AUS DEM LEHRSTUHL
FÜR PSYCHIATRIE UND PSYCHOTHERAPIE
PROF. DR. R. RUPPRECHT
DER MEDIZINISCHEN FAKULTÄT
DER UNIVERSITÄT REGENSBURG

Neural Correlates of Moral Decision-Making in Psychopaths

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An fMRI Study

Inaugural-Dissertation
zur Erlangung des Doktorgrades der Medizin
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Abstract

The present fMRI study is the first that investigates the neural correlates of everyday moral decision-making in psychopaths. Patients suffering from psychopathy show an emotional detachment as well as an antisocial and often immoral behavior. In contrast to the neural correlates of moral reasoning in healthy individuals, the corresponding neural correlates in psychopaths are poorly understood. In the present study, twelve psychopathic subjects were presented with 56 verbal stories describing conflicts with either moral or neutral content. In the moral conflicts, subjects had to decide between a personal-desire guided immoral response and a conflicting moral standard. The neutral conflicts required a decision between two conflicting personal desires. On a post-scanning questionnaire, subjects had to indicate their feelings and certainty about each conflict. Behavioral as well as imaging data were compared to a non-psychopathic control group consisting of twelve criminal subjects.

On behavioral level, compared to non-psychopathic criminal control subjects, there was a statistical tendency to more immoral personal desire-guided decisions in psychopaths as well as a significantly better feeling when deciding immorally. In the fMRI scanning experiment, moral conflicts were compared to neutral conflicts in order to identify brain areas related to moral reasoning. In psychopaths, this contrast induced higher activity in a neural network that included the medial and superior frontal gyrus, the superior temporal gyrus and the posterior cingulate and precuneus region. Further analysis of the moral conflicts in psychopaths revealed that immoral decisions in contrast to moral decisions elicited higher activation in the medial frontal gyrus and in the cingulate gyrus. When compared to the activity in the moral > neutral contrast in non-psychopathic criminal control subjects, a lack of activation in right-sided middle temporal gyrus in psychopaths was revealed.

The results of the present study provide further information about everyday moral decision-making and its neural underpinnings in psychopaths. The study shows that processing moral conflicts induces a similar pattern of brain activation in psychopaths and in non-psychopathic criminal control subjects as it is known from healthy individuals. As the revealed brain areas are known to be strongly interconnected, the present findings lead to the conclusion that the antisocial and impaired affective behavior that is characteristic for psychopaths may be due to a deficient interconnectivity among the single brain areas in psychopaths. Deficient inputs from limbic areas such as the amygdala may lead to a deficiency in emotion processing that results in immoral behavior and emotional detachment. As a general conclusion, this study suggests a deficient emotion processing mechanism in psychopaths that is reflected by their emotional detachment on behavioral level.

1 INTRODUCTION

Since human life exists on earth, morality and moral decision-making have always been important issues in all human cultures and will never decrease in their importance. The number of examples for morality, moral questions and moral decision-making in history, presence and future is enormous and concerns every aspect of life: Religion, politics, society, family life, so to speak the whole environment that surrounds a human being.

How many unreasonable, immoral wars on our planet have killed so many (innocent) people? The two World Wars for example, the genocide in Rwanda in 1994 – can these wars be morally justified? Or can any war be a "moral" war? The same with political rulers. How many leading political personalities (not only in history) have caused poverty and disastrous conditions in their countries only because of power, greediness, irresponsibility, selfishness and callousness? But not only politicians lack sometimes moral behavior.

Each individual gets into moral conflicts – every day. For example, when I run to the bus station to catch the waiting bus home, I see an old lady who stumbled and needs help. How would I behave? Would I help the old lady to pick up her purchases? Even though I had a long working day and I would have to wait two more hours for my next bus home? And what, if the cashier gave me too much change? What would I do? Would I keep the money or would I give it back?

Every moral conflict represents a weighing of personal benefits against moral conscience. Probably our society could not survive if the majority of people would decide always in an immoral way that leads to a maximum of their personal benefits. But, in each society, individuals exist who show personality traits that dominate their moral conscience such as shallowness, lack of guilt and empathy, or a grandiose sense of self-worth. If these characteristics appear in combination with impulsivity, irresponsibility, delinquency and poor behavioral controls (among others), this individual is called a psychopath. Therefore, it was supposed that psychopaths could be impaired in moral reasoning and show pathological correlates for this behavior. For that reason, it would be interesting to know more about deficiencies in brain mechanisms and activations in psychopaths that could help to understand other neuropsychiatric questions in relation with violent and social or moral behavior, emotion processing and morals and moral decision-making as well as their deficits.

So, not only morality but also psychopathy are both subjects about which many philosophers, psychologists, psychiatrists and other scientists wondered and still wonder. A lot of research has been initiated in these fields and literature offers a wide spectrum of ideas, theories and data. Especially in healthy subjects a lot of research has been done concerning moral decision-making and its neural correlates. However, in most of these studies, abstract moral dilemmas have been used. As for psychopaths, the psychopathological correlates and mechanisms of psychopathy were subjects of interest in several studies. But, so far no study has investigated realistic and everyday moral conflicts in psychopathic individuals. .

This is what the present fMRI study has attempted to achieve. Therefore, twelve psychopathic subjects were presented with verbal stories describing realistic everyday conflicts with either moral or neutral content. Results were analysed on functional imaging and on behavioral level and compared to the results of twelve non-psychopathic criminal control subjects. With the obtained results, the present study wants to contribute to further understanding of the pathological mechanisms in psychopaths in relation to their deficiency or differences in moral decision-making, in their behavior in everyday life as well as in their neural correlates. This may help to understand psychiatric, psychological and neurological problems in the fields of antisocial behavior and emotional detachment as well as deficient emotion processing. In addition, this study could help to generalize findings of moral decision-making to everyday moral conflicts.

The following theoretical part of this thesis will be separated into two main sections. First, definition and theories of morality and moral reasoning, as well as the neural correlates of moral reasoning in healthy individuals are going to be described. The second theoretical part describes the concept of psychopathy, theories on its development and neural correlates of psychopathy. A description of the present study's aim concludes this part.

2 THEORETICAL AND EMPIRICAL BACKGROUND

2.1 Morality and Moral Reasoning

2.1.1 Definition and Theories of Morality, Moral Reasoning and Moral Emotions

How is morality defined? And what is moral? These very general but important questions have been discussed by many scientists in the past, in the philosophical as well as in the psychological field, in the legal as well as in the ethical field, and are still subjects of interest. In this chapter, the different definitions and theories of morality and moral reasoning as well as their development in human history, are going to be described. For this, philosophical views are going to be included as well as psychological and neuroscientific aspects.

A very general description of morality can be drawn from the literal meaning of the Latin word *moralitas* which is 'manner, character, proper behavior'. This means that morality subsumes customs, norms and moral values within a social group (Adolphs, 2003). So, morality is universal, but culturally variable. In general, a consensus about the valid moral norms of a social group is crucial for a possible coexistence of several individuals within a social group. To judge the adequacy of one's own or others' moral behaviors according to the socially and culturally shaped social agreements and values, the mechanism of moral reasoning, that includes moral judgment, is extremely important for the human being. By and by, the definition and understanding of morality, moral reasoning and moral emotions and their importance changed a lot.

Moral theories have a long history that begins with the Greek philosophers Plato (427-347 BC) and Aristotle (384-322 BC) who represented a virtue-theoretic psychology that demanded the virtuous person to cultivate their virtues and to avoid vices. Plato suggested the model of the divided self saying that reason rules over passions and soul. Thus, it depends on the person's reasoning how to reach a state of maximal moral behavior (Plato, 1888).

Another important moral theory is the one by Immanuel Kant (1724-1804) who focused on the maxim of an action. With his 'categorical imperative' Kant premised the ability to 'reason purely' and required that all human beings act only on the maxims of what they want to become a universal law, other maxims are morally impermissible (Casebeer, 2003).

The psychiatrist Sigmund Freud (1856-1939) defined moral development as a product of aspects of the super-ego as guilt-shame avoidance. He emphasizes the influence of emotional and non-rational processes in the development of moral judgments (Freud, 1923).

Another important contribution to the definition of moral development was developed by the Swiss psychologist Jean Piaget (1896-1980) who studied the child's developing understanding of fairness and rules. Piaget's theory of the cognitive development includes four stages, each stage describing a general cognitive structure that predominates in the child's thinking. The first stage is called the sensimotor stage and lasts from the child's birth to the age of two. This stage is characterized by an extreme egocentricity of the child, as it cannot perceive the world from others' viewpoints. The child experiences the world through its own senses and movements. In the following preoperational stage, from ages two to seven, egocentricity weakens and disappears in the subsequent concrete operational stage, from ages seven to twelve, when children start with logical reasoning. In the fourth and last stage, the formal operational stage, children older than twelve years develop abstract reasoning (Piaget, 1965).

With the cognitive revolution of the 1950s and 1960s, the American psychologist Lawrence Kohlberg (1937-1987) described a six-stage model of cognitive-developmental levels in the child's moral reasoning based on the pioneering work of Piaget. In effect, he described how the child's theories of morality change when it grows up. Kohlberg demonstrated that morality can be studied as a system of transformations of underlying cognitive constructs. His best known dilemma is the Heinz dilemma. A man called Heinz must decide whether he should break into a druggist's shop to steal a drug that may save the life of his dying wife. Kohlberg's theory of the development of morality includes three levels and six stages. Level one is the level of pre-conventional morality. It is subdivided into the first stage of obedience and punishment orientation which is characterized by a childish behavior that attempts to avoid punishment and to act with unquestioning obedience, and the second stage of self-interest orientation (individualism and exchange) characterized by the relativeness of right and wrong which implicates individual interests. The second cognitive-developmental level of Kohlberg's model is the level of conventional morality assuming that the attitude adopted by the child/teen would be shared by the entire social community. Thus, in stage three, children believe that good behavior is important and equivalent to what society requires, and implies the experience of interpersonal feelings such as empathy, trust and love. In stage four, subjects start to see society as a whole and try to maintain the social order by obeying laws and respecting authorities. In level three, morality is post-conventional and people start to take a prior-to-society perspective in stage five which emphasizes a social contract and individual rights orientation with the aim of determining how a society ought to be like. In stage six, the principles by which justice is achieved are defined. These principles of justice include the respect for the basic dignity of all people (Kohlberg, 1969; Kohlberg et al., 1983).

Thus, moral psychology was dominated for a long time by the developmental theories of Piaget and Kohlberg who stressed the influence of reasoning in the moral judgment process. But recently, a new trend emphasizing the role of intuitive and emotional processes in human decision making and sociality came up. The American psychology professor Jonathan Haidt (2001) developed the social intuitionist model which is an alternative to rationalist models and emphasizes social and cultural influences. Haidt doubts reasoning models because of four reasons. First, the dual process problem: whereas reasoning has been overemphasized in moral judgment, intuition has been under-studied. Second, reasoning is often motivated. Third, the reasoning process constructs post hoc justifications of intuitive judgments. And fourth, moral action co-varies with moral emotion more than with moral reasoning. The social intuitionist model is not an antirationalist model but an alternative model that connects intuition, reasoning and social influences. The intuitionist part of the social intuitionist model proposes moral judgments as the result of fast, automatic and often affect-laden processes (intuitions) in which an evaluative feeling of good-bad or like-dislike appears in consciousness without any conscious awareness of having gone through steps of searching, weighing evidence, or inferring a conclusion. Haidt describes moral judgment as an interpersonal process. So, in his social intuitionist model, he claims that in an eliciting situation, person A's intuition, judgment and reasoning are well interconnected with and influenced by person B's reasoning, judgment and intuition, and vice versa. As morality is unique to a culture or group, Haidt proposes that although moral intuitions are innate, the development of intuitions in children depends on three processes which modify within different cultures: the selective loss of intuitions as cultures specialize in a subset of human moral potential; the immersion in custom complexes which implicates social learning and imitation of moral intuitions by children; and the peer socialization during the sensitive period of late childhood and adolescence. Thus, moral development is a matter of maturation and cultural shaping of endogenous intuitions (Haidt, 2001).

So, moral judgment is driven primarily by rapid, affectively based, intuitive responses, with deliberate justifications in response to social demands. Haidt's social intuitionist model was picked up as a basis for further research in moral emotions and Haidt himself discussed the importance of moral emotions. He defined moral emotions as emotions "that are linked to the interest or welfare either of society as a whole or at least of persons other than the judge or agent" (Haidt, 2003). Prototypical moral emotions such as anger, elevation, guilt, compassion, are easily triggered by a disinterested elicitor that does not directly affect the individual. Haidt uses the image of homo economicus, a perfectly selfish creature that was already described by John Stuart Mill (1806-1873) in oder to create a being that cares only about its own well-being. Haidt alludes to the comparison of the homo economicus with a psychopathic individual and because of this, he describes moral emotions as "the difference between the emotional life of homo sapiens and the emotional life of homo economicus or of a psychopath" (Haidt, 2003). For example, one of the prototypical emotions, guilt, an emotion that motivates people to treat their relationship partners well (Baumeister et al., 1994) and that is triggered by the appraisal that one has caused harm, loss or distress to a relationship partner, is, if it is lacking, one of the defining factors of psychopathy (see table 1; Hare et al., 1991).

Recently, Greene et al. (2004) suggested a synthesis of both perspectives: emotion and reasoning. They distinguish "personal" moral judgments from "impersonal" moral judgments which means that "personal" moral judgments are "driven largely by social-emotional responses while other "impersonal" moral judgments are driven less by social-emotional responses and more by “cognitive” processes” “while the term “cognitive” is referring here to a class of processes that contrast with affective or emotional processes”(Greene et al., 2004).

Thomson (1985) invented two moral dilemmas to give an example for each personal and impersonal moral judgment (Thomson, 1985): the trolley dilemma is an example for an impersonal moral dilemma: A runaway trolley is headed for five people who will be killed if it proceeds on its present course. The only way to save them is to hit a switch that will turn the trolley onto an alternate set of tracks where it will kill one person instead of five. Should you turn the trolley in order to save five people at the expense of one? Greene et al. (2001) found out that most people say yes. The problem of moral dilemmas is that they are choices for which all outcomes are morally undesirable. A similar problem is the footbridge dilemma that represents a moral-personal judgment: again, a trolley threatens to kill five people. The only way to save them is to push a stranger off the bridge so that he will die instead of the five people. Ought you to push the stranger to his death in oder to save the five others? In this case, most people say no. The two different forms of dilemmas show that some moral dilemmas engage emotional processing more than others and these differences in emotional engagement affect people's judgments (Cushman et al., 2006; Greene et al., 2001).

Therefore, moral judgment is defined as an evaluative judgment of the actions, behaviors, their adequacy and the character of a person, that is influenced by socially shaped ideas of right and wrong behavior and that applies to every member within a social group (Haidt, 2001; Moll et al., 2005). In conclusion, people who fail to embody these ideas and present with inadequate and wrong behavior, are socially criticized, ostracized or even punished (Ross, 1030; Shweder & Haidt, 1993).

Summing up the different theories of morality, moral reasoning and moral emotions, it can be said that moral theories were dominated for a long time by the influence of reasoning (Kohlberg, 1969; Piaget, 1965). But a recent new trend emphasizes the role of intuitive and emotional processes in human decision-making processes and leads to a theory of synthesis of emotion and reasoning in moral processes (Greene et al., 2004; Haidt, 2001). Furthermore, it is important to emphasize that moral development is an individual process that happens in several stages and levels in a child and leads, if it was successful, to an intact moral judgment and behavior that is crucial for social interacting.

By the development of new technologies such as functional magnetic resonance tomography, the above mentioned and described theories on morality as well as the influence of emotion and reasoning processes, can be investigated and underpinned by neural correlates of certain brain areas. In the following part, several neuroimaging studies that investigated moral reasoning in healthy individuals and contributed to further understanding of brain activation mechanisms in human being during moral decision-making are going to be described.

2.1.2 Neural Correlates of Moral Reasoning in Healthy Individuals

As moral reasoning is an area of intense interest in the recent and current neuroimaging research, there have been several studies that addressed the neural correlates of moral emotions and moral judgments in healthy individuals. Functional imaging studies have involved different paradigms such as simple moral judgments, moral dilemmas, and moral emotions, using different tasks and stimulus presentation schemes. The most important results and neural correlates are summarized in this chapter.

First, typical activations of frontal lobe areas such as the orbitofrontal cortex (OFC) and the medial frontal gyrus are going to be described. Then, study results that show the neural correlates of moral decision-making in the parietal lobe such as the precuneus and the posterior cingulate gyrus are going to be described. Further, studies that found activated brain areas in the temporal lobe such as the superior temporal sulcus (STS) and the temporal poles are going to be described. In addition, other associated brain areas that activated in several studies on moral decision-making such as the cerebellar cortex and the amygdala are going to be summarized.

Frontal Lobe. A brain area of great interest regarding moral decision-making in healthy individuals is the frontal lobe and within it especially the medial frontal gyrus and the orbitofrontal gyrus. Several neuroimaging studies revealed activation in these areas when investigating judgments about simple moral claims (Moll et al., 2001), pictures with moral content (Moll et al., 2002a) or moral dilemmas (Greene et al., 2001).

In an fMRI study, Moll et al. (2001) presented subjects with simple claims, some with moral content ("The boy stole his mother's savings") and others without moral content ("Every text has words"). Judgments in response to claims with moral content produced increased activity bilaterally in the frontal pole (BA 10) and in the medial frontal gyrus bilaterally (BA 9/10; Moll et al., 2001). The results of another fMRI study by Moll et al. (2002a) where pictures with emotionally charged scenes with or without moral content and pictures with emotionally neutral content were presented in a passive visual task to healthy subjects, showed an increased activation of the right medial orbitofrontal cortex (OFC) and the medial frontal gyrus elicited by moral in comparison with nonmoral unpleasant stimuli. By analyzing the different effects of faces and moral stimuli on brain activation, they also showed that the medial OFC and the medial frontal gyrus were centrally involved in processing pictures with high moral content (Moll et al., 2002a). Heekeren et al. (2003; 2005) investigated brain areas that showed activation when subjects judged sentences decribing behaviors as moral or immoral. They, too, confirmed the importance of the medial OFC (Heekeren et al., 2003 Heekeren et al., 2005). In a third fMRI study by Moll and colleagues (2002), subjects were presented with short statements with either nonmoral neutral ("Fat children should make a diet"), nonmoral unpleasant ("Pregnant women often throw up"), moral ("Criminals should go to jail") or scrambled content ("Kick like poor rain old have"). Compared to the nonmoral unpleasant condition, the moral condition induced increased activation in the medial OFC (BA 10/11), whereas for the nonmoral social judgments the left lateral OFC (BA 11/47) showed increased activitation. These results suggest a functional dissociation between neural networks within the OFC itself (Moll et al., 2002b).

An fMRI study that used moral dilemmas such as the footbridge dilemma (for a moral-personal dilemma) or the trolley dilemma (for a moral-impersonal dilemma) in order to investigate emotional engagement in moral judgment, was performed by Greene and colleagues (2001). They showed that subjects had increased activation for moral-personal dilemmas in the medial prefrontal cortex (BA 9/10) compared to moral-impersonal dilemmas and non-moral judgments (Greene et al., 2001).

The role of medial frontal gyrus is furthermore emphasized by Greene and Haidt

(2002). They describe the medial frontal gyrus as a brain area located around the border of Brodmann areas (BA) 9 and 10 which is supposed to integrate emotion into decision-making and planning and which also seems to be involved in theory of mind (ToM, the capacity to represent other's mental states) (Greene & Haidt, 2002). This region should be distinguished from the OFC (BA 10/11) which might play a role in simple moral judgments and moral tasks (Moll et al., 2002). Moll et al. (2002) split up the OFC as they found out that moral judgments associated with unpleasant emotions induced activation in the anterior aspect of the medial OFC, whereas nonmoral social judgments associated with unpleasant emotions induced lateral activation (Moll et al., 2002b).

In conclusion, the areas involved in moral decision-making that are located in the frontal lobe, are the medial and superior frontal gyrus (BA 9/10) as well as the orbitofrontal gyrus (BA 10/11). Besides their involvement in moral processes, some of their further functions are related to theory of mind, viewing emotional pictures, integrating emotion into decision-making and reactive aggression (Blair, 2001; Damasio et al., 1994; Gallagher et al., 2000).

Parietal Lobe. Besides the above mentioned areas of the frontal lobe, brain areas located in the parietal lobe such as the posterior cingulate gyrus and the precuneus have been investigated in several moral decision-making tasks. The investigators of the different studies used paradigms such as moral dilemmas (Greene et al., 2001), simple moral judgments (Moll et al., 2001), pictures with emotionally charged moral content (Moll et al., 2002a) and empathic and forgivability judgments (Farrow et al., 2001).

When investigating emotional engagement in moral judgment in an fMRI experiment, Greene and colleagues (2001) revealed a significantly higher activation of the posterior cingulate gyrus (BA 31) in moral-personal conditions (judging moral-personal dilemmas such as a version of the footbridge dilemma) than in moral-impersonal (judging moral-impersonal dilemmas such as a version of the trolley dilemma) and non-moral conditions (Greene et al., 2001). Furthermore, Moll et al. (2001) showed left precuneus activation (BA 7) in moral judgments ("The boy stole his mother's savings") compared to factual judgments ("Every text has words") in an fMRI study. In another fMRI study by Moll et al. (2002a), they investigated brain activation in a passive visual task when subjects were presented with pictures with scenes of moral or neutral content. Right precuneus activation (BA 7) was shown in the moral emotion condition (Moll et al., 2002a). In addition, Farrow et al. (2001) investigated the neural correlates of empathy and forgiveness in an fMRI study and revealed increased precuneus activation (BA 7) in empathic and forgivability judgments as well as significant activation in the posterior cingulate gyrus (BA 31) in empathy judgments compared to social reasoning judgments (Farrow et al., 2001).

Summing up the findings of parietal lobe brain activation in previous studies, the posterior cingulate cortex region and the precuneus around BA 31/7, areas that are known to be important for emotional and memory-related processes, seem to be crucially involved in moral decision-making (Maddock et al., 2003).

Temporal Lobe. Additional to frontal and parietal lobe involvement in moral decision-making, several areas of the temporal lobe play a crucial role in moral decision-making. Especially the superior temporal sulcus (STS, BA 39) and the temporal poles (BA 38) were revealed in studies that investigated judgments about moral claims (Moll et al., 2002b), moral dilemmas (Greene et al., 2001) and moral pictures (Moll et al., 2002a).

Moll et al. (2002) for example, found an activation of a network comprising the STS and the temporal pole of the left hemisphere when subjects were presented with moral judgments (Moll et al., 2002b). Greene and colleagues (2001) supported these findings and showed increased activation bilaterally in the angular gyrus (BA 39) while subjects responded to personal moral dilemmas relative to impersonal moral dilemmas and non-moral dilemmas (Greene et al., 2001). In another fMRI study by Moll and colleagues (2001), increased activation in the right temporal pole (BA 21/22/38) and the right posterior temporal sulcus (BA 39) was shown when subjects were presented with moral judgments compared to factual judgments (Moll et al., 2001). Investigating subjects during viewing pictures with moral content, Moll et al. (2002) also found an increased activation in the right posterior STS (BA 21/39; Moll et al., 2002a).

Together with parts of the angular gyrus and the supramarginal gyrus, the STS region is a part of the so-called temporo-parietal junction (TPJ), an area at the border of the temporal and the parietal cortices. This area is located mostly in Brodmann Areas 39, 40 and 41. Concerning the function of the STS / TPJ region, it is supposed to play an important role in theory of mind (ToM) and therefore is necessary for the ability to make inferences about the beliefs and intention of others (Allison et al., 2000; Sommer et al., 2007). But the STS / TPJ region is not only associated with ToM but also with social perception, facial emotion recognition, and the representation of intentional actions as well as imitation, imitation learning and action understanding (Allision et al., 2000; Narumoto et al., 2001; Rizzalotti & Craighero, 2004; Saxe et al., 2004). Beyond, this region plays an important role in forgiveness and empathy processing (Carr et al., 2003; Farrow et al., 2001; Leslie et al., 2004).

In sum, there are brain regions located in the temporal lobe that are involved in moral decision-making processes. Besides the temporal pole, it is especially the STS region which plays an important role in moral reasoning. The STS regions corresponds in part to the TPJ which is known to be involved in ToM, social perception, forgiveness and empathy processing.

Other Brain Areas. Besides the above mentioned brain areas of the frontal, parietal and temporal lobe that are involved in moral processing, there are other brain areas that were investigated in previous studies on moral judgments (Moll et al., 2001) and on moral pictures (Moll et al., 2002a). These other brain areas include the amygdala and the cerebellar cortex. Increased activity in the right cerebellar cortex was shown by Moll and colleagues (2001) in an fMRI study when moral judgments were compared to factual judgments (Moll et al., 2001).

An area that showed increased activation in moral tasks is the amygdala. For example, Moll et al. (2002a) presented subjects with pictures with moral contents and pictures with neutral contents, and found greater activity in the amygdala during the presentation of moral pictures compared to neutral pictures (Moll et al., 2002a). Heekeren et al. (2005) support the finding of amygdala involvement in moral judgment (Heekeren et al., 2005). Furthermore, studies using facial expressions as stimuli revealed that the human amygdala is involved in the processing of fear and related emotions (Adolphs et al., 1994; Morris et al., 1996).

To conclude, the growing interest in the neural correlates of moral reasoning has lead to several neuroimaging studies that investigated judgments about simple moral claims, moral dilemmas or moral emotions. The findings of these studies can be summarized as an involvement of brain areas that are located in the frontal, parietal and temporal cortices as well as limbic structures. Specific brain areas that are associated with increased activity in studies with moral decisions are the medial frontal gyrus, the orbitofrontal gyrus, the precuneus and the posterior cingulate cortex, the STS (TPJ) and the temporal poles, and the amygdala. Summarizing all these findings, Greene and Haidt (2002) contributed to the definition and the development of "the moral brain" (see figure 1) that includes all brain areas associated with moral reasoning. But, they emphasized that there is no specifically moral part of the brain, as every brain region of the above mentioned has also been implicated in other and non-moral processes (Greene & Haidt, 2002). Figure 1 illustrates "the moral brain" reproduced from Greene and Haidt (2002) and shows brain areas that are associated with moral reasoning.

