

Risk Factors for Criminal Behavior

A Biopsychosocial Study

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List of Papers

Abrahamsen, S., & Melinder, A. (2013). Effects of Birth weight and Placement in Out-of-Home Care on Criminal Behavior. (Submitted.)

Abrahamsen, S., Foss Haug, K. B., & Melinder, A. (2013). The Importance of COMT, Relationships with Caregivers, and Emotional Stability for Prosocial Sensation Seeking and Antisocial Behavior. (Submitted.)

Abrahamsen, S., Foss Haug, K. B., & Melinder, A. (2013). Predicting Incarceration: The Influences of Witnessing Domestic Violence, Variation in the MAOA and SLC6A4 genes, and Emotional Stability. (Submitted.)

We owe our children – the most vulnerable citizens in any society – a life free from violence and fear. In order to ensure this, we must be tireless in our efforts not only to attain peace, justice and prosperity for countries, but also for communities and members of the same family. We must address the roots of violence.

Nelson Mandela (2002)

General Summary

The price of crime is enormous. In addition to the monetary costs of the investigative process and the criminal procedure, crime often leads to health and social problems for victims and perpetrators. Approximately 5% of the population is responsible for a sizeable portion of the total amount of crime; thus, preventing high-risk individuals from developing into offenders can provide society with significant savings. To track high-risk individuals and tailor prevention programs, risk factors for criminal behavior must be identified. Knowledge about risk factors for criminal behavior can further expand the range of treatment possibilities and increase their effectiveness.

The thesis that follows will further explore psychological, social, and biological risk factors for criminal behavior and investigate the possibility that stress hyperreactivity (i.e., an excessively active stress response), as indexed by high scores on the Neuroticism personality trait, may mediate the impact of social, as well as biological, risk factors for antisocial behavior.

The *first* aim of the thesis is to identify psychological, social, and biological risk factors for criminal behavior. The first paper of this dissertation investigates the effects of low birth weight and being a client of Child Protective Services on criminal behavior. The paper has a particular focus on the impact of being placed outside of the home, i.e., in foster care or an institution, and examines whether low birth weight interacts with being placed in out-of-home care to further increase the risk hypothesized to be associated with low birth weight. The other two papers investigate the influences of genetic variance in monoamine oxidase A (MAOA), serotonin transporter (SLC6A4), and catechol-O-methyltransferase (COMT) genes, which are implicated in serotonergic, dopaminergic, and/or noradrenergic neurotransmission, on criminal behavior. These papers further examine the impacts of personality, the quality of relationship with caregivers, and having witnessed domestic violence. Moreover, Paper II fulfills the *second* goal of the thesis: To investigate whether stress hyperreactivity may mediate the relationships between social and biological risk factors and criminal behavior. The *third* objective of the thesis is to investigate possible explanations of why antisocial individuals have been found to score high on Neuroticism, indicating stress *hyper*reactivity, as well as sensation seeking, indicating stress *hypo*reactivity (i.e., an unusually diminished stress response). Paper II investigates the possibility that high versus low scores on Neuroticism predict different types of sensation seeking.

The results showed that the personality factor of Neuroticism predicted a prosocial type of sensation seeking, with individuals working in a high-risk profession having high scores and inmates showing low scores. Furthermore, the MAOA polymorphism was related to criminal behavior and the COMT Val158Met polymorphism to sensation seeking. Having a poor relationship with caregivers predicted low scores on sensation seeking. Moreover, Neuroticism was observed to mediate the associations between the relationship with caregivers and the COMT Val158Met polymorphism and sensation seeking. Having witnessed domestic violence and being a client of Child Protective Services predicted an increased risk of criminal behavior. Finally, low birth weight interacted with placement in out-of-home care among clients of Child Protective Services to predict decreased risk of criminal behavior. In conclusion, this dissertation sheds further light on how psychological, social, and biological factors and their interrelationships may impact the development of criminal behavior. Disclosing vulnerability and resilience factors for antisocial behavior, the results may contribute to the detection of high-risk individuals and the formation of effective prevention policies.

Introduction

Risk factor research

There is no agreed definition of “risk factors” (see Case & Haines, 2009, 2010; Kraemer et al., 1997). In this dissertation, the following definition is used: Factors related to a high risk of a negative outcome – with or without causal influences (Raine, Brennan, & Farrington, 1997). Antisocial behavior refers to a range of disruptive behaviors that have in common transgressions against social norms (Stoff, Breiling, & Maser, 1997). Dodge and Pettit (2003) use heart disease research as an analogy for the study of antisocial, including criminal, behavior. The goal of much medical research is to explain a group of symptoms with one single cause, an objective that heart disease research will never meet because there might be a number of pathways to heart disease. Additionally, subtypes of heart disease may exist, with different paths to each. In the same manner, several risk factors may lead to antisocial behavior, and different factors may predict different subtypes (Dodge & Pettit, 2003). Not only are there numerous possible risk factors, but there is also ample evidence that social and biological factors may interact to increase risk (Caspi et al., 2002).

A further complexity lies in the fact that the identification of risk factors generates little information regarding the pathway to antisocial behavior. Returning to the heart disease analogy, distal risk factors, e.g., diet or stressful lifestyles, need to be connected to proximal processes, e.g., arterial plaque buildup and blood flow. Likewise, distal risk factors, e.g., a difficult temperament, must be tied to experiences, e.g., harsh discipline (physical and psychological punishment), which eventually must be related to processes, e.g., emotional reactions, that ultimately generate antisocial behavior (Dodge & Pettit, 2003). Research on antisocial behavior thus needs to incorporate social and biological factors and the interactions between them and explore factors that may mediate the observed relationships. Psychological, social, and biological factors that have been related to antisocial behavior are presented in the following.

Personality traits

Traits are “dimensions of individual differences in tendencies to show consistent patterns of thoughts, feelings, and actions” (McCrae & Costa, 1990, p. 23). The construct of personality may play an integral role in the study of antisocial behavior, for example, by helping to explain its stability and heritability (Miller, Lynam, & Leukefeld, 2003). That is, because personality shows high temporal stability (Bazana & Stelmack, 2004), it is reasonable

that if certain personality characteristics are related to criminal offending, criminal behavior remains rather stable as well. Furthermore, despite the relative stability of personality, there are changes in mean levels of personality throughout development, e.g., people become more emotionally stable (Roberts & Mroczek, 2008). These changes concur with age-related changes in rates of antisocial behavior; thus, they further demonstrate the importance of including personality factors in the study of antisocial behavior (Jones, Miller, & Lynam, 2011). Moreover, because the heritability of personality is high (Carey & Goldman, 1997), personality may contribute to explaining the heritability of antisocial behavior. Lastly, personality characteristics that show a stable association with criminal behavior may be pivotal to target in prevention and intervention efforts (Miller et al., 2003). Notwithstanding the possible benefits of incorporating personality traits in the study of antisocial behavior, the role of personality has been largely disregarded (Jones et al., 2011).

Starting in the early 1960s, factor analyses of comprehensive inventories of trait descriptive adjectives have resulted in five robust factors (Bazana & Stelmack, 2004). The five factors, referred to as the “Big Five”, make up the Five-Factor Model of personality (FFM; McCrae & John, 1992) and have been detected across various languages, cultures, and nationalities (Paunonen, Jackson, Trzebinski, & Forsterling, 1992). Thus, despite the existence of various personality models, there is strong empirical evidence that these different models can be comprehended by means of the FFM framework (Markon, Krueger, & Watson, 2005). The factors are as follows (related labels in parentheses): Extraversion (assertive, adventurous, energetic), Agreeableness (caring, trusting, tolerant), Conscientiousness (responsible, careful, orderly), Emotional Stability (secure, stable, self-sufficient), and Openness to Experience (curious, imaginative, broad-minded; Mount, Barrick, & Stewart, 1998).

A review examining the relationships between the Big Five factors and antisocial behavior found a moderately negative effect for Agreeableness, followed by a smaller negative effect for Conscientiousness, and lastly, an even smaller positive relation for Neuroticism (Jones et al., 2011). Extraversion and Openness to Experience were not significantly related to antisocial behavior. These findings are largely in agreement with the results of a previous meta-analytic review (Miller & Lynam, 2001).

Social risk factors

Approximately 20% of the population variation in antisocial behavior is due to shared environmental effects, i.e., the environment shared by family members (Moffitt, 2005a),

precluding environmental influences implicated in interactions between genetic and environmental factors. Most behavior results from interactions between genes and environmental factors; thus, it is noteworthy that 20% of population variation in antisocial behavior is due to direct environmental effects (Moffitt, 2005a).

For some people, the threat of violence occurs behind closed doors (Brundtland, 2002). Exposure to violence, e.g., in terms of abuse or witnessing domestic violence, is stressful experiences that strongly impact children's well-being (Krug, Mercy, Dahlberg, & Zwi, 2002). Stress activates the hypothalamus-pituitary-adrenal (HPA) axis, which stimulates the production of glucocorticoids (Lupien, McEwen, Gunnar, & Heim, 2009). Receptors for glucocorticoids are expressed all over the brain; thus, these steroids may have long-lasting effects on several brain regions. The hippocampus might be the brain region that is most vulnerable to the effects of chronic childhood stress (Lupien et al., 2009). Because the hippocampus modulates HPA axis activity, damage to the hippocampus results in impaired shut-off of the HPA stress response, resulting in a lengthier HPA response (Herman & Cullinan, 1997). Chronic stress diminishes the dendrites of neurons in the hippocampus and medial prefrontal cortex. The consequence is reduced synaptic input, which again decreases abilities for self-regulation (Hunter & McEwen, 2013). The basolateral amygdale and orbitofrontal cortex, on the other hand, expand dendrites as a result of chronic stress, causing increased aggressiveness (Hunter & McEwen, 2013).

