaviour can result in punishment, which causes a decline in comfort and stimulation. You can, for example, be subjected to house arrest so you can not play with friends anymore. And if children become older the antisocial behaviour can also result in being placed in a prison or institute. This causes a large decline in comfort and stimulation.

But what is it that people make behaving antisocial or what is it they are restrained from this kind of behaviour? The following section tries to give an answer to this question.

People who behave antisocially

The arousal theory, which encompasses the fearlessness theory and the stimulation seeking theory, is based on the assumption that people with low HR's increase their arousal level by behaving antisocial. The SPF-theory is also assuming this. The low level of stimulation can be a cause for exhibiting antisocial behaviour, because this produces a normal or higher level of stimulation. But besides this goal the SPF-theory assumes there are several other goals which can be obtained by antisocial behaviour. This is discussed above. The initial cause for behaving antisocially can be a low level of stimulation, but the goals which are reached by this behaviour are much wider in the SPF-theory, opposed to the arousal-theory.

The SPF-theory also assumes that a low level of stimulation can be replaced by other means producing other goals, like comfort, status, behavioural confirmation and affection. If a person receives sufficient behavioural confirmation and affection from parents or other family members, he or she is less likely to behave antisocial, because the lack of stimulation can be compensated by this affection and behavioural confirmation and the same level of well being is produced by other means. However there are persons who can not compensate a lack of stimulation by other means and are therefore behaving antisocial. Ormel (in press) cites four conditions which causes persons to behave antisocial much sooner if they satisfy the following conditions.

a) You have reached a low level of well being by 'normal' activities, which means without antisocial activities or gifts. This low level of well being makes it that you have less to lose by behaving antisocially.
b) The costs for behaving antisocial are low. Antisocial behaviour is easier to exhibit, because there are for example more possibilities to do so.
c) Antisocial behaviour is very productive for obtaining well being. It is a multifunctional mean to reach several goals in once.
d) The costs for reaching well being in a 'normal' way are high.

These conditions will be discussed in turn.

a) People with low HR's have little stimulation. If they also have obtained few other means or resources in the past to produce well being they are not able to fulfil the lack of stimulation. That is why they are going to seek for other means to obtain well being. Antisocial behaviour can be one of these means. Furthermore, people with for example little behavioural confirmation, status and affection have less to lose. So, besides the low HR there are other causes which settle the manner of behaving antisocial.

b) To behave antisocial you need possibilities to do so. If you do not know how to behave antisocial it is harder for you to perform this behaviour. If you have antisocial friends you will perform antisocial behaviour easier. Friends can for example operate together in a burglary or explain how to perform certain antisocial acts. Furthermore it is easier to perform antisocial behaviour if you have little supervision. A lack of supervision can therefore play part in behaving antisocial.

c) In the beginning of this section it was discussed how antisocial behaviour can be productive by obtaining well being. It was also discussed why this behaviour can be

non-productive by obtaining well being. The reason why a person would choose for behaving antisocial is because he or she finds it more important to receive behavioural confirmation and affection from friends and peers instead of receiving this from parents, other family-members or the society in general.

d) The costs of reaching well being in a 'normal' way can be high. A low IQ for example can lead to a worse job and less income. That is how a person has less status and can not 'buy' much comfort. Furthermore unemployment leads to high costs for reaching well being in a normal way. An unemployed person has less income and therefore less status and comfort. Few social skills lead to high costs to develop friendships, which can lead to little behavioural confirmation, affection and stimulation. In short, the second-order instrumental means are not sufficient to produce well being. That is why someone has to open up new resources to produce this well being. This raises the risk that someone will go and look for this in antisocial behaviour.

In short, there are a lot of risk factors, which lead to the exhibition of antisocial behaviour. Low HR is a physiological risk factor. The risk factors discussed here are social risk factors. Low HR does not have to be sufficient for the start of exhibiting antisocial behaviour. There are several other factors, which have roles to play.

People who do not behave antisocially

As mentioned in section 2.2.3.2, the arousal theory describes why some people with low HR's are likely to behave antisocially. This theory does not describe why other people with low HR's do not behave antisocially. The SPF-theory however is able to give an explanation. The reasons why people do not behave antisocial can be explained by the four conditions of Ormel (in press):

a) A high level of well being is reached with 'normal' activities, so without antisocial activities or gifts. Because of this high level of well being, a lot is at risk to be lost.
b) The costs for antisocial behaviour are high. Antisocial behaviour is harder to exhibit, because there are less opportunities to do so.
c) Antisocial behaviour is less productive by obtaining well being. It is not a multifunctional mean to obtain several goals in once.
d) The costs for obtaining well being in a 'normal' way are low.

These will be discussed in turn.

a) A high level of well being is obtained. A lack of stimulation is sufficiently compensated by other means which also produce well being. For example, you have sufficient friends, healthy family relationships, intact homes or you receive enough love and affection, have a high IQ or a good job. It is not necessary to behave antisocial to raise the level of well being. Furthermore, you can experience the level of stimulation to be too low and raise this level by stimulation seeking activities, such as doing exciting things with friends or sports or activities that will bring the arousal at a very high level, such as making a parachute jump or bungee jumping, as well as practicing a 'dangerous' job, such as a bomb disposal expert. Finally a person with a high level of well being will risk loosing this by behaving antisocially. Many

resources that produce well being will drop off, for example behavioural confirmation and affection from family and prosocial friends.

b) The costs for behaving antisocial are high. You have for example no antisocial friends and are therefore not familiar with antisocial activities such as how to break into a house. You can also have fewer possibilities, because you have more supervision of parents or attendants, so you are better looked after.

c) As discussed in the beginning of section 2.3.2 antisocial behaviour can be a multifunctional mean to obtain well being. This is however not always the case. It can contribute to stimulation, but not to behavioural confirmation and affection. For example if you have no antisocial friends, so the behaviour is rejected by the peers or friends.

d) The costs to produce well being in a 'normal' way are low. People have access to enough resources to produce well being. Just as in 'a', examples are sufficient friends, a good job, a high IQ, a good family structure, etc.

People with low HR's, who do not behave antisocial do have sufficient possibilities to compensate the lack of stimulation caused by a low HR. There are therefore sufficient factors of protection that will restrain people from behaving antisocial.

Risk and protection factors

The SPF-theory is a social-theoretical approach and can give an explanation about why people with low HR's behave antisocial or why these people do not behave antisocial. Whether a person behaves antisocially or not depends on the risk factors to which they are exposed. In the above-mentioned, several risk and protection factors are discussed. To compare these factors and to form a picture about the completeness of the SPF-theory, risk factors from other studies are discussed below. These studies are from Rutter et al. (1998), Loeber and Farrington (1998) and Raine (1993).

Rutter et al. (1998) discuss several factors, which are divided into two groups, the individual factors and the psychosocial factors. The individual factors contain genetical influences, birth complications, low intelligence, temperament, few friendships, hyperactivity, drugs- and alcohol abuse and possible biological risk factors. The psychosocial factors include risk factors such as teenage parenting, large family size, broken homes, neglect and abuse, antisocial friends, poverty and unemployment.

Loeber and Farrington (1998) also discuss risk factors. These factors are divided into four groups, the child factors, family factors, macrofactors and neighbourhood factors. Child factors include low intelligence and low school achievement, hyperactivity and impulsivity and characteristics as being shy and having a lack of guilt. The family factors are little supervision by parents, delinquency by parents and siblings and separation of the child from the parents. Macrofactors include poverty, bad housing, unemployment of the parents, one-parent families, large family size and young mothers. Concerning the neighbourhood, a bad, dilapidated neighbourhood is a risk factor.

The above-mentioned factors can be considered social factors. Raine (1993) has concentrated on biological factors, as well as on social factors. He discusses genetical influences, the influence of neurotransmitters, neuropsychological influences, a low level of arousal, head injuries, pregnancy and birth complications, physical fitness and hormones. Furthermore he discusses cognitive shortages. Family factors and social factors are discussed as well. These includes criminality of the parents, child abuse, death of parents, divorce of the parents, poor supervision by the parents, marriage conflicts of the parents, neglect, few friendships, poor school achievements, large family size, social class, unemployment, a low income, living in a city and poor housing.

Comparing the risk factors discussed in the SPF-theory with the risk factors in the other researches of Loeber and Farrington (1998), Rutter et al. (1998) and Raine (1993) it can be said that the factors are largely corresponding with each other. Besides low HR people can be exposed to other biological, psychological and social factors.

§2.3.3 SES and antisocial behaviour

In this thesis, how one aspect of sociology – SES – relates to antisocial behaviour will be discussed.

For a long time it was believed that juvenile delinquency was much more common in those from the low SES groups. Many social theories of crime are based on this assumption (e.g. the social control theory of Hirschi, 1969). However, most data contradict these sociological assumptions (Rutter and Giller, 1983). Most research only show a slight negative association between SES and antisocial behaviour. Loeber and Dishon (1983) did a meta-analysis on seven studies in this field. There was only one study, by Knight and West (1975), showing that SES was a good predictor for antisocial behaviour.

It seems that the main SES effect is seen with serious offences and especially with crimes of violence. Earlier research show some association between SES and official statistics, but they also indicate that delinquency occurs in all social groups and is far from restricted to only the low SES groups (Rutter and Giller, 1983).

The relation between SES and antisocial behaviour is however also examined with the data of the Dunedin Study. These results are more recent and show that people from the lower SES groups were at increased risk to develop antisocial behaviour (Moffitt et al., 2001). Because in this thesis SES will be used as an interaction-variable, the discussion about SES as a main effect will not go further in detail. The interaction-effect will be scrutinised in the next section.