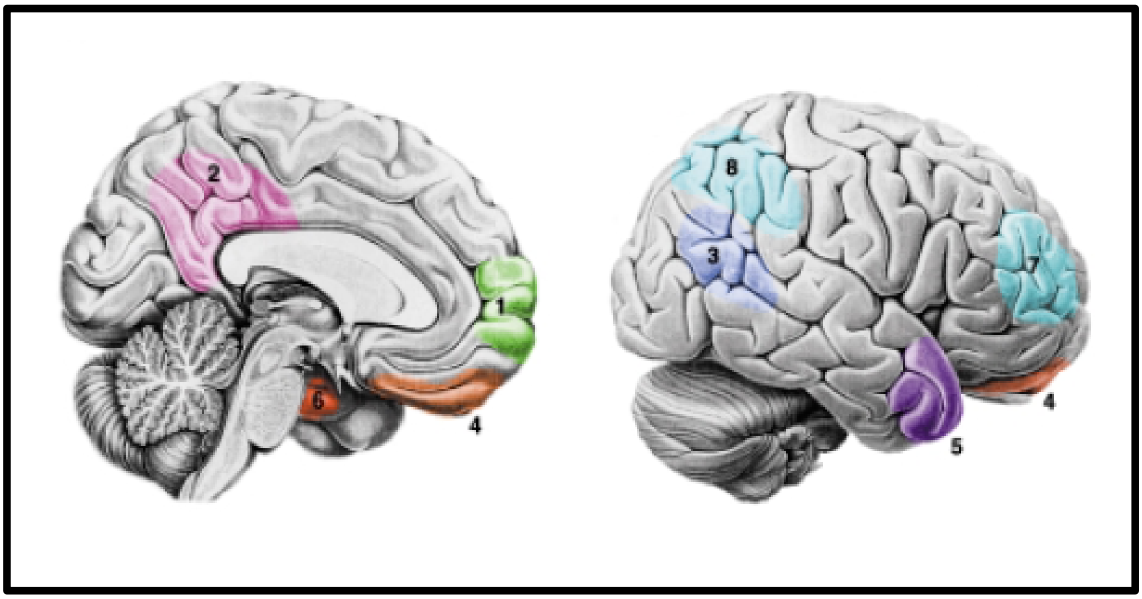

Figure 1. **Brain areas associated with moral reasoning, reproduced from Greene and Haidt (2002).** Greene and Haidt summarized the brain areas that activated in several moral decision-making studies (Greene et al., 2001; Moll et al., 2002a; Moll et al., 2002b). The activated brain areas are numbered and consist of: 1 medial frontal gyrus; 2 posterior cingulate, precuneus, retrosplenial cortex; 3 superior temporal sulcus, inferior parietal lobe; 4 orbitofrontal/ventromedial frontal cortex; 5 temporal pole; 6 amygdala; 7 dorsolateral prefrontal cortex; 8 parietal lobe.

2.2 The Concept of Psychopathy

This introductory part gives an insight into the concept of psychopathy. First, historical views and the historical development of the concept of psychopathy are going to be described. Then, Hare's clinical construct of psychopathy as well as the Psychopathy Checklist - Revised will be explained (Hare, 1980; Hare et al., 1991). Following this, some theories of the development of psychopathy are going to be described. And finally, several neuroscientific studies that investigated the neural correlates of psychopathy will be delineated.

2.2.1 Historical Views on the Concept of Psychopathy

200 years ago, in 1809, the French psychiatrist Philippe Pinel was one of the first in the scientific literature to describe a mental disorder with emotional involvement. Pinel used the term “manie sans délire” to describe a state of rage without any signs of delirium (Pinel, 1801). Whereas these individuals did not have deficits in intellectual functions, their behavior was characterized by a lack of morality (Weber et al., 2008). Jean-Étienne Esquirol, one of his students, extended this concept to his own theory of “monomania”. This concept defined a partial disturbance of mental functions and involved for example intellectual, emotional, or volitional moral functions (Esquirol, 1838; Herpertz & Sass, 2000).

In the Anglo-American area there were psychiatrists like James Cowles Prichard who coined the term “moral insanity” (1835) defining a “madness consisting in a morbid perversion of the natural feelings, affections, inclinations, temper habits, moral dispositions, and natural impulses” (Prichard, 1835). Thus, moral insanity was for the first time a hypothetical cause of social deviance (Blackburn, 1988).

The Italian psychiatrist Cesare Lombroso popularized the concept of the “delinquente nato” (born criminal) in 1876, believing that criminal individuals can be identified by “deformations of their skulls”. Thus, the idea of the “criminal mind” was born (Lombroso, 1876).

At the beginning of the 20th century, the German psychiatrist Emil Kraepelin (1904) constructed a classification of psychopathic personalities (Blackburn, 1988). The most influential of several similar typologies that followed, was the one by Kurt Schneider, a

German psychiatrist who divided abnormal personalities into “those who suffer from their psychic abnormality, and those from whom society suffers” (Herpertz & Sass, 2000). He described these abnormal personalities as a heterogeneous group and divided this group into ten specific types of classes mainly by terms of trait (Blackburn, 1988). This definition of abnormal personalities led to the basics of today's concept of personality disorders that are categorized in the modern classification systems DSM-IV and ICD-10 (Herpertz & Sass, 2000).

It was in 1941 when the American psychiatrist Hervey Cleckley published his book *The Mask of Sanity* and described the psychopathic individual as a person that could be socially well adjusted and successful but that is characterized by deviant and irresponsible behavior (Cleckley, 1941). His pioneering theory was picked up and operationalized by the Canadian criminal psychologist Robert D. Hare who defined and developed the Psychopathy Checklist (PCL) (see table 1) (Hare et al., 1991).

So, in the past 200 years, the concept of psychopathy developed from a general mental disorder with emotional involvement, a lack of moral behaviors but intact intellectual functions to an irresponsible and socially deviant but successful personality that represents the basis of the current understanding and definition of psychopathy.

2.2.2 Definition and Concepts of Psychopathy and Antisocial Personality

At the moment, there are three different diagnostic categories in use to diagnose a socially harmful antisocial personality: the DSM-IV criteria of antisocial personality disorder (APD), the ICD-10 criteria of dissocial personality disorder and Hare's psychopathic personality disorder.

The diagnosis of antisocial personality disorder in the DSM-IV is based on antisocial behavioral qualities. These antisocial criterion are easy to investigate, like for example repetitive delinquency or aggressive behavior, but they do not implicate personality traits, such as egocentricity, lack of remorse, callousness and so forth.

Another diagnostic criterion is the ICD-10 criterion of dissocial personality disorder that extends the criteria of a personality disorder to affective personality traits, such as lack of remorse and callousness (Habermeyer & Herpertz, 2006).

An alternative to antisocial and dissocial personality disorder is the diagnosis of psychopathy measured and defined by Hare's Psychopathy Checklist - Revised (PCL-R) (Hare et al., 1991) that was also used in the present study. The original Psychopathy Checklist (PCL) based on Cleckley's work and consisted of a 22-item clinical rating scale designed to assess the traditional clinical construct of psychopathy (Hare, 1980). The PCL-R now consists of 20 items measuring behaviors and inferred personality traits that are considered to be fundamental for the clinical construct of psychopathy (Hare et al., 1991; see table 1). Each of the 20 items is scored on a three-point scale according to specific criteria through institutional file information and a standardized semistructured interview by a professional. Each item can be scored with 0 to 2 points, whereas 0 indicates that it definitely does not apply, 1 that it applies somewhat or only in a limited sense, and 2 that it definitely does apply to the person (Hare et al., 1991) resulting that "total scores can range from 0 to 40 and represent the extent to which a person matches the prototypical psychopath" (Hare et al., 1991). Furthermore, each of the 20 items belongs to one of two stable factors (see table 1). Affective-interpersonal characteristics, such as glibness, lack of remorse, callousness, and so forth are summarized by 8 items in factor 1, whereas factor 2 includes 9 items describing an antisocial and social deviant personality (Hare et al., 1991). The result is a maximum score on factor 1 of 16 points and on factor 2 of 18 points. Three items (promiscuous sexual behavior, many short-term marital relationships and criminal versatility) are not subordinated to none of the two factors.

A new three-factor model was presented by Cooke and Michie (2001) which omitted items that described directly criminal activities, and factor 1 was divided into deceitful interactive style (new factor 1) and affective hypo-responsiveness (new factor 2), while factor 2 approximately corresponds to the new factor 3 (Cooke & Michie, 2001). Hare himself, developed a four-factor model that includes the interpersonal factor 1, the affective factor 2, the lifestyle factor 3 and the antisocial factor 4 (Hare, 2003; see table 1).

It is important to note that the term "psychopathy" is not synonymous with the DSM-IV concept of the APD but that psychopaths form a special subgroup of the APD (Herpertz & Sass, 2000). Compared to Hare's concept of psychopathy that implicates a high score on both factor 1 and factor 2, persons with APD are mostly restricted to score high on factor 2. So, the diagnosis of APD concentrates mostly on antisocial behavior (Blair, 2003; Hare et al., 1991; Weber et al., 2008). That is the reason why the prevalence of APD is very high especially in prison inmates: Schönfeld et al. (2006) reported prevalence rates of APD of nearly one-third in both incarcerated female and male subjects whereas Hart and Hare (1996) found that only one-third of those who were diagnosed with APD met criteria for psychopathy (Hart & Hare, 1996; Schönfeld et al., 2006). Altogether, psychopathy is believed to affect approximately 1% of the general population and approximately 15-25% of incarcerated offenders (Hare et al., 1991).

Besides providing some epidemiological data, the PCL-R score is correlated with other criminal qualities and provides predictive criterion-related evidence, for example for recidivism rates for violent offenses or substance misuse. In a follow up study, Rice et al. (1990) revealed that in 54 rapists, the PCL-R score was positively correlated with a recidivism rate for violent offenses in general and for sexual offenses in particular (Rice et al., 1990). Furthermore, Hart and Hare (1989) found a positive correlation between substance misuse and PCL-R total scores (Hare et al., 1991).

Concluding, psychopathy is the theoretical construct of a disorder, defined by Hare's Psychopathy Checklist-Revised (PCL-R) and characterized in part by emotional detachment and poor behavioral controls (Hare et al., 1991). In comparison to APD, psychopathy is not only defined by antisocial behavior (factor 2), but also by the lack of emotional impairment (factor 1) such as the lack of guilt (Blair, 2003). So, the definition of psychopathy is more than the literal meaning of the simple word (Greek *η ψυχη – soul* and *τα παθη – disease)* that describes no more than a mental illness. Rather, it is a complex personality disorder with antisocial and deficient affective personality traits.

Table 1. **The 20 items of the Psychopathy Checklist-Revised (PCL-R) classified into the two-factor model and the four-factor model (Hare et al., 1991; Hare, 2003). Two-factor model:** developed by Hare (1991). Each of the 20 items belongs to one of two stable factors. Whereas factor 1 subsumes eight affective-interpersonal characteristics, factor 2 includes nine items describing an antisocial and social deviant personality. Three items are not subordinated to none of the factors. Each of the items is scored on a three-point scale and the total score can range from 0 to 40 and represents the extent to which a person matches the prototypical psychopath. **Four-factor model:** also developed by Hare (2003). The four factors consist of the interpersonal factor 1, the affective factor 2, the lifestyle factor 3 and the antisocial factor 4. Two items (promiscuous sexual behavior and many marital relationships) do not load on any factor.

	Item	**Two-factor model**	**Four-factor model**
1	Glibness/superficial charm	1	1
2	Grandiose sense of self-worth	1	1
3	Need for stimulation	2	3
4	Pathological lying	1	1
5	Conning/manipulative	1	1
6	Lack of remorse or guilt	1	2
7	Shallow affect	1	2
8	Callous/lack of empathy	1	2
9	Parasitic lifestyle	2	3
10	Poor behavioral controls	2	4
11	Promiscuous sexual behavior	-	-
12	Early behavioral problems	2	4
13	Lack of realistic, long-term goals	2	3
14	Impulsivity	2	3
15	Irresponsibility	2	3
16	Failure to accept responsibility	1	2
17	Many marital relationships	-	-
18	Juvenile delinquency	2	4
19	Revocation of conditional release	2	4
20	Criminal versatility	-	4

2.2.3 Theories of the Development of Psychopathy and Psychopathic Tendencies

In general, personality disorders have a multi-causal genesis ranging from genetic and neural defects to disorders in psychoanalytical aspects, and from childhood trauma to social influences and situational conditions. The same seems to apply for the pathogenesis of psychopathy. Neurobiological, psychological and social factors seem be interconnected factors that contribute to the development of the psychopathic personality disorder (Paris, 1993). The following part gives an insight into some important etiological factors such as genetic and neurocognitive factors that play a role in the pathogenesis of psychopathy.

Concerning the genetic factors, studies revealed an association between monoaminoxiase A (MAO-A) genetic polymorphism, neglect in childhood and antisocial behavior of children. They showed that neglected children with a genetic variant on X-chromosome followed by a reduced activity of MAO-A had a much more higher risk to develop an antisocial personality disorder (Goodman et al., 1997). Another study has investigated the genetic risk for psychopathy. Viding et al. (2005) examined twins regarding callous-unemotional traits (CU) and high levels of antisocial behavior (AB) at the age of seven. The results indicated that high levels of CU is under strong genetic influence as well as AB for children who are high on CU is highly heritable (Viding et al., 2005). So, genetic changes seem to play a role in the pathogenesis of psychopathy. But it has to be considered that neurobiological and genetic research is a wide field where more research is necessary for a better assessment of its importance and its involvement in personality disorders such as psychopathy.

Besides genetic influences, theoretical neurocognitive models try to give an explanation for the development of psychopathy. Actually, there are different current theoretical models: i) the response modulation hypothesis by Newman, ii) the Violence Inhibition Mechanism by Blair, iii) the somatic marker hypothesis by Damasio and, iv) the social response reversal hypothesis by Blair. In the following part, the basic ideas of these four theories are going to be summarized.

The response modulation hypothesis by Newman defines response modulation as a process that involves a rapid and relatively automatic shift of attention from a dominant response that is expected to be rewarded to the evaluation of response consequences (Newman, 1998; Newman et al., 1997; Patterson & Newman, 1993). This shift allows individuals to adjust their responses, if needed, by suppressing the dominant response instead of intensifying the dominant response which will lead to non-rewarded consequences. This is where psychopaths are supposed to have deficits. They persist more likely in the dominant and originally rewarded response, even if they know previously that this response will later be punished (Fisher et al., 1998). The consequences of this shift deficit may be impulsive and antisocial behavior. So, this model indicates an impairment of automatic processing mechanisms in psychopaths that may explain in part why psychopaths tend to antisocial and violent behavior and why they lack premeditation or perseverance. But it has to be considered, that this model is a very general approach to the development of psychopathy and does not explain all characteristic features of psychopaths.

As mentioned above, there is another important neurocognitive theoretical model that should be considered when trying to explain the development of psychopathy. It was Blair (1995) who proposed the Violence Inhibition Mechanism (VIM; Blair, 1995), a model that is based on animal observation findings of the ethologists Eibl-Eibesfeldt (1970) and Lorenz (1981). As they noted that some social animal species display submission cues to a conspecific aggressor which resulted in the termination of the attack, the ethologists suggested that in these animal species certain aggression-control-mechanisms might exist (Eibl-Eibesfeldt, 1970; Lorenz, 1966). So, Blair considered the VIM to be a functionally similar cognitive mechanism in human beings that leads to a withdrawal reaction of the observer when the observed human being displays distress cues (e.g. sad facial affects). Blair (1995) suggests that the VIM is a prerequisite that is importantly involved in normal moral development implicating the development of moral emotions, the inhibition of violence and the moral/conventional distinction. Therefore, individuals with a lack of VIM tend to violent and immoral behavior and to impaired experiencing of moral emotions. And vice versa, Blair proposes that psychopaths, who are characterized by their violent behavior and their lack of moral emotions such as empathy, have a deficient VIM (Blair, 1995). In addition, Blair confirmed that psychopaths fail to distinguish between moral and conventional transgressions in their judgments and that total PCL scores correlated with the tendency to judge conventional transgressions as moral (Blair, 1995). So, the VIM is an alternative theoretical model that explains parts of the psychopathological mechanisms in psychopaths, especially their violent and antisocial behavior and their lack of moral emotions.

A third theoretical alternative that is used to explain deficits in aggression control in psychopaths, is the somatic marker hypothesis by Damasio (1994). The key idea of this hypothesis is that decision-making is a process that is influenced by marker signals that arise in bioregulatory processes (Damasio, 1994b). Damasio described the ventromedial PFC (orbitofrontal and medial frontal cortex) as a “repository” that links factual knowledge and bioregulatory states. He suggested that a disturbance of the somatic marker system leads to an insensitivity for potential negative consequences and results in antisocial and immoral behavior (Damasio, 1994b).

Finally, another theoretical model was proposed by Blair (2001). The social response reversal model (SRR) stresses the influence of social cues in the modulation of social behavior. The SRR seems to be activated by angry expressions or the expectation of another's anger. This activation results in a modulation of reactive aggression and behavioral responding mediated by the hypothalamus and the periaqueductal grey, and leads to a shift of responding (Blair, 2001). It was shown that response reversal was impaired in individuals with psychopathy (Budhani & Blair, 2005; Budhani et al., 2006).

In sum, several hypotheses and theoretical models exist that may explain, at least in part, the deficient moral development of psychopaths as well as their antisocial behavior. But, the pathogenesis of psychopathy cannot be explained by these theoretical models alone. This is, first, due to the fact that other factors have to be considered, such as genetic, psychosocial and neurobiological factors. And second, because the interaction and interconnection of all these factors is poorly understood. So, further research is necessary to find out all aspects that contribute to the development of psychopathy.

An aspect that is studied already relatively well concerns the neural correlates of psychopathy. This topic will be described in the subsequent part.

2.2.4 Neural Correlates of Psychopathy

It was an accident report that aroused growing interest in the neural correlates of psychopathy. In 1848, the railway foreman Phineas Gage experienced severe brain injury when an iron rod passed through his skull and damaged his prefrontal and especially his orbitofrontal cortex. After this incident, Gage's personality changed profoundly and his behavior was characterized by antisocial and aggressive behavior patterns. This pseudopsychopathic behavior was called “acquired sociopathy”. Based on the exhibited pseudopsychopathic behavior of frontal lobe patients such as Phineas Gage, it was thought that prefrontal brain regions were crucially involved in social behavior and therefore, dysfunctions of the frontal lobe might play a major role in the psychopathic personality (Anderson et al., 1999; Damasio, 1994). Besides the prefrontal and orbitofrontal cortex, other brain areas that seem to play a role in psychopathy are temporo-limbic areas such as the anterior cingulate, the posterior cingulate, the amygdala and the superior temporal sulcus.

Below, different studies that revealed structural as well as functional abnormalities in psychopaths are going to be described. First, structural brain abnormalities in psychopaths are going to be summarized. Then, studies that used new technologies such as functional magnetic resonance tomography in psychopaths and found functional abnormalities are going to be pointed out.

2.4.4.1 Structural Brain Abnormalities in Psychopaths

Concerning structural abnormalities in psychopaths, prefrontal impairments are, perhaps, the best-replicated finding in the imaging literature. It is important to indicate that not all studies investigated psychopaths, but many studies investigated individuals with antisocial personality disorder (APD). For example, Raine et al. (2000) studied structural brain abnormalities in a volumetric MRI study on individuals with APD and psychopathic-like behavior, on male individuals with substance dependency, on psychiatric male controls and on healthy male subjects. They found a significant volume reduction of 11 % in the prefrontal gray matter volume in subjects with APD and psychopathic-like behavior compared to the healthy male control group. Furthermore, the APD group showed a reduction of 14 % in prefrontal gray matter compared with the psychiatric control group and a reduction of 13.9 % compared with the substance-dependent group (Raine et al., 2000). Specifying these findings, Yang and colleagues (2005) distinguished between successful (psychopathic individuals who were not detected for their crimes) and unsuccessful psychopaths (who were detected and convicted for their crimes) and found that only unsuccessful psychopathic individuals had a reduced prefrontal cortex volume of 22.3 % compared with control subjects (Yang et al., 2005a). Furthermore, Yang and colleagues (2005b) found a reduction in the prefrontal gray/white matter ratio and an increase of prefrontal white matter in association with pathological lying (Yang et al., 2005b), which is one of the PCL-R items.

However, none of these studies could show a more specific region within the gray matter of the frontal cortex. Hence, Blair (2003) points out that it is not a generalized frontal cortex dysfunction in psychopathic individuals, but that there must be specified regions within the frontal cortex that might be impaired in their functions, e.g. the orbitofrontal cortex (Blair, 2003). Differentiating the frontal cortex regions, Oliveira-Souza et al. (2008) investigated psychiatric patients with high PCL scores in comparison to healthy control subjects in a voxel-based morphometry study and revealed gray matter reductions in frontopolar, medial and lateral orbitofrontal cortices. In addition to these frontal lobe abnormalities in psychopathic individuals, Oliveira-Souza and colleagues (2008) found gray matter reductions in the left anterior temporal cortex. So, they discussed not only frontal dysfunctions but a fronto-temporal network that plays a critical role in moral behavior and that might be dysfunctional in psychopaths (Oliveira-Souza et al., 2008).

This assumption is supported by another voxel-based morphometry study by Müller et al. (2008), who compared psychopathic individuals with PCL-R scores above 28 with control subjects (PCL-R scores < 10). They found a significant reduction of gray matter volume in psychopaths in the right middle frontal gyrus, the right cingulate gyrus, and the superior temporal sulcus bilaterally (Müller et al., 2008).

Summing up structural findings in the frontal cortex in psychopathic or antisocial individuals, it seems that there is no generalized frontal cortex dysfunction in individuals with psychopathy but that there are some special regions of the frontal cortex that could be impaired, e.g. the orbitofrontal cortex (OFC) (Blair, 2003). It is suggested that OFC is directly involved in the modulation of reactive aggression, but it is less obviously involved in the modulation of instrumental aggression (Blair, 2004). Furthermore, the OFC is involved in response reversal. Impairments in response reversal are seen in psychopathic individuals (Blair, 2004).

But, not all studies could support frontal dysfunctions in psychopaths, there are also contradictory findings. For example, Dolan et al. (2002) did not find significantly reduced prefrontal gray matter in a structural MRI study in a group of criminal offenders (18 psychopaths and 6 patients with another personality disorder) in comparison to control subjects (staff members). But, they revealed 20% smaller temporal lobe volumes in criminal offenders when compared to control subjects (Dolan et al., 2002). Laakso and colleagues (2002) published contradictory findings, too. They investigated incarcerated males with APD and high PCL-R scores and did not find differences in total prefrontal, prefrontal white, or gray matter volumes when data were controlled for education and duration of alcohol abuse (Laakso et al., 2002).

Another brain region that seems to be crucially involved in psychopathy besides the above mentioned fronto-temporal areas is the amygdala. The amygdalda is thought to respond to cues indicating distress in others, thus guiding individuals away from antisocial behavior (Blair, 2007b). So, reduced amygdala functioning in psychopathic individuals suggests reduced responsiveness to the thought of causing harm to others when contemplating personal moral dilemmas. In consequence, individuals with dysfunctional amygdala activation may show conning and manipulative behavior, impulsive decision-making, and antisocial and criminal behavior without the feeling of guilt or remorse – the typical characteristics of the psychopathic individual (Glenn et al., 2009). Several studies investigated structural amygdala abnormalities in psychopathic individuals.

In a volumetric neuroimaging study, Tiihonen et al. (2000) showed that amygdala dysfunction is associated with psychopathy. They used volumetric magnetic resonance imaging to explore the relationship between amygdaloid volume and the degree of psychopathy in violent offenders as measured by the PCL-R and found that high levels of psychopathy were associated with significantly reduced amygdaloid volume of 20-21 % (Tiihonen et al., 2000). These findings were replicated by Yang et al. (2006) who found significant reductions in the volume of the amygdala in psychopathic individuals in a structural imaging study (Yang et al., 2006).

In sum, most of the structural brain imaging studies in psychopaths and individuals with antisocial personality disorder found decreased prefrontal cortex volumes, especially in the frontopolar, medial and lateral orbitofrontal cortices (Müller et al., 2008; Oliveira-Souza et al., 2008; Raine et al., 2000; Yang et al., 2005a; Yang et al., 2005b). In addition to frontal cortex involvement, several studies showed volume reduction in the anterior temporal cortex and the superior temporal sulcus as well as in the amygdala in psychopathic individuals (Müller et al., 2008; Oliveira-Souza et al., 2008; Tiihonen et al., 2000; Yang et al., 2006). So, based on structural imaging findings, a dysfunctional fronto-temporo-limbic network in psychopaths is discussed (Müller et al., 2008; Oliveira-Souza et al., 2008). Functional imaging studies that support this assumption are going to be described in the following part.

2.4.4.2 Functional Brain Abnormalities in Psychopaths

In addition to the investigated anatomical and structural brain abnormalities in psychopathic individuals, there have been some studies that used technologies such as functional magnetic resonance imaging in order to reveal functional abnormalities in psychopaths.

A functional imaging study by Soderstrom et al. (2002) investigated the regional cerebral blood flow by single-photon emission computed tomography (SPECT) in psychopathic personalities and found, especially in those psychopaths with a high scoring on factor 1 (deceitful interactive style) of the three-factor model by Cooke and Michie (2001), reduced perfusion in medial and lateral frontal areas, in the hippocampus and in the amygdala (Soderstrom et al., 2002).

Another functional imaging study was initiated by Müller et al. (2003) who studied the influence of affective contents and emotion processing on brain activation in psychopaths compared to healthy control subjects in an fMRI experiment. They revealed that in psychopaths, increased activation through negative contents during watching negative affective pictures was found right-sided in prefrontal regions and in the amygdala. Activation was reduced through negative affective pictures right-sided in the subgenual cingulate and the temporal gyrus as well as left-sided in the dorsal cingulate. Increased activation through positive contents was found left-sided in the orbitofrontal regions. Reduced activation through positive contents was revealed in right medial frontal and medial temporal regions (Müller et al., 2003). Müller et al. concluded that a deficient functional connectivity of emotion-related brain regions in frontal and limbic areas might be the neurobiological reason for the abnormal affective behavior that is displayed by psychopaths (Müller et al., 2003).