In line with the assumption that stressful events increase the risk of crime, a number of studies have found that witnessing domestic violence predicts increased risk of externalizing problems and antisocial and aggressive behavior (Caputo, Frick, & Brodsky, 1999; Ehrensaft et al., 2003; Evans, Davies, & DiLillo, 2008; Fergusson & Horwood, 1998; Howard, Kimonis, Muñoz, & Frick, 2012; Leschied, Chiodo, Nowicki, & Rodger, 2008; McCloskey & Lichter, 2003; Mrug & Windle, 2010; Righthand & Welch, 2001; Sternberg, Baradaran, Abbott, Lamb, & Guterman, 2006; Wolfe, Crooks, Lee, McIntyre-Smith, & Jaffe, 2003). The *spillover hypothesis* suggests that parents whose relationship is characterized by a high level of conflict are more liable to engage in dysfunctional parenting practices; disharmony in one relationship spills into other relationships within the family (Benson, Buehler, & Gerard, 2008). In accord with this theory, domestic violence appears to co-occur with certain parenting styles (Erel & Burman, 1995; Krishnakumar & Buehler, 2000), e.g., harsh discipline (Brody, Arias, & Fincham, 1996; Buehler & Gerard, 2002; Erath, Bierman, & Conduct Problems Prevention Research Group, 2006) and reduced amount of positive interactions with children (Holden & Ritchie, 1991). Marital conflict further heightens the risk

of low inter- and intraparental consistency in parenting practices, both of which generate an unpredictable environment for children (Fincham, Grych, & Osborne, 1994). Such negative parenting practices have been found to mediate the relationship between interparental hostility and children's externalizing problems (Benson et al., 2008). One study found that the association between marital violence and children's antisocial behavior was completely mediated by parenting practices, e.g., harsh discipline and intraparental consistency (Gámez-Guadix, Almendros, Carrobes, & Muñoz-Rivas, 2012).

Although studies have discovered a link between adverse childhood experiences, which if uncovered may lead to the involvement of Child Protective Services (CPS), and antisocial behavior, there has been little research regarding how experiences within the CPS may impact offending (Cusick, Courtney, Havlicek, & Hess, 2011). CPS clients have been found to be at higher risk of criminal behavior compared with non-CPS clients (Clausen, 2004); however, variation in underlying causes of CPS involvement is likely to predict variation in criminal behavior. Reasons for CPS involvement are, among others, child abuse or neglect, behavioral problems in the child, or the death of parents.

In addition to assistance, e.g., economic aid and advice and guidance for parents and families, the outcome of CPS involvement may be out-of-home placement, i.e., in an institution or foster care. In 2012, 53,200 Norwegian children between 0 and 22 years of age received CPS interventions, 83% of which obtained assistance (Statistics Norway). In 17% of cases, the CPS got custody of the child, implying placement in foster care or an institution. By the end of 2012, 10 out of 1,000 children between 0 and 22 years of age were placed outside of the home. Of these children, 70% were placed in foster care and 30% in an institution. Being in a group home (residential treatment facilities) compared with foster care has shown to increase the risk of violent crime (Cusick et al., 2011).

Biological risk factors

The serotonin system, the dopamine system, and the noradrenaline system make up the three major monoamine systems in the brain. Serotonin is positively associated with inhibition, dopamine with approach, and noradrenaline with arousal (Zuckerman, 2007). The behavioral inhibition system is an aversive motivational system (Carver & White, 1994) that inhibits behavior that may lead to negative outcomes (Gray, 1987). Activity in the behavioral approach system, on the other hand, causes an individual to instigate or increase movement toward a goal. Due to prenatal experiences or genetic factors, some children are born with a

hyperpersistent behavior approach system or an underactive behavioral inhibition system (see Fowles, 2001; Gray, 1987).

Low birth weight. Low birth weight (LBW; <2500 g) is an environmentally affected index of prenatal stress (Maccari & Morley-Fletcher, 2007; Thapar et al., 2005). LBW is assumed to cause damage to the central nervous system (Brennan, Mednick, & Raine, 1997; Fletcher, Levin, & Landry, 1984); thus, LBW seems to be a reasonable proxy for increased risk for neuropsychological disorders (Tibbetts & Piquero, 1999). Neurobiological deficits may result in self-regulatory problems (Beaver & Wright, 2005), which again increase the risk of antisocial behavior (Calkins & Keane, 2009).

Few studies have investigated the association between LBW and antisocial behavior. In these studies, an increased risk for LBW individuals has been found (Breslau, Klein, & Allen, 1988; Ross, Lipper, & Auld, 1990; Tibbetts & Piquero, 1999). There is abundant evidence that the relationship between LBW and antisocial behavior can be tied to “early central nervous system dysfunction or development, neurological abnormalities, and neurodevelopmental problems and deficits” (Tibbetts & Piquero, 1999, p. 850).

Quite surprisingly, given the observation of a positive correlation between LBW and antisocial behavior, a study of extremely low birth weight (ELBW; <1000 g) children in four countries found no differences in externalizing behavior compared with controls (Hille et al., 2001). Furthermore, a Norwegian cohort study did not detect a relationship between gestational age (low gestational age implicating LBW) at birth and criminal activity (Moster, Lie, & Markestad, 2008). A *lower* obstetric risk score has been found to predict antisocial behavior among boys (Pitzer, Esser, Schmidt, & Laucht, 2010). Finally, less risk taking and delinquent behavior have been discovered among individuals born with a very low birth weight (VLBW; <1500 g), very preterm, or at an extremely low gestational age (Gardner et al., 2004; Hack, 2006; Hack et al., 2002; Hack et al., 2004; Hille et al., 2008).

Higher parental monitoring and a specific resilience among VLBW children and their families have been suggested as explanations of the lower risk of antisocial behavior and risk taking among VLBW individuals (Hack et al., 2002; McCormick & Richardson, 2002). However, these proposals have been disputed (Gardner et al., 2004; Harrison, 2002). Other possible explanations are higher behavioral inhibition, i.e., a more sensitive aversive motivational system (see Carver & White, 1994) among VLBW individuals (Hack et al., 2004), and that the interaction between perinatal and social risk may be crucial (Raine, Brennan, & Mednick, 1997).

In sum, although LBW has been associated with an increased risk of criminal behavior, VLBW, ELBW, and low gestational age have either failed to predict criminal behavior or predicted less engagement in criminal behavior. However, although there is extensive literature examining the influences of VLBW and ELBW on criminal behavior, few studies have investigated the association between LBW and crime.

Genes. Approximately 50% of the population variation in antisocial behavior is explained by genes (Moffitt, 2005a). Genes control the production and regulation of proteins that function as neurotransmitters, enzymes, and hormones. Although certain genes may be of particular importance, a multitude of genes are likely to play a role, operating additively or interactively to increase risk (Dodge & Pettit, 2003).

Dopamine and noradrenaline belong to a subcategory of monoamines called catecholamines. Catecholamines are implicated in the regulation of aggressive behavior (Haller, Makara, & Kruk, 1998). Most of the available evidence suggests that catecholamines lower the threshold for an aggressive response to environmental stimuli; thus, aggression may depend on serotonin level and level of catecholamines, the former reducing and the latter increasing the risk of aggression (Volavka, Bilder, & Nolan, 2004).

Two major enzymes are responsible for catecholamine catabolism in the brain: Catechol-O-methyltransferase (COMT) and monoamine oxidase A (MAOA). The regulation of the genes coding for these enzymes is governed by common, functional polymorphisms. The COMT gene is positioned on chromosome 22q11 and holds a valine/methionine (Val/Met) polymorphism at codon 158. The COMT enzyme inactivates catecholamines in the synaptic cleft. The Met allele in the COMT has been shown to be associated with an approximately 40% lowered enzyme activity in the prefrontal cortex, most likely causing higher dopamine level. Among Europeans, approximately equal proportions of Val and Met alleles have been detected (Palmatier, Kang, & Kidd, 1999).

Monoamine oxidases (MAOs) catalyze the oxidative deamination of several neurotransmitters and thus regulate their levels, especially those of serotonin (5-HT; Zuckerman & Kuhlman, 2000). MAOA breaks down neurotransmitters prior to storage in the neuron or synaptic space. Genetic variation in the promoter regions of the MAOA gene, located on the X chromosome, may influence antisocial behavior (Raine, 2008). The length of a functional 30-bp variable number of tandem repeat (VNTR) polymorphism in the promoter of the MAOA gene determines the allele-specific variation of the transcriptional potential and production of the MAOA enzyme (Denney, Koch, & Craig, 1999; Sabol, Hu, & Hamer, 1998). The 3.5- and 4-repeat alleles (frequency of approximately 60%) have been shown to

transcribe more efficiently than alleles with 2, 3, and 5 repeats (40%), generating high (MAOA-H) and low (MAOA-L) genotypes, respectively (Sabol et al., 1998).

If aggressive behavior is enhanced by catecholaminergic activity, then lower COMT and MAOA activities, resulting in a slower inactivation of catecholamines, should indirectly enhance aggression. This prediction has been supported by most, but not all, studies. The low-activity Met allele of the COMT gene has been related to aggressive behavior among youths (Albaugh et al., 2010) and in adult clinical populations (Kotler et al., 1999; Lachman, Nolan, Mohr, Saito, & Volavka, 1998; Rujescu, Giegling, Gietl, Hartmann, & Moller, 2003; Strous, Bark, Parsia, Volavka, & Lachman, 1997). However, increased risk of antisocial personality disorder has been found for Val carriers (Aluja, Fibla, & García, 2012). Furthermore, higher risk of antisocial behavior has been shown for ADHD children homozygous for the Val allele (Caspi et al., 2008).

Complete MAOA deficiency due to a point mutation in the gene coding for MAOA has been related to criminal behavior (Brunner, Nelen, Breakefield, Ropers, & van Oost, 1993). An association between lower MAOA enzyme activity and aggression has also been found in nonhuman animal studies (Cases et al., 1995). MAOA-L has been tied to antisocial personality traits (Williams et al., 2009) and increased risk of antisocial behavior (Fergusson, Boden, Horwood, Miller, & Kennedy, 2011). However, MAOA-H has been related to childhood aggression (Beitchman, Mik, Ehtesham, Douglas, & Kennedy, 2004). Several studies have found an association between MAOA-L and antisocial behavior only in interaction with environmental adversity (Caspi et al., 2002; Foley et al., 2004; Frazzetto et al., 2007; Nilsson et al., 2006; Taylor & Kim-Cohen, 2007; Widom & Brzustowicz, 2006). A longitudinal study showed a stronger relationship between abuse and antisocial behavior among boys with low MAOA levels compared to those with high levels (Caspi et al., 2002). The risk of being convicted of a violent crime by 26 years of age was three times higher for abused boys with MAOA-L compared to abused boys with MAOA-H. Among abused boys with MAOA-L, 85% had engaged in antisocial behavior. Although they made up only 12% of the sample, they explained 44% of violent convictions. In conclusion, COMT and MAOA polymorphisms appear to represent a basic neurobiological mechanism that plays a part in the regulation of aggressive behavior (Volavka et al., 2004).