§2.4 PHYSIOLOGY AND SOCIOLOGY INTEGRATED

Firstly, in section 2.2 was discussed how physiology can influence behaviour, and in particular antisocial behaviour, whereafter a rationale was given for the use of HR in this thesis. In section 2.3 was discussed how sociology can influence behaviour, and, in particular, antisocial behaviour, whereafter the variable SES was introduced. In this section the two disciplines are brought together. It will be discussed how SES can

influence the relation between HR and antisocial behaviour. In section 2.4.1 the earlier research into this subject will be discussed. In section 2.4.2 a theoretical point of view will be given for the influence of SES on this relation.

§2.4.1 Earlier findings

Can the relation between low HR and antisocial behaviour be applied to everyone? A few studies have examined the influence of SES on the relation between HR and antisocial behaviour. Raine and Venables (1984) examined 101 fifteen-year-old schoolboys from England. They measured antisocial behaviour using the Behaviour Problem Checklist of Quay and Parsons (1970) and using self-reports of delinquent behaviour. They found that low HR was a predictor of antisocial behaviour in the high SES group but not in the low SES group. SES was based on a measure of parental occupation.

In addition, Raine et al. (1997a, 1997b) studied the impact of SES on the relation between low HR and antisocial behaviour in a much larger sample. They examined 1795 girls and boys from the island of Mauritius. The two main ethnic groups were Creoles and Indians. Resting HR was assessed at age 3 years and antisocial behaviour was assessed at age 11 years using the Child Behaviour Checklist from Achenbach and Edelbrock (1983). SES was developed from a factor analysis of social variables collected in a social worker's interview with the mothers (variables loading on this factor were parental occupation, number of years of education of the parents, additional educational training of the parents, number of rooms per person, number of rooms in the house, and appearance of the home). They found an ethnicity by SES by HR interaction, such that for Creoles only, the low HR group was more antisocial than the high HR group, but only in those from the high SES group (Raine et al., 1997b).

These studies are the only investigations into the influence of SES on the relation between HR and antisocial behaviour. This thesis contains another investigation. This time a large, population-based, Westernised sample is used.

§2.4.2 Theoretical approach

The existing theory (arousal theory) on the relation between HR and antisocial behaviour is not sufficient to explain the influence of SES on this relation. That is why the SPF-theory will be used to give a possible explanation to this question. This explanation is discussed in this section.

The SPF-theory postulates that when a good is scarcer, it is easier to obtain status with it. For example, if you possess some kind of property and others do not, you are more likely to distinguish yourself from the rest of the people than if there is plenty of this property or good. An expensive car in front of your house only provides status if all other people in the neighbourhood do not have such an expensive car. The expectation is that in the higher SES groups the 'good' or resource of fearlessness (what is associated with antisocial behaviour) is much scarcer than in the lower SES groups. This means that someone being fearless in the high SES group can distinguish himself much better from other people than someone being fearless in the low SES group. There are several reasons to suggest that people in the higher SES groups are less fearless.

First of all, the assumption is that people from the higher SES groups have in general more skills to monitor the consequences of their behaviour, for example being aware of the fact that you will be punished if you behave antisocially. But also is assumed that, in general, people from the high SES groups also have more social skills, so they are more able to realise that they can upset others by exhibiting antisocial behaviour. If someone is more conscious of the consequences of the exhibited behaviour he or she will therefore abandon this behaviour much sooner. They are afraid of the consequences of the behaviour and will avoid it.

Another reason why persons of the higher SES groups will be less fearless can be that they have more to lose. The suggestion is that in the higher SES groups parents or caretakers attach more value to for example independence, creativity and ambition and that these characteristics are also often found in the parents or caretakers themselves. However it is suggested that in the lower SES groups these values are less important and a characteristic such as ambition does not appear that much in the lower classes as in the higher classes. Behaving antisocial is a sign of not confirming to the values of for example independency and ambition. If a person behaves antisocial it is against the values which are important for parents or caretakers (and people in general) in the high SES group. A certain amount of appreciation is lost by behaving antisocial. On the contrary it is supposed that these values are not that important for people from the lower SES groups, so if a person behaves antisocial less appreciation will be lost in these groups.

Furthermore the environment plays a part. Using the SPF-theory, it is assumed that children from the higher SES groups will receive negative reactions from people in their environment in an earlier stage than children from the lower SES groups. This is because children from the higher SES groups in general have more supervision by parents or caretakers, and will be confronted with their behaviour earlier. So they are more afraid of being punished than children of the lower SES groups. In summary, the environment is another reason why children of the higher SES groups are less fearless than children of the lower SES groups.

All the above-mentioned suggests why there may be less fearlessness in children of the higher SES groups. As said, the SPF-theory explains that if a good is scarcer, status can be gained more easily if you have more of it. This means that if you are mixed in a group where less fearlessness (more fear) is present, or are in a group where the members are relatively fearful for the consequences of behaviour, you can gain status very easily if you are fearless. As discussed in section3.2, antisocial behaviour can also lead to other goals of well being.

In the lower SES groups there are more peer groups containing members who are fearless. Fearlessness even occurs when people do not have a low HR. A reason for this can be that these people do have fewer abilities to oversee the consequences of their behaviour. Furthermore children from the lower SES groups do have less to lose than children from the higher SES groups. Finally the environment plays a smaller part. The difference between children with a low HR and those with a high HR in the lower SES groups is smaller than this difference is between these two groups in the higher SES groups. In the low SES group it is therefore more difficult to obtain status by being fearless.

In short, the afore-mentioned gives a possible explanation of why the relation between low HR and antisocial behaviour is stronger for people living in high SES groups than for people living in low SES groups. If someone has a low HR it is more 'lucrative' for this person to behave antisocial if he or she is from the higher SES groups.

However this mechanism will only work out in stable peergroups. People will not obtain status if a group consistently change members and will not contain the same persons for a long period of time. If you are participating in a stable peergroup, you have the possibility to show what kind of behaviour you dare to exhibit. If people go around more often with you, they will experience that you dare a lot. Status can be obtained, because you are seen as 'the big hero' of the group who dares everything.

§2.5 HYPOTHESES

Concerning the theories and the empirical findings in this chapter the hypothesis for the first research question is the following:

Hypothesis I*:* *'People with low HR's will be more likely to engage in high antisocial behaviour than people with high HR's'*

Because most of the earlier studies investigated the relation between HR and antisocial behaviour in boys and not girls, sex will be taken into account while testing this hypothesis in order to find out if the relation can be applied to both sexes or to only one. Further, since boys tend to have lower HR's (Moffitt et al., 2001) and exhibit higher levels of antisocial behaviour (Moffitt et al., 2001), controlling for sex will ensure that any relation found between low HR and high levels of antisocial behaviour will not simply be due to 'maleness'.

The results of earlier research concerning SES as an interaction variable are limited. The hypothesis for the second research question is the following:

Hypothesis II*:* *'The relation between low HR and high antisocial behaviour will be stronger for people in the high SES group'*.

These two hypotheses will be investigated using the data of the Dunedin Study.

§2.6 DATA OF THE DUNEDIN STUDY

Many studies described previously have found a relation between low HR and antisocial behaviour. However, there are several reasons to research it further in the context of the data available from the Dunedin Study. Firstly the Dunedin Study has many study members; approximately one thousand respondents were examined, while previous research was mainly based on fewer respondents. Wadsworth (1976), with 1813 study members, and the Mauritius project (Raine et al., 1997a, 1997b), with 1795 study members, are the exceptions.

A second reason why the results from the Dunedin Study will add to the research in this field is because of the longitudinal character of the data. With the data from this study, the development of behaviour can be traced. Concerning HR and antisocial

behaviour, the study members were examined at the ages 7, 9, 11, 13, 15, 18 and 26. Measures at different ages are important to be able to examine the timing of the relation. If the relation between low HR and antisocial behaviour only occurs at one age, the only way to find out is to examine several measurements in time. Only Little (1978), Raine et al. (1997a, 1997b) and West and Farrington (1977, Farrington, 1987) have used data with measurements taken across time. All other research has been based on cross-sectional data.

A third advantage of the data from the Dunedin Study is the number of variables used. The study has very detailed information on antisocial behaviour. The study members themselves were questioned, as well as friends or family. Police arrests and court convictions were also taken into account. No previous study of the relation between low HR and antisocial behaviour used this many variables to measure antisocial behaviour.

Finally, the effect of SES can also be examined, because it has been determined from age 0 to age 15. The stability of the SES measures across time is not high and that is why this measure is a real strength of the Dunedin Study. It takes into account the changes of SES occurring in a study member's childhood.

In brief it can be said that previous research has some disadvantages, which the data from the Dunedin Study does not have.

Chapter 3

Method

§3.1 THE DUNEDIN STUDY

The Dunedin Study is an ongoing, longitudinal study of health, development and well being of a large sample of young New Zealanders. They were studied at birth (1972-73), followed up and assessed at the age of three, then every two years until the age of 15, then at age 18 (1990-91), 21 (1993-94) and 26 (1998-99).

Dunedin is the major city of Otago, a province of the South Island of New Zealand. All children born to Dunedin mothers at Dunedin's Queen Mary Hospital between 1 April 1972 and 31 March 1973 and still living in Otago at age three were eligible for membership of the study sample. During this 12-month period, there were 1661 live births. Of these, 12 died prior to the age of three. By the time they were three years of age, 315 were known to be living outside the province of Otago and a further 195 were believed to be living outside Otago. This left 1139 children eligible for enrolment in the study.

Of the 1139 eligible children, 68 were not assessed as three-year-olds because of parental refusal and a further 34 were not located in time to be included. A total of 1037 children (91 per cent of the eligible sample) were assessed within a month of their third birthday; there were 535 boys and 502 girls, comprised of 1013 singletons and 24 twins.