Kiehl et al. (2001) investigated limbic abnormalities in affective processing by criminal psychopaths in an fMRI study. They examined neural responses in 8 criminal psychopaths with high scores on the PCL-R (>28/40), in 8 criminal non-psychopaths with low PCL-R scores (<23/40) and in 8 non-criminal control participants during an emotional memory task where participants processed words of neutral and negative valence (Kiehl et al., 2001). Compared to criminal non-psychopaths and non-criminal controls, criminal psychopaths showed less affect-related activity during processing emotionally valenced words in the rostral and caudal anterior cingulate, posterior cingulate, left inferior frontal gyrus, right amygdala, and ventral striatum. Criminal psychopaths also showed less affect-related activity than non-criminal controls in the left amygdala and parahippocampal gyrus, and bilateral anterior superior temporal gyrus. There were no group differences in the above regions for processing neutral stimuli compared to the resting condition. Kiehl and colleagues (2001) draw the conclusion that psychopaths lack appropriate input from limbic structures and therefore, they use other cognitive mechanisms for processing affective stimuli (Kiehl et al., 2001).

Whereas Müller et al. (2003) revealed increased amygdala activation during watching negative affective pictures, the findings of Kiehl et al. (2001) are contradictory. This discrepancy of amygdaloid activation may be explained by the different stimulation paradigm, as Kiehl et al. (2001) used a memory task whereas Müller and colleagues used a visual task (Kiehl et al., 2001; Müller et al., 2003).

In another fMRI study, Kiehl et al. (2004) tested the association between psychopathy and abnormalities in a semantic processing task. Therefore, they compared brain activations of 8 criminal psychopathic individuals and 8 healthy control subjects in a lexial decision task. Kiehl et al. revealed activation deficits of the right posterior superior temporal gyrus in psychopaths when compared to control subjects. They concluded that in psychopaths there is an abnormality in the function of the right anterior superior temporal gyrus (Kiehl et al., 2004).

Summing up, the predominant conclusion of the findings in previous studies is that psychopaths differ from healthy individuals in their neural structures and functioning. It is supposed that the neural pathogenesis of psychopathy is based on a disturbed fronto-temporo-limbic network. On the one hand, this was shown in structural imaging studies. On the other hand, functional neuroimaging studies specified these findings and showed deficits in the prefrontal cortex, especially in the orbitofrontal cortex, in the cingulate gyrus, and in the superior temporal gyrus, as well as in the amygdala when psychopaths were tested with tasks on affective or semantic processing, and on decision-making of moral dilemmas (Glenn et al., 2009; Kiehl et al., 2001; Kiehl et al., 2004; Müller et al., 2003). This leads to the conclusion that the pathogenesis of social and affective detachment and antisocial behavior observed in psychopaths is underpinned by a deficient neural network that concerns frontal, temporal and limbic brain areas.

2.3 Summary and Aim of the Study

In the previous theoretical part, first, a definition and theories of morality and moral reasoning, as well as the neural correlates of moral reasoning in healthy individuals were described. Then, the concept of psychopathy, theories on its development and neural correlates of psychopathy were summarized.

The first part emphasized the role of morality and normal moral development for an individual within a social group. Further, it emphasized the role of intuitive and emotional processes in human decision-making processes (Greene et al., 2004; Haidt, 2001) that led to a theory of synthesis of emotion and reasoning in moral processes. In addition, studies that investigated the neural correlates of moral decision-making in simple moral judgments and moral dilemmas in healthy individuals were described. In sum, the findings of these show an involvement of brain areas that are located in frontal, parietal and temporal cortices and in limbic areas. Specific brain areas that are associated with increased activity in studies with moral decisions are the medial frontal gyrus, the orbitofrontal gyrus, the precuneus and the posterior cingulate cortex, the STS (TPJ), the temporal poles, and the amygdala (Greene et al., 2001; Greene & Haidt, 2002; Moll et al., 2001; Moll et al., 2002a; Moll et al., 2002b) .

The second theoretical part of this thesis gave a definition of the concept of psychopathy based on Hare's Psychopathy Checklist (Hare et al., 1991). Furthermore, structural and functional brain abnormalities in psychopathic individuals investigated in different neuroimaging studies were described. In sum, a deficient fronto-temporo-limbic network was revealed in psychopaths. Specific brain regions that showed impairment in psychopathic individuals are the prefrontal cortex, especially the orbitofrontal cortex, the cingulate gyrus, and the superior temporal gyrus, as well as the amygdala (Glenn et al., 2009; Kiehl et al., 2001; Kiehl et al., 2004; Müller et al., 2003; Müller et al., 2008; Oliveira-Souza et al., 2008; Raine et al., 2000; Yang et al., 2005a; Yang et al., 2005b).

So, whereas the neural correlates of morality and moral decision-making in healthy individuals as well as the neural basis of emotional processing in psychopaths is relatively well studied, the neural basis of moral decision-making in psychopaths is poorly understood.

The present study attempts to provide further understanding of exactly this point: the neural underpinnings of moral decision-making in realistic everyday moral conflicts in psychopaths. This is the first fMRI study that presented stories describing morally relevant or neutral (morally irrelevant) situations to psychopathic individuals in order to reveal neural processes associated with decision-making in everyday moral conflicts. In the moral conflicts condition, subjects had to choose between a morally-guided response and a personal desire-guided (immoral) response. In the neutral conflict condition, subjects had to choose between two conflicting personal desires. Participants indicated how they would decide if they were in the presented conflicting situation. After the experiment in the scanner, subjects had to indicate their emotion and certainty for each decision they made on a questionnaire.

On behavioral level, it was expected that psychopaths would decide immorally (personal desire-guided) more frequently than non-psychopathic criminal control subjects. Additionally, it was hypothesized that on the post-scanning questionnaire, compared to the control subjects, psychopaths would indicate higher emotion and certainty ratings (better feelings and more certainty) when deciding immorally.

In order to reveal brain areas that are associated with everyday moral decision-making in psychopathic individuals, 12 psychopaths were presented with the conflicts and the moral conflict condition was contrasted to the neutral conflict condition. For this contrast, it was hypothesized that brain areas that are known to be involved in moral decision-making processing in healthy individuals such as the medial and orbitofrontal gyrus, the superior temporal sulcus, the precuneus and the cingulate cortex region would show activation in psychopaths. This implicated the hypothesis that everyday moral conflicts, as moral dilemmas, would also evoke an activation of moral- and emotion-related brain areas. It was furthermore hypothesized that psychopaths, when compared to non-psychopathic criminal control subjects, would show reduced activation in the mentioned brain regions.

By testing all these hypotheses, this study could help to extend functional neuroscientific findings in psychopaths to a better understanding of everyday moral decision-making and its neural underpinnings in psychopaths. Further, it could help to provide more information about how psychopaths behave and decide in everyday moral conflicting situations and how they feel about their decision.

In conclusion, this is the first fMRI study on psychopaths that investigates everyday moral conflict situations and the neural basis of moral decision-making in such situations.

3 METHODS

3.1 Subjects

Altogether, 24 male subjects participated in the present study. The subjects were divided into two groups depending on their total PCL-R score. One group consisted of 12 criminal psychopaths (PCL-R $\geq$ 27), and the second group consisted of 12 non-psychopathic criminal control subjects (PCL-R $\leq$ 15).

The age of the 12 male psychopathic subjects ranged from 21 to 50 years, with a mean age of 30.75 years (SD = 8.56; see table 2). To assess the mean intelligence quotient (IQ) of the subjects, a verbal measure of intelligence was used (Mehrfachwahl-Wortschatz-Intelligenztest; MWT-B; Lehrl, 2005). The sum of correct answers indicated the IQ. In the psychopathic group, IQs ranged from 93 to 118 with a mean of 99.4 (SD = 7.06). Furthermore, the Beck's Depression Inventory (BDI) was administered to investigate whether subjects showed signs of clinical depression (Hautzinger et al., 1994). The test consists of 21 questions that include typical symptoms of patients with depression. The test is completed by the subjects themselves and they can reach a sum of 0 to 63 points as every item is assessed with 0 to 3 points. In the psychopathic group, the mean BDI score was 13.5 with a SD of 10.15 (see table 2). All participants were free from clinical depression. To assess the score on the Psychopathy Checklist-Revised (PCL-R; Hare et al., 1991), two independent raters interviewed each subject with a semi-structured interview according to the PCL-R and completed the given information with the files of the subjects. The affective-interpersonal factor 1 and the antisocial behavior indicating factor 2 were analyzed separately. The maximum score is 16 on factor 1 and 18 on factor 2, and 40 for the total PCL-R score. Psychopathic subjects had a total PCL-R score range from 27 to 35 with a mean of 28.91 and SD of 2.3 (see table 2). Their scoring on factor 1 ranged from 7 to 14 (Mean = 10.3, SD = 2.11) and from 14 to 17 on factor 2 (Mean = 15.3, SD = 0.82). For the psychopathic group a cutoff score of more than 26 total points on the PCL-R was defined.

The same data were collected of each subject in the non-psychopathic criminal control group (see means and SD in figure 2). The mean age of this group was 28.83 years (SD = 3.88, range = 23-36; see figure 2). According to the MWT-B the IQ ranged from 88 to 104 (Mean = 94, SD = 4.9). In the non-psychopathic group, the mean BDI score was 9.67 (SD = 4.21, range = 4-17) and all control subjects were free from clinical depression. Subjects of this control group had a total PCL-R score range from 2 to 15 (Mean = 10.67, SD = 4.44) and a mean of 2.42 on factor 1 (SD = 1.98, range = 0-6) and of 6.83 on factor 2 (SD = 3.54, range = 0-11). For the non-psychopathic criminal control group a cutoff score below 16 total points on the PCL-R was defined.

All 24 subjects of the two groups were right-handed and had a normal or corrected to normal vision. Exclusion criteria were a history of other neurological or psychiatric disorders as well as organic or traumatic head injuries, metallic implants and a total PCL-R score between 16 and 26. These criteria were excluded in all participating subjects.

All 24 subjects were recruited from the Clinic of Forensic Psychiatry of the University Medical Center of Regensburg, Germany. Subjects were informed about the study by a short presentation in a meeting of their ward. All subjects gave written informed consent according to the guidelines of the local Ethics Committee. Regarding their participation and statements, data protection was confirmed. The participation of all subjects was voluntary and they received no payment for it. At request, a printed image of the brain was given to the subject.

Table 2. **Demographic data of the criminal psychopathic individuals.** This table shows age and total PCL-R score of each psychopathic subject. Furthermore, it shows the different scoring of each subject on factor 1 (affective-interpersonal factor) and factor 2 (antisocial factor) of the PCL-R. The scoring on the Beck's Depression Inventory (BDI) is shown to indicate signs of clinical depression. In addition, the IQ was calculated by the scoring on a verbal measure of intelligence (MWT-B).

Subject number	**Age (years)**	**PCL-R total score (max 40)**	**PCL-R factor 1 score (max 16)**	**PCL-R factor 2 score (max 18)**	**BDI**	**IQ**
1	33	28	12	15	18	94
2	24	29	10	16	5	118
3	50	27	11	15	2	100
4	31	29	9	15	9	95
5	22	28	11	16	14	100
6	26	27	8	15	1	94
7	27	28	12	16	9	100
8	30	30	12	15	18	95
9	40	35	14	15	6	97
10	21	27	9	14	18	93
11	26	29	13	17	32	100
12	39	30	7	17	30	107
Mean	30.75	28.91	10.3	15.3	13.5	99.4
SD	8.56	2.3	2.11	0.82	10.15	7.06

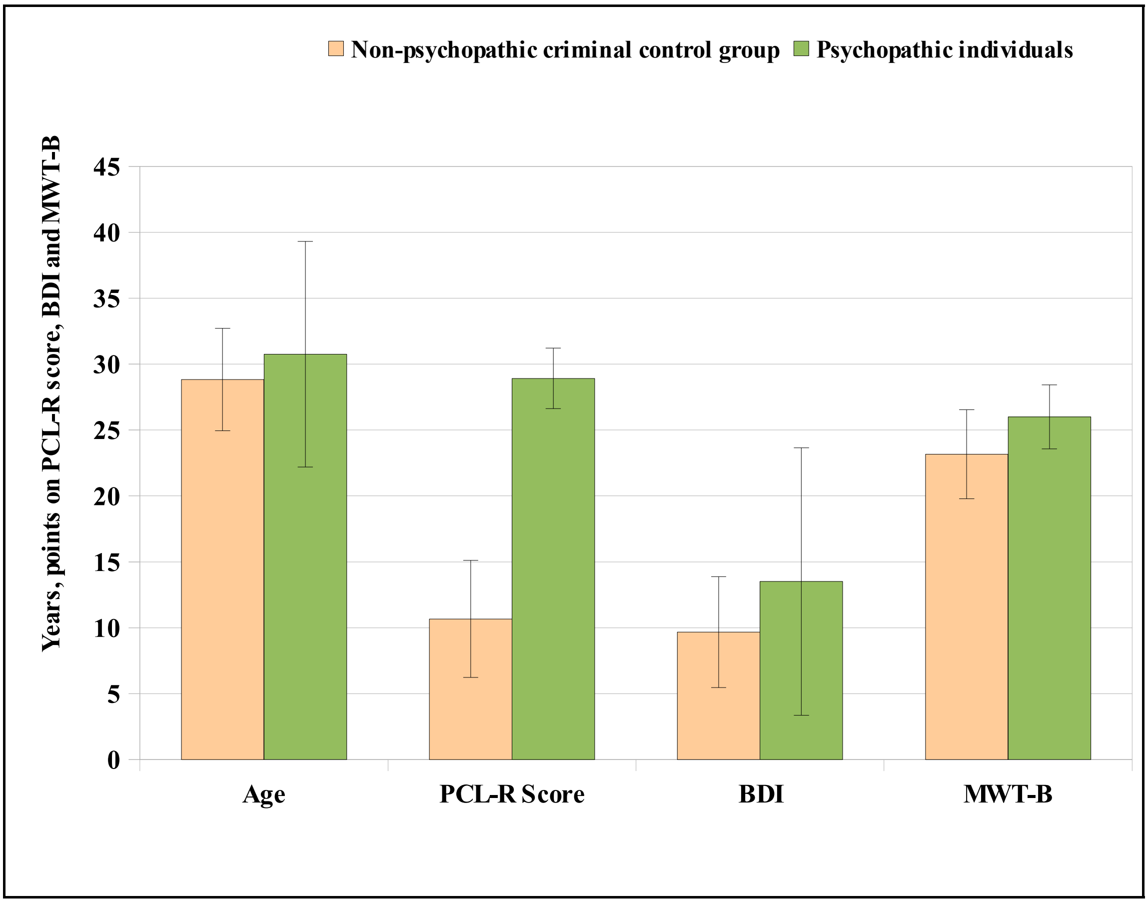

Figure 2. **Comparison of age, total PCL-R scores, BDI and MWT-B between criminal psychopaths and non-psychopathic criminal control subjects.** The bars show age, total score on the Psychopathic Checklist – Revised (PCL-R), Beck's Depression Inventory (BDI) and MWT-B. The MWT-B indicates the IQ. The mean MWT-B score of 23 of the non-psychopathic criminal control group indicates a mean IQ of 94 for this group whereas the mean MWT-B of 26 in the psychopathic group indicates a mean IQ of 97 for the psychopathic group.

3.2 Stimuli

Stimuli consisted of a total of 56 stories that described conflicts with either moral or neutral content. The 28 stories describing a moral conflict (Moral Conflicts condition) required subjects to choose between a moral, socially desired response and a conflicting immoral, personal desire guided response (e.g. helping the elderly lady to pick up her purchases as a socially desired and moral decision or taking the bus home that leaves only every two hours as a personal desire guided decision; see figure 3). The 28 neutral stories without moral content (Neutral Conflicts condition) described conflicts requiring a decision between two conflicting personal desires (e.g. choosing between pasta or pizza in a restaurant).

The course of trial presentation was equal in both conditions. First, the conflict was presented in first-person narrative text form together with the concluding question “What should I do?”. This slide remained on the screen for 15 seconds. To account for differences in average length and reading time between the stories, all conflicts were rated by 23 independent raters. The presentation of the conflict was followed by a slide presentation with the two possible response alternatives depicted in two boxes at the center of the screen. This slide was presented for 5 seconds. Subjects were instructed to press the button not yet but to wait for the presentation of the next slide which displayed the letters “A” above the left response alternative and “B” above the right response alternative on the display. This instruction was important in order to exclude neural activation caused by motor processes. Subjects were instructed to now press one of two buttons of the response pad with their right index and middle finger. If they chose the response alternative presented on the left side of the display and marked with the letter “A”, subjects pressed the left button with their right index finger. For choosing the response alternative presented on the right side of the display and marked with the letter “B”, they pressed the right button of the response pad with their right middle finger. The last slide of each trial consisted of a fixation cross that was presented at the center of the display. The duration of the fixation cross presentation varied randomly between 8 and 12 seconds in order to jitter the trial onset time. A schematic depiction of a trial with respective durations is shown in figure 3.

The presentation of moral and neutral conflicts was in random order. The allocation of the finger to the answer was counterbalanced as well.

Entire scanning time for functional image acquisition was approximately 30 minutes. After the functional T2* image acquisition, a structural image of the subject's brain was obtained, lasting some 7 minutes. So, the entire scanning time for every subject was approximately 37 minutes.

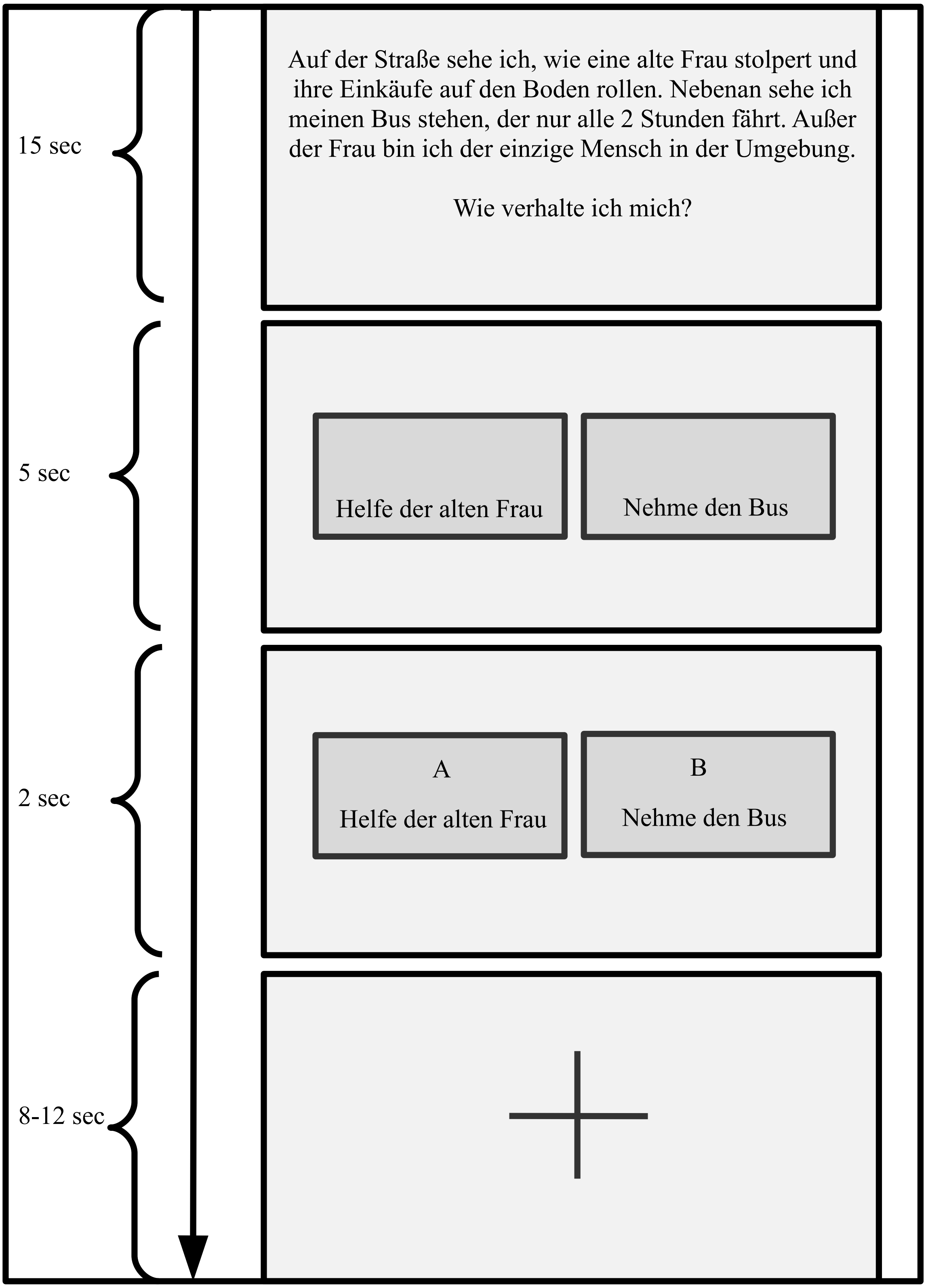

Figure 3. **Schematic depiction of a moral conflict trial with respective durations.** The first slide presented the conflict for a duration of 15 seconds. With the second slide the response alternatives appeared on the screen for 5 seconds. Subjects were instructed to press the response button when the letters “A” and “B” appeared with the third slide that remained on the screen for 2 seconds. After each trial, a fixation cross was presented during a fixation period lasting between 8 and 12 seconds.

3.3 Experimental Design

Subjects came to the MRI room of University Medical Center Regensburg by themselves or were accompanied by clinical staff or security service. After the greeting, subjects were asked again for any contraindications for the fMRI experiment. The course and duration of the experiment was explained to the subjects and any question of the subjects was answered. When subjects had no more doubts and were still willing to participate, they signed a letter of agreement. Then, subjects got standardized instructions and it was emphasized that they should put themselves in the place of the protagonist described in the conflicts and choose the answer they would also choose in real life. Prior to the experiment in the scanner, subjects received a training session on a standard PC outside the scanner that consisted of 4 moral and 4 neutral conflicts. None of these presented training conflicts were used in the subsequent fMRI experiment. In this training session, subjects were instructed to press a button for their decision not until the appearance of the letters “A” and “B” above the response alternatives.

Before subjects entered the MR room, they were asked to remove all metallic objects from their pockets, clothes and bodies. In the MR room, subjects were instructed to sit down on the lie down area of the MR-system and earplugs and headphones were handed to them to protect them from noise. Then they were asked to lie down and to place the head in the correct position where it was fixed with two foam pads to avoid motion. For the same reason, subjects were instructed to move the least as possible during the entire scanning experiment. The response pad was given to the subjects and again they were told which buttons should be pressed by the index and middle finger of the right hand. They were asked to position the right hand with relaxed fingers above the buttons of the response pad close to their right thigh. An alarm button was handed to the subjects which was held with the left hand. It was explained to the subjects to use the alarm button in case of emergency (such as sudden claustrophobia) and that the experiment could be stopped in any moment. Then subjects were positioned in the MR tomograph.

The experiment was generated with Presentation 11.3 software (Neurobehavioral Systems Inc., Albany, CA). Inside the scanner, stimuli were back-projected onto a mirror. The subjects' responses in the scanner were retrieved with LUMItouch optical response device (Photo Control, Burnaby, Canada) and were also recorded with

Presentation 11.3.

Subjects were asked if they were ready for the experiment. None of the subjects expressed any doubts and none of them interrupted the scanning process. Prior to the experiment, an anatomical reference image was obtained. Then the experiment started with the presentation of 56 moral and neutral conflicts presented in random order. After the conflict experiment, subjects were asked to remain relaxed and calm for a subsequent structural image acquisition. When the scanning process finished, subjects were asked to remove the equipment that was handed to them for the experiment, and to get up slowly.

After the scanning experiment, subjects were kindly requested to complete a questionnaire that contained the 56 moral and neutral conflicts presented in the scanner but in a deviating order. They were asked to indicate their responses once again and to evaluate their certainty (how sure they were about the decision) and their emotions (how good they felt with their decision) for each decision. The two latter questions had to be answered by means of a 5-point scale (certainty: 1 = extremely uncertain, 5 = extremely certain; emotion: 1 = extremely bad feeling, 5 = extremely good feeling).

The investigator returned all private items to the subjects, thanked the subjects for their participation and the subjects returned to their wards by themselves or accompanied by clinical staff or security service.

3.4 fMRI Parameters

Functional MRI imaging was recorded with a 3-Tesla Siemens Allegra Head Scanner (Siemens Inc., Erlangen, Germany) located at the University Medical Center Regensburg for measuring the blood-oxygen level-dependent (BOLD) contrast. The scanner acquired echo-planar-imaging (EPI) sequences using fast gradients. During T2* data acquisition, 32 slices were recorded (whole brain; slice thickness = 3mm, no skip) in interleaved order with a Time-to-Repeat (TR) of 2000ms, a Time-to-Echo (TE) of 30ms, a flip angel of 90°, a Field of View (FoV) of 192 x 192 mm and a voxel size of 3 x 3 x 3 mm. A total of 964 functional images were recorded in the entire experiment.

After the T2* data acquisition, a structural image was recorded from every subject. These high-resolution T1-weighted images were obtained using a MPRAGE (Magnetization Prepared Rapid Acquisition Gradient Echo) pulse sequence (TR = 2250ms, TE = 3.93ms, flip angle = 9°, FoV = 256 x 256 mm) scanning 160 axial slices with isotropic voxels of 1 x 1 x 1 mm.

3.5 Statistical Analysis

3.5.1 Analysis of Behavioral Data

The statistical analysis of the behavioral data acquired during the fMRI experiment as well as from the post-scanning questionnaire were processed with SPSS 16 software package (SPSS Corp., Chicago, IL). The non-parametric Wilcoxon-Test was used for the number of moral and immoral answers in the moral conflicts. For analyzing the certainty about the decisions and the emotional reaction during the decision process, paired T-tests were used.

3.5.2 Analysis of Functional Imaging Data

All functional imaging data were preprocessed and analyzed statistically with SPM5 software package (http://www.fil.ion.ucl.ac.uk/spm/software/spm5/) based on Matlab 7.0 software (The Math Works Inc., Natick, MA).