Serotonin (5-HT) levels are balanced by several mechanisms, one being the serotonin transporter (5-HTT) enzyme, which regulates reuptake (Lesch et al., 1996). 5-HTT is coded by the SLC6A4 gene located on chromosome 17. Concordant with the MAOA 5'-regulation, the level of 5-HTT is regulated by the presence of a serotonin-transporter polymorphic region

(5-HTTLPR), a VNTR located in the promoter region of SLC6A4. This DNA variation contributes to generation of either short (S) or long (L) variant alleles, directing low or high transcriptional activity, respectively (Lesch et al., 1996). Thus, carriers of at least one S allele produce significantly less mRNA than homozygous L carriers. Recent work has identified an additional A > G single nucleotide polymorphism (SNP) in the L allele, designated L_A and L_G, associated with higher and lower transcriptional activity, respectively. The allele frequencies among Northern Europeans are 40% S, 60% L (Gelernter, Kranzler, & Cubells, 1997). Among individuals who have experienced childhood adversity, the L/L-genotype has been shown to protect against the development of violent crime (Reif et al., 2007), whereas the S allele has been associated with violent behavior (Retz, Retz-Junginger, Supprian, Thome, & Rösler, 2004).

Low MAOA and SLC6A4 activities result in high synaptic levels of serotonin. Antisocial behavior, however, is related to decreased serotonin levels (for possible explanations, see Nordquist & Orelund, 2010).

A biosocial perspective

Although multiple social and biological risk factors for antisocial behavior have been identified, few studies have investigated the interaction between social and biological risk (Raine, 2002). An interaction effect occurs when the effect of one independent variable on the dependent variable depends on the level of another independent variable. Whereas social factors may be most important in explaining criminal behavior for some offenders, biological factors may be most pronounced for others. For yet others, both biological and social factors may be vital (Raine, Brennan, Mednick, & Mednick, 1996). A study of 4269 males revealed an interaction between birth complications and early maternal rejection in the prediction of violent crime (Raine, Brennan, & Mednick, 1994, 1997). Those who experienced birth complications as well as early maternal rejection were most likely to become violent, whereas experiencing only one risk factor, i.e., birth complications or maternal rejection, did not predict higher rates of violence. In a review of 39 studies that demonstrated the effects of biosocial interaction on antisocial behavior, the rates of antisocial and violent behavior were observed to increase exponentially when both biological and social risk factors are present (Raine, 2002).

The diathesis-stress model (see Monroe & Simons, 1991) can be used to indicate the potential for increased risk of criminal behavior resulting from a biosocial interaction. The diathesis-stress model proposes that psychopathology is a consequence of a combination of a

diathesis and exposure to stress. The diathesis creates a vulnerability to stress; thus, although stress may affect the development of the disorder, much more stress is needed to produce psychopathology in a person with a low diathesis than in someone with a high diathesis (Zuckerman, 1999). Applying this in the context of criminal behavior, vulnerability may reside in biological factors such as neurobiological deficits. Stress may activate this predisposition, leading to criminal actions.

Stress reactivity as a mediator

In addition to the possibility that a given factor (X) may interact with another factor to influence criminal behavior (Y), X may influence Y either completely or in part by means of an intervening factor (M), which in turn affects Y. Such indirect effects are called mediation (Tabachnick & Fidell, 2007). Van Goozen, Fairchild, and Harold (2008) propose a theoretical model in which stress hyporeactivity mediates the influences of early adversity and genetic factors on persistent and severe antisocial behavior. A down-tuning of the stress-response system due to early and persistent stress would be an effective way of escaping constant arousal and extreme energy expenditure. Van Goozen et al. (2008) discuss two theories of why lower stress sensitivity might characterize antisocial individuals. One theory posits that antisocial individuals are less responsive to the negative consequences of behavior; thus, they are less receptive to learning from punishment (Raine, 1996). Sensation seeking is the key concept in the second theory; antisocial individuals participate more in high-risk behaviors, suggesting that they have higher stress thresholds (Zuckerman, 1979). In support of the latter theory, the personality trait of sensation seeking has proved to be essential in the prediction of antisocial behavior, with antisocial individuals scoring higher than the general population (Herrero & Colom, 2008).

Sensation seeking. High sensation seeking is a function of a strong approach and weak inhibition and arousal systems. These are interactive, as are the neurotransmitters underlying them. Because dopamine is positively associated with approach, serotonin with inhibition, and noradrenaline with arousal, high sensation seekers are characterized by strong dopaminergic reactivity and weak serotonergic and noradrenergic reactivities (Zuckerman, 2007).

Given that weak inhibition and strong approach systems characterize antisocial individuals as well as high sensation seekers, a pivotal question is why certain high sensation seekers choose to engage in *prosocial* sensation-seeking behaviors. A model that studies the biological basis for sensation seeking and how environmental factors navigate the

manifestation of the trait may provide knowledge regarding why sensation is sought in conventional ways by some people and in criminal ways by others (Franques et al., 2003). Such research might draw from studies showing that the personality trait of Neuroticism differentiates antisocial and prosocial sensation seekers. The relationship between Neuroticism and sensation-seeking tendency is discussed in the following subsection.

Neuroticism. Higher scores for Neuroticism (N), defined as the “chronic tendency to experience negative emotional states such as depression, anxiety, and anger” (Ellis, Beaver, & Wright, 2009, p. 122), have been found among high-sensation-seeking inmates compared to the general population (Rebollo, Herrero, & Colom, 2002) and were positively correlated with sexual risk-taking in a review (Hoyle, Fejfar, & Miller, 2000). Paradoxically, given the detection of high N scores among antisocial sensation seekers, N is associated with a preference for the secure and well-known (Zuckerman, 1991). *Low* N has been related to a wide range of prosocial risk behaviors (Kajtna, Tušak, Barić, & Burnik, 2004; Nicholson, 2005). The Neuroticism trait thus distinguished high-sensation-seeking inmates and sexual risk takers (high N) from prosocial risk takers (low N). Emotional stability is the counterpoint of N (i.e., low N) and has emerged as one of the most salient personality characteristics typical of police officers (Abrahamsen & Strype, 2010), suggesting, in tandem with the abovementioned findings, a pivotal role in prosocial sensation seeking. In conclusion, N scores may differentiate prosocial from antisocial sensation seekers.

Correlations between N and autonomic arousal have proven to be weak, however (Matthews, 2004). Overall, “results relating personality to noradrenaline remain somewhat unsatisfying” (Hennig, 2004, p. 402). If N is *not* a marker of stress reactivity, antisocial high sensation seekers may well score high on N. There is also a possibility that antisocial sensation seekers make up a subgroup of high sensation seekers with high basal levels of noradrenaline (high N), although noradrenergic reactivity (depends on sensitivity of receptor cells; Zuckerman, 2007) is low.

In sum, psychological, social, and biological factors have been shown to predict variation in criminal behavior. Higher scores on sensation seeking as well as on the personality trait of Neuroticism have been found among antisocial individuals compared to the general population. N has been associated with noradrenaline levels, although the correlations are weak. *If* N is an indicator of autonomic arousal, the detection of high N among inmates should suggest that stress hyperreactivity rather than hyporeactivity mediates associations between social and biological risk factors and criminal behavior. However, high N scores among inmates contradict findings of high sensation-seeking scores in the same

population. One possible explanation of the opposing findings could be that a subgroup of high sensation seekers, i.e., those scoring high on certain “antisocial” types of sensation seeking, are characterized by high N.

Main Research Goals

Paper I

The first objective of Paper I was to determine whether low birth weight and being a client of Child Protective Services (CPS) influence criminal behavior, as measured by criminal charges. Based on the premise of the diathesis-stress model, we assumed that the influence of reduced neuropsychological functioning, as indicated by LBW, may be amplified by stressful childhood experiences. Therefore, the second goal of the study was to examine whether low birth weight interacts with placement in out-of-home care to further increase the risk of criminal behavior. Moreover, the associations between the main reasons for CPS intervention and criminal behavior were investigated to control for the possibility that different charge rates for low birth weight and normal birth weight individuals actually reflect environmental differences. Whether placement in an institution rather than foster care predicts a higher charge rate was also examined.

Paper II

The first aim of Paper II was to investigate personality, social, and genetic factors that may predict prosocial versus antisocial sensation seeking. Although the Val/Val genotype of the Val158Met functional polymorphism of the COMT gene has been associated with high sensation seeking, there is little information regarding whether factors related to personality and the environment affect decisions to engage in prosocial, as opposed to antisocial, sensation-seeking behaviors among homozygous Val carriers. The study investigated the associations between the Val158Met COMT polymorphism, relationships with caregivers, the personality trait of Neuroticism, and sensation seeking. The second goal of the study was to investigate the possibility that stress hyperreactivity may mediate relationships between social and genetic factors and sensation seeking; thus, the study examined whether the personality trait of Neuroticism mediates the associations between relationships with caregivers and the Val158Met COMT polymorphism and sensation seeking. Furthermore, to shed further light on the importance of the relationship with caregivers for sensation seeking, differences

between groups in self-reported relationships with caregivers among Val/Val individuals were investigated.

Paper III

Because criminal behavior has been found to be influenced by a combination of personality, early adversity, and genetic factors, the goal of Paper III was to provide a biopsychosocial perspective of the development of criminal behavior. The main effects of polymorphisms in two genes of the serotonergic system, the monoamine oxidase A (MAOA) and serotonin transporter (SLC6A4) genes, having witnessed domestic violence, and the personality factor of Neuroticism on incarceration were investigated.

Materials and Methods

Two distinct samples were considered in the papers of this thesis. One sample (Paper I) consisted of CPS clients for the period 1997-2005 and a matched control group of non-CPS clients, whereas the other sample (Papers II and III) was made up of police officers, inmates, and controls.

Participants and procedure, Paper I

Participants were recruited from a longitudinal registered data study including all Norwegian CPS clients from 1990 to 2005 (the Child Welfare in Norway 1990-2005 Study; Clausen, 2004); however, data on criminal charges and CPS measures were from the period of 1997 to 2005. The database also included a control group of non-CPS clients randomly assigned from the general population and matched by age with the CPS clients. The data were merged at the individual level based on the Norwegian Personal Identification Number and connected and delivered by Statistics Norway. The current study included only males because a significantly higher proportion of males than females receive criminal charges. The age of criminal responsibility in Norway is 15; thus, only individuals of at least 23 years of age in 2005 were included, meaning that they were at least 15 years of age in 1997. Finally, only individuals with a Norwegian background, i.e., with both parents being born in Norway and having Norwegian citizenship, were included due to a high proportion (77.3%) of individuals with non-Norwegian background not having a registered birth weight. Individuals who had been placed in foster care or an institution in the relevant period (1997-2005) were assigned to

one group (placed CPS clients) and compared with the non-placed CPS clients (not placed in foster care or an institution in the relevant period) and controls.