Those who were followed up were compared with those not followed up in terms of SES. The sample followed up at age three was slightly under-representative of the highest and lowest SES levels, and slightly over-representative of the middle SES group in comparison with those who were not followed up (Silva & Stanton, 1996). Furthermore there were significant differences between those seen and those not seen at age three in terms of the marital status of mothers at the time the children were born. While 95 per cent of the mothers of those followed up at age three were married, only 85 per cent of those not followed up were married.

Further comparisons between the 1037 children followed up at age three and national SES data suggested that the Dunedin sample was slightly advantaged in SES levels when the fathers were compared with all males in the New Zealand labour force (Silva & Stanton, 1996).

The follow-up rates for each assessment phase from three to 26 are shown in table 3.

Table 3 *Sample members assessed at each age*

Year	*Age*	*No. eligible*	*No. assessed*[c]	*% assessed*[c]
1972-73	Birth	1661	1661	100
1975-76	3	1139[a]	1037	91
1977-78	5	1037[b]	991	96
1979-80	7	1035[b]	954	92
1981-82	9	1035[b]	955	92
1983-84	11	1033[b]	925	90
1985-86	13	1031[b]	850	82
1987-88	15	1029[b]	976	95
1990-91	18	1027[b]	993	97
1993-94	21	1020[b]	992	97
1998-99	26	1019[b]	980	96

[a] Number resident in Otago
[b] Surviving sample members
[c] Assessed in full or partly assessed

The table shows a slightly decrease in the numbers seen between age three and 13, followed by an increase at age 15, 18 and 21. The increased numbers from age 15 reflect the fact that study members in other parts of New Zealand were flown back to Dunedin for their assessments. Also, study members living in Australia were visited for interviews at age 15 and 18. At age 21, study members living in Australia were flown back to Dunedin for assessment. At age 26, the study members living outside of New Zealand were flown back to New Zealand to be assessed at the Unit. This year, the study members will be 30 years old. The next phase will be when they are 32, in 2004 and 2005.

At each phase of the study, four study members were invited to the research unit each day for interviews, tests and examinations. The assessment year usually commences about March and concludes in June or July of the following year. Most of the study members were assessed within a month or two of their birthdays. In later years, the period between birthdays and assessment days has increased for some study members to fit in with their schedules.

Assessments at each phase have involved study members rotating through a series of assessments where they have been seen by staff who have been trained to carry out their particular interviews, tests and examinations. The assessment programme has always been planned to balance mental and physical activities to avoid tiring the participants. Parents (to the age of 15) and teachers (to the age of 13) have also filled out extensive questionnaires describing aspects of study members' development, behaviour, history and background. Other informants, nominated by study members, also filled in questionnaires describing them at age 18, 21 and 26. From the age of 15, most study members have also consented to allow the research unit to access information about them from sources such as hospitals and police on the understanding that this is confidential and for research purposes only.

§3.2 DATA

A lot of data have been collected during the different phases. To test the hypotheses in this thesis, only the data concerning HR, antisocial behaviour and SES will be used. These data will be discussed below.

§3.2.1 HR data

At ages 7, 9, 11 and 13 the resting HR was measured by averaging resting HR taken on three occasions during the course of a physical examination. At the ages 15 and 18 several measures of HR are available. First of all the recumbent HR was measured. This is the HR measured when the study members were lying down. Secondly, the resting HR was measured while the study members were sitting on a bike, before they exercised. At age 15 and 18 the recumbent and resting HR's were averaged together as one measure of HR at these ages. At age 26 the resting HR was measured, averaged over five measures while seated.

To investigate the two hypotheses, the HR's at the different ages were combined into three developmental stages. These stages are childhood, adolescence and adulthood. The childhood variable comprises the HR's at ages 7, 9 and 11. Adolescence contains the HR's at ages 13, 15 and 18. Adulthood contains the HR's at age 26. The HR's were combined within a developmental stage by z-standardising and averaging them.

There are two reasons to combine the HR's into developmental stages. The first reason is simplicity. To get a good overview of the results it is easier to examine the combined HR measures instead of looking at the results of the analyses of the individual ages. Presenting the results for the individual ages would result in a shower of tables. However, to examine the differences between results of the individual ages and results of the developmental stages, the analyses for the individual ages were done. Combining the data into developmental stages did not result in a different relation between HR and antisocial behaviour.

The second reason is that statements can be made about developmental stages. That is, the effect of childhood HR, adolescent HR and adult HR can be used. This improves the comprehensibility of the findings to the reader.

§3.2.2 Antisocial behaviour data

In the Dunedin Study, antisocial behaviour was measured in three ways, namely by self-reports, other-reports and official reports. To test the two hypotheses posed in chapter two, it was decided to compare HR and antisocial behaviour measures age for age. For that reason, only the antisocial behaviour measures for ages 11, 13, 15, 18 and 26 were used. The measures at age 21 were not used, because HR was not measured at this age. Measures before age 11 were not used because self-report, informant-report and official report antisocial measures were not available before this age. All the antisocial behaviour measures used are explained more fully below.

Symptom scales of conduct disorder (CD)/ antisocial personality disorder (ASPD)

Symptom scales of CD and ASPD were made by summing CD/ASPD items from the Diagnostic and Statistical Manual of Mental Disorders (DSM). DSM is a standard classification of mental disorders which has been designed for use across different settings (inpatient, outpatient, partial, hospital, clinic, private practice, with community populations, by psychiatrists, psychologists, social workers, nurses, counsellors and other health and mental health professionals) (www.psych.org; DSMIII: APA (1980); DSMIIIR: (1987); DSMIV: APA (1994)).

At the several ages symptom scales were made for CD. At age 11 this was derived from questions from the Diagnostic Interview Schedule for Children, child version (DISC-C). At the later ages this was derived from the Self-Reported Delinquency Interview. To make comparisons across ages, it is necessary to make the symptom scales according to the same criteria. In this report analyses will be based on the symptom scales of CD according to the now-current criteria of DSM-IV (Moffitt et al., 2001).

The DSM-IV diagnosis for CD contains 15 criteria or symptoms. Of these 15 criteria, eight were assessed at age 11, 13 were assessed at the ages 13, 12 at the age of 15, and 10 criteria were assessed at age 18. A table of these criteria is shown in the appendix. The criteria were assessed by interviewing the study members (DISC-C at age 11 and Self-reported Delinquency Interview at later ages). The parent and teacher ratings of behaviour were used to supplement the child interviews at earlier ages. A symptom was counted as present if there was evidence from all sources (parents, teachers, as well as the study members themselves). The symptom scales at every age are an average measure ranging from zero to one. For example, at age 11 eight symptoms were assessed. If a person scores on one symptom his or her score is 0.13. If a person scores on two symptoms his or her score is 0.25, etc.

At age 26 a symptom scale of ASPD was made by summing across 65 items, which could be subsumed under the six ASPD criteria. These items are listed in the appendix. If the study members committed an act once or more in the past twelve months they got a score of one and if they had not committed the act they got a score of zero. To construct a scale, all the items are counted together. The scale ranges from 0 to 65. A higher score represents greater levels of antisocial behaviour. The reliability of this scale is 0.73, which is acceptable (Moffitt & Silva, 1988).

Self-reported delinquency (SRD)

At age 13, the Self-Reported Early Delinquency interview (SRED) was administered to the study members. This interview contains 29 items about ‘norm violating’ behaviours and 29 items about more serious illegal behaviours. For the age 13 interview only the 29 items about serious illegal behaviours are used. The items are described in the appendix. The items are rated on a three-point scale (no (0), once or twice (1) or three or more times (2)). The 29 items are weighted according to their levels of seriousness. Weights were obtained from a survey of 30 local professionals involved in the problem of juvenile delinquency. Survey responses were also obtained from a class of 30 psychology undergraduates at the University of Otago. Respondents rated each of the items on a scale from 0: ‘harmless prank’, to 20:

'extremely serious, requiring police intervention'. Item ratings for the student and professional groups did not differ, so the responses were combined. The weights are given in the appendix. The scale is constructed by multiplying the score of an item by its weight and then summing all the scores to one scale. The range of the scale is 0 to 85.52. A reliability analyses shows that the reliability of the 29-item illegal behaviour scale is 0.81 and is well within the acceptable range for social science research instruments (Moffitt & Silva, 1988).

At age 15, the same SRED was administered to the study members. For the age 15 interview, only the twenty-nine items about serious illegal behaviours (described in the appendix) were used. This time variety scores are constructed. This means that study members who performed an act once or more are rated one and study members who did not perform an act are rated zero on an item. A variety score presents how many types of acts are committed and not how many times. It is not a frequency scale. Taking all the items together, the scale of SRD at age 15 ranged from 0 to 29. Higher scores are associated with more antisocial behaviour. The reason to use a variety score instead of a frequency score is that the scale has a much greater reliability if it is a variety score. The reliability of this scale at age 15 is 0.87. A frequency score gives relatively more weight to minor delinquent acts, because these acts are more frequently performed than more serious criminal behaviour. This makes the data more skewed and a smaller alpha coefficient is the result.

At the ages 18 and 26, the SRD interview was administered to the study members. The SRD is used, because this instrument is more age-appropriate than the SRED. This instrument contains forty-eight different illegal acts. Study members had to answer if they have committed these acts in the past twelve months. All the items are described in the appendix. The same method is used to combine these items into a scale (a variety scale), as is used with the SRED at age 15. The scale has a range of 0 to 48. The alpha coefficient of the reliability analysis is 0.88 at age 18 (Moffitt, Silva, Lynam & Henry, 1994) and 0.83 at age 26.