3.5.2.1 Data Preprocessing

The first step of the preprocessing was the transformation from DICOM to NIFTI format. The recording format of functional and structural imaging data in the fMRI was DICOM (Digital Imaging and Communications in Medicine). For further preprocessing and analyzing steps, data had to be transformed into a format that is recognized by SPM5. This format is called NIFTI (Neuroimaging Informatics Technology Initiative).

The second preprocessing step was the slice timing. As the recording of the 32 slices was in an interleaved fashion, which means that slices with an even number were recorded first (in the following order: 1, 3, 5, ...29, 31, 2, 4, ...30, 32), the time difference between the recording of two adjacent slices was ½ of the time-to-repeat (TR). The interleaved measuring has the advantage that slices next to each other do not interfere with each other. The result is a more accurate estimate of the hemodynamic response function. It is necessary to correct the staggered order of image acquisition and to make the data on each slice correspond to the same point in time. This leads to a slightly shift of the original data. So, all 966 image volumes were slice-timed to account for differences in acquisition time. Therefore, the middle slice was used as a reference slice (Henson et al., 1999).

Next, realignment routine was done to account for motion artefacts. For this routine, a time-series of functional images were realigned to a representative reference scan. The first volume of a scan was chosen as the reference scan. In addition, a functional mean image was generated for further use in the following preprocessing steps.

In the coregistration step, this functional mean image was realigned to the subject's structural image. The result is a structural three-dimensional image in order to yield more accurate normalization estimates in the subsequent preprocessing step.

In the next step, functional images were normalized to a standard template brain that represents an average of structural brain images from several subjects that were recorded at the Montreal Neurological Institute (MNI). This normalization routine is necessary for the comparability of all single-subjects in a group analysis.

In the last step, image volumes were smoothed with a Gaussian kernel of a specified width. In the present study a 8 mm full-width half-maximum Gaussian filter was used for smoothing. This routine is used to suppress noise and effects that are due to residual functional and anatomical inter-individual differences.

3.5.2.2 Statistical Analysis of Functional Imaging Data

After the previous preprocessing steps, individual first-level regressors were specified. Regressors represent time intervals that are of particular interest to the study. In the present study, 6 regressors were modelled, three of them in the Moral Conflicts condition and three in the Neutral Conflicts condition. The first regressor of both conditions lasted 15s and covered the duration of the entire conflict presentation on the first slide. The second regressor in every condition comprised the presentation time of the response alternatives on the second slide (5s). And the third regressor in each condition comprised the third slide which showed the response alternatives and the letters “A” and “B” (2s). The appearance of the two letters was the signal for the subjects to press a response button. In addition, 6 more regressors were modelled which included translation and rotation parameters of the subject's movement.

An estimation of the statistical significance on single-subject level for the hereby created model was based on the assumptions of the General Linear Model (GLM) that includes multiple t-tests.

In a first analysis, the first regressor (comprising the conflict presentation) in the Moral Conflicts condition was contrasted to the first regressor in the Neutral Conflicts condition in order to identify brain regions that are associated with everyday moral reasoning. Therefore, activity during conflict and question presentation during the first regressor in the Neutral Conflicts condition was subtracted from the corresponding activity in the Moral Conflicts condition. This contrast was analyzed for both, the psychopathic group and the non-psychopathic criminal control group.

A second analysis of the moral conflict condition was applied, but only for the psychopathic group. The focus of this analysis was to identify brain areas related to immoral decision-making. For this purpose the contrast immoral decision versus moral decision was analyzed only in those psychopathic individual subjects who had decided immorally in at least 30% of the moral conflicts (equal to at least 8 immoral answers out of 28 moral conflicts). Eight of the 12 psychopathic subjects decided at least 30% immorally in the conflicts with moral content. The first-level analysis of this additional analysis corresponded to the first analysis with the exception that the regressor Moral Conflicts was divided into the regressors Immoral Decision and Moral Decision. In order to identify brain activity related to choosing immoral decisions over moral decisions, activity in the Moral Decision was subtracted from the Immoral Decision condition.

After the estimation of both different first-level analyses on single subject level, the results were introduced into two group analyses. A random-effect analysis that accounts for individual functional and anatomical variability among the single subjects was conducted for this purpose.

Significant activation of a brain region was reported if the corrected p-value did not surpass the statistical treshold of $P < 0.05$.

4 RESULTS

4.1 Behavioral Data

4.1.1 Behavioral Data from the fMRI Scanning Experiment

4.1.1.1 Psychopathic Individuals

In the Moral Conflicts condition, the number of given immoral answers varied from only one immoral answer (out of 28 answers) up to 23 immoral answers in the psychopathic group (see table 3). With a mean of 11.08 immoral answers, which is equal to an average of 39.57%, a SD of 6.75 points out the wide span of the quantity of given immoral answers. According to that, the mean number of given moral answers in the Moral Conflict condition within the psychopathic group was 15.92 with a SD of 6.79 (see table 3). So, psychopathic individuals gave 56,86% morally-guided responses. The difference between the average of personal desire-guided immoral answers and the average of morally-guided responses was statistically not significant (Wilcoxon Z = -1.099; p = 0.272, n.s.). Misses in the Moral Conflicts condition occurred with a mean of 2.00 (SD = 0,63).

In the Neutral Conflict condition, psychopathic subjects chose one of the two presented responses with conflicting personal desires in 97 % of all presented neutral conflicts (Mean = 27.17, SD = 1.34). The mean of misses in the Neutral Conflicts condition was 2.5 (SD = 1).

Mean reaction time (RT) when psychopathic subjects chose the immoral and personal desire-guided answer in the Moral Conflict condition was 876.57 ms (SD 341.75 ms). Mean RT when choosing the morally-guided responses was 785.64 ms (SD 153.33 ms). The mean RT in the Neutral Conflicts condition amounted to 688.27 ms (SD 169.87 ms). A detailed description of mean reaction times (RT) and amount of given answers of every psychopathic subject in each condition is shown in table 3.

Table 3. **Number and reaction time of each psychopathic subject in moral, immoral and neutral answers.** This table indicates the number of chosen moral or immoral answers and neutral answers of each subject in the psychopathic group and shows the reaction time (RT) for all types of answers and for every psychopathic subject in the scanner. In the Moral Conflict condition, psychopathic individuals chose the moral answer with a mean of 15.92 (SD = 6,79) and the immoral, personal desire-guided answer with a mean of 11.08 (SD = 6.75).

Subject number	Moral answers		Immoral answers		Neutral answers	
	Number	RT [ms]	Number	RT [ms]	Number	RT [ms]
1	16	699.87	10	84.94	28	666.38
2	14	663.39	11	708.09	25	677.85
3	23	799.89	3	885.37	28	743.90
4	11	1089.77	16	1005.25	25	997.74
5	3	785.53	23	689.68	28	619.25
6	22	875.73	4	765.96	25	440.94
7	21	995.10	7	971.98	28	899.38
8	18	618.70	10	549.39	28	593.89
9	9	763.21	19	648.39	28	594.46
10	16	683.33	12	788.02	28	636.28
11	11	877.91	17	841.76	28	903.15
12	27	575.24	1	1880.00	27	486.07
Mean	15.92	785.64	11.08	876.57	27.17	688.27
SD	6.79	153.33	6.75	341.75	1.34	169.87

4.1.1.2 Non-Psychopathic Criminal Control Group

In the Moral Conflicts condition, non-psychopathic criminal control subjects chose significantly more often moral responses (M = 20.0; SD = 6.9) than responses fulfilling a conflicting immoral personal desire (Mean = 5.72; SD = 4.22; Wilcoxon Z = -2.805; $p \leq 0.005$). Mean miss rate in the Moral Conflicts condition was 4.17 (SD = 7.76). In the Neutral Conflict condition, non-psychopathic criminal control subjects chose one of two presented conflicting personal desires with a mean of 25.73 (SD = 5.9). The mean of misses in the Neutral Conflicts condition was 5.5 (SD = 6.45).

Mean RT when subjects chose the immoral response was 754.52 s (SD = 199.07ms) and 746.03 ms (SD = 175.65 ms) when choosing the morally-guided response. Overall

RT in the Moral Conflicts condition independent of the subject's response choice was 751.82 (SD = 175.04). In the Neutral Conflicts condition, mean RT was 718.31 ms (SD = 166.21).

4.1.1.3 Statistical Comparison Between the Psychopathic and the Non-Psychopathic Criminal Control Group

The amount of immoral and moral decisions in the Moral Conflict condition was compared between the psychopathic and the non-psychopathic criminal control subjects (see figure 4). In the psychopathic group, there was a statistical tendency towards more immoral personal desire-guided decisions compared to the non-psychopathic criminal control group (Mann-Whitney-U: 37.0; p = 0.073). For the amount of moral decisions in the Moral Conflict condition, there was no significant difference between the two groups (Mann-Whitney-U: 40.0; p = 0.109, n.s.).

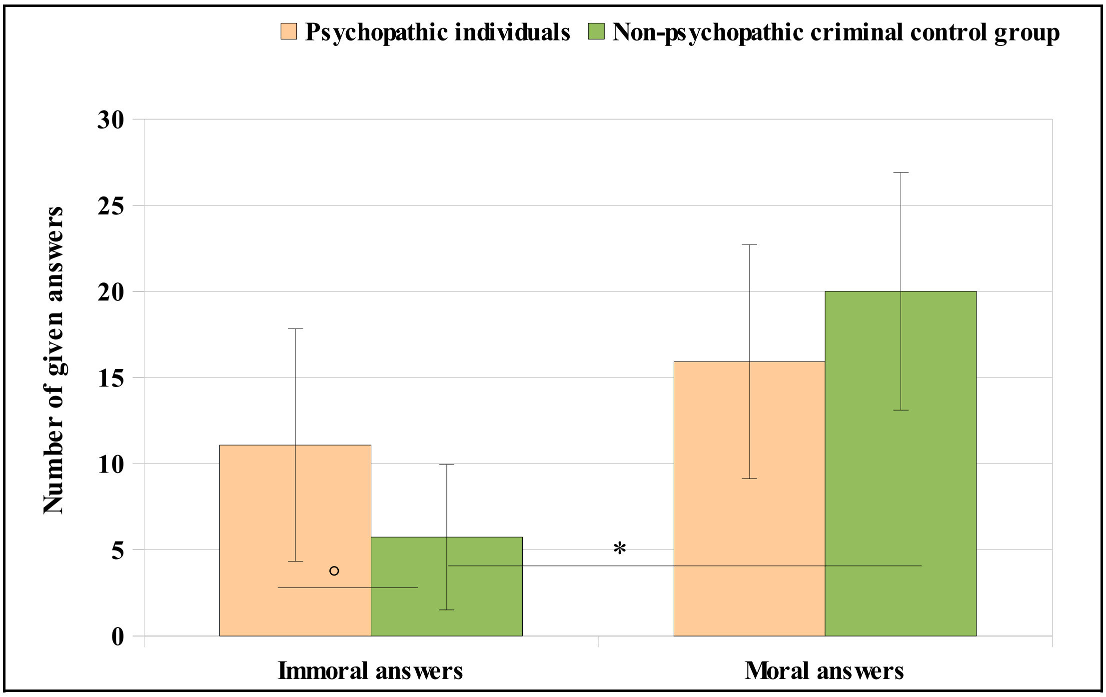

Figure 4. **Behavioral results during scanning.** This figure shows a comparison between the amount of immoral and moral answers in the psychopathic group and in the non-psychopathic criminal control group during scanning. There is a statistical tendency that psychopaths decide immorally more frequently than non-psychopathic criminal control subjects (°). The amount of moral decisions does not differ significantly between the two groups. Whereas non-psychopathic criminal control subjects decide significantly more moral than immoral (*), this difference is not significant in the psychopathic group.

4.1.2 Behavioral Data from the Post-Scanning Questionnaire

The analyses of the post-scanning behavioral data confirmed the response pattern of the scanning procedure and provided further information about the emotions and the certainty of the subjects concerning the decisions they made.

4.1.2.1 Psychopathic Individuals

In the Moral Conflict condition, psychopathic participants chose morally-guided responses with a mean number of M = 15.18 (SD = 5.95) and immoral personal desire-guided decisions with a mean number of M = 12.73 (SD = 5.95; see table 4). The difference was statistically not significant.

A further analysis of the moral conflicts showed that immoral decisions in contrast to morally-guided decisions were associated with significantly lower emotion rating (immoral decisions: M = 3.43; SD = 0.96; moral decisions: M = 4.17; SD = 0.83; $t(344) = 7.7$; $p < 0.001$) and with significantly lower certainty ratings (immoral decisions: M = 3.98; SD = 1.11; moral decisions: M = 4.62; SD = 0.77; $t(344) = 6.3$; $p < 0.001$) (see table 4 and figures 5 and 6).

For the comparison between the Moral Conflicts condition and the Neutral Conflicts condition in psychopaths, a statistical analysis was not done as the Moral Conflicts condition subsumes emotions and certainty for both decisions, moral as well as immoral decisions. Therefore, a statistical analysis of all Moral Conflicts would not be representative. So, a non-statistical comparison for the Moral Conflicts condition and the Neutral Conflicts condition revealed a mean certainty of M = 4.34 (SD = 0.55) in moral situations and a mean certainty of M = 4.38 (SD = 0.48) in the neutral condition. The mean emotion rating in moral situations was M = 3.85 (SD = 0.48) and M = 4.06 (SD = 0.51) in neutral situations.

Table 4 shows the number of given moral, immoral and neutral answers as well as the associated emotion and certainty ratings of each subject in the psychopathic group. The data of subject number 12 are missing, because the patient was transferred to another clinic and therefore, he could not return his questionnaire.

Table 4. **Post-scanning questionnaire data of psychopathic individuals.** This table shows the number of given moral, immoral and neutral answers of each subject. Furthermore, it shows their emotions (E) and certainty (C) which were scored on a 5-point scale from 1 = very bad feeling / very uncertain to 5 = very good feeling / very certain.

Subject number	Moral answers			Immoral answers			Neutral answers		
	Number	E	C	Number	E	C	Number	E	C
1	15	4.13	4.93	12	3.75	4.17	28	4.04	4.43
2	13	4.85	5.00	15	3.13	3.40	28	4.64	4.71
3	24	4.42	4.33	4	3.75	2.25	28	4.36	4.29
4	13	4.08	3,85	15	2.40	3.13	27	3.63	3.37
5	4	5.00	5.00	24	3.96	4.92	28	4.89	4.93
6	22	3.45	4.86	6	2.17	4.50	28	3.25	4.68
7	20	3.55	4.80	8	3.36	4.63	28	4.61	4.79
8	18	4.28	4.00	10	3.90	2.90	28	4.07	3.68
9	9	4.22	4.89	19	3.37	4.16	28	3.71	4.39
10	18	3.61	4.27	10	2.90	2.60	28	3.36	3.89
11	11	4.54	4.82	17	4.06	5.00	28	4.00	4.79
12	-	-	-	-	-	-	-	-	-
Mean	15.18	4.19	4.61	12.73	3.34	3.79	27.91	4.05	4.36
SD	5.95	0.51	0.42	5.95	0.64	0.97	0.3	0.54	0.51

4.1.2.2 Non-Psychopathic Criminal Control Group

In the Moral Conflicts condition, non-psychopathic criminal control subjects chose morally-guided responses with a mean of 20.55 (SD = 5.63) and immoral personal desire-guided decisions with a mean of 7.45 (SD = 5.54).

In a further analysis of the moral conflicts it was shown that immoral decisions in contrast to morally-guided decisions were associated with significantly lower certainty ratings (immoral decisions: M = 4.04; SD = 1.03; moral decisions: M = 4.60; SD = 0.73; $t(331) = 5.52$; $p < 0.001$) and significantly lower emotion rating (immoral decisions: M = 3.02; SD = 1.14; moral decisions: M = 4.41; SD = 0.98; $t(331) = 10.71$; $p < 0.001$; see figures 5 and 6).

The comparison between the Moral Conflicts condition and the Neutral Conflicts condition revealed that non-psychopathic criminal control subjects reported lower certainty during decision-making in moral situations than in neutral situations (moral situations: M = 4.46; SD = 0.38; neutral situations: M = 4.43; SD = 0.37) and lower emotion ratings (moral situations: M = 4.07; SD = 0.60; neutral situations: M = 4.17; SD = 0.44).

4.1.2.3 Statistical Comparison Between the Psychopathic and the Non-Psychopathic Criminal Control Group

The results of the post-scanning behavioral data were statistically compared between both groups, the psychopathic group and the non-psychopathic criminal control group.

When compared to the non-psychopathic criminal control group, in the psychopathic group there was a statistical tendency towards more immoral personal desire-guided decisions (Mann-Whitney-U: 37.0; $p = 0.073$). For the amount of moral decisions in the Moral Conflict condition, there was no significant difference between the two groups (Mann-Whitney-U: 40.0; $p = 0.0109$, n.s.).

Within the Moral Conflicts condition, non-psychopathic criminal subjects reported significantly higher emotion ratings than psychopaths when they chose a morally-guided response (non-psychopathic criminal control subjects: M = 4.41, SD = 0.98; psychopaths: M = 4.17, SD = 0.83; $t(449) = -2.7$; $p < 0.01$). When deciding immorally and personal-desire guided, psychopaths reported significantly higher emotion ratings than non-psychopathic criminal control subjects (psychopaths: M = 3.43, SD = 0.96; non-psychopathic criminal control subjects: M = 3.02, SD = 1.14; $t(226) = 2.85$; $p < 0.01$). Concerning certainty ratings in the Moral Conflict condition, there were no significant differences between non-psychopathic criminal control subjects and psychopaths when choosing a moral option (non-psychopathic criminal control subjects: M = 4.60, SD = 0.73; psychopaths: M = 4.62, SD = 0.77; $t(449) = 0.18$; $p = 0.855$, n.s.) and when choosing the personal desire-guided option (non-psychopathic criminal control subjects: M = 4.04, SD = 1.03; psychopaths: M = 3.98, SD = 1.11; $t(226) = -0.381$; $p = 0.704$, n.s.). Figures 5 and 6 illustrate the differences between both groups concerning emotion and certainty in the post-scanning data comparison.

In the Neutral Conflicts condition, there were no significant differences between both groups concerning emotion ratings (t(22) = 0.527; p = 0.603, n.s.) and certainty ratings (t(22) = 0.323; p = 0.75, n.s.).

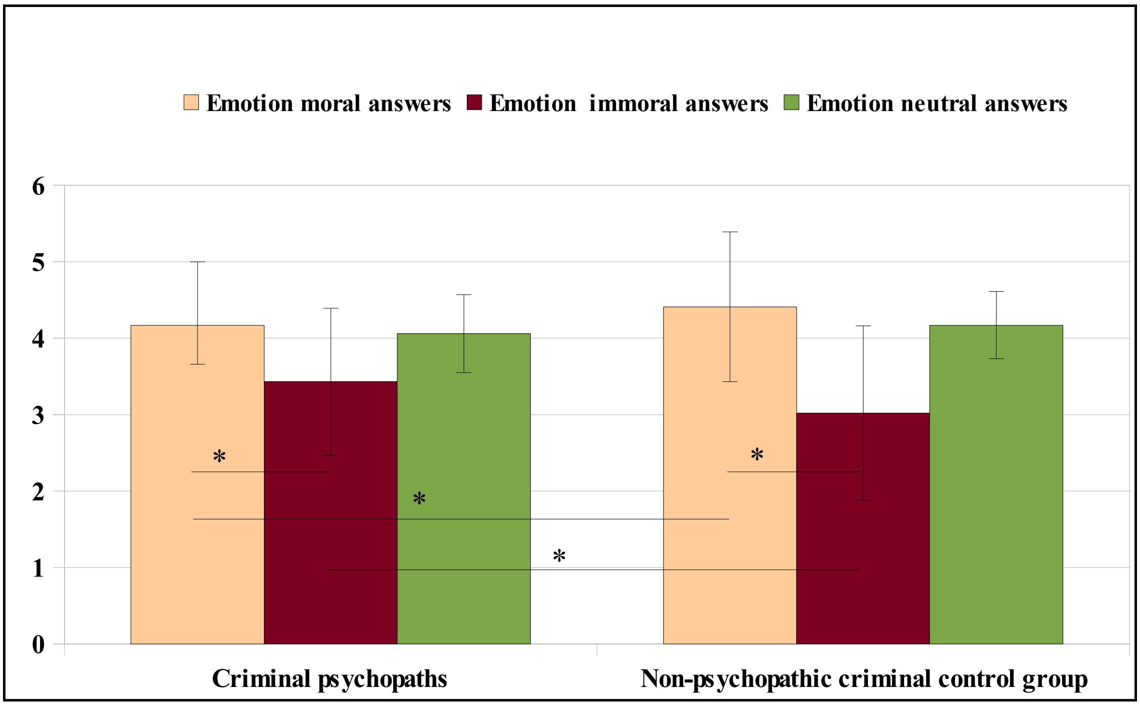

Figure 5. **Post-scanning data comparison of emotion ratings in criminal psychopaths and non-psychopathic criminal control subjects.** This figure shows the differences of emotion ratings when psychopathic inidividuals (left side) and non-psychopathic criminal control subjects (right side) chose morally-guided responses (orange bars), personal desire-guided responses (red bars) and neutral responses (blue bars). In both groups, choosing an immoral option compared to a moral option was associated with significantly lower emotions (*). Compared to psychopaths, non-psychopathic criminal individuals reported significantly higher emotion ratings when choosing a morally-guided response (*). When choosing an immoral decision, psychopaths reported significantly higher emotion ratings than non-psychopathic criminal control subjects (*).

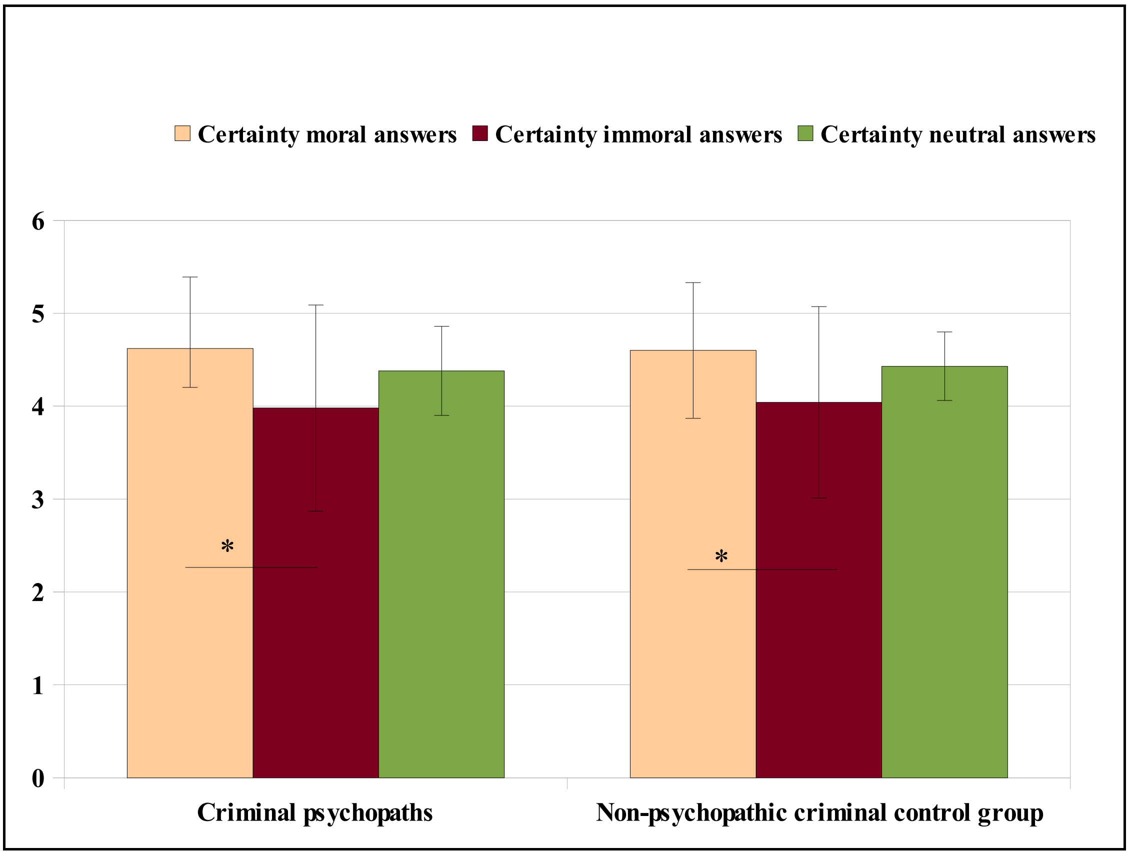

Figure 6. **Post-scanning data comparison of certainty ratings in criminal psychopaths and non-psychopathic criminal control subjects.** This figure shows the differences of certainty ratings when psychopathic (left side) and non-psychopathic criminal control subjects (right side) chose morally-guided responses (orange bars), personal desire-guided responses (red bars) and neutral responses (blue bars). In both groups, choosing an immoral option compared to a moral option was associated with significantly lower certainty (*).

4.2 Functional Imaging Data

4.2.1 Contrast Moral > Neutral

In the contrast Moral > Neutral, activity during conflict and question presentation in the Neutral Conflicts condition was subtracted from the corresponding activity in the Moral Conflicts condition in order to reveal brain regions that are dedicated to everyday moral reasoning. This contrast was analyzed for psychopathic individuals and for non-psychopathic criminal control subjects.

4.2.1.1 Psychopathic Individuals

Psychopathic individuals showed significant activation in the moral > neutral contrast in the medial and superior frontal gyrus bilaterally (BA 9/10/11), in the superior temporal gyrus bilaterally and the supramarginal gyrus bilaterally (BA 39/40), in the left-sided middle temporal gyrus (BA 21), in the right posterior cingulate (BA 31), bilaterally in the cingulate gyrus (BA 31) and in the precuneus (BA 7; see table 5). Figure 7 illustrates the activation of the contrast moral > neutral in psychopaths.