Measures, Paper I

Dependent variable. The outcome variable was the number of criminal charges over the period 1997-2005. One case may involve multiple charges, i.e., drugs, theft, violence, fraud, and/or sexual crime, against the same individual. The number of criminal charges was summarized and used as a continuous variable in the analyses, independent of the content of the charge. Importantly, although a person has been charged of a crime, this person has not necessarily been convicted of the crime. The charge data were obtained from The Crime Statistics of Statistics Norway.

Birth weight. Birth weight was categorized as low or normal. Normal birth weight was defined as a birth weight above 2500 g (Nelson, Morgenstern, & Bennett, 1998). The data on birth weight were obtained from The Medical Birth Registry of Norway (managed by The Norwegian Institute of Public Health).

Type of placement. Placement in an institution was compared with placement in foster care for placed CPS clients. Individuals who had been placed in both foster care and an institution were excluded from the analysis. The data on CPS measures were obtained from The Child Welfare Statistics of Statistics Norway.

Main reason for CPS intervention. All of the main reasons for CPS intervention, e.g., abuse (sexual, physical, or emotional), neglect, child's behavior, child's drug use, were included as dichotomous variables in the analysis (not main reason/main reason).

Control variables. The control variables comprised the subject's age and father's and mother's level of education, all of which have been previously tied to antisocial behavior (Patterson, DeBaryshe, & Ramsey, 1989). The data on parents' education were obtained from The Education Register of Statistics Norway.

Participants and procedure, Papers II and III

In total, the sample included 261 participants. Of these, 135 were police officers in the Norwegian Emergency Response Unit (Delta) or SWAT team, 24 were inmates, and 102 were controls (employees in two Norwegian enterprises and students at the University of Oslo). Only men were invited to participate because the MAOA gene is X-linked and the male allelic frequency will equal the phenotypic frequency. The Oslo Police District approved of the study being carried out in the Emergency Response Unit and the SWAT team (both counter-

terrorism units). Based on the location and number of inmates, several prisons were asked to partake via the appropriate regional administration of The Norwegian Correctional Services. All employees in two large enterprises, chosen due to their central location, together with students from the University of Oslo, recruited randomly from the campus area, served as the control group.

Participation entailed filling a questionnaire and submitting to the collection of a swab sample. After receiving instructions, the participants from the police and the enterprises conducted the biosampling themselves and returned the sample and the completed questionnaire in closed envelope. A researcher assisted the inmates and students individually. The researcher stayed in an adjacent room to answer any questions and received the completed questionnaires in sealed envelopes.

Measures, Papers II and III

Dependent variable, Paper II. An 18-item short version of Zuckerman's Sensation Seeking Scale V (SSS-V; Zuckerman, 1994), translated into Norwegian by Pedersen, Clausen, and Lavik (1988), was employed (SSS18). The SSS measures the general factor of sensation seeking as well as four specific factors: TAS, Dis, ES, and BS. *Thrill and Adventure Seeking* (TAS): The TAS items mirror a desire to partake in physical activities giving extraordinary impressions, such as alpine skiing, mountain climbing, and scuba diving. *Disinhibition* (Dis): This factor reflects the seeking of sensation via wild parties, drinking, and sexual variety. *Experience Seeking* (ES): The items in this subscale refer to the desire to have new experiences by engaging in music, art, and travel or by living an unusual lifestyle. *Boredom Susceptibility* (BS): The items in this factor reflect restlessness and a distaste of routine and boring people.

A principal component analysis supported the construction of three factors (TAS, DiS, and ES) in a Norwegian sample (Pedersen et al., 1988), together explaining 35.4% of the variance. BS was not identified as a separate factor. This finding is in line with Zuckerman's (1979) research in which the BS factor has been harder to identify as a separate factor. Five items made up the TAS subscale, while the Dis subscale consisted of six and the ES subscale of seven, items. In our sample, Cronbach's alphas were .69 for TAS, .38 for Dis, and .50 for ES. In Pedersen et al.'s study (1988), Cronbach's alphas were .63 for TAS, .57 for Dis, and .56 for ES. Due to low reliabilities for Dis and ES in our sample, only TAS was further considered.

Dependent variable, Paper III. A dichotomous variable, i.e., “not incarcerated” and “incarcerated”, served as the dependent variable.

Personality characteristics. We tested personality using the Big Five Inventory (BFI; John, Naumann, & Soto, 2008) translated into Norwegian by Engvik and Føllesdal (2005). The BFI is based on the Big Five personality characteristics and consists of 44 items, which measure each of the five personality dimensions. Test-retest reliability is between .80 and .90 (Engvik & Føllesdal, 2005). The BFI also has good concurrent validity with other inventories measuring the FFM, such as the NEO-FFI (Costa & McCrae, 1992). In our sample, Cronbach’s alphas were .87 for Neuroticism, .79 for Extraversion, .72 for Agreeableness, .75 for Conscientiousness, and .75 for Openness to Experience.

Relationship with caregivers. The respondents were asked to “mark how good/bad a relationship you had with your parents during your childhood (or the parent/other caregivers with whom you grew up) (0-18 years)” and responded on a 5-point scale (1 = very bad to 5 = very good).

Witnessing domestic violence. The respondents were asked to mark “no”, “yes, once”, “yes, several times”, or “do not know” to indicate whether they noticed that their caregivers “ever had visible marks as a result of violence he/she was exposed to at home without he/she needing medical treatment” or “was ever injured as a result of violence he/she was exposed to at home such that he/she needed medical treatment” while growing up (0-18 years). Respondents who marked that they had had one of the relevant experiences at least once were assigned to one group and compared with individuals without such experiences.

Biosample collection. DNA for genotyping analysis is present in all nucleated cells in the body. In an effort to reduce demands on the laboratory facility caused by using whole blood samples, more easily accessible mouth epithelial cells were selected for DNA sampling. Buccal mucosa cells were collected from all participants by extensively scraping the inside of the mouth with a cotton swab (3520CA 4N6, COPAN, Brescia, Italy). Samples were placed in 2-ml marked vials before storage at 4 °C.

DNA isolation. DNA has been shown to be an extremely stable molecule, but obtaining high quality, intact genomic DNA is important when performing molecular biology experiments. In this study, DNA was isolated by robot technology. The isolation procedure consisted of cell lysis, clearance of proteins, cell debris, and contaminants, before recovery of pure DNA through use of magnetic bead technology. Swabs were rehydrated in 500 µl H₂O and rotated for 10 min at room temperature before centrifugation at 5000 g for 30 s. Swabs were then pressed towards the vial wall to collect the attached liquid and then removed before

a quick centrifugation of the vial at 5000 g. Genomic DNA was isolated from 200 μ l liquid using the high-throughput MagNA Pure LC robot (Roche, Mannheim, Germany) according to the manufacturer's instructions using a MagNA Pure LC High Performance Isolation kit (cat. no. 03003990001, Roche). DNA was eluted in 50 μ l H₂O, and the average DNA yield was in the range of 5-60 ng/ μ l (Nanodrop, Thermo Fischer Scientific, Wilmington, DE, USA).

Genotyping. Detecting DNA variations and performing genotyping can be carried out by the Polymerase Chain Reaction (PCR), which is one of the most powerful and sensitive gene analysis techniques available. The PCR is an exponential amplification technique consisting of repetitive enzymatic and temperature-dependent reactions that produce significant numbers of identical copies of a specific DNA sequence of interest. A PCR analysis includes up to 45 cycles of three distinct steps: An initial denaturation step at 95 °C, a hybridization step at 50-60 °C that facilitates binding between specific DNA and complementary PCR primers, and a polymerization step at 72 °C resulting in the synthesis of a specific DNA copy through use of a DNA Polymerase enzyme. The PCR-product, which is a copy of the target DNA-sequence, is doubled at each PCR cycle, which is why the technique is termed a chain reaction. Depending on which scientific questions or hypotheses one may have in mind, PCR can be employed for qualitative or quantitative purposes. All genotyping analyses in this study were examined qualitatively using PCR.

Conventional PCR is the more "old-fashioned" PCR variant, requiring end point analysis of the PCR-product, whereas real-time PCR enables the monitoring of accumulated PCR-product after each cycle as a function of product increase through fluorescence labeling of primers, probes or the PCR-product itself. In this study, genotyping of COMT was performed with a real-time fluorescence PCR, whereas 5-HTTLPR and MAOA were carried out with conventional end-point PCR with the use of gel electrophoresis and Restriction Fragment Length Polymorphism (RFLP) or Fragment analysis, respectively.

Paper II. The functional DNA variation in the catechol-O-methyltransferase (COMT) gene (Val158Met, rs4680) was genotyped by allelic discrimination using a specifically designed TaqMan SNP genotyping assay (Applied Biosystems, Life Technologies, Carlsbad, CA, USA, cat. no. 4362691) with a Viia7 real-time PCR system (Applied Biosystems) as recommended by the manufacturer. The allelic discrimination experiment consisted of three steps: A pre-PCR read at 60 °C for 30 s to collect baseline fluorescence data, an amplification run (quantitative real-time PCR), and a post-PCR read at 60 °C for 30 s to collect endpoint fluorescence data and determine the genotyping results. Real-time PCR was conducted with 12.5 μ l 2xTaqMan Universal PCR Master Mix (Applied Biosystems, cat. no. 4304437), 1.25

µl TaqMan® SNP Genotyping Assay, 5 µl genomic DNA and 6.25 µl DNase free water. The PCR reaction comprised a 10-min polymerase activation at 95 °C followed by 40 cycles of 95 °C for 15 s and 60 °C for 1 min. A non-template control and longitudinal controls with the three different genotypes (Val/Val, Val/Met, and Met/Met) were included in each run. After signal normalization and multicomponent analysis, Viia7 RUO Software v1.2 (Applied Biosystems) was used to express the results in scatterplot form.