Informant reports

At age 18, subjects were asked to nominate a friend or family member who knew them well and to give informed consent to send informants a 41-item questionnaire. Among these 41 items there were four items pertaining to the study members' antisocial behaviour during the past 12 months (problems with aggression, doing things against the law, problems related to the use of alcohol and problems related to the use of drugs). The items were coded as doesn't apply (0), applies somewhat (1), and certainly applies (2). These items are taken together to create a scale, which has a range from zero to eight. The reliability analysis showed a rather low alpha, of 0.56.

At age 26, subjects were asked to nominate three people who knew them well. These people were then sent questionnaires. This time the questionnaire contained 60 items, seven of which pertained to antisocial behaviour. The items were coded in the same way as for the informant reports at age 18. These items are described in the appendix. These items are averaged for the three different informant reports. After averaging them, they were summed to get one scale with a range from zero to 14. This scale has a good reliability, of 0.84.

Police contacts

Police contacts included all police actions that resulted in the filing of a standard incident form on which a New Zealand constable reports offences known to be committed by a juvenile between age 10 and 16 years. In New Zealand, 'juvenile' status ends when offenders enter the adult justice system on their seventeenth birthday. At police departments throughout New Zealand, juvenile records were searched for 97 per cent of the study members, who consented to have their records searched[2]. When study members never had contact with the police they were rated zero and when they had one or more contacts with the police they were rated one.

Court convictions

Records of convictions at all courts in New Zealand and Australia were searched, with the informed consent of the study members, using the computer system of the New Zealand Police. Records included convictions in Children's and Young Persons' Court from age 13 to age 16 years and convictions in adult Criminal Court from age 17 years to age 26. Convictions included non-violent offences (e.g., possession or sale of illegal substances, theft, burglary, shoplifting, vandalism) and violent offences (e.g., disorderly behaviour likely to cause violence, using an attack dog on a person, assault with intent to injure, rape, aggravated robbery, manslaughter). When study members had no court convictions they were rated zero and when they had one or more court convictions they were rated one.

§3.2.3 SES data

The SES of study members' families was measured with a six-point scale assessing parents' occupational status (Elley and Irving, 1972). The scale places each occupation into one of six categories based upon the educational levels and income associated with that occupation in data from the New Zealand census. The scale ranges from one ('professional') to six ('unskilled labourer'). In table 4 examples of the Elley and Irving Socio-economic Index occupations levels are given.

Table 4 *Examples of the Elley and Irving Socio-economic Index occupation levels*

SES level	*Example occupations*
1 (highest)	Accountant, airline pilot, architect, dentist, headmaster, teacher (secondary school)
2	Agricultural technician, airport supervisor, company manager (not retail), computer programmer, teacher (primary school), armed forces officer
3	Agricultural instructor, aircraft mechanic ambulance driver, building inspector, company sales manager
4	Armed forces personnel (not officer), baker, bank teller, builder, farmer
5	Bus driver, constructional steel erector, ditch digger, farm manager, fisherman
6 (lowest)	Barman, builder's labourer, farmhand, fish shop workers, food packer

Source: *Silva & Stanton, 1996*

The variable SES is the average of the highest SES level of either parent across the interviews of the Dunedin Study from the study member's birth to age 15. This

[2] Besides the informed consent Study members gave for all other assessments, they had to give separate consent for searching the police and court records.

variable reflects the socio-economic conditions experienced by study members while they grew up. The reliability of the scale is 0.92. For the analyses a categorised variable is used. The six levels are divided into three groups, the low SES group (group five and six, N = 215), the middle SES group (group three and four, N = 649) and the high SES group (group one and two, N = 167).

§3.3 ANALYSIS

The first hypothesis (*'People with low HR's will be more likely to engage in high antisocial behaviour than people with high HR's'*) and the second hypothesis (*'The relation between low HR and high antisocial behaviour will be stronger for people in the high SES group'*) were tested, using HR as the independent variable and antisocial behaviour as the dependent variable. To test if people with low HR's behave more antisocially than people with high HR's, HR was divided into two groups, the low and the high HR group. This is done by using quartiles. The low HR group contained people with HR's in the lowest 25 per cent and the high HR group contains people with HR's in the highest 25 per cent. This division is made for the HR's at the three developmental stages. Similar, though weaker, results were found when the analyses were performed with the median split and using linear regression analyses on the whole sample.

The dependent variable is antisocial behaviour. A goodness-of-fit test showed that the self-reported and informant-reported antisocial behaviour measures were not normally distributed. As the data were skewed, an inverse transformation[3] was performed. This transformation resulted in less skewed data, so that parametric tests, such as factorial analysis of variance (ANOVA) could be performed.

The two hypotheses were tested by conducting a three-way (HR by sex by SES) ANOVA for the self-reported (CD/ASPD symptom scales and SRD) and other reported (informant reports) measures of the antisocial behaviour data. Sex was used to determine whether the first hypothesis can be confirmed or rejected for both males and females or just one of them. SES was used to test the second hypothesis.

Dichotomous official report measures (police contacts and court convictions) were tested in a logistic regression framework. The regression model estimates the effect of HR controlling for sex and SES. To test hypothesis two, a second regression equation was estimated with a HR by SES interaction variable included in the model. A significant interaction here would indicate that the relation between HR and antisocial behaviour was mediated by SES.

To get an impression of the size of the relation between HR and antisocial behaviour, or the size of the interaction-effects with sex and SES, effect sizes are calculated using the following formula: $(mean_1 - mean_2)/SD$. Effect sizes of less than 0.10 are regarded as negligible, effect sizes of 0.10 to 0.25 as small, effect sizes of 0.25 to 0.40 as moderate and effect sizes of 0.40 or more as large (Cohen, 1992).

[3] The transformation was done with the following formula: 1-(1/1+x). A constant (=1) is added so that the denominator is never zero. As taking the inverse of scores reverses their rate order, the inverse scores were substracted from 1 so that the original rank-order was maintained.

Most of the earlier research analysed the relation between HR and antisocial behaviour in another way. Low and high antisocial groups were compared with each other on HR to examine whether the high antisocial group had lower HR's than the low antisocial group. In this report the differences between the low and high HR group are examined, because hypothesis one suggests that people with low HR are more likely to behave antisocially, not that those who are antisocial have lower HR's. However, doing analyses to examine the differences between the low and high antisocial group with the data used in this report showed the same results as doing it the other way around. For reasons of simplicity these analyses are omitted.

To control for type I errors (to make sure that significant results could not be expected by chance), a Bonferroni-procedure was applied to each ANOVA model. If, after this Bonferroni correction, the F-ratio of the whole ANOVA model was significant at $p < 0.05$, all effects within that ANOVA were considered significant if $p < 0.05$. However, if, after this Bonferroni correction, the F-ratio of the whole ANOVA model was non-significant ($p > 0.05$), all effects within that ANOVA were considered non-significant.

Chapter 4

Results

The results are presented in three tables. The first table presents the analyses with the childhood HR's, the second table with the adolescence HR's and the third table with the adult HR's. In all the results no three-way interaction-effects of HR, sex and SES were found, so for simplicity these results are not presented in the tables. The main effects of sex and SES are also not tabulated, but these effects are discussed in the text.

§4.1 CHILDHOOD HR AND ANTISOCIAL BEHAVIOUR

Table 5 presents the results of the association between childhood HR and antisocial behaviour with sex and SES as mediators.

Table 5 *Association between childhood heart rate (age 7, 9, 11) and antisocial behaviour with sex and socio-economic status as mediators*

Type of report	*Measure*	*Age*	*Low hr*[a] *Mean (SD)*	*High hr*[a] *Mean (SD)*	*Main effect*[b] *of HR*	*Interaction effect*[b] *hr*sex*	*Interaction effect*[b] *hr*ses*
Self-reports	CD/ASPD symptom scales	11	0.14 (0.16)	0.14 (0.16)	0.01	1.52	0.52
		13	0.13 (0.11)	0.10 (0.13)	3.53	3.46	4.94**
		15	0.13 (0.13)	0.11 (0.14)	1.51	0.10	0.90
		18	0.14 (0.11)	0.11 (0.13)	4.47	0.00	0.61
		26	0.68 (0.31)	0.62 (0.33)	3.74	0.01	0.82
	Self-reported delinquency	13	0.54 (0.42)	0.51 (0.46)	0.53	1.03	2.98
		15	0.42 (0.41)	0.35 (0.45)	2.76	0.26	1.54
		18	0.71 (0.32)	0.61 (0.36)	8.23**	1.65	0.03
		26	0.59 (0.31)	0.56 (0.35)	1.08	0.33	0.15
Other reports	Informant report	18	0.24 (0.36)	0.22 (0.38)	0.14	0.03	0.43
		26	0.50 (0.31)	0.44 (0.34)	3.18	0.17	0.54
Official reports	Police contacts	18	15.6%	11.1%	1.48 (0.86-2.56)	1.76 (0.15-20.62)	0.39 (0.03-5.25)
	Court convictions	26	18.5%	15.1%	1.27 (0.77-2.11)	4.71 (0.41-54.45)	0.90 (0.07-11.91)

[a] Means and standard deviations for the self-reports and other reports are the transformed scores, ranging from zero to one. The values for the official reports are percentages.
[b] These values are F-values for the self-reports and the other reports, while for the official reports these values are odds ratios (95% confidence interval).
* Value is significant at the 0.05 level
** Value is significant at the 0.01 level

Table 5 shows that those with low childhood HR had significantly higher SRD scores at age 18 ($F(1, 390) = 8.23$, $p = 0.004$). The effect size was small (0.28). No other self-reported measure of antisocial behaviour showed significant differences between the low and high HR group. Neither did the other reports and the official reports.

Except for the results with the CD symptom scale at age 15, the SRD at age 15 and the informant reported measure at age 26, the main effects of sex were all significant (all at least $p < 0.05$). All these significant results indicate that males were more antisocial than females. There were no significant interaction-effects with sex, indicating that where there was a significant relation between HR and antisocial behaviour, it held both for females and males.

