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Anatomical and behavioural correlates of emotion-induced social decision-making

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Abstract

This thesis explored the behavioural and neural processes associated with the effect of sympathy and anger on socio-economic decision-making. Experiment 1 showed the defection rate decrease in sympathy and increase in anger compared to the neutral condition in the Prisoner's Dilemma and the Trust Game. Experiment 2 revealed that block and event-related designs have the same effect on defection over the three emotion conditions in the Prisoner's Dilemma. Experiment 3 indicated that direct, but not displaced, emotion group participants' defection rate replicated the finding of Experiment 1. Additionally, cognitive inhibition showed a consistent pattern over three experiments; while in the Prisoner's Dilemma low cognitive inhibition participants' defection decreased in sympathy and increased in anger compared to neutral, high cognitive inhibitors' defection was similar across conditions. Yet, cognitive flexibility (Experiment 3) did not affect participants' defection rate. Similarly, Experiment 2 and Experiment 3 found that defection rate in the Prisoner's Dilemma was modulated by expressive suppression, but not cognitive reappraisal; low expressive suppression participants were defecting more in the anger and less in the sympathy compared to the neutral condition. The fMRI analysis in Experiment 4 showed increased left amygdala activation while defecting in the sympathy condition and decreased putamen activation while cooperating in the anger condition. These areas are possibly necessary to overcome the emotion driven impulses to cooperate in the sympathy and defect in the anger conditions. Finally, Experiment 5 revealed that vmPFC patients' accuracy decreased from neutral to emotional exclusive disjunction trials, while parietal lobe and normal controls showed a reversed pattern signifying vmPFC's role while making decisions under emotion. The combination of these findings highlights the importance of individual difference and the role of the amygdala, putamen and prefrontal cortex in socio-economic decision-making under emotion. However, alternative interpretations cannot be ruled out without further investigation.

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Declaration

This thesis comprises the candidate's own original work and has not, whether in this or other form, been submitted to this or any other University for a degree. Selected parts of this thesis have been largely based on work that was published in a peer-reviewed journal or presented elsewhere.

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Chapter 1 Introduction

An essential part of human social life is spent on decision-making which can range from simple deliberations -whether one should invite a friend for a coffee- to more complex ones such as whether to remove life support for a family member. To date, most experimental studies on decision-making have examined choices with clearly defined probabilities and outcomes, such as monetary decisions in gambling tasks. Given that we live in highly complex social environments, however, many of our most important decisions are made in the context of social interactions and involve emotional processes (Carstensen, Gross, & Fung, 1997). Although relatively understudied, these social situations offer a useful window into more complex forms of decision-making, which may better approximate many of our real-life choices.

For centuries, people have been interested in how the mind works and in particular the conflict between the two opposing aspects of the mind: rationality and deliberate logic versus emotion and impulsiveness. At first, it was a question for philosophy. Early Greek philosophers such as Plato thought that the human soul was divided into separate parts: reason and emotion. He suggested that people should make decisions only when emotions were separated from the reasoning process. Others emphasized the nature of the interaction between emotions and reasoning describing the relationship as akin to a master and his slave, with the master being logic and the slave emotion (Lewis, Haviland-Jones, & Barrett, 2010). With the rise of psychology as a science, the main currents of behaviourism and early cognitive psychology neglected the role of emotions even more seeing them as confounding variables. This is understandable as emotions are hard to trigger in an experimental setting, and even harder to control and direct, therefore highly subjective results were difficult to avoid (Lane & Nadel, 2002; LeDoux, 1998).

Besides psychology, another important area of research in decision making is economics. Classic economic theory follows a normative approach to understanding human decision-making. That is, humans are assumed to be rational beings, motivated purely by the goal of maximizing gains and minimizing losses (Camerer, 1997). However, from studies investigating decision-making in socio-economic games it is evident that people do not always make purely “rational” choices (Dawes & Thaler, 1988). One possible factor explaining these deviations from rationality is that socio-economic decisions are influenced by emotions (Elster, 1997; Frank, 1988). In this respect reasoning does not seem to be an exception as a variety of other cognitive processes were found to be influenced by emotion such as attention (Matthews & Wells, 2005; Öhman, Flykt, & Esteves, 2001; Phelps, Ling, & Carrasco, 2006), perception (Phelps et al., 2006; Rainville, Bao, & Chrétien, 2005; Slovic & Peters, 2006), and memory (Cahill & McGaugh, 1998; D'Argembeau & Van der Linden, 2007; Kensinger, 2007; Phelps, 2004).

Interestingly, although emotions for a long time were assumed to have a negative impact on decision-making and rational thinking (Camerer, 1997; Carstensen et al., 1997; Lewis et al., 2010), recent evidence suggests that this is not always the case. For example, Damasio (1994) observed a group of patients with lesions in the ventromedial prefrontal cortex; they showed normal cognitive abilities, yet their emotional responses were muted and resulted in difficulties with even simple decision-making tasks such as scheduling time for the next appointment (Damasio, 1994). Other studies, with healthy participants demonstrated that reasoning with emotional content can draw attention to the problem and facilitate its correct solution when compared to equivalent problems with neutral content (Blanchette, Richards, Melnyk, & Lavda, 2007; Goel & Vartanian, 2011).

This reasoning literature sheds different light on the topic. Although emotions are thought to impair the decision-making and reasoning processes, the recent experimental evidence shows that emotional processing is necessary for successful choices. It helps to achieve normatively correct answers in reasoning tasks and in the social context helps individual's everyday life decision-making. Yet the main issues left to be clarified are how different emotions affect decision-making in social contexts and if individual differences can modulate this effect.