Paper III. Serotonin transporter polymorphisms. The 5-HTTLPR polymorphism, located in the regulatory region of the serotonin transporter gene (SLC6A4), was genotyped essentially as described elsewhere (Gelernter et al., 1997; Stein, Seedat, & Gelernter, 2006). A real-time fluorescence LightCycler instrument (Roche) was used to amplify genomic DNA by polymerase chain reaction (PCR) in a final volume of 20 µl using a LightCycler FastStart DNA SYBR Green Kit (Roche cat. no. 12239264001) with specific primers (0.5 µM; Gelernter et al., 1997) generating a long (L; 419 base pair [bp]) or short (S; 375 bp) PCR product for biallelic genotyping. Differences in the product length depend on the variable number of a 22-bp tandem repeat (VNTR) sequence in the promoter region. Cycle conditions were initiated by 10 min denaturation (95 °C) followed by 45 cycles at 95 °C (10 s), 66 °C (10 s), and 72 °C (10 s). For the detection of an additional A > G SNP (rs25531) in the L allele, the PCR products were digested with 1 U MspI restriction enzyme (New England Biolabs, Beverly, MA) for 2 h at 37 °C and separated by agarose gel electrophoresis, as the A > G substitution creates an additional MspI site. The presence of the L_A allele has been shown to have a higher transcription of the SCL6A4 gene than the L_G allele, providing subclassification into three alleles: S, L_A, and L_G. Classification of 5-HTTLPR genotypes can therefore be performed in several ways. The triallelic subclassification can be reclassified into a functional biallelic model based on the transcriptional activity. L_G/S, L_G/L_G, and S/S genotypes are classified as S/S (low-leveled RNA transcription); L_A/S and L_A/L_G genotypes are classified as L/S (intermediate-leveled); and L_A/L_A genotype is classified as L/L (high-leveled; Neumeister et al., 2006). The presented 5-HTTLPR results in this study are based on the well-established classification composed of only two alleles, generating S/S, S/L, and L/L genotypes, without subdividing into L_A and L_G. Furthermore, the three groups were reclassified into two distinct groups: Homozygous L/L and carriers of at least one S allele (S/L and S/S). This model is favorable in smaller studies.

Monoamine oxidase A (MAOA) polymorphism. The VNTR polymorphism in the promoter region of the MAOA gene was PCR amplified on a real-time fluorescence UNO-

cycler instrument (VWR, Radnor, PA, USA) with specific primers (0.5 μ M), as previously described by Ducci et al. (2006). The 20- μ l PCR reaction, containing genomic DNA, 1 X PCR mix (Qiagen, Hilden, Germany), 2.0 mM MgCl₂, 200 μ M dNTPs, 1 X Q-solution (Qiagen), and 2.5 U DNA polymerase, was amplified by an initial denaturation at 95 °C (15 min) followed by 35 cycles each containing a denaturation step at 94 °C (30 s), an annealing step at 60 °C (30 s), and an extension step at 72 °C (30 s). Finally, the reaction was concluded with a 10-min extension step at 72 °C. PCR products were separated on a 3% agarose gel with Gelstar (Lonza, Basel, Switzerland). Genotyping was based on the number of repeat alleles detected, into 2, 3, 3.5, 4, and 5 repeats, as the study group was composed of men only.

Control variables. The control variables were the subject's age and level of education.

Ethical considerations

Both studies (i.e., the study reported in Paper I and the study reported in Papers II and III) were conducted in accordance with the 1964 Declaration of Helsinki and approved by the Regional Committee for Medicine and Health Research (REK sør-øst) and the Norwegian Social Sciences Data Services (NSD). The second study was also approved by the Norwegian Directorate of Health (Helsedirektoratet). All participants in the second study received written information in the letter of invitation and signed a consent form before participation. All participants in the second study were compensated with a gift certificate of NOK 200 (US\$ 34) for lost work. The option of withdrawing from the study at any point in time was clearly stated in the letter of invitation, and the participants were reminded of this opportunity when they received their participant number in a note to ensure anonymity. The letter of invitation provided the researcher's telephone number and e-mail address and encouraged the participants to contact the researcher with questions or a wish to withdraw.

A study investigating risk factors for antisocial behavior requires careful consideration of ethical aspects. In particular, an investigation of genetic factors that may be associated with increased risk of crime is ethically challenging in the context of the early understandings that individuals who commit crimes are born criminals and that characteristics of individuals that guarantee future criminal behavior can be identified. Efforts to identify predictors of criminal behavior must therefore be accompanied by a thorough understanding that criminal behavior can only be studied on a group level and, therefore, that individual behavior cannot be predicted from the results. The letter of invitation (the second study) communicated that the findings were interesting only at the group level and that individual results would not be

discernible in reports from the study. The same information was given orally to the inmates. As an attempt to safeguard against unanswered questions, the researchers initiated a conversation with each inmate prior to the data collection, asking whether they were aware of the purpose of the study and whether they had any questions.

Another ethical concern is the lack of usefulness of the study for the participants. The purpose of research on risk factors for antisocial behavior is often to contribute to the knowledge base, which is necessary to design effective prevention and intervention programs. However, for the foundation to reach sufficient solidity, more research is needed into the complex net of psychological, social, and biological risk factors for antisocial behavior. The letter of invitation stated that the results of the study would not have any direct impact on the participants but was intended to be used in future prevention and intervention.

Statistical analyses

Paper I. All analyses were performed using SPSS software, version 19.0. A negative binomial regression analysis (Gardner, Mulvey, & Shaw, 1995) was conducted because the dependent variable was a count variable and the variance of the dependent variable was higher than the mean (suggesting a negative binomial rather than a Poisson regression). We examined the relationships between LBW and group affiliation, i.e., to control, non-placed CPS, and placed CPS groups, to the number of criminal charges. We also employed a negative binomial regression analysis to examine whether the influence of LBW on criminal charges interacts with group affiliation. Furthermore, we investigated the influences of LBW, placement in an institution versus foster care, and the main reason for CPS intervention among placed CPS clients. All analyses controlled for the age of the subject and the father's and mother's education. A significance level of $p < .01$ was used to determine statistically significant results.

Paper II. All analyses were conducted using SPSS software, version 19.0. Analysis of variance (ANOVA) was used to examine group differences in mean TAS scores. Hierarchical multiple regression analysis (Cohen, Cohen, West, & Aiken, 2003) was applied to investigate the associations between the Val158Met genotype, relationships with caregivers, N-reversed (i.e., N scores reversed such that scores indicated Emotional Stability), and TAS scores and to control for the effects of age and level of education, which have previously been found to predict sensation seeking (Roth, Schumacher, & Braehler, 2005; Steinberg et al., 2008; Zuckerman, 1994). In Model 1, the Val158Met genotype, the relationship with caregivers, and the control variables were entered. In Model 2, N-reversed

was added to the Model 1 equation. The chi-squared statistic was used to examine (1) whether the distribution of Val/Val homozygous individuals who reported very good relationships with caregivers differed between police officers, controls, and inmates and (2) whether the distribution of Val/Val homozygous individuals who reported very bad relationships with caregivers differed between police officers, controls, and inmates. A *p* value of .05 was used to determine statistically significant results. We employed Cohen's (1988) suggestion, in which eta-squared (η^2) values of .01 signify a small effect, .06 a medium effect, and .14 a large effect.

Paper III. All analyses were performed using SPSS software, version 19.0. Logistic regression analysis (Cohen et al., 2003) was applied to investigate the associations between MAOA-L, the short allele in the SLC6A4 gene, witnessing domestic violence, N-reversed, and incarceration and to control for the effects of age and level of education. A *p* value of less than .05 was considered statistically significant. The VNTR frequencies in the MAOA and SLC6A4 genes were tested for deviation from Hardy-Weinberg (H-W) equilibrium using Michael H. Court's (2005-2008) online calculator (<http://www.tufts.edu/~mccourt01/Documents/Court%20lab%20-%20HW%20calculator.xls>). The multiple MAOA repeat alleles were grouped into length marker alleles according to Sabol et al. (1998), designated MAOA-H (3.5 and 4 repeats) and MAOA-L (2, 3, and 5 repeats).

Results

Paper I

Birth weight and group affiliation. LBW individuals had a lower charge rate than normal-birth-weight individuals, incidence rate ratio (IRR) = 0.91, 99% CI [0.82, 1.00]. Thus, LBW was associated with a 9% decrease in charge rate compared with normal birth weight. The charge rate of the non-placed CPS clients was 8.46 times greater than that of the controls, and the charge rate of the placed CPS clients was 15.14 times greater than that of the controls. The charge rate was lower for individuals whose parents had an education higher than junior high school. For each additional year of the subject's life, the charge rate increased by 2%.

Interaction between birth weight and group affiliation. Whether LBW interacts with group affiliation was investigated. The results showed an interaction between LBW and placement in out-of-home care. Due to that interaction, the effect of LBW on criminal charges was investigated for controls, non-placed CPS clients, and placed CPS clients. Controlling for

the effects of age and parents' education, the results showed a non-significant relationship between LBW and criminal charges for controls and non-placed CPS clients and a significant association for placed CPS clients, $B = -0.66$, $p < .001$, IRR = 0.52, 99% CI [0.38, 0.70].

Birth weight, placement type, and main reasons for CPS intervention. The effects of LBW and placement type, i.e., in an institution versus foster care, on charge rate were investigated in an analysis including placed CPS clients only. Placement in an institution was associated with an increased charge rate, $B = 1.26$, $p < .001$, IRR = 3.51, 99% CI [2.93, 4.20]. When the main reason for CPS intervention was incorporated into the analysis, the association between LBW and charge rate became non-significant. The child's behavior and drug use were related to an increased charge rate. In contrast, neglect, parents' mental health, parents' lack of caring, parental death, and child disablement were related to a decreased charge rate. The inclusion of the main reason for CPS intervention reduced the effect of institutional placement. However, the increased risk associated with placement in an institution was not fully accounted for by the main reason for CPS intervention, e.g., behavior problems.

Paper II

The allelic distributions of the COMT Val158Met sequence were not significantly different from the distributions expected under Hardy-Weinberg equilibrium ($\chi^2 = 0.13$, $p > .05$). A one-way analysis of variance (ANOVA) with group (police officers versus controls versus inmates) as the factor was employed to test our hypothesis that police officers and inmates would be high sensation seekers. A significant group difference appeared, $F(2, 258) = 52.24$, $p = .000$, $\eta^2 = 0.29$. Consistent with our prediction, a Tukey's post-hoc analysis showed that police officers ($M = 4.41$, $SD = 0.81$) scored significantly higher in TAS ($p = .000$) than controls ($M = 3.16$, $SD = 1.50$) and inmates ($p = .000$), who scored the lowest ($M = 2.21$, $SD = 1.64$). Controls scored significantly higher than inmates ($p = .002$).

Predicting TAS scores. Using linear regression analysis, we investigated the effects of the Val158Met polymorphism and reported relationships with caregivers on TAS scores while controlling for the influences of age and level of education. The Val158Met polymorphism was a significant predictor of TAS score. Relationship with caregivers was positively predictive and age was negatively predictive of TAS score; i.e., older participants had lower scores. Level of education did not predict TAS score.