Four main effects of SES were found. For the results with the CD symptom scales at age 13 and 15, SRD at age 15 and informant reports at age 26 it was found that people from the low SES group were most likely to behave antisocially, people from the middle SES group were less likely to behave antisocially and the people from the high SES group were the least likely to behave antisocially (all at least $p < 0.05$). Furthermore one SES by HR interaction was found. This effect was on the relation between the childhood HR and the CD symptom scale at age 13. To test the nature of this, simple effects of HR at each SES level were tested for using t-tests. In only the low SES group, people with low HR's had a higher antisocial behaviour score than the people with high HR's ($t(67) = 3.62$, $p = 0.001$). No other interactions were significant.

§4.2 ADOLESCENT HR AND ANTISOCIAL BEHAVIOUR

In table 6 the results for adolescence HR are presented.

Table 6 *Association between adolescence heart rate (age 13, 15, 18) and antisocial behaviour with sex and socio-economic status as mediators*

Type of report	*Measure*	*Age*	*Low hr*[a] *Mean (SD)*	*High hr*[a] *Mean (SD)*	*Main effect*[b] *of HR*	*Interaction effect*[b] *hr*sex*	*Interaction effect*[b] *hr*ses*
Self-reports	CD/ASPD symptom scales	18	0.15 (0.13)	0.11 (0.13)	7.47**	0.25	1.37
		26	0.66 (0.36)	0.61 (0.38)	1.78	4.15*	5.32*
	Self-reported delinquency	18	0.70 (0.36)	0.61 (0.38)	5.80*	0.49	0.15
		26	0.62 (0.38)	0.53 (0.40)	5.53*	0.06	3.10*
Other reports	Informant report	18	0.24 (0.39)	0.19 (0.38)	1.92	0.01	0.51
		26	0.51 (0.35)	0.46 (0.39)	2.28	2.15	0.03
Official reports	Police contacts	18	15.7%	7.4%	2.34** (1.26-4.37)	1.27 (0.07-24.76)	0.29 (0.01-6.81)
	Court convictions	26	15.5%	10.0%	1.65 (0.91-2.97)	3.74 (0.12-112.48)	0.92 (0.02-46.27)

[a] Means and standard deviations for the self-reports and other reports are the transformed scores, ranging from zero to one. The values for the official reports are percentages.
[b] These values are F-values for the self-reports and the other reports, while for the official reports these values are odds ratios (95% confidence interval).
* Value is significant at the 0.05 level
** Value is significant at the 0.01 level

Table 6 shows that three out of four associations between HR and self-reported antisocial behaviour were significant. Those who had lower adolescent HR's had higher scores on the CD symptom scale at age 18 ($F(1, 399) = 7.47$, $p = 0.007$) and higher SRD scores at age 18 ($F(1, 395) = 5.80$, $p = 0.016$) and 26 ($F(1, 399) = 5.53$, $p = 0.019$) than those who had higher adolescent HR's. Again, the effect sizes for these

three results were small (0.31, 0.24 and 0.23 respectively). The informant reports did not show significant results. For the official reports only the police contacts showed significant results, indicating that people with low HR's were more than twice as likely to have police contacts than people with high HR's (OR = 2.34, 95% CI = 1.26-4.37, p = 0.007).

Except the results for the measures of informant reports at age 26 and police contacts at age 18, all main effects of sex were significant (all at least $p < 0.05$). All these significant results indicate that males were more likely to be antisocial than females. There was one HR by sex interaction: for females only, those with low HR's were more likely to have higher ASPD scale scores at age 26 ($t(200) = 1.99$, $p = 0.048$).

Concerning the main effects of SES, only the official reports had significant results. A linear trend was found that people from the low SES group were most likely to have police contacts and court convictions, the middle SES group was less likely to have them and the high SES group was least likely to have them (police contacts at age 18: OR = 0.24, 95% CI = 0.14-0.41, $p < 0.001$; court convictions at age 26: OR = 0.38, 95% CI = 0.23-0.63, $p < 0.001$). Furthermore, two HR by SES interaction-effects were found. SES mediated the relation between adolescent HR and the ASPD symptom scale at age 26 and the relation between adolescent HR and the SRD at age 26. Simple effects t-tests for the first HR by SES interaction-effect showed that in both the low and the high SES group (not in the medium SES group), people with low HR's were more likely to have higher ASPD symptom scores at age 26 than people with high HR's (low SES group: $t(49) = 2.22$, $p = 0.031$; high SES group: $t(55) = 4.27$, $p < 0.001$). The simple effects t-tests for the second HR by SES interaction-effect showed that in both the medium and the high SES group (not the low SES group), people with low HR's were more likely to have higher SRD scores at age 26 (medium SES group: $t(278) = 2.39$, $p = 0.018$; high SES group: $t(55) = 4.02$, $p < 0.001$) than people with high HR's.

§4.3 ADULT HR AND ANTISOCIAL BEHAVIOUR

The last results concern the differences between people with low and high adult HR's. These results are presented in table 7.

Table 7 *Association between adulthood heart rate (age 26) and antisocial behaviour sex and socio-economic status as mediators*

Type of report	*Measure*	*Age*	*Low hr[a] Mean (SD)*	*High hr[a] Mean (SD)*	*Main effect[b] of HR*	*Interaction effect[b] hr*sex*	*Interaction effect[b] hr*ses*
Self-reports	DSM ASPD diagnosis	26	0.69 (0.30)	0.65 (0.31)	2.41	0.20	0.34
	Self-reported delinquency	26	0.58 (0.35)	0.55 (0.37)	0.70	0.00	0.62
Other reports	Informant report	26	0.48 (0.33)	0.50 (0.35)	0.16	0.67	0.20
Official reports	Court convictions	26	14.86	12.50	1.22 (0.74-2.02)	1.59 (0.12-21.19)	0.52 (0.03-9.26)

[a] Means and standard deviations for the self-reports and other reports are the transformed scores, ranging from zero to one. The values for the official reports are percentages.
[b] These values are F-values for the self-reports and the other reports, while for the official reports these values are odds ratios (95% confidence interval).

Table 7 shows no main effect of HR for any antisocial behaviour outcome.

All main effects with sex, except the effect of the informant reports, were significant. In all cases males were more likely to behave antisocially than females (all at least $p < 0.05$). No HR by sex interaction-effects were found.

One main effect of SES was significant. A trend was detected that people from the low SES group were most likely to behave antisocially according to the informant reports at age 26, people from the middle SES group less likely and people from the high SES group least likely ($F(2, 457) = 3.35$, $p = 0.036$). There were no HR by SES interaction-effects.

Chapter 5

Conclusion & discussion

This thesis tested two hypotheses:

Hypothesis I: *'People with low HR's will be more likely to engage in high antisocial behaviour than people with high HR's'*

and

Hypothesis II: *'The relation between low HR and high antisocial behaviour will be stronger for people in the high SES group'*.

Summary of results

Considering hypothesis I, it can be concluded that there is a small to moderate difference between the high and low HR groups in terms of antisocial behaviour, during adolescence. Significant effects were especially found in the self-reports, less for the official reports and nothing was found for the other reports. The differences between the low and high HR group on antisocial behaviour are very small considering the childhood HR and there is no difference at all between these two groups when looking at the results with adult HR. Hypothesis one can therefore be confirmed for adolescent HR only.

Considering the interaction-effect of sex, it can be said that there is only one interaction-effect of this variable. The relation between adolescent HR and the DSM antisocial personality diagnosis at age 26 can only be applied to females and not to males. For all other results can be concluded that the differences between the low and high HR group are the same for both sexes.

The second hypothesis considered SES as an interaction-variable. Three out of the 25 results were significant. The relation between childhood HR and the CD symptom scale at age 13 was only found to be significant in the low SES group. The relation between adolescent HR and the ASPD symptom scale at age 26 was only found to be significant for the low and the high SES group (not for the medium SES group) and finally, the relation between adolescent HR and SRD at age 26 was only found to be significant for the middle and the high SES group (not for the low SES group). The second hypothesis has to be rejected since the results from this study do not show that the relation between HR and antisocial behaviour is stronger for those from the high SES group. Where there was an interaction effect of SES, the relation between HR and antisocial behaviour was not specific to one SES group.

Interpretation

In several respects these results differ from earlier research. Concerning the first hypothesis it can be said that the results in this thesis are less strong than most of the findings in earlier research. The effect size of the results in this thesis are low in comparison with the effect sizes of the earlier studies. A reason for this might be that the effects of sex are controlled in all analyses. Preliminary analyses, without controlling for sex showed that the relation between low HR and antisocial behaviour is much stronger before controlling for this variable. This is possibly because the boys

are overrepresented in the low HR group (Moffitt et al., 2001) and in the antisocial behaviour group as shown by the main effects of sex in this study. Most of the earlier research did not need to control for sex, because they used samples only containing boys, or only containing girls, but nor could they consider complex effects including sex as could the present research.

Besides controlling for sex, the results are also controlled for SES. Including SES in the model also results in less significant findings. So controlling for these variables may be a reason that the results in this report are less strong than the results in earlier research. This ability to control for both SES and sex is a strength of the present research as a whole, and implies that earlier findings may have been over-estimating the relation between HR and antisocial behaviour due to confounding factors that have been controlled for here. However, there are some aspects, for which not is controlled, and this will be discussed later on in this discussion (section: validity of the measures).

The second respect in which the results of this report differ from other studies is the influence of SES. Not much earlier research was done into the influence of this variable. Raine and Venables (1984) found a relation between HR and antisocial behaviour only in the high SES group and not in the low SES group. Raine et al. (1997b) found the same result, but this could only be applied to Creoles and not to Indians.