Table 5. **Brain regions with significantly increased activation in psychopathic individuals in the moral > neutral condition.** 12 psychopathic individuals, T = 4, voxel size: 2 x 2 x 2 mm

Region	Brodmann Area (BA)	Center MNI coordinates in mm			Z-score	Voxels (n)
		x	y	z		
M > N						
Posterior cingulate (R) Cingulate Gyrus (L/R) Precuneus	7/31	4	-58	34	5.14	1170
Medial Frontal Gyrus (L/R) Superior Frontal Gyrus (L/R)	9/10	-2	58	34	4.43	690
Superior Temporal Gyrus (L) Supramarginal Gyrus (L)	39	-50	-60	28	4.84	611
Superior Temporal Gyrus (R) Supramarginal Gyrus (R)	39/40	54	-52	22	4.18	331
Middle Temporal Gyrus (L)	21	-62	-12	-12	4.40	195
Medial Frontal Gyrus (L/R)	11	4	58	-16	4.23	123

Clusters with p (corrected) < 0.05 are listed. x, y, z are coordinates according to MNI system. L, left; R, right.

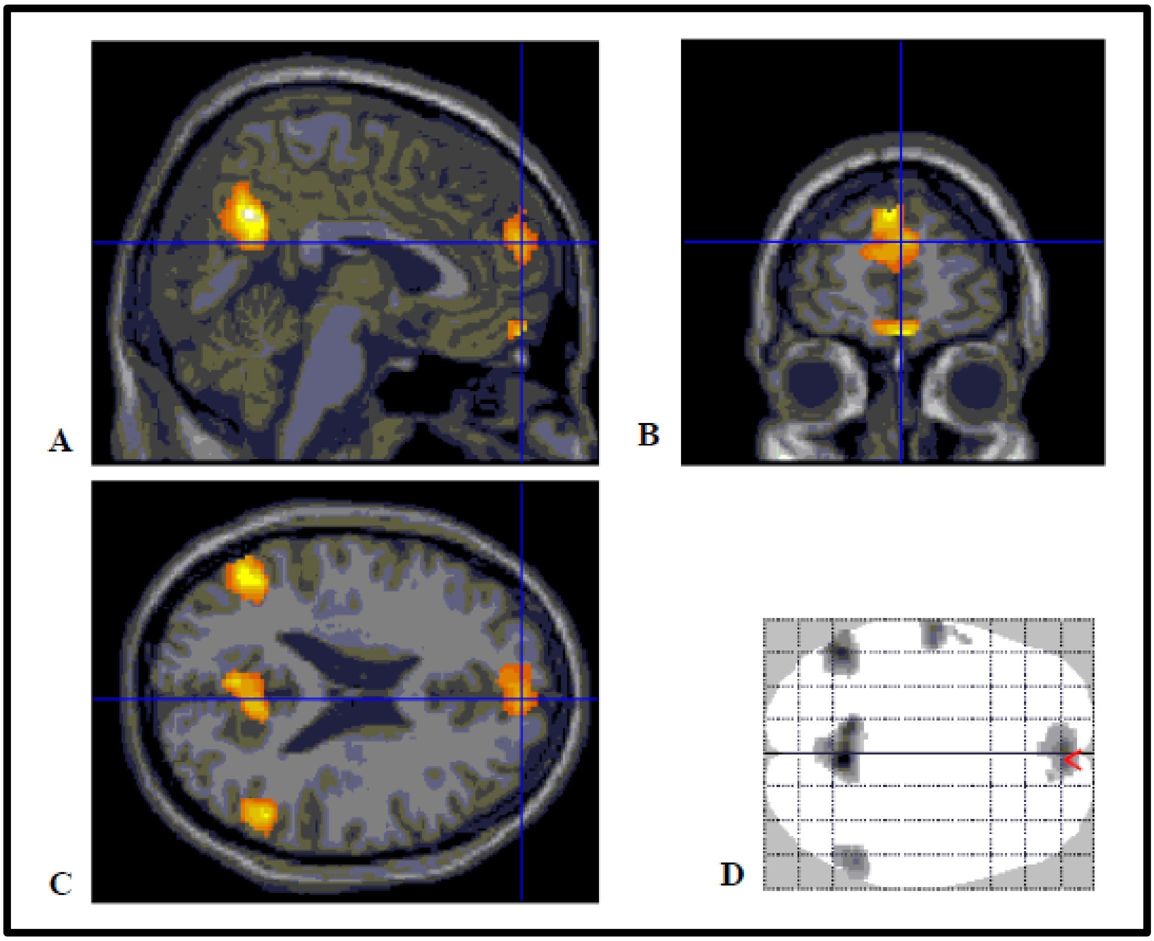

Figure 7. **A-D: Significant brain activity in psychopaths in the moral > neutral contrast on a sectional view at MNI coordinates x = 4, y = 58 and z = 22.** The figure shows different brain areas that activated significantly in the moral > neutral contrast in a moral conflict decision-making task in criminal psychopaths. Significant activated areas are shown in yellow/orange color. **A:** Significant brain activation in the posterior cingulate, the cingulate gyrus and the precuneus and in the medial and superior frontal gyrus and in the medial frontal gyrus bilaterally. **B:** Significant brain activation in the medial and superior frontal gyrus bilaterally. **C:** Significant brain activation in the left superior temporal gyrus and supramarginal gyrus and in the right superior temporal gyrus und supramarginal gyrus as well as in the posterior cingulate, cingulate gyrus and precuneus region and in the medial and superior frontal gyrus. **D:** Glass brain showing significant activation in the aforementioned areas plus in the left middle temporal gyrus.

4.2.1.2 Non-Psychopathic Criminal Control Subjects

In order to reveal brain regions that are involved in everyday moral reasoning in non-psychopathic criminal control subjects, the contrast Moral > Neutral was analyzed. In the control group, this contrast highlighted significant activations in the medial and superior frontal gyrus (BA 6/9/10), the inferior and middle temporal gyrus bilaterally (BA 20/21), the right superior temporal gyrus (BA 22/38), the supramarginal gyrus and the left angular gyrus (BA 39/40), the cingulate gyrus bilaterally (BA 31), the posterior cingulate (BA 31), the precuneus bilaterally (BA 7) and the right cuneus (BA 18) (see table 6). The activation of this contrast is illustrated in figure 8.

Table 6. **Brain areas with significantly increased activation in the non-psychopathic criminal control group in the moral > neutral contrast.** 12 non-psychopathic criminal individuals, T = 4, voxel size: 2 x 2 x 2 mm

Region	**Brodmann Area (BA)**	**Center MNI coordinates in mm**			**Voxels (n)**
		x	**y**	**z**	
M > N					
Cingulate Gyrus (L/R)	31	-4	-46	38	1138
Precuneus (L/R)	7				
Superior Temporal Gyrus (R)	22/38	64	-12	-8	896
Inferior Temporal Gyrus (R)	20				
Middle Temporal Gyrus (R)	21				
Superior Frontal Gyrus (R)	9	6	58	12	700
Medial Frontal Gyrus (L/R)	10				
Middle Temporal Gyrus (L)	21	-62	-58	20	611
Supramarginal Gyrus, Angular Gyrus (L)	39/40				
Superior Frontal Gyrus (L)	6	-4	12	74	154
Middle Temporal Gyrus (L)	21	-52	-10	-16	153
Inferior Temporal Gyrus (L)	20				
Cuneus (R)	18	98	4	-60	98
Posterior Cingulate (L/R)	31				

Clusters with p (corrected) < 0.05 are listed. x, y, z are coordinates according to MNI system. L, left; R, right.

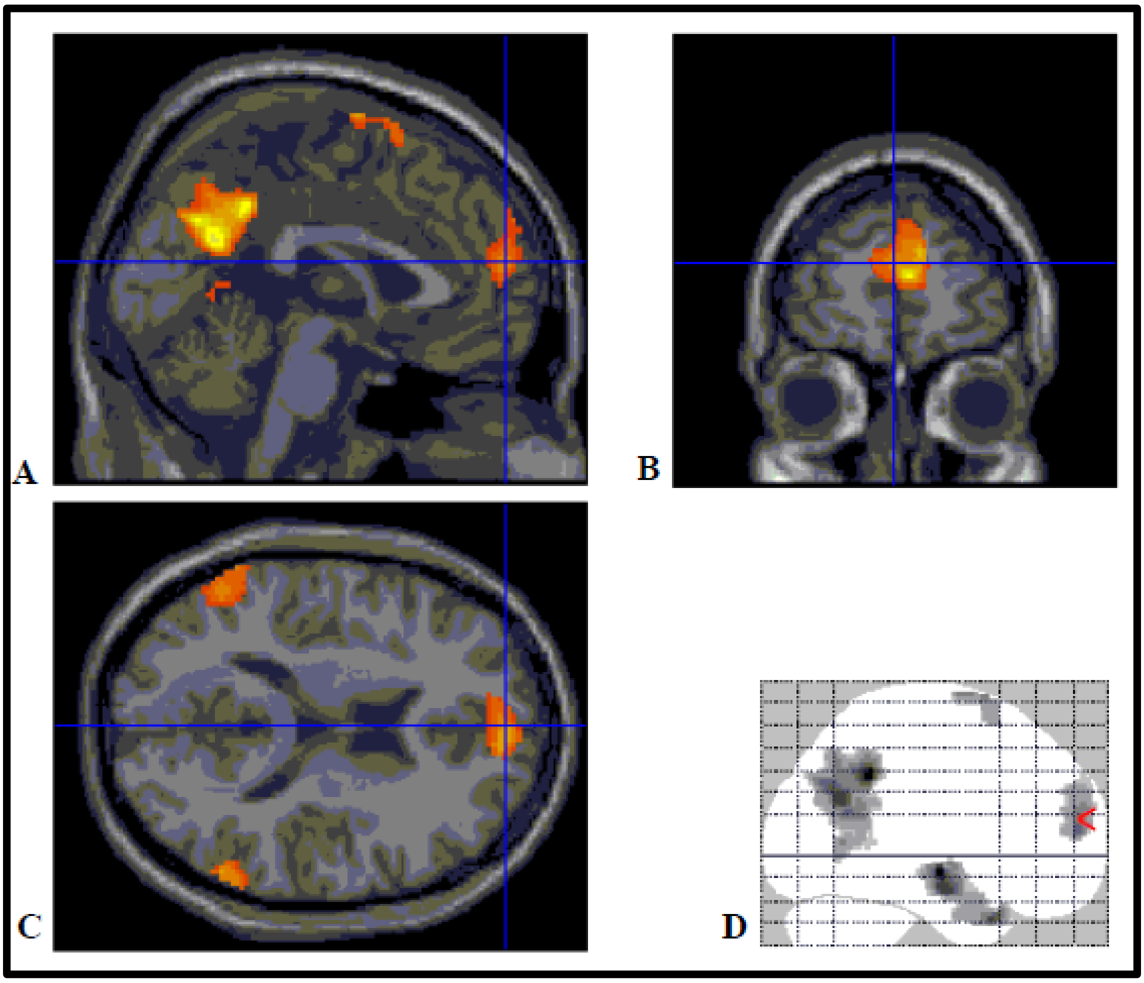

Figure 8. **A-D: Significant brain activity in the non-psychopathic criminal control group in the moral > neutral contrast on a sectional view at MNI coordinates x = 4, y = 58 and z = 16.** Brain areas that showed significantly increased activation in the moral condition compared to the neutral condition in non-psychopathic criminal control subjects are shown in orange color. **A:** Significant brain activation in the medial and superior frontal gyrus bilaterally, in the left superior frontal gyrus, in the cingulate gyrus and precuneus region bilaterally and in the cuneus and posterior cingulate gyrus bilaterally **B:** Significant brain activation in the medial and superior frontal gyrus bilaterally. **C:** Significant brain activation in the right superior temporal gyrus and in the left supramarginal and angular gyrus as well as in the medial and superior frontal gyrus. **D:** Glass brain showing significant activation in the medial and superior frontal gyrus (BA 9/10), in the superior frontal gyrus (around BA 6), in the superior temporal and supramarginal gyrus as well as in the middle temporal gyrus and temporal pole.

4.2.2 Contrast Immoral > Moral in Psychopathic Individuals

In addition to the analysis of brain regions that are associated with moral > neutral conflicts in psychopaths, moral conflicts were investigated in more detail by a second analysis of the moral conflict condition. In this analysis, activity in the moral decision condition was subtracted from activity in the immoral decision condition. The aim of this analysis was to identify brain activity related to deciding personally-guided versus deciding morally-guided in an everyday moral conflict.

The contrast immoral > moral answers was calculated with eight of the twelve psychopathic subjects who showed a response pattern of at least 30% immoral decisions in the moral conflict condition. In contrast to morally-guided responses, immoral responses induced significantly more activation in the medial frontal gyrus bilaterally and in the cingulate gyrus bilaterally (Brodmann Areas 6/24) (see table 7). The activation of this contrast is illustrated in figure 9.

***Table 7.* Brain areas with significantly increased activation in psychopathic individuals in the contrast immoral > moral.** 8 psychopathic individuals, T = 4, voxel size: 2 x 2 x 2 mm

Region	Brodmann Area (BA)	Center MNI coordinates in mm			Z-score	Voxels (n)
		x	y	z		
M_im > M_m						
Medial Frontal Gyrus (L/R) Cingulate Gyrus (L/R)	6/24	4	-28	60	3.62	861

Clusters with p (corrected) < 0.05 are listed. x, y, z are coordinates according to MNI system. L, left; R, right.

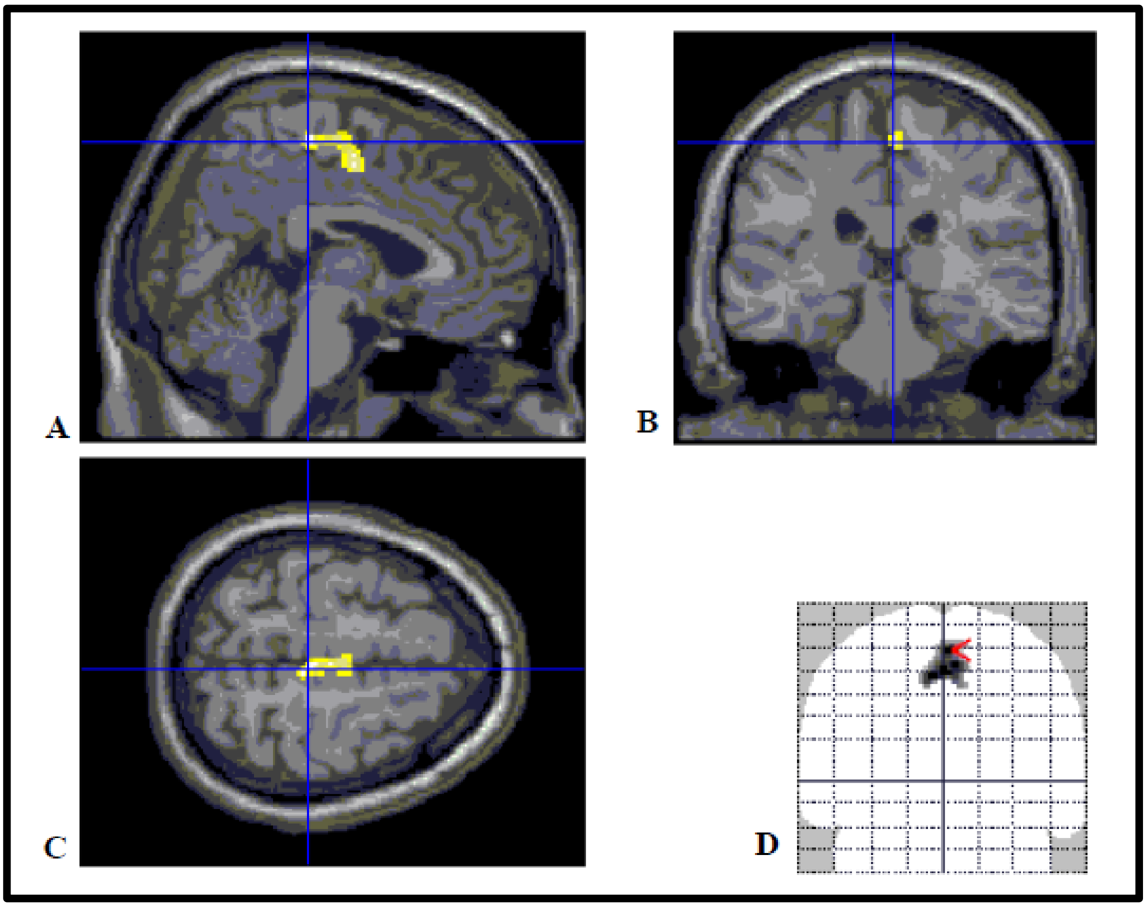

Figure 9. **A-D: This image depicts a sectional view of significant brain activity in the immoral > moral contrast in psychopaths at MNI coordiantes x = 4, y = -28 and z = 60.** This figure shows brain areas with significant activation in the immoral condition when compared to the moral condition in psychopaths. The significant activated areas are shown in yellow color. **A-C:** Significant brain activation bilaterally in the medial frontal gyrus and cingulate gyrus. **D:** Glass brain showing significant activation in the aforementioned areas.

4.2.3 Descriptive Comparison of the Imaging Data of Psychopathic Individuals and the Non-Psychopathic Criminal Control Group

A comparison of activated brain areas in the moral > neutral contrast between psychopaths and non-psychopathic criminal control subjects was only possible on a descriptive but not on a statistical level because of the wide range of given immoral/moral answers within the psychopathic group (moral answers: M = 15.92, SD = 6.79; immoral answers: M = 11.08, SD = 6.75).

On descriptive level, non-psychopathic criminal control subjects showed increased activation in the (middle) temporal lobe (BA 20/21) bilaterally. In contrast, psychopaths showed activation in the left middle temporal lobe, but not in the right. Furthermore, in the non-psychopathic criminal control group brain activation was revealed in the superior frontal gyrus (BA 6) and in the Cuneus area (BA 18), whereas in psychopaths there is no activation in these areas. On the other hand, criminal psychopaths showed activation in the orbitofrontal cortex bilaterally (BA 10/11), whereas non-psychopathic criminal control subjects activation was shown only in the medial and superior frontal gyrus (BA 9/10). Figure 10 illustrates the descriptive comparison between psychopaths and non-psychopathic criminal control subjects in the moral > neutral contrast.

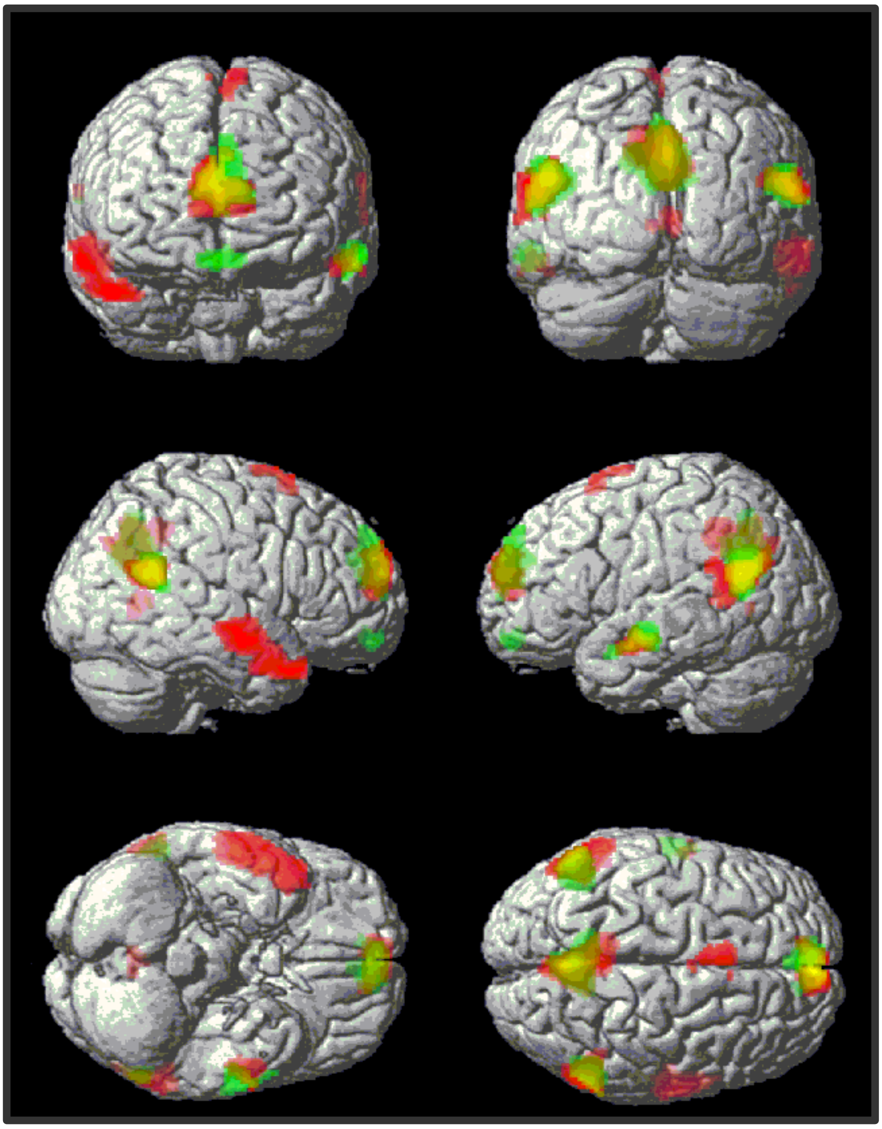

Figure 10. **Descriptive comparison of brain areas with increased activation in psychopaths (green) compared to non-psychopathic criminal control subjects (red).** Obvious differences between the activations of the two groups can be seen in the right (middle) temporal lobe (BA 20/21) which shows high activation in the non-psychopathic control group whereas there is no activation in the psychopathic group. High activation in the non-psychopathic control group is furthermore in the superior frontal gyrus (BA 6) and in the Cuneus area (BA 18) which is lacking in the psychopathic group. Psychopaths show activation in the orbitofrontal cortex (BA 11), but criminal non-psychopaths do not.

5 DISCUSSION

As already mentioned in the theoretical part of this thesis, moral decision-making processes and the corresponding neural correlates in healthy individuals have become an active area of functional neuroimaging research. Several studies investigated simple moral judgments and moral dilemmas in order to reveal brain areas associated with moral decision-making. These studies showed that a variety of brain areas located in frontal, parietal, temporal and limbic cortices are involved in moral reasoning. Specific brain areas that are associated with increased activity in studies with moral decisions are the medial frontal gyrus, the orbitofrontal gyrus, the precuneus and the posterior cingulate cortex, the superior temporal sulcus and temporo-parietal junction, the temporal poles, and the amygdala (Greene et al., 2001; Greene & Haidt, 2002; Moll et al., 2001; Moll et al., 2002a; Moll et al., 2002b). Whereas many studies investigated moral reasoning processes in healthy subjects, moral reasoning in psychopathic individuals is poorly understood. Most of the studies that investigated psychopaths in structural and functional imaging studies concentrated on judgments about moral dilemmas and emotion processing. These studies revealed that several brain regions within a fronto-temporo-limbic network showed deficient activation in functional studies or reduced volumes in structural studies. Specific brain regions that showed impaired activation in psychopathic individuals are the prefrontal cortex, especially the orbitofrontal cortex, the cingulate gyrus, and the superior temporal gyrus, as well as the amygdala (Glenn et al., 2009; Kiehl et al., 2001; Kiehl et al., 2004; Müller et al., 2003; Müller et al., 2008; Oliveira-Souza et al., 2008; Raine et al., 2000; Yang et al., 2005a; Yang et al., 2005b). But none of these studies used realistic everyday moral conflicts in order to reveal the neural correlates of decision-making in everyday situations.

The present study attempts to close this gap by investigating the neural underpinnings of moral decision-making in realistic everyday moral conflicts in psychopaths. Therefore, stories describing morally relevant or neutral (morally irrelevant) situations were presented to psychopathic individuals. In the moral conflicts condition, subjects had to choose between a morally-guided response and a personal desire-guided (immoral) response. In the neutral conflict condition, subjects had to choose between two conflicting personal desires. After the experiment in the scanner, subjects had to indicate their emotion and certainty for each decision they made. The imaging and behavioral results from criminal psychopaths were compared to those from a non-psychopathic criminal control group in order to highlight differences between the two groups and to provide higher informative value about the interpretation of the results revealed in psychopaths.

Before discussing the results from this study in more detail, the main findings will briefly be summarized here.

On behavioral level, there was a statistical tendency towards more immoral decisions in the psychopathic group when compared to the non-psychopathic criminal control group and psychopaths reported significantly higher emotion ratings than non-psychopathic criminal control subjects when deciding immorally.

In order to identify brain regions involved in everyday moral decision-making in psychopaths, activity during conflict and question presentation in the neutral conflicts condition was subtracted from the corresponding activity in the moral conflicts condition. In psychopathic individuals, this contrast revealed activity in bilateral medial and superior frontal areas (BA 9/10/11), bilateral superior temporal and supramarginal gyrus (BA 39), left middle temporal gyrus (BA 21), and the posterior cingulate and precuneus region (BA 7/31). These findings were compared on descriptive level to the brain areas that showed activation in the same contrast in non-psychopathic criminal control subjects. In this comparison, the orbitofrontal cortex (BA 11) showed activation in psychopaths but not in control subjects. No activation was found in psychopaths in the right middle temporal lobe (BA 20/21), the superior frontal gyrus (BA 6) and the cuneus area (BA 18) when compared to non-psychopathic criminal control subjects.

In addition to the moral > neutral contrast and in order to identify brain activity related to choosing immoral responses over moral responses, the moral conflict condition was analyzed in more detail, and activity in the moral decision condition was subtracted from activity in the immoral decision condition. In psychopaths, immoral responses induced more activity in the medial frontal gyrus bilaterally and in the cingulate gyrus bilaterally (BA 6/24) when compared to moral decisions.

The following discussion is divided into two main parts. In the first part, behavioral data will be described and commented. Functional imaging data of psychopathic individuals and non-psychopathic criminal control subjects is going to be described and discussed in the second part. Finally, a short summary of the present discussion and a short outlook for future research is given.

5.1 Behavioral data

5.1.1 Behavioral Data from the fMRI Scanning Experiment of Psychopathic Individuals

During the fMRI scanning experiment, psychopathic individuals were presented with realistic conflicts that contained either a moral or a neutral conflict. In the moral conflicts, the subject had to choose between a personal desire and a conflicting moral standard. In the neutral conflicts, a decision between two morally irrelevant but conflicting personal desires was required.