To test our assumption that high TAS scores are associated with low Neuroticism, N-reversed was included in the analysis. As expected, N-reversed was positively related to TAS score (i.e., increased Emotional Stability was correlated with higher TAS scores). Age

continued to be negatively related to TAS score, whereas level of education was not significant. With the inclusion of N, the Val158Met polymorphism and relationship with caregivers became non-significant, suggesting a mediating role of N in the associations between the Val158Met polymorphism and relationship with caregivers and TAS score. Agreeableness was a significant predictor of TAS score, $B = -0.46$, $SE = 0.13$, $t(249) = -3.61$, $p < .001$, $\Delta R^2 = .04$. However, due to the lack of predictions for this personality factor, its influence on sensation-seeking tendencies was not further examined.

To further investigate the possibility that N mediated the connection between relationship with caregivers and TAS score, we examined the association between relationship with caregivers and N-reversed. Relationship with caregivers significantly predicted N-reversed, $B = 0.53$, $SE = 0.07$, $F(1, 259) = 62.03$, $p < .001$, $R^2 = .19$.

Neuroticism scores across genotypes. To investigate whether N acts as a mediator in the association between the Val158Met polymorphism and TAS, N-reversed was entered as a dependent measure into an ANOVA with genotypes (Val/Val versus Val/Met versus Met/Met) as the between-group factor. The Val158Met polymorphism was significantly related to differences in N, $F(2, 253) = 5.77$, $p = .004$, $\eta^2 = .04$. A Tukey's post-hoc analysis showed significant group differences in N scores; the Met/Met genotype had significantly higher scores ($M = 5.68$, $SD = 0.84$) than the Val/Met ($M = 5.13$, $SD = 1.02$) genotype ($p = .003$) and the Val/Val ($M = 5.22$, $SD = 1.09$) genotype ($p = .027$).

Relationships with caregivers among homozygous Val carriers. We examined Val/Val officers' ($n = 39$) reports of their relationships with caregivers compared with Val/Val controls ($n = 31$) and inmates ($n = 9$). More Val/Val officers (76.9%) reported a very good relationship (the highest possible score) with their caregivers compared with Val/Val controls (38.7%) and inmates (33.3%; $\chi^2 = 12.60$, $p < .01$). Anecdotally, two out of nine Val/Val inmates reported a very poor relationship (the lowest possible score) with their caregivers, whereas no participants in the control or police groups did so.

Paper III

The distribution of the MAOA and SLC6A4 repeat variants in this study group correlated well with the carrier frequencies reported by Sabol et al. (1998) and Lesch et al. (1996), respectively. No significant differences from Hardy-Weinberg equilibrium were found in either group or in the overall sample.

The 5-HTTLPR genotyping of the study was classified into both a biallelic and a triallelic functional model, whereas only the results from the biallelic classification are

presented. However, the genotype frequencies from the two models corresponded. MAOA-L and the witnessing of domestic violence were associated with an increased risk of incarceration. N-reversed and education were negatively related to incarceration, and the remaining variables were not significant. Conscientiousness was a significant predictor of incarceration, $B = 1.06$, $p < .05$, $OR = 2.89$, 95% CI [1.23, 6.83].

Summary of Papers

Paper I: Effects of Birth weight and Placement in Out-of-Home Care on Criminal Behavior

Importance: There is accumulating evidence that biological factors interact with childhood adversity to increase the risk of criminal behavior. *Objective:* To determine whether the risk of criminal behavior associated with low birth weight is higher among clients of Child Protective Services and whether this risk varies depending on experiences with placement in out-of-home care. *Design:* The Child Welfare in Norway 1990-2005 Study was based on longitudinal registered data. *Participants:* A total of 12,695 male Norwegian clients of Child Protective Services and 13,425 matched controls. *Main Outcome Measure:* The outcome variable was number of criminal charges from the Crime Statistics of Statistics Norway. *Results:* The results showed an increased charge rate for clients of Child Protective Services compared with controls (incidence rate ratio = 8.46, 99% CI [8.06, 8.88] for clients who *had not* been placed in out-of-home care and 15.14, 99% CI [13.85, 16.56] for clients who *had* been placed in out-of-home care). Compared with normal birth weight, low birth weight was associated with a *decreased* charge rate for clients of Child Protective Services in out-of-home care (incidence rate ratio = 0.52, 99% CI [0.38, 0.70]). However, the main reasons for intervention by Child Protective Services made the association between low birth weight and criminal charges for clients placed in out-of-home care non-significant. Placement in an institution resulted in an increased charge rate compared with placement in foster care (incidence rate ratio = 2.06, 99% CI [1.68, 2.52]). *Conclusion:* The results suggest that characteristics of low-birth-weight individuals and their environments mediate the association between low birth weight and criminal behavior for clients of Child Protective Services who are placed in out-of-home care.

Paper II: The Importance of COMT, Relationships with Caregivers, and Emotional Stability for Prosocial Sensation Seeking and Antisocial Behavior

Importance. The catechol-O-methyltransferase (COMT) gene, which is important in the regulation of catecholamine neurotransmitter levels, contains a common, functional DNA variant: The Val158Met polymorphism. Higher frequencies of the Val/Val genotype have been found among high sensation seekers. Little is known about whether factors related to personality and the environment influence Val/Val individuals' decisions to engage in prosocial, as opposed to antisocial, sensation-seeking behaviors. *Objective.* This study explored environmental and personality differences between two groups of alleged high sensation seekers and non-sensation seekers. *Design.* DNA and questionnaire data were collected from police officers in two counter-terrorism units ($n = 135$), inmates ($n = 24$), and a control group of non-police, non-inmate participants ($n = 102$). The associations between the Val158Met polymorphism, relationships with caregivers and sensation seeking were investigated; the role of the personality trait of Neuroticism in sensation seeking was also investigated. Finally, differences between groups in self-reported relationships with caregivers during childhood were examined. *Results.* More Val/Val officers than Val/Val inmates and controls reported having had very good relationships with their caregivers. Neuroticism mediated the associations between relationships with caregivers and the Val158Met polymorphism and sensation seeking. *Conclusion.* This study found preliminary evidence that the Met/Met genotype in the Val158Met polymorphism and very good relationships with caregivers may help protect against engagement in antisocial behaviors and lay the foundation for prosocial sensation-seeking behaviors through the development of Emotional Stability (i.e., low Neuroticism).

Paper III: Predicting Incarceration: The Influences of Witnessing Domestic Violence, Variation in the MAOA and SLC6A4 genes, and Emotional Stability

Importance. Traumatic childhood experiences as well as variation in certain genes of the serotonergic system have been identified as predictors of criminal behavior. Furthermore, personality factors may differ between inmates and non-inmates. Biopsychosocial risk factors for criminal behavior form the basis of effective prevention policies. *Objective.* This pilot study examined the influences of polymorphisms in monoamine oxidase A (MAOA) and serotonin transporter (SLC6A4) genes, on criminal behavior. The influences of witnessing domestic violence and the personality characteristic of Neuroticism were also examined. *Results.* Preliminary results from 24 inmates and 237 non-inmates showed that having

witnessed domestic violence, odds ratio (OR) = 2.12, 95% CI [1.17, 58.19], as well as low MAOA activity, OR = 3.76, 95% CI [1.01, 13.97], and having low Emotional Stability, OR = 0.49, 95% CI [0.26, 0.82] predicted a higher risk of incarceration. *Conclusion.* The findings suggest that environmental, genetic, and personality factors influence the development of criminal behavior.

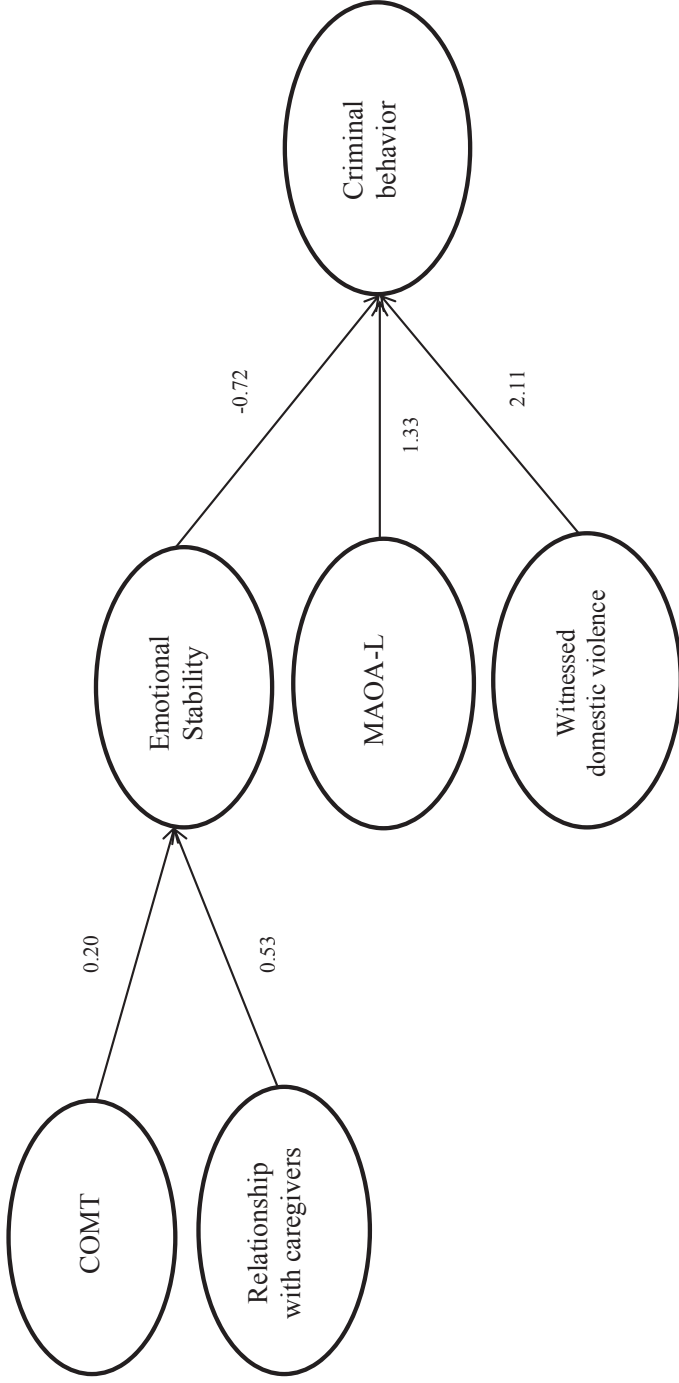


Figure 1. An overall model of the findings reported in Papers II and III. The Met/Met genotype of the COMT Val158Met polymorphism predicted increased Emotional Stability. Quality of relationship with caregivers was positively correlated with Emotional Stability. Emotional Stability was negatively associated with criminal behavior, whereas MAOA-L and having witnessed domestic violence were positively correlated with criminal behavior.