Theory

Related to the theory it can be said that the results are consistent with the arousal theory, but only as it pertains to adolescent levels of arousal. These significant main effects do show that people with low adolescent HR's are more antisocial. However the results with childhood and adult HR were not in consistency with the arousal theory.

The results are however not consistent with a prediction derived from the SPF-theory. The prediction was that the relation between low HR's and antisocial behaviour could be confirmed for the high SES group and not for the low SES group. The results show that the relation between HR and antisocial behaviour is the same for the three groups of SES in most cases and that three results show that the relation between HR and antisocial behaviour can be applied to either the low, the middle or the high SES group. A possible reason for this can be the way in which the data are analysed. The self-reported delinquency scale contains a lot of items that is not status-providing antisocial behaviour. This kind of behaviour is mentioned as covert behaviour (Loeber & Farrington, 1998); behaviour that do not provide status, because nobody knows that you committed an antisocial act. If the antisocial behaviour was divided into status-providing behaviour (covert behaviour) and non-status-providing behaviour (overt behaviour), the theory might have been a better predictor for the influence of SES on the relation between HR and antisocial behaviour.

There is another possible reason for the fact that no interaction-effect with SES could be found. The SPF-theory assumes that antisocial behaviour can give status in high SES groups, when the peer groups, in which a person participates, are stable. However, it is not tested whether these groups were stable. Maybe they are not and than no interaction-effect with SES is found.

Differences across types of data and differences across time
The relation between HR and antisocial behaviour was strongest for the self-reports in childhood as well as in adolescence. Nothing was found for the informant reports. And only adolescent HR had one significant result with an official measure of antisocial behaviour. A possible explanation could be that the people with lower HR's are less afraid (fearlessness theory) to self-report their antisocial behaviour. They are less afraid that something will be done with their confidential information or are less afraid of negative reactions. Therefore it is possible they self-report antisocial behaviour much sooner than people with higher HR's. The reporting of antisocial behaviour according to official and informant reports is however less dependent on the HR's of the study members. However, this can not be the only reason why the relation with only self-reports is found, because earlier findings also confirm a relation between low heart rate and official reports of antisocial behaviour (e.g., Wadsworth, 1976). Therefore this argument needs further exploration, because this could be a possible partial reason for the differences in antisocial behaviour between the low and high HR groups.

Furthermore, the relation between adolescent HR and antisocial behaviour was strongest, the relation between childhood HR and antisocial behaviour was very small and there was no relation between adult HR and antisocial behaviour at all. In this report, only one age (26) was measured during adulthood. Possibly there is a delayed effect of HR on antisocial behaviour, which means that HR will predict antisocial behaviour at a later age in adulthood. To examine this, measures of antisocial behaviour at a later age are required. Most of the earlier studies only examined the relation between HR in childhood or adolescence, and antisocial behaviour. An interesting possibility for the future is to investigate whether the finding of the relation between low HR and antisocial behaviour can be replicated in adulthood beyond age 26.

Validity of measures
As discussed in section 3.2.2, antisocial behaviour is measured in several ways. Official records were searched for, but also the self-reports of study members and the reporting of others were taken into account. The measuring also controlled for the fact that individuals undergo remarkable developmental changes. The measures were made age-appropriate at every age. Antisocial behaviour is therefore very well measured.

The HR measure is less valid than the antisocial behaviour measure. HR can be influenced by a lot of factors, such as body weight, height, body bulk, physical development and muscle tone. It would have been better to control for these variables in this study. HR is multiple determined and changes over time. Controlling for physical development before taking the measures together to form a HR measurement for each developmental stage would also have been better. Not controlling for these confounders is a weakness of this study.

Raine (2002) says, however, that the relation between HR and antisocial behaviour is not artificial. Studies have repeatedly ruled out potential artifacts (Wadsworth, 1976; Raine et al, 1997a). Furthermore it is difficult to control for all confounders possible. HR can be influenced by many factors. Not only physical measures as discussed in

the last section play a part. Also the point in time of measuring HR or the activities previous to the measuring play a role. It is very difficult to rule out all these factors.

Limitation
The sample was from New Zealand, an ex-British colony, and the findings are thus primarily applicable to Europeans and to the inhabitants of other English speaking countries, which have a similar cultural ambience.

Strengths
No study into the relation between HR and antisocial behaviour contained so many study members and at the same time contained measures from age 7 to 26. In this aspect the findings of this study are new and add a lot to the existing research. Because the results are an important addition to the existing research it has become more profound to draw conclusions on the relation between HR and antisocial behaviour.

Another strength of the Dunedin Study is the low attrition. The attrition in this study is 10% or less in all but one case (age 13). This low percentage result in the fact that the missing data have not significantly affected the results reported (Silva & Stanton, 1996). Greater attrition would result in a sample that, on average, committed less antisocial behaviour (Poulton, in preparation) and, as such, a sample that was biased with respect to the general population.

Conclusions
The results in this report can add important findings to the field of biosocial research. The results are based on a large sample with few missing values and on a lot of measures of antisocial behaviour. The conclusion to the first hypothesis is quite consistent with earlier research, although a less strong relation between HR and antisocial behaviour was found in relation to most of the earlier studies. The relation between these two variables held both for males and females, as well as for the three groups of SES. Furthermore, the second hypothesis had to be rejected. As said before this could be due to the fact that the self-reported delinquency scale contains many items of non-status-providing antisocial behaviour. A conclusion can be that the items of the dependent variable (not only the independent variable) had to be chosen in line with the theory. In this case the variable antisocial behaviour had to contain items of status-providing antisocial behaviour. This can be taken into account when doing future research.

Research into the influence of other social variables on the relation between HR and antisocial behaviour is recommended. Examples of possible social influences are those of broken homes, neglect and abuse, extreme poverty, income and family size.

References

Achenbach, T.M. & Edelbrock, C.S. (1983). Manual for the Child Behaviour Checklist and Revised Child Behaviour Profile. Cited in: Raine, A., Venables, P.H. & Mednick, S.A. (1997a). Low resting HR at age 3 predisposes to aggression at age 11 years: evidence from the Mauritius Child Health Project. *Journal of Academic Child and Adolescence Psychiatry, 36,* 1457-1464.

American Psychiatric Association (1980). *Diagnostic and statistical manual of mental disorders* (3rd ed.). Washington DC: Author.

American Psychiatric Association (1987). *Diagnostic and statistical manual of mental disorders* (3rd ed., rev.). Washington DC: Author.

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington DC: Author.

Becker, G.S. (1996). *Accounting for tastes*. Cambridge: Harvard University Press.

Bergman, B. & Brismar, B. (1994). Hormone levels and personality traits in abusive and suicidal male alcoholics. Alcoholism, *Clinical and Experimental Research, 18*, 311-316.

Berman, M.E., Kavoussi, R.J. & Coccaro, E.F. (1997). Neurotransmitter correlates of human aggression. In: Stoff, D.M., Breiling, J. & Maser J.D., *Handbook of antisocial behaviour*. New York: John Wiley and sons, inc.

Brain, P.F. & Susman, E.J. (1997). Hormonal aspects of aggression and violence. In: Stoff, D.M., Breiling, J. & Maser J.D., *Handbook of antisocial behaviour*. New York: John Wiley and sons, inc.

Buikhuisen, W. & Mednick, S.A. (1987). *Explaining Criminal Behaviour*. Leiden: Brill.

Bullock, (1988). Tonic HR, social class, and antisociality in adolescent girls. Unpublished manuscript. University of York, England. Cited in: Raine, A. (1993) *The psychopathology of crime. Criminal behaviour as a clinical disorder*. London: Academic Press.

Carey, G. & Goldman, D. (1997). The genetics of antisocial behaviour. In: Stoff, D.M., Breiling, J. & Maser J.D., *Handbook of antisocial behaviour*. New York: John Wiley and sons, inc.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155-159.

Cox, D., Hallam, R., O'Connor, K. & Rachman, S. (1983). An experimental study of fearlessness and courage. *British Journal of Psychology, 74*, 107-117.

Davies, J.G.V., & Maliphant, R. (1971). Autonomic responses of male adolescents exhibiting refractory behaviour in school. *Journal of Child Psychology and Psychiatry, 12*, 115-127.

Diener, E. (1984). Subjective well-being. *Psychological Bulletin, 95*, 542-575.

Elley, W.B. & Irving, J.C. (1972). A socio-economic index for New Zealand based on levels of education and income from the 1966 Census. *New Zealand Journal of Educational Studies, 7*, 153-167.

El-Sheikh, M., Ballard & M., Cummings, E.M. (1994). Individual differences in preschoolers' physiological and verbal responses to videotaped angry interactions. *Journal of Abnormal Child Psychology, 22,* 303-320.

Eysenck, H.J. (1964). *Crime and personality*. London: Routledge & Kegan Paul Ltd.

Farrington, D.P. (1987). Implications of biological findings for criminological research. In: S.A. Mednick, T.E. Moffitt, & S.A. Stack (Eds.), *The causes of crime: new biological approaches* (pp. 42-64). New York: Cambridge University Press.

Farrington, D.P. (1997). The relationship between low resting HR and violence. In: Raine, A., Brennan, P.A., Farrington, D.P. & Mednick, S.A. *Biosocial bases of violence* (pp. 89-105). New York: Plenum Press.

Hirschi, T. (1969). *Causes of delinquency*. Berkeley and Los Angeles: University of California Press.

Hollin, C.R. (1992). *Criminal Behaviour. A psychological approach to explanation and prevention*. London: The Falmer Press.

Hulle, C.A. Van, Corley, R., Zahn-Waxler, C., Kagan, J. & Hewitt, J.K. (2000). Early childhood HR does not predict externalising behaviour problems at age 7 years. *Journal of the American Child and Adolescence Psychiatry, 39:10,* 1238-1244

Kindlon, D.J., Tremblay, R.E., Mezzacappa, E., Earls, F. Laurent, D. & Schall, B. (1995). Longitudinal patterns of HR and fighting behaviour in 9 to 12 year old boys. *Journal of the American Child and Adolescent Psychiatry, 34,* 371-377.