In the following part, two interesting results of the statistical analysis of the behavioral data during the scanning experiment are going to be discussed. First, psychopaths chose the immoral decision within the moral conflicts in a relatively high number. The possible reasons for this result as well as the peculiarity of realistic moral conflicts as they were used in this study are going to be explained. And second, the fact that within the psychopathic group there was a wide span of given moral or immoral answers questions the existence of the prototypical psychopath and emphasizes the heterogeneity within a group of psychopathic individuals.

In order to explain the relatively high number of chosen immoral decisions by psychopaths (average of 39.57% compared to an average of 56.86% of chosen moral answers) the differences between realistic moral conflicts as they were presented in the present study and moral dilemmas as used in previous functional imaging studies are going to be pointed out.

The main characteristics of moral dilemmas are that, first, all possible choices have morally undesirable outcomes and second, moral dilemmas are not very realistic and not representable for everyday life conflicts. An example for a moral dilemma is the trolley dilemma where a runaway trolley is headed for five people who will be killed if the trolley proceeds on its present course. The two possible choices of this dilemma are: to hit a switch that will turn the trolley onto an alternate set of tracks where it will kill one person instead of five or to let the trolley continue on its present course where it will kill five people (Thomson, 1985). Both outcomes are morally undesirable as in each case people will die. Besides the undesirable outcomes, moral dilemmas are characterized by their lack of reality which makes them not reproducible for everyday moral situations.

In contrast to this are everyday moral conflicts as used in the present study. In these realistic conflicts, a choice is required between a hedonistic, personal desire-guided, but not illegal, decision on the one hand and the fulfillment of a moral obligation towards another person on the other hand. For example, when I run to the bus station to catch the waiting bus home, I see an old lady who stumbled and needs help. Would I fulfil my moral obligation towards the lady and help her to pick up her purchases? Even though I had a long working day and I would have to wait two more hours for my next bus home? Or would I fulfil my personal desire and take the bus home? Choosing the latter, immoral decision would lead to a personal advantage – in this case, getting the bus home instead of waiting two more hours after a long working day. But, fulfilling the personal desire may also result in self-reproach, shame and unpleasant emotions about the own egoistic behavior. But, the resulting disadvantage for another person, in this case the old lady, is not that serious compared to the outcomes of a moral dilemma. In a moral conflict nobody will get into a life-threatening situation when choosing the immoral decision. As a consequence, choosing the personal desire-guided decision would not have any legal consequences. Choosing the morally-guided decision instead, would be a fulfillment of the socially-desired and socially-required way of behaving. In this case, the personal desire would be inhibited in order to fulfill a moral obligation. The personal consequence of choosing the moral decision would be a personal discomfort, for example waiting to more hours for the bus.

In contrast to moral dilemmas, realistic moral conflicts allow a supposition about the behavior of psychopaths in moral conflicts in real life. It seems that in the present study, psychopaths answered very frankly due to the certainty about not being punished neither in the study nor in real life for choosing an immoral option. Based on this more or less honest behavior of the psychopaths in the present study, it can be concluded that psychopaths, in real life, would behave similar in case of experiencing such a moral conflict. Maybe the imagination of a psychopath as an individual fulfilling moral norms and standards sounds a little bit strange. But an explanation for their “moral” behavior or decision-making could be that in most of the presented conflicts the moral option consisted in a short-time action or behavior of the subject, e.g. to take care for the neighbor's son for a few hours or to offer the seat in the train to an elderly lady. In none of these cases the psychopath needs to accept deeper interpersonal connections. He can keep up his superficial charm instead and maybe he can even increase his grandiose sense of self-worth. Concluding, it can be said that whereas psychopaths are often arrested due to their enormous aggressive potential in combination with emotional detachment that characterizes their offenses, they may not attract any attention in everyday life in simple moral conflicting situations. Additionally, it has to be pointed out that it is difficult to make reliable statements about the behavior of psychopaths in real life as the moral conflicts presented in this study are constructed cases that lack a comparable match sample.

In addition to the way how psychopaths decide and behave in a moral conflict, the behavioral data analysis of the present study provides further information about the inhomogeneity within the group of psychopaths. Whereas one psychopathic subject chose the personal desire-guided decision only once out of 28 conflicts, another subject chose the immoral decision 23 times out of 28. This represents the influence of each psychopathic individual and leads to a very inhomogeneous group of psychopaths. Of course, all of the participating psychopathic individuals scored high on the Psychopathy Checklist-Revised but it has to be considered that not all of them reached high scores on both factors. They all had high scores on the antisocial factor, but on the affective-interpersonal factor subsuming for example pathological lying, lack of empathy and guilt or failure to accept responsibility, not all of the psychopathic subject reached high scores. Keeping in mind this differences within a group of psychopaths, the question for the prototypical psychopath gets some more aspects. Nevertheless, within a collective of psychopaths, the prototype of a psychopath fulfilling all characteristics and scoring on each criterion exists. But most of the patients diagnosed with psychopathy have to be investigated in more detail to find out their specific problems in order to adapt further therapy procedures to their grade of emotional detachment and to their affective and interpersonal ability for cooperation, and not only to their aggressive and impulsive behavior.

In sum, the moral conflicts presented in the present study were suitable for detecting the decisions of psychopathic individuals in the study and allowed to make assumptions for the behavior of psychopaths in everyday life. Furthermore, the behavioral results emphasize the individuality of each human being – of a non-psychopathic individual as well as of a psychopath.

5.1.2 Behavioral Data from the fMRI Scanning Experiment Compared between Psychopathic Individuals and Non-Psychopathic Criminal Control Subjects

In order to reveal differences between psychopaths and non-psychopathic criminal control subjects, the behavioral data of both groups acquired during the scanning experiment was statistically compared. In the psychopathic group, a statistical tendency to more immoral and personal desire-guided decisions was revealed when compared to the non-psychopathic criminal control subjects.

In the following, the meaning of this result is going to be discussed. Therefore, it is helpful to define the characteristics of psychopaths on the one hand and of non-psychopathic criminal control subjects on the other hand. An individual that is diagnosed with psychopathy reaches a high score on the Psychopathy Checklist-Revised (PCL-R). The score consists of two factors: one factor that subsumes affective-interpersonal personality traits such as pathological lying, lack of remorse or empathy and superficial charm and a second factor that includes items describing an antisocial, impulsive and delinquent personality. The non-psychopathic criminal control subjects tested in this study differ from psychopaths in their lower total scoring that is mainly due to a very low score on the affective-interpersonal factor. So, whereas both, psychopaths and non-psychopathic criminal control subjects are characterized by their high grade of aggressive and antisocial behavior, only psychopaths are additionally defined as affected on emotional level.

As a conclusion from the just mentioned differences between psychopaths and non-psychopathic criminal control subjects, the tendency to choose more immoral answers revealed in psychopaths can be explained by an impairment of affective and emotional behavior in psychopaths compared to the non-psychopathic criminal control subjects. Considering this aspect from the point of view that for intact moral reasoning and decision-making both emotion and reasoning are important, the tendency for immoral behavior in psychopaths could be a consequence from an impaired emotional mechanism in their moral reasoning processing.

5.1.3 Post-Scanning Questionnaire Data of Psychopathic Individuals

In order to provide further information about the emotions and the certainty that were experienced by the psychopathic subjects when deciding in a moral conflict, a further analysis of the moral conflicts showed that in contrast to morally-guided behavior, personal desire-guided immoral behavior was associated with significantly lower certainty and emotion ratings. This means that psychopaths when choosing a morally-guided decision felt better and more certain than when choosing a personal desire-guided decision. But can it therefore be concluded that psychopaths, who are characterized by an emotional deficient behavior, experience unpleasant emotions or even some kind of "bad conscience" when deciding immorally? Of course, this is not impossible. In spite of the characteristic features such as lack of guilt and empathy, shallow affect and pathological lying, the psychopath is still a human being equipped with human qualities. In addition, psychopaths are, as already mentioned, a very inhomogeneous group and therefore it is not totally unthinkable that within this group some individuals may really experience unpleasant emotions in terms of a bad conscience.

But, an explanation that seems to be more possible and true than a more or less intact bad conscience in psychopaths, is that when choosing an immoral decision, psychopaths know that this decision is socially not desired. Therefore their emotions concerning this decision are lower and they feel more uncertain about this decision. But finally, they do not care about these emotions and the uncertainty and decide the way they would have decided anyways, without respecting social norms and knowing that they chose the "bad" alternative of the decision. Therefore, it can be concluded that psychopaths know what is socially desired and what is against social standards, but they simply do not care about such knowledge and the consequences that ensue from their immoral behavior. Thus, their resulting behavior may also be characterized by the influence of unpleasant emotions.

5.1.4 Post-Scanning Questionnaire Data Comparison between Psychopathic Individuals and Non-Psychopathic Criminal Control Subjects

The post-scanning questionnaire data of psychopaths was statistically compared to the data of non-psychopathic criminal control subjects in order to point out differences on behavioral level between the two groups. For this comparison it was hypothesized that psychopaths would indicate higher emotion and certainty ratings (better feelings and more certainty) when deciding immorally compared to non-psychopathic criminal control subjects. In the moral condition, higher emotion ratings were revealed in psychopaths compared to criminal non-psychopaths when choosing the moral decision and when choosing the personal desire-guided immoral option. For the certainty ratings, the hypothesis was not confirmed as no significant differences were revealed.

In the following part, the results of this comparison between the two groups and especially their meaning for the behavior of psychopaths are going to be interpreted and discussed briefly. The interesting outcome of this statistical analysis is that psychopaths did not feel as emotionally affected as the non-psychopathic criminal control group when choosing an immoral decision. So, the main behavioral difference between the two groups which is the emotional detachment of the psychopathic group, is also reflected in this result that indicates the relatively lower involvement of emotions in the decision-making process in psychopaths.

In addition to the aforementioned hypothesis that psychopaths know the differences between socially desired and non-desired behaviors in moral conflicts, it can be concluded that psychopaths do not care about their immoral or moral decision-making as they are emotionally impaired and do not feel unpleasant emotions or rather they are not inhibited in their immoral decision-making process by a “bad conscience”.

5.2 Functional Imaging Data

5.2.1 Contrast Moral > Neutral in Criminal Psychopathic Individuals

In order to investigate the neural underpinnings of everyday moral decision-making in psychopaths, 12 psychopathic individuals were presented with realistic moral conflicts with either moral or neutral content. In the moral conflicts condition, subjects had to decide between a morally-guided response and a personal desire-guided immoral response. The activity in the neutral conflicts condition was subtracted from the corresponding activity in the moral conflicts condition in order to identify brain areas associated with everyday moral reasoning in psychopaths.

For this contrast, it was hypothesized that realistic everyday moral conflicts would evoke activity in brain areas that are known to show activation in simple moral judgment or moral dilemma tasks. Furthermore, it was hypothesized that psychopaths would show a similar pattern of activation as healthy individuals when processing moral decision-making tasks. Previous studies investigated judgments about simple moral claims or moral dilemmas in healthy individuals and revealed brain areas such as the medial and orbitofrontal gyrus, the superior temporal sulcus (TPJ), the precuneus and the cingulate cortex region (Greene et al., 2001; Greene & Haidt, 2002; Moll et al., 2001; Moll et al., 2002a; Moll et al., 2002b).

In the present study, activity in the moral > neutral contrast in psychopathic individuals was revealed in bilateral medial and superior frontal areas (BA 9/10/11), bilateral superior temporal and supramarginal gyrus (BA 39/40), left middle temporal gyrus (BA 21), and the posterior cingulate and precuneus region BA 7/31). All of these regions have been known to be involved in moral reasoning processes in healthy individuals. Thus, the above mentioned hypotheses for this study were confirmed. First, realistic everyday moral conflicts stimulated brain regions that are known to show activation in simple moral judgment or moral dilemma tasks. In addition, psychopaths showed a similar pattern of brain activation when judging everyday moral conflicts as healthy individuals when judging moral claims or moral dilemmas.

Before discussing the meaning of the imaging findings in the moral > neutral contrast in psychopaths revealed in the present study, the difference between realistic everyday moral conflicts used in this study and moral dilemmas used in previous studies on moral reasoning is going to be summarized briefly.

The main characteristics of moral dilemmas are that, first, all possible choices have morally undesirable outcomes and second, moral dilemmas are not realistic and not representable for everyday life conflicts. In contrast to this are everyday moral conflicts as used in the present study. In these realistic conflicts, a choice is required between a hedonistic, personal desire-guided, but not illegal decision on the one hand and the fulfillment of a moral obligation towards another person on the other hand. The moral conflicts used in the present study are all very realistic and concrete.

So, it can be concluded that whereas everyday moral conflicts differ from moral dilemmas in their (personal and legal) consequences and outcomes, they evoke activity in the same brain areas that are known to show activation in moral dilemma tasks. This result was already obtained in a study that tested 12 healthy individuals with the same paradigm as used in the present study (Sommer et al., 2010). In the moral conflicts > neutral conflicts comparison, an activation of medial prefrontal cortex (BA 8, 9, 10, 11), bilateral temporo-parietal junction (BA 39, 40), bilateral middle and superior temporal cortex (BA 21, 22), posterior cingulate cortex (BA 23, 31), bilateral thalamus and right inferior frontal gyrus (BA 45) was shown in healthy individuals. Based on the obtained findings, the authors concluded that cortical brain areas associated with moral cognition are not only involved in and stimulated by reasoning about unrealistic moral dilemmas (as described above) but also in realistic moral decisions on everyday conflicting situations (Sommer et al., 2010).

By the findings of the present study, the conclusion drawn by Sommer and colleagues concerning healthy individuals can be expanded to psychopathic individuals. So, generally and at first view, brain activation evoked by realistic moral conflicts seems to be similar in psychopaths and in healthy individuals. But does this implicate that psychopaths do not differ from healthy individuals in their neural correlates of moral decision-making? And further, can therefore be concluded that psychopaths are not impaired in moral reasoning? Or is it due to other influences and reasons such as impaired emotional detachment, differences on behavioral level or disturbed connectivity of neural circuits that psychopaths show a similar pattern of brain activation to healthy individuals when processing moral conflicts but differ from healthy individuals in their immoral, antisocial and emotionless behavior?

In order to find an answer to these questions and to analyze the meaning of the imaging findings obtained in the moral > neutral contrast in psychopaths, in the following part all obtained brain areas are going to be discussed related to their functions in moral reasoning, social interacting and emotional decision-making as well as relating to their involvement in psychopathy.

5.2.1.1 Medial Prefrontal Cortex

In the moral conflicts condition compared to the neutral conflicts condition, significant activity was shown in bilateral medial frontal gyrus and bilateral superior frontal gyrus. These frontal lobe areas correspond to the Brodmann Areas 9/10 and 11 and can be divided by their localization and functions into the medial frontal gyrus (BA 9/10) and the orbitofrontal cortex (OFC, BA 11). The important role of these areas in moral reasoning was already pointed out by previous lesion and neuroimaging studies (Damasio et al., 1994; Greene & Haidt, 2002; Greene, 2007).

In order to interpret the obtained frontal activations in psychopaths in the moral > neutral contrast, first, the findings of previous studies that concentrated on the functions of the OFC and the medial frontal gyrus in healthy individuals are going to be summarized. Then, studies that showed an involvement of OFC and medial frontal gyrus in psychopathy are going to be delineated.

In several fMRI studies, Moll and colleagues (2001; 2002a; 2002b) found significant activations in the frontopolar cortex and the medial frontal cortex in healthy subjects in a moral judgment task, as well as a medial orbitofrontal/medial frontal gyrus activation when healthy subjects were presented with moral pictures. Furthermore, they found orbitofrontal cortex (OFC) activation in association with negative emotions in moral judgments (Moll et al., 2001; 2002a; 2002b). Additionally, a strong interconnection between the medial OFC and the superior temporal sulcus, the precuneus and the medial frontal gyrus was revealed in healthy individuals in a moral condition when compared to an unpleasant condition (Moll et al., 2002a). Greene and colleagues (2001), too, found medial frontal gyrus (BA 9 and 10) activation in healthy individuals in a moral-personal condition (dilemma) compared to non-moral conditions (Greene et al., 2001).

So, all of these studies found OFC and medial frontal gyrus activation in moral reasoning-associated tasks. A more general function of the medial prefrontal cortex was revealed by Grabenhorst et al. (2008) who found medial prefrontal cortex (BA 10) activation in binary decision-making (Grabenhorst et al., 2008). In sum, the involvement of the medial frontal gyrus and the OFC in processes that require moral reasoning and decision-making is already replicated by several neuroimaging studies. In line with these findings, the present results support OFC (BA 11) and medial/superior frontal cortex (BA 9/10) activation in a moral conflict judgment task. But, in contrast to the previous studies that investigated either simple moral judgments or moral dilemmas, the present study used realistic everyday moral conflicts for the moral decision-making task. Regarding this point, the activation revealed in the above mentioned frontal areas expand previous findings by showing that the OFC and medial frontal gyrus are not only involved in reasoning about abstract moral dilemmas but also in conflicts about realistic moral situations.

Though, it has to be considered that the discussed frontal brain regions are not only known to be involved directly in moral reasoning processes but they are also associated with processes and functions that are relevant for decision-making processes in general and for moral reasoning processes in particular. For example, the medial frontal gyrus was shown to be involved in integrating emotions into decision-making and planning (Partiot et al., 1995) as well as in theory of mind (Castelli et al., 2000; Gallagher et al., 2000). Moreover, Amodio and Frith (2006) emphasize the role of the medial frontal cortex in social cognitive processes that include, for example, self-reflection and person perception (Amodio & Frith, 2006). An additional function of the OFC is its key role in emotional processes. In an fMRI study, Farrow et al. (2001) tested the functional anatomical bases of empathy and forgiveness in healthy subjects and showed orbitofrontal gyrus (BA 11) and superior frontal gyrus (BA 9) activation in empathic and forgivability judgments (Farrow et al., 2001).

For further attribution of functions, it is important to keep in mind the functional divisions within the medial frontal cortex. Therefore it is helpful to distinguish between the medial frontal gyrus (around BA 9/10) and the orbitofrontal areas (BA 10/11) (Amodio, 2006). Even the different connectivities of these areas, which are known from studies in monkeys, should be taken into consideration. In general, the majority and the strongest projections of the medial frontal cortex are intrinsic ones or are projections to adjacent prefrontal areas (Barbas et al., 1999). An important connection exists between the OFC and the medial prefrontal cortex region and the amygdala (Carmichael & Price, 1995; Cavada et al., 2000). The superior part of the medial frontal cortex (BA 9) is connected to the lateral premotor cortex, the supplementary motor area (SMA) and the cingulate motor area (Barbas et al., 1999). The medial OFC receives afferents from the dorsolateral prefrontal cortex, the temporal pole, the superior temporal gyrus, the parietotemporal cortex and the posterior cingulate cortex, whereas the lateral OFC is strongly connected to sensory-related areas (Barbas et al., 1999; Carmichael & Price, 1996; Cavada et al., 2000). The division into medial and lateral OFC is not only due to its different connectivities but also to the different functions. O'Doherty et al. (2001) tested OFC involvement in an fMRI reversal-learning task and found medial OFC activation following a rewarding outcome, whereas lateral OFC activated following a punishing outcome (O'Doherty et al., 2001). So, the OFC is supposed to be crucially involved in the evaluation and monitoring of the possible future outcome of a behavior (Walton et al., 2004).

In sum, functions that can be attributed to the OFC and medial frontal gyrus in healthy individuals extend from general involvement in moral decision-making to the integration of emotion into moral reasoning and to other social and emotional processes such as self-reflection, forgivability and empathy. Another important function of the OFC in particular is the evaluation of possible future outcomes of a decision or a behavior. All these abilities and functions are associated with OFC / medial frontal gyrus activation in healthy individuals. But what is the role of these frontal brain areas in psychopathic individuals? Several studies investigated this point. The main findings are going to be summarized in the following part.

The involvement of OFC in emotion and decision-making processes was already pointed out for healthy individuals. The role of these areas in psychopaths can be explained based on OFC and prefrontal cortex lesion studies. As already mentioned, the railway foreman Phineas Gage experienced severe personality change after an acquired prefrontal cortex brain lesion (Brodmann Areas 11, 12, 8-10) which resulted in impaired social behavior, lack of responsibility and compromised emotion processing and decision-making in spite of largely preserved intellectual abilities and working memory

(Damasio et al., 1994). Other studies that investigated prefrontal cortex lesion patients emphasize its involvement in emotion, social and moral behavior and decision-making (Anderson et al., 1999; Bechara et al., 1996; Bechara et al., 2000; Damasio et al., 1994; Hornak et al., 2003).

Due to the fact that psychopathic individuals are characterized by an impairment of exactly these features (emotional detachment, deficient social and moral behavior) (Hare et al., 1991), a prefrontal cortex dysfunction or lesion in psychopaths was suggested and is supported by several study results. Kiehl and colleagues (2001) revealed significantly reduced affect-related activation in the rostral anterior cingulate cortex/medial OFC in criminal psychopaths (Kiehl et al., 2001). Reduced OFC activation in psychopaths was also shown during an aversive conditioning task (Birbaumer et al., 2005). In addition to functional impairment of the OFC in psychopaths, several studies revealed structural volume reduction in this area (Müller et al., 2008; Oliveira-Souza et al., 2008; Raine et al., 2000). For example, Oliveira-Souza et al. (2008) used voxel-based morphometry and revealed gray matter reduction in the OFC in psychopaths (Oliveira-Souza et al., 2008).

In sum, not only lesion studies but also functional and structural brain imaging studies revealed an impairment of OFC and medial frontal cortex in psychopaths. So, how can the obtained activations of these brain areas in psychopaths be explained in this study?

First and as already mentioned above, the OFC and medial frontal gyrus are brain regions typically involved in moral reasoning in healthy individuals (Greene et al., 2001; Greene & Haidt, 2002; Moll et al., 2001; 2002a; 2002b). In this study, a decision between a morally-guided response and a personal desire-guided response or between two conflicting personal desires was required. In each case, the subject had to choose one out of two presented options and therefore, a moral decision-making process was inevitably induced. Whereas previous studies showed an impairment of OFC and medial frontal gyrus in psychopaths especially in affect-related tasks (Kiehl et al., 2001; Birbaumer et al., 2005), it seems that in the present study, the moral decision-making process itself evoked an activation of these areas. This means that frontal brain regions that are typically involved in moral decision-making processes in healthy individuals, show activation in a moral conflict decision-making situation in psychopaths.

It has to be considered, that the simple activation of the OFC and medial frontal gyrus in a realistic moral conflicts does not allow to draw a conclusion about the intactness of emotion processing in the decision-making process in psychopaths. Possibly, the evaluation of the possible future outcomes of the decisions plays a role in the OFC activation in moral conflicts in psychopaths. Whereas the decision for one of the two conflicting personal desire options in the neutral conflict has relatively little emotional consequences, the moral conflict situation leads to different outcomes. In case of choosing a moral decision, the subject evaluates the positive feelings associated with helping compared to the resulting personal disadvantages. And in the case that the person decides to fulfill the personal desire, the feelings about the personal advantage compensate possible negative feelings such as shame. So, in line with previous findings (O'Doherty et al., 2001; Walton et al., 2004) the OFC activation could be explained by a strong evaluative process of the possible outcomes and their consequences. Keeping in mind the findings by O'Doherty et al. (2001) who revealed medial OFC activation following a rewarding outcome in an fMRI reversal-learning task in healthy individuals, it could be concluded that especially the evaluation of a rewarding outcome evokes an activation of the OFC in psychopaths. The rewarding outcome may be the fulfillment of a personal desire on the one hand, or a socially-desired behavior that may result in social reward on the other hand . In conclusion, the obtained activation in medial frontal brain areas in psychopaths, especially in the OFC, can be explained by the moral decision-making process and the evaluation of the future, especially rewarding outcomes of the chosen decision.

But what is the explanation for the obtained OFC activation in psychopaths in this study considering that psychopaths are characterized by emotional and social deficiency, features that were related to OFC lesions or functional impairment in previous studies (Damasio et al., 1994; Hare et al., 1991; Kiehl et al., 2001)? There are several aspects that should be considered. First, a compensatory mechanism within the OFC could be discussed. And second, the connectivity of the OFC with other brain areas, especially with the amygdala (Carmichael & Price, 1995; Cavada et al., 2000) has to be considered. In the following, the mentioned aspects are going to be explained and discussed.

First, the activation of the OFC in moral conflicting situations in psychopaths in the present study could be explained by a compensatory mechanism within the OFC. As mentioned above, it seems that in the moral condition the OFC activation is strongly influenced by the evaluation of the future outcome in the decision-making process. In healthy subjects, the OFC is furthermore involved in emotional and social processes such as empathy, self-reflection and person perception (Amodio, 2006; Farrow et al., 2001). Possibly, psychopaths who lack social functions such as empathy, can have a deficient affect-related OFC function (Kiehl et al., 2001), but a strong evaluative function of the OFC that compensates the deficient affect-related activation and leads to the obtained OFC activation in the moral condition.

Another aspect that could explain the obtained OFC activation in emotional deficient psychopaths concerns the connectivity between OFC and other brain areas. As mentioned above, the OFC is strongly interconnected with the amygdala and the medial part of the OFC receives afferents from the dorsolateral prefrontal cortex, the temporal pole, the superior temporal gyrus, the parietotemporal cortex and the posterior cingulate cortex (Barbas et al., 1999; Carmichael & Price, 1996; Cavada et al., 2000). Several authors investigated and discussed an insufficient amygdala function or deficient inputs from the amygdala to the OFC (Blair, 2007b; Kiehl, 2006; Kiehl et al., 2001). This explains, on the one hand, the OFC impairment revealed in previous studies (Kiehl et al., 2001) and on the other hand, the disturbed affective behavior in psychopaths as the amygdala is known to be crucially involved in the processing of affective stimuli (Adolphs, 2008; Sommer et al., 2008). In the present study, in the moral > neutral condition, no amygdala activation was shown in psychopaths. This supports the assumption that the amygdala might be deficient in psychopaths and that therefore the OFC receives reduced inputs from the amygdala (Blair 2007b; Kiehl, 2006; Kiehl et al., 2001). Reduced inputs from the amygdala would further explain general characteristics of psychopaths such as emotional detachment. Keeping in mind that the amygdala region is also involved in neural circuits that underly unpleasant emotions (Lane et al., 1997; Phan et al., 2002), it could be possible that psychopaths with a deficient amygdala function lack those unpleasant emotions. Colloquially it could be said that psychopaths lack “bad conscience”. This would extend the findings by Sommer et al. (2010) in healthy individuals to psychopaths (Sommer et al., 2010). They revealed amygdala activations when subjects chose the personal desire-guided response when compared to the morally-guided responses. Therefore, the authors concluded that the activation in the amygdala region indicates the subject's unpleasant emotions about the immoral decision (Sommer et al., 2010). In psychopaths, it seems that there are no unpleasant emotions that could control behavior and decision-making. So, the role of a deficient amygdala region and reduced inputs from the amygdala to the OFC seems to be a mechanism that explains in part the emotional detachment of psychopaths. As for the OFC activation, it could be assumed that the OFC with afferents from the dorsolateral prefrontal cortex, the temporal pole, the superior temporal gyrus, the parietotemporal cortex and the posterior cingulate cortex (Barbas et al., 1999; Carmichael & Price, 1996; Cavada et al., 2000) compensates the reduced amygdala inputs.