Discussion

Main findings

The *first* objective of this dissertation was to identify psychological, social, and biological risk factors for antisocial behavior. Paper I revealed a decreased risk associated with low birth weight and an increased risk for clients of Child Protective Services (CPS) compared with controls. Paper I further showed an interaction between low birth weight (LBW) and placement in out-of-home care; LBW predicted a decreased charge rate only for CPS clients who had been placed away from biological parents in foster care or an institution. Further analyses showed that certain characteristics of LBW individuals and their environments, as indexed by the main reason for CPS intervention, completely mediated the relationship between LBW and decreased charge rate. Paper II identified the COMT Val158Met polymorphism and relationship with caregivers as predictors of the Thrill and Adventure Seeking (TAS) score, which was shown to differentiate prosocial sensation seekers (high TAS scores) from inmates (low TAS scores). However, the personality trait of Neuroticism (N) completely mediated the associations between COMT and relationship with caregivers and TAS. N-reversed (high scores indicating Emotional Stability) was positively correlated with TAS. Paper III showed a negative relationship between N-reversed and incarceration. Furthermore, the low-activity MAOA variant (MAOA-L) and having witnessed domestic violence predicted increased risk of incarceration.

The *second* goal of this thesis was to investigate whether stress hyperreactivity, as indexed by low scores on N-reversed, may mediate relationships between social as well as biological risk factors and criminal behavior. As previously described, Paper II showed a mediating role of N in the associations between relationship with caregivers and the COMT Val158Met polymorphism and TAS.

The *third* objective of this thesis was to investigate the apparently conflicting findings that antisocial individuals score high on Neuroticism, indicating stress *hyper*reactivity, as well as sensation seeking, indicating stress *hypore*activity. Paper II examined the possibility that high versus low scores on Neuroticism predict different types of sensation seeking. Inmates scored low on N-reversed, indicating low Emotional Stability, as well as on sensation seeking. The remainder of the discussion will further elaborate on the findings as well as discuss certain shortcomings of the study and the implications for future research.

Social risk factors

Paper I describes findings of increased charge rate for CPS clients compared with controls. Being a CPS client placed in out-of-home care predicted the highest charge rate. CPS involvement is likely to be preceded by stressful events or chronically stressful conditions, with particularly severe experiences underlying the decisions to place children in out-of-home care. As previously described, chronic stress on the brain can result in impaired self-regulation and increased aggression. Importantly, adverse childhood experiences appear to produce different stress response patterns (differentiation effects, see Lupien et al., 2009) depending on the nature of the experiences; although severe abuse seems to be related to glucocorticoid hyosecretion, low parental care has been associated with hypersecretion. Thus, to the extent that the increased risk of criminal behavior for CPS clients is due to an impact of chronic stress on the brain, the elevated risk may be a result of stress hypo- or hyperreactivity, depending on the character of the stressful events. In addition to the type and timing of adverse or maltreating experiences, individual, including genetic, differences most likely also influence the type of stress response (Gunnar & Quevedo, 2007).

The higher risk of criminal behavior for CPS clients could also be due to a social learning process. Social learning theory (Bandura, 1977; Widom, 1989) suggests that individuals learn from observing other people's behavior and its consequences for them. Thus, watching parents' antisocial behavior and the potential gains of such behavior may increase the probability that children resort to antisocial behavior. Attachment theory (Bowlby, 1982) may provide yet another framework for explaining the higher risk of criminal behavior for CPS clients. Attachment theory emphasizes the significance of developing a positive attachment with a caregiver. Responsive parents, who react rapidly and amply to the distress of their children, lay the ground for a secure attachment and model the use of empathy (van IJzendoorn, 1997). Several studies have detected a protective effect of a secure attachment to parents in relation to the development of antisocial behavior (for a review, see van IJzendoorn, 1997).

For CPS clients placed in out-of-home care, the results presented in Paper I showed an elevated charge rate associated with placement in an institution compared with placement in foster care. This finding is in accord with previous research (Cusick et al., 2011; McDonald, Allen, Westerfelt, & Piliavin, 1996). One proposed explanation for the higher risk of criminal behavior for institution-placed children is that children with serious problems are less likely to be placed in foster care (McDonald et al., 1996). Paper I demonstrates that although the inclusion of the main reasons for CPS intervention led to a reduction in the risk associated

with institutional placement, the heightened risk was not fully accounted for by differences between children as described by the main reason for CPS intervention, e.g., behavior problems. Certainly, pre-placement differences may exist between children placed in an institution versus foster care that were not captured by the main reason for CPS intervention. A further conceivable account of the higher risk for children placed in institution may be that the opportunity to attach to foster parents protects clients from involvement in criminal behavior.

The discovery in Paper I that neglect was associated with lower charge rate contrasts with previous findings of a positive association between neglect and criminal behavior (Maxfield & Widom, 1996; Widom, 2010). Importantly, our finding, unlike previous studies, was based on a sample consisting solely of individuals placed in out-of-home care. A possible explanation for the discrepancy could therefore be that individuals placed in out-of-home care due to neglect have had particularly grave experiences. Thus, future studies may benefit from examining the possibility of differential effects based on the severity of the neglect.

Paper II revealed an effect of self-reported relationship with caregivers on TAS. The association was mediated by Emotional Stability such that a good relationship with caregivers was positively correlated with Emotional Stability, which again positively predicted TAS. Although we do not know what lies beneath the judgments of relationship quality, it is interesting that parental love has shown to be negatively related to N (McCrae & Costa, 1994). In Paper III, the witnessing of domestic violence predicted increased risk of incarceration. The association may be due to a social learning process (Bandura, 1977; Widom, 1989) in which children understand that it is proper to behave violently, particularly to end conflict (Nofziger & Kurtz, 2005).

Biological risk factors

Although reduced neuropsychological functioning is only one of many risk factors for antisocial behavior, it has proven to be among the most consistent ones (Beaver, Vaughn, Delisi, & Higgins, 2010). In fact, “the link between neuropsychological impairment and antisocial outcomes is one of the most robust effects in the study of antisocial behavior” (Moffitt, 1993, p. 680). Given that LBW is a reliable index of reduced neuropsychological functioning, our discovery in Paper I that LBW predicted a decreased charge rate is in contrast to previous research relating reduced neuropsychological functioning to an increased risk of antisocial behavior (Morgan & Lilienfeld, 2000). The lower charge rate for LBW individuals found in Paper I thus merits explanation. First, this finding is in accord with

several studies failing to detect increased risk of antisocial behavior among individuals with very low birth weight or low gestational age (Gardner et al., 2004; Hack, 2006; Hack et al., 2002; Hack et al., 2004; Moster et al., 2008; Pitzer et al., 2010). Second, LBW predicted criminal charges only among CPS clients placed in out-of-home care, suggesting that LBW may interact with high social risk to predict decreased charge rate. Third, the relationship between LBW and criminal charges was mediated by the main reason for CPS intervention. Although a child's behavior and drug use were related to increased charge rate, neglect, parents' mental health, parents' lack of caring, parents' death, and child disablement predicted decreased charge rates. Individuals with physical or mental disabilities may have more difficulties engaging in criminal behavior. Although information regarding why the relevant environmental factors predicted lower charge rates cannot be derived from the current study, a common denominator seems to be reduced or absent parent involvement or reduced quality of interaction with parents, as may be the case in instances of mental health problems (Herrera, Reissland, & Shepherd, 2004). Why such experiences are associated with less engagement in criminal behavior is an issue to be explored in future research.

Paper III reports increased risk of incarceration for individuals with the low-activity variant of the MAOA gene (MAOA-L). Although this finding is consistent with existing research, most studies have found that MAOA-L predicts increased risk of antisocial behavior only in concert with environmental adversity. The current study thus joins the ranks of the few studies reporting a main effect of MAOA-L in the development of antisocial behavior (e.g., Fergusson et al., 2011). Variation in the serotonin transporter (SLC6A4) gene did not predict incarceration. The results reported in Paper II showed that Emotional Stability completely mediated the relationship between the COMT Val158Met polymorphism and the TAS dimension of the Sensation Seeking Scale. Although previous research has demonstrated an association between the COMT Val158Met polymorphism and antisocial behavior, a mediating role of Emotional Stability has not previously been reported. Although the TAS score is not a direct measure of liability for antisocial behavior, the possibility that low TAS scores may characterize antisocial individuals will be further discussed in a later subsection.

Emotional Stability

Genes may indirectly impact antisocial behavior through influences on personality traits (Palermo, 2010). The results reported in Paper II showed that the Met/Met genotype of the COMT Val158Met polymorphism was associated with higher Emotional Stability than were the Val/Met or Val/Val genotypes. This finding suggests that Emotional Stability may

be affected by dopaminergic activity. Individuals scoring high on N have been found to be more psychologically and physiologically reactive to emotional events (Larsen & Ketelaar, 1991; Norris, Larsen, & Cacioppo, 2007). Given that high N indicates reduced ability to cope with stress, lower sensation-seeking scores for individuals with low Emotional Stability would be expected, as were found in the current study.

The results described in Paper II further indicated an influence of the self-reported relationship with caregivers during childhood on Emotional Stability. Parents may shape the development of personality through the provision of psychological resources (Pomerantz & Thompson, 2008). In providing, or not providing, affective, behavioral, and cognitive resources, biologically founded predispositions can be strengthened or weakened. The greater the needs of children, the more important parents are (Pomerantz & Thompson, 2008). Pomerantz and Thompson (2008) call for research that clarifies the degree to which personality in adulthood is formed by parental influences on personality during childhood. The findings described in Paper II suggest that the quality of the relationship with caregivers during childhood may influence personality in adulthood. However, myriad factors can influence individuals' perceptions of their relationships with caregivers; thus, what types of experiences underlie the positive correlation between quality of relationship with caregivers and Emotional Stability cannot be determined from our results.

Sensation seeking

The results reported in Paper II replicated those of a previous study showing lower TAS scores among criminals compared to prosocial sensation seekers (Dåderman, Meurling, & Hallman, 2001). In contrast to Dåderman et al.'s (2001) study, however, criminals scored lower than controls. The present study further replicated an earlier finding of a negative association between N and TAS (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993). Zuckerman (1978) considered TAS to be the most conventional type of sensation seeking and Dis and ES the less socially acceptable types. Because N has been negatively related to TAS and positively related to Dis (Zuckerman et al., 1993), the possibility exists that our sample of inmates might seek sensation in ways reflected in the Dis and ES subscales of the Sensation Seeking Scale, i.e., that N-reversed may correlate negatively with these subtypes. It is worth mentioning in that respect that the inmates scored lowest also on DiS and ES, although the findings were not reported in the results due to low reliability for these subscales.