Knight, B.J. & West, D.J. (1975). Temporary and continuing delinquency. *British journal of criminology, 15,* 43-50.

Lindenberg, S.M. (1996). Continuities in the theory of spf. In: Ganzeboom, M., *Verklarende sociologie: opstellen voor Reinhard Wippler.* Amsterdam: Thesis Publishers.

Little, B. (1978). Physiological correlates of antisocial behaviour in children and young adults. Cited in: Raine, A., & Venables, P.H. (1984). Tonic HR level, social class, and antisocial behaviour. *Biological Psychology, 18,* 123-132.

Loeber, R. & Dishion, T. (1983). Early predictors of male delinquency: a review. *Psychological Bulletin, 94,* 68-99.

Loeber, R. & Farrington, D.P. (1998). *Serious and violent juvenile offenders: risk factors and successful interventions.* California: Thousand Oaks.

Lösel, F. & Bender, D. (1997). HR and psychosocial correlates of antisocial behaviour in high-risk adolescents. In: Raine, A., Brennan, P.A., Farrington, D.P. & Mednick, S.A. *Biosocial bases of violence* (pp. 321-324). New York: Plenum Press.

Maliphant, R., Hume, F., & Furnham, A. (1990a). Autonomic nervous system (ANS) activity, personality characteristics and disruptive behaviour in girls. *Journal for Child Psychology and Psychiatry, 31,* 619-628.

Maliphant, R., Watson, S.A., & Daniels, D. (1990b). Disruptive behaviour in school, personality characteristics, and HR levels in 7-9 year old boys. *Educational Psychology, 10,* 199-205.

Mangan, G. (1982*). The biology of human conduct: East-West models of temperament and personality*. Oxford: Pergamon Press.

Maslow, A. (1970). *Motivation and personality*. New York: Harper.

Moffitt, T.E. (1993). Adolescence-limited and life-course-persistent antisocial behaviour: a developmental taxonomy. *Psychological Review, 4,* 674-701.

Moffitt, T.E. & Caspi, A. (2001). Childhood predictors differentiate life-course persistent and adolescence-limited antisocial pathways among males and females. *Development and Psychopathology, 13*, 355-375.

Moffitt, T.E. & Silva, P.A. (1988). Self-reported delinquency: Results from an instrument for New Zealand. *Australian and New Zealand Journal of Criminology, 21*, 227-40.

Moffitt, T.E., Caspi, A., Rutter, M. & Silva, P.A. (2001). *Sex differences in antisocial behaviour*. Cambridge: University Press.

Moffitt, T.E., Silva, P.A., Lynam, D. & Henry, B. (1994). Self-reported delinquency at age 18: New Zealand's Dunedin Multidisciplinary Health and Development Study. In J. Junger-Tas, G.J. Terlouw & M.W. Klein (eds.), *Delinquent behaviour among young people in the western world* (pp. 354-369). Amsterdam: Kugler Publications.

Ormel, J. & Lindenberg, S.M., Steverink, N. & Verbrugge, L.M. (1996). Welbevinden en de theorie van de Sociale Productie Functies. In: G.I.J.M. Kempen & Ormel, J. *Dagelijks functioneren van ouderen*. Assen: Van Gorcum.

Ormel, J. (in press) Social Production Function (SPF) theory as an heuristic for understanding developmental trajectories and outcomes. In: Pulkinnen, L. & Caspi, A. (eds.). *Developmental Psychopathology*. Cambridge: Cambridge University Press.

Pitts, T.B. (1997). Reduced HR levels in aggressive children. In: Raine, A., Brennan, P.A., Farrington, D.P. & Mednick, S.A., *Biosocial bases of violence* (pp. 317-320). New York: Plenum Press.

Poulton, R. (in preparation). *Personal communication*. 25 June 2002.

Quay, H.C. & Parsons, L.B. (1970). The differential classification of the juvenile offender. Cited in: Raine, A., & Venables, P.H. (1984). Tonic HR level, social class, and antisocial behaviour. *Biological Psychology, 18*, 123-132.

Quay, H.C. & Peterson, D.R. (1987). Manual for the Behaviour Problem Checklist. Cited in: Moffitt, T.E., Caspi, A., Rutter, M. & Silva, P.A. (2001). *Sex differences in antisocial behaviour*. Cambridge: University Press.

Quay, H.C. (1965). Psychopatic personality as pathological stimulation-seeking. *American Journal of Psychiatry, 122*, 180-183.

Raine, A. (1993) *The psychopathology of crime. Criminal behaviour as a clinical disorder*. London: Academic Press.

Raine, A. (1997). Antisocial behaviour and psychophysiology: a biosocial perspective and a prefrontal dysfunction hypothesis. In: Stoff, D.M., Breiling, J. & Maser J.D., *Handbook of antisocial behaviour*. New York: John Wiley and sons, inc.

Raine, A. (2002). Annotation: The role of prefrontal deficits, low autonomic arousal, and early health factors in the development of antisocial and aggressive behaviour in children. *Journal of Child Psychology and Psychiatry, 43:4*, 417-434.

Raine, A., & Jones, F. (1987). Attention, autonomic arousal, and personality in behaviourally disordered children. *Journal of Abnormal Child Psychology, 14*, 583-599.

Raine, A., & Venables, P.H. (1984). Tonic HR level, social class, and antisocial behaviour. *Biological Psychology, 18*, 123-132.

Raine, A., Reynolds, C., Venables, P.H. & S.A. Mednick (1997b). Biosocial bases of aggressive behaviour in childhood. Resting HR, skin conductance orienting, and physique. In: Raine, A., Brennan, P.A., Farrington, D.P. & Mednick, S.A., *Biosocial bases of violence* (pp. 107-126). New York: Plenum Press.

Raine, A., Reynolds, C., Venables, P.H., Mednick, S.A. & Farrington, D.P. (1998). Fearlessness, stimulation-seeking, and large body size at age 3 years as early predispositions to childhood aggression at age 11 years. *Archives of General Psychiatry, 55,* 745-751.

Raine, A., Venables, P.H. & Mednick, S.A. (1997a). Low resting HR at age 3 predisposes to aggression at age 11 years: evidence from the Mauritius Child Health Project. *Journal of Academic Child and Adolescence Psychiatry, 36,* 1457-1464.

Raine, A., Venables, P.H., & Williams, M. (1990). Relationships between CNS and ANS measures of arousal at age 15 and criminality at age 24. *Archives of General Psychiatry, 47,* 1003-1007.

Rutter, M. & Giller, H. (1983). *Juvenile delinquency. Trends and perspectives.* New York: Penguin books.

Rutter, M., Giller, H. & Hagell, A. (1998). *Antisocial behaviour by young people*. Cambridge: Cambridge University Press.

Rutter, M., Tizard, J., Whitmore, K. (1970). *Education, health and behaviour*. Harlow: Longman.

Silva, P.A. & Stanton, W.R. (1996). *From child to adult.* Auckland: Oxford University Press.

Valovka, J. (1995). *Neurobiology of violence*. Washington, DC: American Psychiatric Press, Inc.

Virkkunen, M., Rawlings, R., Tokola, R., Poland, R.E., Guidotti, A., Nemeroff, C., Bissette, G., Kalogeras, K., Karonen, S.L. & Linnoila, M. (1994). CSF biochemistries, glucose metabolism, and diurnal activity rhythms in alcoholic, violent offenders, impulsive fire setters, and healthy volunteers. *Archives of General Psychiatry, 51,* 20-27.

Wadsworth, M.E.J. (1976). Delinquency, pulse rate and early emotional deprivation. *British Journal of Criminology 16,* 245-256.

West, D.J., & Farrington, D. (1977). *The delinquency way of life.* London: Heinemann.

www.nlm.nih.gov/medlineplus

www.psych.org

Zahn, T.P. & Kruesi, M.J.P. (1993). Autonomic activity in boys with disruptive disorders. *Psychophysiology, 30,* 605-614.

Zuckerman, M., Simons, R.F. & Como, P.G. (1988). Sensation seeking and stimulus intensity as modulators of cortical, cardiovascular, and electrodermal response: a cross-modality study. *Personal and Individual differences, 9,* 361-372.

Appendix

DSM CD AND ASPD DIAGNOSES

Table a1 *diagnostic criteria for DSM-IV diagnosis of conduct disorder that were available in the Dunedin data archives at each assessment age, as reported by self, parent and teacher*

DSM-IV symptom criterion	*Age 11*	*Age 13*	*Age 15*	*Age 18*
Physical fights	S, P, T	S, P, T	S, P	S
Destroys property	S, P, T	S, T	S	S
Tells lies	S, P, T	P, T	S, P	S
Runs away	S	S	S	S
Truants	S, P, T	S, P, T	S, P	S
Steals without confrontation	S, P, T	S, P, T	S, P	S
Bullies	P, T	P, T	P	
Carries or uses weapon		S	S	S
Steals with confrontation		S	S	S
Sets fires		S	S	S
Breaks and enters		S	S	S
Cruel to people		P	P	
Cruel to animals		S		
Stays out late at night despite parents' prohibition	S			
Forces sex				
Number of the 15 criteria available	8	13	12	10

Source: *Moffitt et al. (2001)*
Notes: S=from self-reported interview, P=from parent checklist, T=from teacher checklist.