In sum, the OFC seems to receive reduced inputs from functional deficient amygdala regions. This may lead to impaired emotional behavior in psychopaths with a lack of unpleasant emotions and “bad conscience”. The OFC activation in the present study can therefore be explained by a compensatory input from other brain regions and by other OFC functions that are involved in moral decision-making processes such as the evaluation of the possible outcomes. Additionally, the activation of the OFC and medial frontal gyrus extend the findings of previous studies on moral reasoning from healthy individuals to psychopaths and indicate that these areas are not only associated with decision-making in abstract moral dilemmas but also with decision-making in realistic everyday moral conflicts.

5.2.1.2 Temporal Cortex and Temporo-Parietal Junction

Additional brain areas that showed activation in the moral > neutral contrast in psychopaths are the superior temporal gyrus and the supramarginal gyrus, both bilaterally, corresponding to Brodmann Areas 39 and 40. Moreover, on the left side, activation of the middle temporal gyrus (Brodmann Area 21) was revealed. In the following part, functions that are associated to Brodmann Areas 39 and 40 and their relevance for moral decision-making are going to be described. Then the role of these brain region in psychopathy and especially in the present study are going to be discussed. Finally, the meaning of left middle temporal gyrus (BA 21) activation in this study will be discussed.

Several neuroimaging studies showed superior temporal sulcus (STS) activation when healthy individuals were presented with moral judgment tasks or moral emotional pictures (Moll et al., 2002a; 2002b). Besides STS involvement in moral reasoning, the STS is associated with social perception, facial emotion recognition, and the representation of intentional actions as well as imitation, imitation learning and action understanding (Allison et al., 2000; Narumoto et al., 2001;Rizzalotti & Craighero, 2004; Saxe et al., 2004). Beyond, the STS region plays an important role in forgiveness and empathy processing (Carr et al., 2003; Farrow et al., 2001; Leslie et al., 2004). In the present study, psychopathic subject were presented with conflicting moral and neutral stories and were asked to choose either a personal desire-guided or a morally-guided response in the moral conflict condition or one of two conflicting personal desires in the neutral condition. In the moral conflicts, processing of action understanding, social perception and empathy is more involved than in neutral conflicts. For example, the neutral conflict to choose between pizza or pasta in a restaurant does not require empathy processing. In a moral conflict, such as helping the old lady to pick up her purchases or taking the waiting bus home after a long working day, the subject may process social perception and empathic associations on neural level that result in the obtained bilateral STS activation.

Furthermore, the temporal cortex plays a role in processing sentence and text materials and in encoding semantic material into the working memory (Cabeza & Nyberg, 2000; Hickok & Poeppel, 2004). As the moral conflicts require more personal identification and attention with the conflicting situation than the neutral conflicts, the increased activation of the temporal cortex in moral conflicts may be associated with increased information and text processing in working memory.

The activation of the bordering area of the posterior STS, the temporo-parietal junction (TPJ), suggests a high cognitive involvement in moral conflicts. The TPJ is involved in Theory of Mind (ToM), a term which is used to refer to any reasoning about another person's representational mental state. ToM is a human ability that allows to attribute mental states to other persons (Saxe et al., 2003). A number of studies (Fletcher et al., 1995; Gallagher et al., 2000; Sommer et al., 2007; Vogeley et al., 2001) have reported increased activity in the temporo-parietal junction (TPJ) when healthy subjects read verbal stories or see pictorial cartoons that require inferences about a character's (false) beliefs. In a moral conflict as used in the present study, the TPJ is probably involved in attributing mental states to other persons that appear in the conflict, such as the old lady. The TPJ activation may represent the ability to take the perspective of the other person. The TPJ is known to be associated with moral reasoning in healthy individuals, as TPJ activation was shown in several studies that used personal moral dilemmas, simple moral judgments or moral pictures (Greene et al., 2001; Moll et al., 2001; Moll et al., 2002a; Moll et al., 2002b). The findings of the present study extend previous findings on moral reasoning to TPJ activation in realistic everyday moral conflicts in psychopaths.

In sum, the TPJ and STS activation in moral conflicts in psychopaths may represent increased information and text processing and a higher involvement of social perception in moral conflicts than in neutral conflicts. But of course, the TPJ activation does not allow any conclusion on the intactness of ToM in psychopaths.

It was suggested that in psychopaths, who exhibit deficits in abilities such as social perception and cognition that are related to ToM, the ToM mechanism might be deficient and therefore they develop antisocial behavior and emotional deficiency (Blair, 1995). Several authors supported this idea by their study results. Kiehl et al. (2004) found decreased activation in the right superior temporal gyrus in criminal psychopaths when differentiating between abstract and concrete stimuli (Kiehl et al., 2004). A loss of gray matter in a Voxel-based morphometry (VBM) study by Müller et al. (2008) revealed significantly gray matter volume loss in the superior temporal gyrus bilaterally and Oliveira-Souza et al. (2008) repeated these findings and found gray matter reductions in the STS region in VBM. Furthermore, several studies suggested that an impaired ToM might lead to antisocial and aggressive behavior and psychopathy (Crick & Dodge, 1994; Feshbach, 1987). Whereas Blair and colleagues did not find ToM impairment in psychopaths (Blair et al., 1996), Widom did (Widom, 1976). Richell and colleagues (2003) tested psychopathic individuals and a non-psychopathic control group with the 'Reading the Mind in the Eyes' test in which participants only see the eye region of individuals in a photograph. From this information alone they have to attribute a mental state to the person in the photograph. But, psychopathic individuals performed equally well on the test as the non-psychopathic control group and Richell and colleagues draw the conclusion that psychopaths do not present with a generalized impairment on ToM (Richell et al., 2003).

In conclusion and in line with previous studies on ToM in psychopaths, the bilateral TPJ activation in this study supports the theory of an involvement of a ToM-related brain region in moral decision-making in psychopaths. Taken together, the present findings of bilateral TPJ and STS activation in the moral conflict condition in psychopaths represent the involvement of a brain region that is associated with moral reasoning, ToM, social perception and working memory. All of these abilities are relevant for moral judgment in realistic moral conflicts.

In addition to bilateral TPJ activation, left middle temporal gyrus (BA 21) activation was revealed in the moral > neutral contrast in psychopaths. This is an interesting fact given that the right hemisphere is dominant in emotional processing (Leslie et al., 2004). So, what is the reason for the absent right-sided middle temporal gyrus activation in criminal psychopaths in moral decision-making? Could it be due to a deficiency in these areas in the right hemisphere in psychopaths? Several studies investigated right hemisphere involvement in emotion processing and in psychopathy. For example, patients with damage to the right hemisphere are not able to recognize several basic emotional expressions (Adolphs et al., 1996; Kucharska-Pietura et al., 2003). Study results emphasize a right-sided temporal volume loss in psychopaths and in early onset conduct disorder (Kruesi et al., 2004; Müller et al., 2008). Müller et al. (2008) draw the conclusion that the right temporal cortex plays a critical role in psychopathy (Müller et al., 2008).

In line with these previous findings, the present results could indicate a right-sided temporal lobe abnormality that contributes to the pathogenesis of psychopathy. This would support the theory of a deficiency in emotion processing in psychopaths that was already proposed by several authors (Kiehl, 2006; Müller et al., 2003).

5.2.1.3 Parietal Lobe

Additional to OFC, STS, TPJ and left middle temporal gyrus activation, another broad cluster of activation was revealed in the parietal lobe: the posterior cingulate and cingulate gyrus (around Brodmann Area 31) and the neighboring precuneus area (Brodmann Area 7) showed activation in the moral > neutral contrast in psychopaths.

These areas are known to be involved in moral reasoning as several previous studies revealed increased activation in different moral tasks with personal and impersonal moral judgment (Greene et al., 2001), viewing moral pictures (Moll et al., 2002a) or viewing ToM cartoons (Gallagher et al., 2000) in healthy individuals.

In the following part, the functions of the precuneus area and then of the posterior cingulate cortex (PCC) are going to be described. Their role in psychopathy and their contribution to the present study results are going to be discussed.

Concerning the precuneus (BA 7), Cavanna et al. (2006) reviewed the most important functions and stated that visuo-spatial imagery and consciousness as well as episodic memory retrieval and self-processing are behavioral correlates of this area (Cavanna & Trimble, 2006). This data partly consists of results of a study by Fletcher et al. (1995) who describe the precuneus as “The Mind’s Eye” because of its high activation during remembering “imageable versus nonimageable paired associates”. Therefore they emphasize the role of this parietal area in memory experiments, especially in episodic memory (Fletcher et al., 1995). As the present study required an intact working memory for processing the conflicts, the activation of an area that is known to be active during memory tasks and episodic memory (kind of memory that refers to autobiographical, personal experiences of an individual (Tulving, 1983) is obvious. The obtained precuneus activation may represent an increased involvement of episodic memory when subjects processed moral conflicts compared to neutral conflicts as the decision in a moral conflict requires more personal experiences than decision-making in neutral conflicts.

Though, the precuneus also seems to play a crucial role in social cognition. Farrow et al. (2001) investigated neural correlates of empathy and forgiveness in healthy subjects in an fMRI study and revealed significant precuneus activation during judgments requiring empathy and forgiveability (Farrow et al., 2001). Furthermore, the strong interconnections between precuneus and prefrontal cortex (BA 8, 9, 46) on the one hand and between precuneus and supplementary motor areas (SMA) and anterior cingulate cortex on the other hand (Cavada & Goldman-Rakic, 1989; Goldman-Rakic, 1988; Leichnetz, 2001; Petrides & Pandya, 1984) could lead to the conclusion that the precuneus is not only involved in memory tasks but also in emotional processes such as empathy. All the mentioned qualities of the precuneus are very compatible with its activation during a moral conflict decision-making task as used in this study.

So, how can precuneus activation in the moral > neutral conflict be interpreted in psychopaths? First, precuneus activation in moral reasoning was already revealed in several studies that investigated moral dilemmas, moral judgments or realistic moral conflicts in healthy individuals (Greene et al., 2001; Moll et al., 2001; Moll et al., 2002a; Moll et al., 2002b; Sommer et al., 2010). The findings of the present study extend precuneus involvement in moral reasoning from healthy individuals to psychopathic individuals. Moral conflicts compared to neutral conflicts seem to induce a higher activation of precuneus associated functions such as episodic memory and emotion integration in moral decision-making. The combination of emotional detachment in psychopaths, as for example a lack of empathy, and precuneus activation as an area that is known to be involved in the integration of emotions in social situations leads to the conclusion that emotion processing deficiency in psychopaths is more related to behavioral deficiencies than to deficient neural correlates in the precuneus area.

A similar role in emotion processing plays the neighboring brain region, the posterior cingulate cortex (PCC; BA 31). Maddock et al. (2003) examined the role of PCC in emotional processing and showed that PCC activated significantly more during evaluating emotionally unpleasant as well as during emotionally pleasant arousing words in comparison to emotionally neutral words (Maddock et al., 2003). These results in combination with the fact that PCC receives strong afferent inputs from brain areas which are known to play an important role in emotion and social behavior, such as ACC, orbitofrontal cortex, dorsolateral prefrontal cortex and superior temporal sulcus, lead to the conclusion that PCC is crucially involved in emotion processing. Vogt (2005) emphasizes this role by describing the PCC as an "emotional pre-processor" (Vogt, 2005). In accordance with these findings in healthy individuals are the results of Kiehl et al. (2001), who found decreased activity in PCC in psychopathic individuals during the processing of affect- and emotion-related words (Kiehl et al., 2001).

In addition to the emotion-related functions, PCC has memory-related functions, not only in episodic memory (like precuneus) but also in the mediation between emotion and memory-related processes (Maddock et al., 2003).

So, in the moral > neutral contrast of this study, the activation of PCC represents the integration of emotion and possible emotional consequences of the decision into the decision-making process. This does not implicate that psychopaths are not impaired in emotion processing, but it seems to be due to other aspects that psychopaths differ from healthy individuals in their emotion processing.

Taken together the findings of PCC and precuneus, the activation of these areas in the moral conflict condition extends findings of previous moral judgment studies in healthy individuals, to psychopathic individuals on the one hand and to realistic everyday moral conflicts on the other hand. In the present study, PCC and precuneus activation may reflect increased emotion- and memory-related processes when subjects judged moral conflicts compared to neutral conflicts.

5.2.1.4 Conclusion

After the discussion of all single brain areas that showed activation in the moral > neutral contrast in psychopaths, the aspect that all revealed brain areas are part of neural circuits and that in psychopaths these circuits may be deficient, is going to be discussed. Finally, the main conclusions of the findings in the moral > neutral conflict in psychopaths are going to be summarized.

In the moral > neutral contrast, increased activation was induced in a broad network including the medial and superior frontal gyrus (BA 9/10, 11), the bilateral temporal gyrus (BA 39/40), the left middle temporal gyrus (BA 21) and the precuneus and posterior cingulate cortex (BA 31/7). This pattern of activation reflects results of previous studies that investigated comparatively abstract moral reasoning (Greene et al., 2001; Greene & Haidt, 2002) in healthy individuals. A study that used the same realistic moral conflicts as used in the present study revealed activation in a similar pattern of brain regions in healthy individuals (Sommer et al., 2010). Therefore, the present findings in psychopaths allow two conclusions. First, moral reasoning evokes an activation of a similar neural network in psychopaths as in healthy individuals. This leads to the second conclusion that the antisocial and impaired affective behavior observed in psychopaths may be due to a deficient interconnection of the revealed brain areas. Unfortunately, effective connectivities that would provide further information about the interaction of multiple brain areas cannot be analyzed in this fMRI study.

Models that reveal dynamics in neural systems, such as dynamic causal modelling (DCM) would be helpful to provide further information about functional connectivity among brain areas (Friston et al., 2003; Marreiros et al., 2008). In literature, no study has investigated the connectivity of brain networks induced by moral reasoning in psychopaths.

In summary, the results of the present study revealed that moral decision-making between a personal desire-guided and a morally-guided response induced activation of the medial and superior frontal gyrus, bilateral STS and TPJ, left middle temporal gyrus, precuneus and PCC. These findings extend previous findings on moral reasoning from abstract moral reasoning to realistic moral conflicts and from healthy individuals to psychopathic individuals. The activation of this broad neural network induced by moral conflicts may represent the increased emotion integration in decision-making in moral conflicts when compared to neutral conflicts. Whereas in healthy individuals the evaluation of the possible emotional consequences and outcomes seem to be influenced by unpleasant emotions and a “bad conscience” that lead to inhibitory processes (Sommer et al., 2010), in psychopaths the processing of unpleasant emotions could be impaired due to deficient amygdala inputs. So, probably, the increased activation is more a representation of emotionally pleasant personal consequences and outcomes that are processed when evaluating the possible outcomes of the decision than a representation of unpleasant emotions. In addition to increased integration of emotions in moral conflicts compared to neutral conflicts, activation in the obtained brain regions represents increased memory-related processes and recruitment of attentional resources in moral conflicts.

In sum, reasoning about realistic moral conflicts seems to involve multiple cognitive sub-processes that lead to an activation of a broad neural network in psychopaths. Though, conclusions about the intactness of the connectivity between the single brain areas in psychopaths cannot be drawn and further research is necessary.

5.2.2 Contrast Immoral > Moral in Psychopathic Individuals

Besides the analysis of brain regions associated with moral versus neutral conflicts in psychopaths, moral conflicts were investigated in more detail. In order to identify brain activity related to choosing a personal desire-guided response versus choosing a morally-guided response, a second analysis was applied on the moral conflict condition. This contrast was analyzed in those eight out of twelve psychopathic subjects who showed a response pattern of at least 30% immoral decisions in the moral conflict condition. In situations in which the subjects chose the immoral personal desire-guided alternative, increased activation was revealed in the medial frontal cortex bilaterally (BA 6) and the cingulate cortex bilaterally (BA 24).

In the following part, functions associated with these brain regions and the meaning of their involvement in the immoral condition are going to be discussed.

First, the functions of BA 24 and its involvement in psychopathy will be described. Vogt et al. (1992) described the middle and anterior part of the cingulate cortex as the executive part of the cingulate cortex. Functions such as emotions, pain and attention were contributed to this part of the cingulate cortex. The reciprocal connection between the cingulate cortex and the amygdala further supports the affective component of the cingulate cortex (Vogt et al., 1992). The involvement of the cingulate cortex in affective and aggressive behaviors was confirmed by several studies. Therapeutic cingulotomy or only small ablative operations in the cingulum bundle were used for treatment of affective mental illnesses. Ballantine et al. (1987) summarized that this kind of therapy was helpful for patients with affective disorders by not only normalizing the functioning but also by reducing their violent behaviors (Ballantine et al., 1987). Besides the role in aggressive behavior, the cingulate cortex seems to be involved in emotion processing, especially of negative emotions. In line with this, Müller et al. (2003) revealed increased activation in right-sided anterior cingulate cortex in psychopaths during processing pictures with emotionally negative contents (Müller et al., 2003). Summing up the findings of previous studies, the cingulate cortex seems to be crucially involved in aggressive behavior on the one hand and in processing negative emotions on the other hand. So, the activation obtained in this area when psychopaths chose the immoral and personal desire-guided decision in the present study, may be explained by the following theories:

First, choosing the immoral response in the moral conflicts might be associated with aggression-related processes in psychopaths. The aggressive component could be due to the attempt to fulfill a personal desire instead of behaving in a morally-guided way. Compared to healthy individuals, choosing the immoral decision could be due to a strong drive for goal-directed behavior in order to fulfill a personal desire in psychopaths. This goal directed-behavior is reflected by the activation of aggression-related brain components.

Besides the aggression-associated activation of the cingulate cortex, the cingulate cortex activation may reflect emotion processing mechanisms in psychopaths. Müller et al. (2003) revealed increased activation of the anterior cingulate cortex when psychopaths were presented with pictures with emotionally negative contents (Müller et al., 2003). In the present study, when choosing a personal desire-guided / immoral decision, negative emotions may rise due to the negative consequences implicated by the immoral decision for somebody else. Therefore, the activation of the cingulate cortex during the processing of moral conflicts resulting in an immoral behavior may indicate the psychopath's negative emotions that are associated with this decision. Nevertheless, in psychopaths, the urge to fulfill the personal desire seems to be stronger than the influence of the negative emotions that could result in an inhibition of the personal desire-guided decision.

The drive to choose the hedonistic decision may further be increased by an amygdala deficiency in psychopaths. As already mentioned above, the amygdala is involved in neural circuits that underly unpleasant emotions (Lane et al., 1997; Phan et al., 2002). The amygdala is known to be reciprocally interconnected with the cingulate cortex (Vogt et al., 1992). When healthy subjects fulfill their personal desire and choose the immoral decision in moral conflicts, amygdala activity was revealed and interpreted as the activation of a “bad conscience” that indicates the subject's unpleasant emotions about the immoral decision (Sommer et al., 2010). In the present study, no amygdala activation was obtained in the immoral > moral contrast in psychopaths. This could explain a deficient interconnection between amygdala regions and cingulate cortex that may result in a lack of unpleasant emotions when processing moral conflicts and choosing the immoral decision. So, the immoral behavior may reflect the lack of a “bad conscience" with the consequence that psychopaths fulfill their goal-directed behavior and choose the personal desire-guided response. They may process negative emotions concerning the consequences for the other person, but the urge to choose the hedonistic decision is stronger. Whereas healthy individuals seem to regret the immoral decision which could be explained by the activation of amygdala regions, in psychopaths a "bad conscience" is not detectable, at least not on neural level.

In sum, the obtained cingulate cortex activation in psychopaths in the immoral > moral condition may reflect a strong drive for the fulfillment of a goal-directed and in this case immoral behavior that cannot be inhibited by unpleasant emotions as the connection between amygdala and cingulate cortex may be deficient in psychopaths.

In addition to affective components of the cingulate cortex, conflict processing and attentional processes were contributed to the cingulate cortex. Van Veen et al. (2001) point out that an activation of cingulate cortex can be observed especially in situations when the decision-making process between the possible responses leads to a conflict (van Veen et al., 2001). In addition, attentional processes were contributed to the cingulate cortex (Vogt et al., 1992). Therefore, the activation of the cingulate cortex during the processing of moral conflicts resulting in an immoral and personal desire-guided behavior may indicate the subject's conflict in the decision-making process. Again, the conflict in psychopaths during choosing the immoral decision may consist in the drive for the goal-directed behavior in order to fulfill a personal desire and the processing of negative emotions that may concern the consequences for somebody else. Further, the activation of the cingulate cortex may reflect higher attentional processes during choosing the immoral response. This may be explained with a higher involvement of cognitive processes when deciding immorally.

Taken together, the activation of the cingulate cortex (BA 24) in the immoral condition in psychopaths may reflect the involvement of emotion processing, conflict monitoring and attentional processes.

In combination with BA 24, additional activation in the immoral > moral condition was revealed in BA 6. This Brodmann Area corresponds to the medial frontal cortex. BA 6 can be subdivided into the supplementary motor areas (SMA) and the premotor cortex (PM) (Hanakawa et al., 2002) and was known as a classical motor area, but Hanakawa et al. (2002) suppose additional non-motoric cognitive functions. In their study they revealed an involvement of BA6 in mental-operation tasks (Hanakawa et al., 2002). According to Petit, 1998, this area is typically involved in working memory tasks (Petit et al., 1998). As already mentioned above, it seems that deciding immorally in a moral conflict induces higher attentional processes and therefore, the activation of BA 6 as an area associated with working memory, could reflect the weighing of the conflict's outcomes against each other. Additionally, BA 6 as well as BA 24 activation may represent higher cognitive demands that are associated with processing of moral conflicts resulting in an immoral behavior.

In conclusion, the obtained activation of BA 6/24 may reflect the strong involvement of cognitive and emotional processes in moral decision-making resulting in an personal desire-guided/immoral response. The results may indicate increased attentional processes and a higher conflicting process in the immoral condition than in the moral condition. Further, an impairment of processing unpleasant emotions that may be due to deficient amygdala activation in psychopaths could be discussed. This may result in immoral and antisocial behavior that is characteristic for psychopaths, and in a lack of “bad conscience” when behaving and deciding immorally.

5.2.3 Contrast Moral > Neutral Comparison Between Psychopathic Individuals and Non-psychopathic Criminal Control Subjects

For the moral > neutral contrast, activity during conflict and question presentation in the neutral conflicts was subtracted from the corresponding activity in the moral conflicts in order to reveal brain regions associated to everyday moral reasoning. This contrast was analyzed in 12 psychopathic individuals and in a control group that consisted of 12 non-psychopathic criminal individuals. In order to find out differences on neural level between psychopaths and non-psychopathic criminal individuals, that may provide further information for differences between the two groups on behavioral level, brain areas that showed activation in the moral > neutral contrast were compared between the two groups.

This comparison was only possible on a descriptive but not on a statistical level because of the wide range of given immoral/moral answers within the psychopathic group.

It was hypothesized that psychopaths, compared to non-psychopathic criminal control subjects, would show reduced activation in brain areas associated with moral reasoning such as the medial and orbitofrontal gyrus, the superior temporal sulcus, the precuneus and cingulate cortex. Based on the results of the descriptive comparison between the two groups, the hypothesis was confirmed only in part. Whereas non-psychopathic criminal control subjects showed increased activation in the middle temporal gyrus (BA 20/21) bilaterally, psychopaths showed activation only in the left middle temporal gyrus (BA 21), but not in the right. Furthermore, in the non-psychopathic criminal control group brain activation was revealed in the superior frontal gyrus (BA 6) and in the cuneus area (BA 18), whereas in psychopaths there was no activation in these areas. Against the hypothesis, psychopaths showed activation in the orbitofrontal cortex (BA 10/11), whereas in non-psychopathic criminal control subjects activation was shown only in the medial and superior frontal gyrus (BA 9/10) but not in the orbitofrontal cortex. A similar pattern of activation in both groups was revealed in medial and superior frontal gyrus (BA 9/10), bilateral superior temporal sulcus and temporo-parietal junction (STS, TPJ; BA 39/40), left middle temporal gyrus (BA 21) and posterior cingulate (BA 31) and precuneus (BA 7).

Before discussing the differences and similarities of brain activations in the moral > neutral contrast in psychopaths and non-psychopathic criminal control subjects, the characteristic qualities of each of the two groups are going to be pointed out briefly. Whereas psychopathic individuals, who are defined as "psychopaths" due to their high scoring on the Psychopathy Checklist-Revised (PCL-R), are characterized by a lack of affective and interpersonal abilities on the one hand and by antisocial and social deviant behavior on the other hand, non-psychopathic criminal control subjects do not reach a very high score on the PCL-R. This is mostly due to low scoring on the affective-interpersonal factor. So, as psychopaths, criminal non-psychopathic control subjects are characterized by their criminal and antisocial behavior but, and in contrast to psychopaths, their behavior contains more emotional and affective features.

Following this short comparison of the behavioral characteristics of the two investigated groups, in the next part, the results obtained from the descriptive comparison between psychopathic individuals and the non-psychopathic criminal control group in the moral > neutral contrast are going to be discussed. First, brain areas that showed a similar pattern of activation in both groups will be described. Then, differences in the activation pattern between the two groups will be discussed and interpreted.