As previously discussed, the literature paradoxically shows high N *as well as* high sensation-seeking scores among antisocial individuals. The findings reported in Paper II replicated previous discoveries of higher N score among inmates but did not find evidence of higher sensation-seeking scores among inmates compared to controls. A possible explanation of the inconsistency, in addition to the possibility that more reliable Dis and ES scales would yield different results, is that diverse offender groups may show dissimilar N and sensation seeking scores. “It could be expected that violent people, with multiple offenses, or with an early onset criminal career, express higher levels of impulsivity, fearlessness, and preference for physically risky activities” (Herrero & Colom, 2008, p. 203). More research is needed to investigate whether a subgroup of criminals may be low sensation seekers.

With this option in mind, the distinction researchers often make between two types of aggressive behavior is interesting. Although *instrumental* aggression is planned and results from blunted emotional sensitivity, *reactive* aggression is triggered by negative experiences and involves exaggerated emotional sensitivity (Blair, Peschardt, Budhani, Mitchell, & Pine, 2006; Crick & Dodge, 1996). Reactive aggression involves inflated levels of negative emotion, e.g., anger or anxiety, and is believed to result from a more reactive threat detection system and a reduced capability to regulate emotional responses (Blair et al., 2006). Instrumental aggression, on the other hand, is typically related to psychopathy (Berkowitz, 1993) and used to obtain a desired goal. Social hyporeactivity increases the risk of instrumental aggression, whereas social hyperreactivity increases the risk of reactive aggression. MAOA-L compared with MAOA-H individuals have been found to be more distressed in negative social situations (Eisenberger, Way, Taylor, Welch, & Lieberman, 2007). Furthermore, this elevated sensitivity to negative socioemotional experiences mediated the relationship between MAOA-L and aggression.

Based on the finding that MAOA-L individuals are at heightened risk of reactive rather than instrumental aggression, our discovery in Paper III of an association between MAOA-L and increased risk of criminal behavior may indicate that reactive aggression characterized our sample of inmates. In support of this assumption, high sensation seekers as well as men with severe psychopathic traits (likely to engage in instrumental rather than reactive aggression) display *low* noradrenaline levels (Zuckerman, 2007), which are perhaps related to low N (Matthews, 2004). Why high-sensation-seeking criminals engage in criminal rather than prosocial sensation-seeking behaviors is a question to be pursued by future research. Given the findings previously discussed, namely, that severe child abuse appears to result in stress hyporeactivity, there is a possibility that childhood experiences with grave

abuse may predict psychopathic, instrumental types of criminal behavior. Low N and high sensation-seeking scores might characterize such perpetrators. Low parental care, on the other hand, being associated with stress hyperreactivity, might increase the risk of reactive types of crime – offenders being described by high N and low sensation-seeking scores. This theory would allow for the detection of high *and* low N and sensation-seeking scores among antisocial individuals. A caveat of the assumption that N indexes stress reactivity are findings of weak correlations between N and autonomic arousal (Matthews, 2004), as discussed earlier. However, given that N is positively correlated with noradrenaline level, the finding reported in Paper III that MAOA-L (related to reactive aggression) predicts increased risk of criminal behavior might fit well with our finding of low Emotional Stability among the inmates, as described in Paper II.

A biopsychosocial model

The papers reported in this dissertation, taken together, indicate that psychological, social, and biological factors and their interrelationships are associated with criminal behavior. Unlike the model of van Goozen et al. (2008), the model depicted in Figure 1 assumes stress hyper- rather than hyporeactivity as a mediating factor in the associations between social and genetic risk factors and criminal behavior. It is worth noting that the model of van Goozen et al. (2008) predicts persistent and severe antisocial behavior. Although the inmates in our sample had committed severe crimes, we did not examine the continuity of antisocial behavior. This deviation from the model of van Goozen et al. (2008) might explain the divergence between their theory and our findings. However, non-persistent criminal behavior is typically limited to adolescence (Moffitt, 1993). None of the inmates in our sample were under 25 years of age, making this explanation unlikely unless they had already spent several years in prison. The data collection did not include information about the number of years they had served.

Methodological considerations

Limitations to the biopsychosocial model. The model presented in Figure 1 is based solely on the findings of the current study; thus, further research must be conducted before it can be postulated that stress hyperreactivity mediates the relationships between social and genetic risk factors and criminal behavior for a subgroup of criminals. Furthermore, given that stress hyperreactivity defines certain criminals, what types of criminals, e.g., criminals characterized by reactive versus instrumental aggression, are described by high versus low

stress reactivity, must be investigated. Finally, whether the personality trait of Neuroticism is a reliable index of stress reactivity should be further examined.

Measurement issues. In Paper II, a single-item measure of relationship with caregivers is used rather than a measure tapping several aspects of the relationship. Additionally, due to the retrospective quality of the measure, the reports might be biased by post-childhood experiences. Furthermore, although N can be strongly affected by caregiver behavior, N might influence perceptions of caregiver behavior. Thus, the finding reported in Paper II of a positive association between quality of relationship with caregivers and N-reversed may in fact reflect a tendency for individuals with low Emotional Stability to report having had poorer relationships with their caregivers. Such a bias would undercut the assumption made in Paper II that a poor relationship with caregivers predicts low Emotional Stability. In the same manner, whether self-reported experiences of having witnessed domestic violence, as used in the analysis in Paper III, correspond to the actual events cannot be known.

Generalizability. An issue pertaining to the generalizability of the results is the inclusion of only inmates in Papers II and III. Inmates represent a small segment of the population of antisocial individuals and may differ from non-incarcerated criminals. Moreover, in any sample of inmates there may be wrongfully convicted individuals, i.e., individuals who have not committed crime. Although Paper I captures a larger part of the antisocial population by studying criminal charges, a significant share of those committing criminal acts are never charged. Another issue in terms of generalization is the small sample size of inmates. Inmates form a heterogeneous group, e.g., in terms of crime/s committed, and a small sample size precludes analyses of subgroups. A Norwegian study (Breivik, 1991, 1993, as cited in Zuckerman, 1994) found that although inmates were not high sensation seekers, those convicted for crimes that were violent, e.g., robbery or murder, or drug-related had higher Total SSS scores than those convicted for sexual or economic crimes. Haapasalo (1990) discovered that criminals convicted for offenses related to property, e.g., theft, and driving, scored higher than a normal sample of men on the Total, ES, and Dis scales but lower on TAS.

Categorization of participants. Paper I benefits from having an exceptionally large sample size, allowing for generalization. Other strengths of the sample in Paper I are the inclusion of all CPS clients from the relevant period of time and the large sample size of the control group. However, a caveat of the results is the categorization of participants based on CPS involvement (CPS/controls) and type of CPS intervention (placed CPS/non-placed CPS).

Evidently, individual variation exists within these groups. For example, despite the controls representing the group with no social risk, a lack of CPS involvement does not guarantee a home environment free of adversity.

Inability to determine causality. Unmeasured variables could potentially have affected all associations between risk factors and criminal/sensation-seeking behaviors reported in the papers of this dissertation. Numerous environmental factors and genetic polymorphisms are likely to impact antisocial behavior. If a heritable third variable explains the relationship between an environmental risk factor and antisocial behavior, a passive or active correlation (rGE) confound has occurred. In such instances, genetic transmission, rather than the environment, causes antisocial behavior. Serious types of poor parenting, e.g., exposing the child to domestic violence, are antisocial behaviors themselves; thus, they are likely to be genetically influenced, similarly to other types of antisocial behavior (Moffitt, 2005b). Furthermore, parenting styles are known to be associated with parents' personality traits (Belsky, Crnic, & Woodworth, 1995; Spinath & O'Connor, 2003), and personality traits are affected by genes (Krueger & Johnson, 2008). Not only may parents' genotype cause bad parenting; the child's genotype may also influence parenting styles. Such a correlation is referred to as evocative rGE, a type of active rGE that refers to individuals' genotypes causing them to actively select environmental conditions (Rutter & Silberg, 2002).

Although the study presented in Paper I was a longitudinal study, data on CPS measures and criminal charges spanned only an eight-year period. Thus, the temporal relationship between CPS intervention and criminal charges cannot be discerned. Consequently, for example, criminal charges could lead to an increased chance of being placed in an institution rather than vice versa. Likewise, the causal relationships between the variables in Papers II and III remain unknown because they were measured at the same time.

Implications

Although it may be difficult to determine what approach works well for whom in terms of crime prevention, the effective use of resources hinges on a good fit between intervention and target groups. The findings presented in the papers of this thesis suggest several focuses for crime prevention programs. Paper I identifies institutionalized children as a particularly vulnerable group, in addition to children showing behavior problems and/or using drugs. Genetic variation was found to predict variation in criminal behavior, as reported in Papers II and III. However, the genotyping of children may not be realistic due to practical problems and ethical considerations. Nonetheless, genotypes may be related to

endophenotypes, which are phenotypes that may mediate the associations between genes and criminal behavior (Beaver, Nedelec, Wilde, Lippoff, & Jackson, 2011). Endophenotypes, e.g., personality traits (Beaver et al., 2011), may more easily be used as a foundation for screening to better match individuals and treatment (Bakermans-Kranenburg & van IJzendoorn, 2011). Paper II reports an association between Emotional Stability and increased TAS score, a prosocial type of sensation seeking. In Paper III, high scores on Emotional Stability were associated with a lower risk of incarceration. Consequently, crime prevention programs may well benefit from targeting factors that increase children's feelings of security and self-sufficiency. According to the findings reported in Paper II, investment into bettering parent-child relationships may result in more emotionally stable children with a lower risk of engaging in criminal behavior.

Conclusions and Future Directions

The origins of criminal behavior are not completely understood, but identifying risk factors is imperative to appropriately target resources and interventions. The findings presented in the papers of this dissertation alternate between being in line with and challenging previous findings. The papers add to the literature by demonstrating relationships between psychological, social, and biological risk factors for criminal behavior that have not previously been detected. Although Paper I reveals an interaction between social and biological risk, a key finding in Paper II is the uncovering of N as a mediator between social and biological risk factors and TAS score – a paramount trait in distinguishing antisocial individuals from prosocial sensation seekers. The discovery of lower Emotional Stability scores among inmates suggests that stress hyperreactivity may characterize a subgroup of antisocial individuals. It is hoped that this thesis will encourage further biopsychosocial research on the development of criminal behavior and its counterpart of sensation seeking. Replications would point to a pivotal role of social, as well as genetic, factors in not only the prevention of criminal behavior but also the fostering of emotionally stable children who are likely to engage in prosocial, rather than antisocial, behaviors.

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Papers I-III