Table a2 *diagnostic criteria fro DSM-IV diagnosis of antisocial behaviour*

DSM-IV symptom criteria	*No*	*Once or more times*
(a) Repeatedly performing acts that are grounds for arrest		
Damage/destroy property		
Set fires		
Break into a building to steal something		
Steal money/things less than $5		
Steal money/things of $5 to $100		
Steal money/things of $100 to $500		
Steal money/things greater than $500		
Shoplifting		
Purse snatching, pick pockets		
Stole something for a car		
Knowingly bought/sold stolen goods		
Converted a car, that you didn't intend to keep/sell		
Stolen a car		
Embezzled money		
Made obscene phone calls		

False info on tax forms, bank or insurance forms		
Interfered with work of law, courts, police		
Driven without driver's licence		
Sold marijuana		
Sold hard drugs		
Paid someone to have sex with you (procure)		
Been paid to have sex (prostitute)		
Contribute to delinquency of a minor		
Failed to obey courts		
Stole money from your work place		
(b) Deceitfulness; repeated lying, use of aliases, or conning others		
Used worthless cheques, fake money		
Used credit cards, bank cards without owner's permission		
Tried to cheat someone by selling them something worthless		
Used false name or alias		
Inflated qualifications to get a job		
Faked illness/injury to collect ACC or sickness benefit		
Collected unemployment payment when not actively looking for work		
Thought you lied quite a lot		
(c) Impulsivity or failure to plan ahead		
Quit a job without knowing where you would get money to live on		
'taken' in for a period of time, no fixed address		
Gambling and betting is a problem for you		
Left partner without warning, because you were bored, felt tied down		
Bought something credit and never made payments		
Have had a totally monogamous relationship		
(d) Irritability and aggressiveness		
Conflicts with boss/supervisors		
Lost temper/got into fight with some at work		
Attacked an adult with idea of hurting them		
Used force to rob someone, bank, shop		
Been involved in a gang fight		
Threatened or hurt someone to have sex with them		
(e) Reckless disregard for the safety of self or others		
Been so angry with a child that you attacked them with a weapon		
Been so angry with a child that you hit them		
Commit serious driving violation (extreme speed, dwi (driving while intoxicated))		
Ever left a child under 6 without an adult/teenager to watch them		

Had a traffic accident while under influence of alcohol		
Been under influence of alcohol in a dangerous situation		
Been under influence of marijuana in a dangerous situation		
Been under influence of other drugs in a dangerous situation		
(f) Consistent irresponsibility		
Walked off job (quit) without giving notice		
Been late to work		
Done a job in a way that might get you fired		
Been under influence of alcohol/drugs at work		
Squandered money needed by you or your family		
Failed to pay child support you owed		
Had trouble with debt, been chased by debt collectors		
Borrowed more than $20 and not paid it back		
Moved away from a flat without paying final bills		

SELF-REPORTED DELINQUENCY

Table a3 *29-item illegal behaviour subscale of the Self-reported Early Delinquency Interview*

	No	*Once or twice*	*Three or more times*	*Weights at age 13*
Playing truant from school (skipping school)				0.90
Getting suspended or expelled from school				1.56
Running away from home and staying away overnight				1.25
Carrying some kind of weapon in case it is needed in a fight (like a knife, chain or piece of wood)				1.67
Going around in a group of 3 or more damaging property or getting into fights				1.70
Damaging something in a public place (such as streets, movie theatres, buses, toilets)				1.46
Purposely damaging or destroying something belonging to your parents				1.36
Starting a fire where you should not burn anything				1.43
Damaging a parked car (like breaking an aerial, slashing tyres, scratching paint)				1.66
Raising a false alarm (such as dialling 111 or setting off a false fire alarm)				1.40
Stealing a thing or money worth between $2 - $40				1.36
Stealing a thing or money worth over $40				1.55
Breaking into a house, flat, building, or vehicle (to try to steal something or just look around)				1.57
Stealing something from an open store or shop (shoplifting)				1.53
Stealing something out of a parked car				1.57
Stealing goods or money from a video machine, public telephone or vending machine				1.44

Taking a bicycle without permission				1.32
Taking a car or motorcycle for a drive without permission				1.44
Sniffing glue, petrol or other things in order to feel 'high'				1.60
Smoking cannabis (pot, marijuana, hashish)				1.36
Using any illegal drugs other than cannabis (heroin, cocaine, speed)				1.73
Buying or drinking alcoholic drinks (beer, wine, or spirits) in hotels or any other public place				1.03
Drinking alcoholic drinks during school hours or at lunchtime on a school day				1.46
Hitting one of your parents in anger				1.41
Fighting in the street or other public place (not fighting at school)				1.42
Struggling to get away from a policeman				1.31
Using force or threats to get money from someone about your age or younger				1.68
Using force or threats to get money from someone older than yourself				1.65
Using any kind of weapon in a fight (like a knife, chain, broken bottle, or rock)				1.89

Table a4 *48 items of the Self-reported Delinquency Interview*

	How many times?
How many times in the last year did you run away from your home and stay away overnight?	
How many times in the last year did you carry a hidden weapon?	
How many times in the last year were you loud, rowdy, or unruly in a public place so that people complained or you got into trouble?	
How many times in the last year did you purposely damage or destroy property that did not belong to you?	
How many times in the last year did you purposely set fire to a house, building, car or other property, or, try to do so?	
How many times in the last year did you break into, or try to break into a building, to steal something?	
How many times in the last year did you steal, or try to steal, money or things worth $5 or less?	
How many times in the last year did you steal, or try to steal, money or things worth between $5 and $100?	
How many times in the last year did you steal, or try to steal, money or things worth between $100 and $500?	
How many times in the last year did you steal, or try to steal, money or things worth over $500?	
How many times in the last year have you taken something from a store without paying for it? (including events you have already told me about)	
How many times in the last year have you snatched someone's purse or wallet, or	

picked someone's pocket?	
How many times in the last year have you taken something from a car that did not belong to you?	
How many times in the last year have you knowingly bought, sold, or held stolen goods, or, tried to do any of these things?	
How many times in the last year have you 'converted' a vehicle, that is, taken a motor vehicle, such as a car or motorcycle, for a ride or drive without the owner's permission, when you didn't intend to keep or sell it?	
How many times in the last year have you stolen, or tried to steal, a motor vehicle, such as a car or motorcycle, to keep or sell?	
How many times in the last year have you used worthless cheques or fake money to pay for something?	
How many times in the last year have you used, or tried to use, credit cards, bank cards or cheques without the owner's permission?	
How many times in the last year have you tried to cheat someone by selling them something that was worthless, or not what you said it was?	
How many times in the last year have you been so angry with a child that you attacked them with a weapon, or with the idea of seriously hurting them?	
How many times in the last year have you been so angry with a child that you hit them (other than the events you told me about)?	
How many times in the last year have you attacked an adult with a weapon or with the idea of seriously hurting or killing them? Don't include partners, as we will ask about hitting partners in a different interview today.	
How many times in the last year have you hit an adult with the idea or hurting them (don't include partners)?	
How many times in the last year have you used a weapon, force or strong arm methods to rob a person, shop, bank, or other business?	
How many times in the last year have you been involved in a gang fight?	
How many times in the last year did you commit a serious driving offence, such as driving while drunk, driving recklessly, or speeding 50km per hour over the posted speed limit (for example, 150 km/hr in a 100 km/hr zone)?	
How many times in the last year have you embezzled money: that means used money entrusted to your care for some purpose not intended? (examples: charity collections, office accounts)	
How many times in the last year have you lied about your age?	
How many times in the last year have you begged for money or things from strangers?	
How many times in the last year have you made obscene telephone calls, such as calling someone and saying rude things?	
How many times in the last year have you been drunk in a public place?	
How many times in the last year have you avoided paying for things such as movies, bus or subway rides, food or computer services?	
How many times in the last year did you give false information on a tax form, an insurance claim, or an application for a loan or bank account?	
How many times in the last year did you use a false name or alias so you couldn't be identified?	
How many times in the last year did you move away from a flat or house without paying the final bills or rent?	
How many times in the last year did you buy something on credit and then never made	

the payments?	
How many times in the last year interfere with the work of the law by trying to get away from police, by hiding someone that the police were looking for, or by telling a lie to a police officer or judge?	
How many times in the last year have you driven a vehicle when you did not have a driver's licence or after your licence had been suspended or disqualified?	
How many times in the last year have you sold marijuana or hashish?	
How many times in the last year have you sold hard drugs, such as heroin, cocaine or LSD?	
How many times in the last year have you used marijuana?	
How many times in the last year have you used a harder drug, such as heroin, cocaine or LSD?	
How many times in the last year have you paid someone to have sex with you?	
How many times in the last year have you been paid, or received other favours for having sex with someone?	
How many times in the last year did you threaten or hurt someone to get them to have sex with you?	
How many times in the last year have you contributed to the delinquency of a person under age 17? That is, you helped them to run away, gave them alcohol or drugs, or had sex with them.	
How many times in the last year have you failed to obey the courts? That is: failed to answer summons by a bailiff, failed to show up for periodic detention, broke conditions of parole, failed to pay a fine, escaped or tried to escape prison or jail, failed to pay child support.	

INFORMANT REPORTS

Table a5 *4-item antisocial subscale of the 41-item informant reports questionnaire at age 18*

	doesn't apply	*applies somewhat*	*certainly applies*
Problems with aggression, such as fighting or controlling anger			
Doing things against the law, such as stealing or vandalism			
Problems related to the use of alcohol			
Problems related to the use of marijuana or other drugs			

Table a6 *7-item antisocial subscale of the 60-item informant reports questionnaire at age 26*

	doesn't apply	*applies somewhat*	*certainly applies*
….. is a good citizen			
	not a problem	bit of a problem	yes, a problem
Controlling anger, hot temper			
Gets into fights			
Blames others for own problems			
Does not show guilt or regret after doing something bad			
Impulsive, rushes into things without thinking about what might happen			
Does things against the law			