5.2.3.1 A Basic Neural Network Associated with Moral Reasoning in Psychopaths and Non-Psychopathic Criminal Control Subjects

In psychopathic individuals as well as in non-psychopathic criminal control subjects, reasoning about realistic moral conflicts induced increased activity in a broad network of brain regions including medial and superior frontal gyrus, bilateral STS and TPJ, left middle temporal gyrus, posterior cingulate cortex and precuneus. This pattern of activation reflects findings of previous studies investigating relatively abstract as well as realistic moral reasoning in healthy individuals (Greene et al., 2001; Greene & Haidt, 2002; Moll et al., 2001; Moll et al., 2002a; Moll et al., 2002b; Sommer et al., 2010). So, the present results expand previous findings from healthy individuals to psychopathic and non-psychopathic criminal individuals. Furthermore, it can be concluded that brain areas associated with moral reasoning are not only involved in reasoning about abstract moral dilemmas and conflicts but also in relatively realistic and harmless moral conflicts.

As already discussed for the moral > neutral contrast in psychopaths, activation in the aforementioned brain areas is related to increased integration of emotions, memory-related processes and recruitment of attentional resources in reasoning about moral conflicts compared to reasoning about neutral conflicts (Partiot et al., 1995). This seems to apply to realistic moral conflicts in healthy subjects (Sommer et al., 2010), in psychopaths and in non-psychopathic criminal control subjects. So, it can be concluded that psychopaths as well as non-psychopathic criminal individuals show activation in a similar pattern of brain regions which seems to be a basis of a neural network involved in moral reasoning and in processes related to moral reasoning.

Besides this basic neural network associated to moral reasoning that is common to psychopaths and non-psychopathic criminal control subjects, there are some brain areas in which activation during moral decision-making differs between the two groups. In the following parts, first, brain areas that showed activation in non-psychopathic criminal control subjects but not in psychopaths are going to be discussed. Then, activation of the OFC (BA 10/11), which was only revealed in psychopaths but not in non-psychopathic criminal subjects, will be discussed. Based on these differences in activation between the two groups, behavioral and characteristic qualities of each group will be interpreted.

5.2.3.2 Lack of Activation in Right-Sided Temporal Gyrus, Superior Frontal Gyrus and Cuneus in Psychopaths When Compared to Non-Psychopathic Criminal Control Subjects

In the moral conflict condition, non-psychopathic criminal control subjects showed activation in bilateral middle temporal gyrus (BA 21), whereas in psychopaths activation was obtained only in left-sided middle temporal gyrus but not right-sided. As already discussed above, this difference in activation could be explained by a right-sided temporal lobe abnormality in psychopaths that leads to a deficiency in emotion processing. This theory could be explained with a general dominance of the right brain hemisphere in emotional processing (Adolphs et al., 1996; Kucharska-Pietura et al., 2003; Leslie et al., 2004). Previous study results emphasize a right-sided temporal volume loss in psychopaths and in early onset conduct disorder (Kruesi et al., 2004; Müller et al., 2008). In line with these previous findings, the present results could indicate a right-sided temporal lobe abnormality that contributes to the pathogenesis of psychopathy. This would support the theory of a deficiency in emotion processing in psychopaths that was already proposed by several authors (Kiehl, 2006; Müller et al., 2003; Rothmayr et al., 2010).

In sum, the here described non-activation of the right-sided middle temporal gyrus as an area involved in emotion processing could emphasize the deficiency of processing emotional contents and the resulting lack of emotion that characterize the behavior of psychopaths.

Additional to the right-sided middle temporal gyrus activation, an activation of the superior frontal gyrus (Brodmann Area 6) was observed in non-psychopathic criminal control subjects in the moral > neutral contrast when compared on descriptive level to psychopathic individuals who did not show activation in this area. The superior frontal gyrus is known to be a classical motor area which is furthermore involved in higher cognitive functions and working memory (Boisgueheneuc et al., 2006; Hanakawa et al., 2002; Petit et al., 1998). Its activation in the present study in non-psychopathic criminal control subjects could be explained by the involvement of working memory in the processing of the conflicts. Compared to neutral conflicts, the recruitment and activation of the working memory is stronger when deciding in a morally relevant conflict. This can be explained by higher attentional processes in the moral conflict condition. Of course, it is supposed that the working memory is also activated in psychopaths during the processing of moral conflicts, but probably the activation in this area in psychopaths was not strong enough for an apparent activation in the descriptive comparison between both groups.

Another difference in brain activation between psychopaths and non-psychopathic criminal control subjects on descriptive level is the activation of Brodmann Area 18, corresponding to the cuneus. Whereas in non-psychopathic criminal control subjects this brain region located in the occipital lobe showed activation, in psychopaths no activation was revealed. The main function of the cuneus is its involvement in basic visual processing (Vanni et al., 2001). Thus, its activation in the present study that used visual presentation of the conflicts, does not surprise. However, in psychopaths, cuneus activation seems to be very little and as a consequence it does not appear as an area of activation in the descriptive comparison between both groups. Based on this minimal difference in the activation pattern of both groups, further conclusions concerning neural dysfunctions or disturbed functioning of the cuneus in psychopaths cannot be supposed and explained as there is no representable literature as scientific background.

Summing up the activations of brain areas that were revealed in non-psychopathic criminal control subjects but not in psychopaths, the most important finding is a lack of activation in right-sided middle temporal gyrus in psychopaths. As discussed above, the missing activation in this area in psychopaths could be a neural correlate of a deficient emotion processing that characterizes the psychopaths' behavior. But it has to be taken into consideration, that other differences in activation pattern such as the superior frontal gyrus and the cuneus do not allow to draw conclusions for deficient neural brain areas in psychopaths. Instead, the similarities of a basic neural network associated to moral reasoning that was revealed in both groups of this study have to be pointed out and allude to the conclusion that main differences between both groups exist on behavioral and not on neural level. Or, that differences on neural level are not detectable in this study, as they might be due to a deficient connectivity of brain areas in psychopaths which could for example be investigated with dynamic causal modelling.

5.2.3.3 Lack of Orbitofrontal Cortex Activation in Non-Psychopathic Criminal Control Subjects When Compared to Psychopaths

Before drawing a general conclusion for the differences in neural activations in the moral > neutral contrast for psychopaths and non-psychopathic criminal control subjects, one more brain area with different activation pattern between the two groups has to be discussed. Against the hypothesis that in psychopaths brain areas associated to moral reasoning would show reduced activation, an activation of the orbitofrontal cortex (OFC, BA 10/11) was revealed only in psychopaths but not in the control group. At first sight, this seems to be a surprising finding, as the OFC is an area typically involved in moral reasoning in healthy individuals (Greene & Haidt, 2002; Moll et al., 2001; 2002a; 2002b). Furthermore, Sommer et al. (2010) revealed OFC activation in healthy individuals in the moral > neutral contrast. In healthy individuals, functions such as the integration of emotions into decision-making, theory of mind, empathy and forgivability as well as the evaluation of possible future outcomes of a behavior are contributed to the OFC (Castelli et al., 2000; Gallagher et al., 2000; Farrow et al., 2001; Partiot et al., 1995; Walton et al., 1994).

In the present study, the meaning of OFC activation revealed in psychopathic individuals in the moral > neutral contrast was already discussed and it was concluded that for psychopaths, the OFC activation can be explained by inputs from other brain regions associated to moral reasoning that compensate deficient amygdala inputs resulting in impaired emotional behavior and a lack of unpleasant emotions that is characteristic for psychopaths.

But how can the lack of activation in non-psychopathic criminal control subjects in the moral > neutral contrast be explained as they are not characterized by emotional detachment on behavioral level? First, it seems possible that in non-psychopathic criminal control subject the medial and superior frontal gyrus (BA 9/10) adopt functions of the OFC. And second, it has to be considered that drug abuse may confound the results. In literature, the association of drug abuse or addiction and structural and functional changes in the OFC is described repeatedly (London et al., 2000; Schoenbaum et al., 2006). Especially the fact that even after long periods of abstinence, reduced baseline measurements of OFC activation were observed (Schoenbaum et al., 2006), could explain the lack of OFC activation in non-psychopathic criminal individuals as most of them were addicted to drugs, even though they were abstinent for at least several months before the beginning of the study. Considering the possibility that previous drug abuse can confound and reduce OFC activation, it seems possible that in non-psychopathic criminal control subjects a combination of the effects of drugs on the one hand and a general dominance of the medial and superior frontal gyrus lead to the lack of OFC activation compared to psychopathic individuals.

5.2.3.4 Conclusion of the Descriptive Comparison Between Psychopaths and Non-Psychopathic Criminal Control Subjects for the Moral > Neutral Contrast

After the description and discussion of brain areas that showed different or similar activations in psychopaths and non-psychopathic criminal control subjects in the moral > neutral contrast, several conclusions should be summarized and emphasized. First, the activation of a basic neural network that is already known to be associated to moral reasoning in healthy individuals (Greene & Haidt, 2002; Sommer et al., 2010) was revealed in psychopaths as well as in non-psychopathic criminal control subjects. On the one hand, this leads to the conclusion that regardless of the grade of criminality and emotional detachment, in healthy individuals as well as in psychopathic and non-psychopathic criminal subjects a neural network including the medial and superior frontal cortex (BA 9/10), bilateral superior temporal sulcus and temporo-parietal junction (BA 39/40), left middle temporal gyrus (BA 21) and posterior cingulate cortex

(BA 31) shows activation when subjects have to decide in a moral conflict compared to a neutral conflict. On the other hand, the simple activation of this basic neural network does not allow to draw any conclusions about the intactness of the functional connectivity between the single brain areas.

Besides the similarities of brain activation in psychopaths and non-psychopathic criminal control subjects, the most important difference is the lack of activation in right-sided middle temporal gyrus in psychopaths compared to non-psychopathic criminal control subjects. As the right brain hemisphere in general and this area in particular are involved in emotion processing, the non-activation of this area in psychopaths could emphasize their deficiency of processing emotional contents and the resulting lack of emotion that is characteristic for psychopaths.

It can be concluded that except for the just mentioned non-activation of right-sided middle temporal gyrus in psychopaths that may indicate the neural basis of the emotional deficient behavior of psychopaths, it seems that on neural level, differences between the two groups cannot be revealed with fMRI but need to be investigated with other methods such as DCM.

5.3 Conclusion and Outlook

This study aimed at investigating the neural underpinnings of decision-making in realistic moral conflicts in psychopaths. Whereas the neural correlates of morality and moral decision-making in healthy individuals as well as the neural basis of emotional processing in psychopaths are relatively well studied, the neural basis of moral decision-making in psychopaths is poorly understood. So, this is the first fMRI study that presented stories with moral or neutral (morally irrelevant) conflicts to psychopathic individuals in order to reveal neural processes associated with decision-making in everyday moral conflicts. In order to increase the informative value, the results of the psychopathic group were compared to those of a non-psychopathic criminal control group.

On behavioral level, the main findings of the present study consisted of a statistical tendency towards more immoral decisions and significantly higher emotion ratings in the psychopathic group when deciding immorally compared to the non-psychopathic criminal control group. Therefore, it was concluded that psychopaths are not influenced and inhibited by unpleasant emotions or a “bad conscience” when choosing an immoral decision. And even if they know that the decision they choose is socially not desired, they do not care neither about this knowledge nor about the consequences of this decision. Thus, psychopaths differ from non-psychopathic criminal control subjects mainly by their poor involvement of emotions in moral decision-making of realistic moral conflicts. Additionally, the inhomogeneity within the psychopathic group concerning the chosen decisions which emphasizes the diversity of emotional detachment in the group of psychopaths has to be pointed out again.

In order to investigate the neural correlates of decision-making in everyday moral conflicts in psychopaths in this fMRI study, brain activity in the neutral conflicts condition was subtracted from the corresponding activity in the moral conflicts condition. A broad neural network that showed increased activation consisted of bilateral medial and superior frontal areas (BA 9/10/11), bilateral superior temporal and supramarginal gyrus (BA 39), left middle temporal gyrus (BA 21), and the posterior cingulate and precuneus region (BA 7/31). All of these brain regions are known to be involved in decision-making of moral dilemmas and simple moral judgments as well as in decision-making of everyday moral conflicts in healthy subjects (Greene et al., 2001; Greene & Haidt, 2002; Moll et al., 2001; Moll et al., 2002a; Moll et al., 2002b; Sommer et al., 2010). Therefore, it was shown that in psychopaths, decision-making in realistic and everyday moral conflicts activates the same basic neural network as in healthy subjects. The same basic pattern of activation was revealed for the non-psychopathic criminal control group. As all of the mentioned brain areas are involved in the integration of emotion in moral decision-making, in higher attentional processes and in social perception processing, it was discussed that the similar pattern of activation in psychopaths as in healthy and non-psychopathic criminals may be due to a deficient interconnection among the single brain areas and to deficient inputs from limbic areas such as the amygdala. But with these findings as a basis, further research could use models such as dynamic causal modelling (DCM) in order to infer direct connectivity among the single brain areas involved in moral decision-making.

A descriptive comparison of the activated brain areas in the moral > neutral condition in psychopaths and non-psychopathic criminal individuals showed that besides a very similar pattern of activation (as mentioned above), psychopaths differed from control subjects in a missing activation in the right-sided middle temporal gyrus which may indicate a neural basis of the emotional detachment that is characteristic for psychopaths. But summing up, the differences between the two groups are more perceptible on behavioral level than on neural level. Of course, this can again be due to a deficiency in the connections of the neural network in psychopaths which could not be investigated in this study.

In addition to the moral > neutral contrast that revealed brain areas implicated in everyday moral reasoning, neural correlates related to choosing a personal desire-guided immoral response over a moral response were identified in psychopaths and revealed increased activation in the medial frontal cortex bilaterally (BA 6) and the cingulate cortex bilaterally (BA 24). This activation pattern reflects the strong involvement of cognitive and emotional processes in moral decision-making resulting in an immoral response and indicates increased attentional processes and a higher conflicting process in the immoral condition than in the moral condition. In this context, once more a deficient input from the amygdala was discussed that may result in an impairment of processing unpleasant emotions on neural level and in immoral and antisocial behavior on behavioral level.

Taken together, the present study provides a better understanding of everyday moral decision-making and its neural underpinnings in psychopaths. Further, it shows that whereas psychopaths are characterized by their emotional detachment on behavioral level, differences on neural level could be explained by a deficient emotion processing due to impaired connectivity among single brain areas, especially with the amygdala.

By investigating the neural and behavioral correlates of moral decision-making of psychopaths in everyday moral conflicts, this study closes a gap in scientific literature on the one hand, but on the other hand several new questions raise from the present findings. Therefore, in future research the interconnectivity among the single brain areas associated with moral decision-making in psychopaths has to be clarified.

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8 Erklärung

Ich erkläre hiermit, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Die aus anderen Quellen direkt oder indirekt übernommenen Daten und Konzepte sind unter Angabe der Quelle gekennzeichnet. Insbesondere habe ich nicht die entgeltliche Hilfe von Vermittlungs- bzw. Beratungsdiensten (Promotionsberater oder andere Personen) in Anspruch genommen. Niemand hat von mir unmittelbar oder mittelbar geldwertige Leistungen für Arbeit erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen. Die Arbeit wurde bisher weder im In- noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt.

9 Zusammenfassung

Neuronale Korrelate moralischen Urteilens bei Psychopathen

-

Eine fMRT-Studie

Während mit Hilfe der fortschreitenden Entwicklung in der medizinischen Bildgebung durch die funktionelle Magnetresonanztomographie (fMRT) die neuronalen Grundlagen moralischen Urteilens bei gesunden Probanden weitgehend gut untersucht sind, gibt es hierzu kaum Studien an Patienten mit dem psychischen Störungsbild der „Psychopathie". Diese Patienten sind charakterisiert durch emotionale Abgestumpftheit, Impulsivität und Aggressivität sowie durch unmoralisches Verhalten im Alltag.

Die vorliegende fMRT-Studie untersucht das moralische Urteilen und dessen neuronale Grundlagen bei „Psychopathen" sowie bei einer aus nicht-psychopathischen forensischen Patienten bestehenden Kontrollgruppe. Die beiden jeweils aus 12 männlichen Probanden bestehenden Gruppen unterschieden sich durch die Höhe ihrer erreichten Punkte auf der Psychopathy Checklist-Revised (PCL-R). Während die Probanden der psychopathischen Gruppe einen PCL-R-Wert von über 26 aufwiesen, wiesen die Probanden der nicht-psychopathischen forensischen Kontrollgruppe einen PCL-R-Wert von unter 16 auf. Um die neuronalen Korrelate moralischen Urteilens in beiden Gruppen zu untersuchen, wurden allen Probanden 56 realistische und alltägliche Konflikte präsentiert. 28 dieser Konflikte bestanden aus moralischen Konflikten, bei denen die Probanden zwischen einem persönlichen Bedürfnis (unmoralische Antwort) und der Erfüllung einer ethischen Norm (moralische Antwort) entscheiden mussten. Die anderen 28 Konflikte waren neutralen Inhalts und erforderten eine Entscheidung zwischen zwei persönlichen Bedürfnissen. Alle Konflikte wurden den Probanden schriftlich und in randomisierter Reihenfolge im MRT präsentiert. Die Probanden wurden aufgefordert, sich nach jedem Konflikt auf die Frage „wie verhalte ich mich?" für eine der dargebotenen Antwortmöglichkeiten zu entscheiden. Im Anschluss an die

Messung im MRT wurden die Probanden gebeten, in einem schriftlichen Fragebogen zu allen Konflikten den Grad ihrer mit der Entscheidung verbundenen Sicherheit sowie ihre damit verbundenen Gefühle auf einer 5-stufigen Skala von „sehr gut / sehr sicher“ bis „sehr schlecht / sehr unsicher“ anzugeben.

Die Auswertung der Ergebnisse auf Verhaltensebene zeigte eine statistische Tendenz zu mehr unmoralischen Entscheidungen innerhalb der moralischen Konflikte bei den psychopathischen Probanden im Vergleich zu den nicht-psychopathischen forensischen Kontrollen. Des weiteren ergaben sich sowohl in der psychopathischen als auch in der nicht-psychopathischen forensischen Kontrollgruppe innerhalb der moralischen Konflikte signifikant schlechtere Gefühle und signifikant weniger Sicherheit bei der Entscheidung für eine unmoralische Antwort im Vergleich zu einer moralischen Antwort. Im statistischen Vergleich zwischen beiden Gruppen zeigte sich allerdings, dass sich Psychopathen bei unmoralischen Entscheidungen signifikant weniger emotional beeinträchtigt fühlen als die nicht-psychopathischen forensischen Kontrollen.

Um die Gehirnareale festzustellen, die an moralischem Urteilen alltäglicher Konflikte beteiligt sind, wurde die Aktivität, die während der neutralen Konflikte gemessen wurde von der entsprechenden Aktivität während der moralischen Konflikte abgezogen. Für diesen Kontrast ergab sich für die psychopathische Gruppe eine signifikante Aktivierung in den folgenden Arealen eines fronto-temporo-parietalen Netzwerks: medialer und superiorer frontaler Gyrus (BA 9/10/11), superiorer temporaler und supramarginaler Gyrus beidseits (BA 39/40), linker mittlerer temporaler Gyrus (BA 21) sowie im Gyrus cinguli (BA 31) und Precuneus (BA 7) beidseits. Diese Ergebnisse wurden auf deskriptiver Ebene mit denen der nicht-psychopathischen forensischen Kontrollgruppe für den Kontrast moralische > neutrale Konflikte verglichen. Hierbei zeigte sich in beiden Gruppen ein ähnliches Aktivierungsmuster im medialen und superioren frontalen Gyrus (BA 9/10), im superioren temporalen Sulcus und der temporoparietalen Junction beidseits (BA 39/40), im linken temporalen Gyrus (BA 21) sowie im posterioren Cingulum und im Precuneus (BA 31/7). Dagegen unterschieden sich die beiden Gruppen in der Aktivierung des orbitofrontalen Kortex (BA 10/11), der nur innerhalb der psychopathischen Gruppe eine Aktivität zeigte. Im Gegensatz dazu wurden in der nicht-psychopathischen forensischen Kontrollgruppe Aktivierungen im Bereich des rechten temporalen Gyrus (BA 21), sowie des superior frontalen Gyrus (BA

6) und des Cuneus (BA 18) beobachtet, wohingegen sich in der psychopathischen Gruppe in diesen Gehirnarealen keine Aktivierung zeigte.

Zusätzlich zu der Analyse der Gehirnareale, die mit moralischem im Vergleich zu neutralem Urteilen assoziiert sind, wurde eine genauere Untersuchung der moralischen Konflikte innerhalb der psychopathischen Gruppe durchgeführt. Das Ziel dieser zweiten Analyse war, die Gehirnareale festzustellen, die mit Entscheidungen für ein persönliches (unmoralisches) Bedürfnis im Vergleich zu den Entscheidungen für eine ethische (moralische) Norm assoziiert sind. Dieser Vergleich wurde mit den 8 der 12 psychopathischen Probanden gerechnet, die ein Antwortmuster von mehr als 30% unmoralischer Antworten innerhalb der moralischen Konflikte zeigten. Das Ergebnis dieses Vergleichs war eine signifikante Aktivierung im medialen frontalen Gyrus und im Gyrus cinguli beidseits (BA 6/24).

Die Ergebnisse dieser Studie liefern einen wichtigen Beitrag zum Verständnis des Störungsbildes der „Psychopathie“ - sowohl auf Verhaltens- als auch auf neuronaler Ebene. Auf Verhaltensebene unterstreichen die Ergebnisse den klinischen Unterschied zwischen Psychopathen und nicht-psychopathischen Kriminellen. Während für beide Gruppen ein antisoziales und kriminelles, aggressives Verhalten typisch ist, sind Psychopathen darüber hinaus typischerweise durch ihre emotionale Abgestumpftheit charakterisiert. Dass sich Psychopathen in den moralischen Konflikten der vorliegenden Studie tendenziell häufiger unmoralisch entscheiden als ihre nicht-psychopathischen kriminellen Kontrollen und sich dabei auch noch weniger emotional beeinträchtigt fühlen als die Kontrollprobanden, spricht stark für eine emotionale Beeinträchtigung bei Psychopathen. Es kann davon ausgegangen werden, dass Psychopathen im Vergleich zu nicht-psychopathischen forensischen Kontrollen bei der Entscheidung für eine unmoralische Option weniger durch unangenehme, negative Gefühle beeinflusst werden, die im Sinne eines „schlechten Gewissens“ die unmoralische Entscheidung inhibieren würden.

Die Resultate der Untersuchung im fMRT tragen ebenfalls einen großen Teil zum besseren Verständnis der neuronalen Grundlagen moralischen Urteilens bei Psychopathen und nicht-psychopathischen forensischen Patienten bei. Ein wichtiges Ergebnis dieser Studie ist, dass bei Psychopathen ein ähnliches Netzwerk an Gehirnarealen beim moralischen Urteilen aktiviert wie es bereits aus mehreren Studien an gesunden Probanden bekannt ist. Das führt zu der Schlussfolgerung, das die realistischen, alltäglichen moralischen Konflikte, die in der vorliegenden Studie verwendet wurden, auch dazu geeignet sind, Gehirnareale zu aktivieren, die bisher vor allem bei der Beurteilung moralischer Dilemmata bei gesunden Probanden Aktivierung zeigten. Allerdings darf aus diesem ähnlichen Aktivierungsmuster weder auf eine intakte Funktion der jeweiligen Gehirnareale noch auf eine intakte Interaktion der Areale bei Psychopathen geschlossen werden. So kann die Aktivierung des orbitofrontalen Kortex bei moralischen > neutralen Konflikten bei Psychopathen unter anderem auf vermehrte Inputs von anderen, z.B. benachbarten Hirnarealen hinweisen, die die fehlenden beziehungsweise defekten Inputs von Seiten der Amygdala kompensieren. Diese Minderaktivierung der Amygdala könnte außerdem die Affektverflachung und das typische unmoralische und emotional kalte Verhalten von Psychopathen erklären. Auch die beobachtete Aktivierung der temporo-parietalen Junction (TPJ; BA 39/40) bei Psychopathen erlaubt keinen Rückschluss auf eine intakte Funktion dieses Areals, wie zum Beispiel die Fähigkeit, sich in andere Personen hineinzuversetzen. Die Ergebnisse führen also zu der Annahme, dass bei Psychopathen die Verbindungen zwischen den einzelnen, mit moralischen Entscheidungen assoziierten Gehirnarealen nicht intakt sind. Leider können diese Verbindungen und Verschaltungen mit Hilfe des fMRT nicht untersucht werden. Hierfür müssten Techniken wie dynamic causal modelling (DCM) verwendet werden um weitere Aussagen treffen zu können. Auch für den Vergleich zwischen Psychopathen und nicht-psychopathischen forensischen Kontrollen gilt ähnliches. Beide Gruppen weisen ein ähnliches Aktivierungsmuster auf, was darauf hinweist, dass die unterschiedlichen Verhaltensmuster beider Gruppen vor allem auf einer funktionell gestörten Verbindung zwischen den einzelnen Hirnarealen bei Psychopathen beruhen. Während allerdings bei den nicht-psychopathischen forensischen Kontrollen eine Aktivierung der mittleren temporalen Gyrus (BA 21) beidseits festgestellt werden kann, lässt sich diese bei Psychopathen nur linksseitig beobachten. Dieses Ergebnis erlaubt die Schlussfolgerung, dass möglicherweise bei Psychopathen die rechte Hemisphäre und speziell der rechte Temporallappen, die mit Emotionsverarbeitung assoziiert sind, funktionelle Einschränkungen aufweisen. Auch das würde die emotionale Abgestumpftheit bei Psychopathen weiter unterstreichen. Zusammenfassend lässt sich festhalten, dass die

Ergebnisse dieser Studie die fehlende Emotionalität von Psychopathen, vor allem im Vergleich zu nicht-psychopathischen forensischen Probanden, sowohl auf Verhaltensebene als auch auf neuronaler Ebene unterstreichen. Bei den neuronalen Grundlagen moralischen Urteilens bei Psychopathen scheinen besonders die Verbindungen zwischen den einzelnen Gehirnarealen beeinträchtigt zu sein, vor allem was die Inputs von Seiten der Amygdala betrifft. So bildet diese Studie einen wertvollen Beitrag zum besseren Verständnis der Psychopathie und ihrer neuronalen Korrelate und schafft darüberhinaus die Grundlagen für zukünftige Studien.