The principal aim of this thesis was to explore the influence of emotion on social decision making via exchange games both behaviourally and at the neural level. This was achieved by contrasting two emotion conditions – sympathy and anger – with a neutral emotion condition in an economic exchange setting. Generally, the interaction between emotion and decision-making was explored in social economic exchange games forming the backdrop for experimental manipulations to give insight into the complexities of human decision-making. More specifically, the interest was two-fold: to disentangle the impact of emotion direction (partner-directed or displaced emotion), and investigate the role of cognitive and emotion regulation abilities on emotion and decision-making. Furthermore, the anatomical correlates involved in decision-making under the influence of emotion were studied to provide insight not only into how the healthy brain makes decisions in social situations, but also into how decision-making is affected by structural brain damage resulting in emotional imbalance (Damasio, 1994; Hornak, Rolls, & Wade, 1996). Therefore, the principal question this thesis tried to answer was 'What neural networks are involved in the application of logic under the influence of emotion in social decision making?' The main research questions that arose from the principal question were (1) the effects of cognitive control and emotion regulation on the interaction between emotion and logic in a social exchange task decision-making and (2) the investigation of the neural correlates involved in representing this interaction in the brain.

Chapter 2 General Introduction

This chapter examines the role of emotion in reasoning and decision-making processes as well as the possible variables shaping how emotions influence human decision-making. In order to address the question of what is currently known about the role of emotions in the decision-making process some background is needed. First an introduction of the study of emotion and logic interaction in social decision-making, with a specific focus on human decision-making theoretical models and behavioural experiments is outlined. Secondly, evidence of different emotion characteristics and possible influences on decision making under emotion from cognitive control and emotion regulation will be discussed. In the final section, the neuropathways of decision-making under the influence of emotion as well as the social aspect of human interaction in the economic exchange will be presented. The specific research questions addressed in the following chapters will then be presented, based on the evidence from this review.

2.1 Emotion and reason interaction in decision-making

Decision-making is thought to involve both rational thinking and an emotional impulsive component. Though for a long time it was considered that decisions made by suppressing the emotional component were more efficient in everyday life as well as resulting in normatively correct answers in formal reasoning tasks, more recent experimental results suggest that emotions can benefit the decision making process. For example, the Iowa Gambling Task where healthy participants would experience regret for losing money, emotions help them to choose optimal winning choices (Bechara, 2000; Bechara, 2004; Bechara & Damasio, 2005; Damasio, 1994). Also reasoning tasks with negative emotional content result in normatively correct answers (Blanchette & Caparos, 2013; Blanchette et al., 2007; Goel & Vartanian, 2011). However, many fundamental aspects of how emotion and rational thinking interact during social decision-making are not yet fully understood. This section will provide definitions of emotion and the decision-making process, followed by current models of how emotion is thought to influence logic in human decision-making, derived from behavioural and neurological studies. Later sections of this review will explore the neuroimaging literature on emotion, reasoning and strategic thinking contributions to social decision-making.

2.1.1 Defining decision-making and emotion

Before starting to analyse human decision-making under emotion, it needs to be considered how optimal decisions based only on rational thoughts are made and how emotional influences on reasoning and decision-making occur. This part of the chapter will discuss how game theory has been used to predict decisions and will provide a working definition of emotion, and how emotion differs from mood and feeling.

Decision-making vs. reasoning?

Before discussing how emotions interact with reasoning in socio-economic decision-making, a comparison between decision-making and reasoning processes is necessary. Although there are two broad methods of reasoning – inductive and deductive – only deductive reasoning will be discussed in this thesis. Deductive reasoning is a "top down" approach working from more general information to more specific. Reasoning and decision-making, while philosophically both dependent on logic, are however, investigated empirically as separate fields. Philosophers distinguish theoretical reasoning which is concerned with beliefs (in other words, preserving truths through deductive reasoning), while practical reasoning (or commonly called decision-making) is concerned with achieving goals (Evans, 2012). From this it follows that traditionally deductive reasoning assumes the truth to be binary (either true or false) while in decision-making the choices are made with a combination of uncertainties, beliefs and desires.

In deductive reasoning tasks, there is a current shift from interpreting the beliefs only as true or false to variable degrees of subjective probability (Evans, 2012). Following this, as Bayesian theory uses probabilities to estimate the outcome of a reasoning task, while individuals in the decision-making tasks make their choices based on probabilities of certain events happening, the study of reasoning and decision-making as one field becomes feasible at least at a psychological level. All this suggests that Bayesian theory could be applied to both deductive reasoning with syllogisms[1] and

[1] Logical argument requiring deductive reasoning to decide if the conclusion is valid depending on two given or assumed prepositions (premises). For example, the syllogism 'All cars have four wheels. No scooters have four wheels. No scooters are cars' is valid as the conclusion 'No scooters are cars' follows from the two premises 'All cars have four wheels. No scooters have four wheels'.

deontic tasks[2], and decision-making.

Furthermore, if individuals reason to make decisions, then phenomena that occur in deductive reasoning should occur in judgment and decision-making processes (Johnson-Laird & Shafir, 1993). In fact, Legrenzi, Girotto and Johnson-Laird (1993) revealed that in a deontic reasoning task (Wason's selection task) and a decision-making task (a riskless tasks where participants need to ask information until they can make a decision) participants construct models with as little explicit information as possible in order to minimize the working memory load. In other words, they find that in both tasks participants focus on the explicit information for their models and do not consider alternatives.

Similarly, while deductive reasoning is mostly studied with syllogisms or deontic tasks, individuals still have decisions to make, e.g. does the conclusion follow from the premise, and which cards to select (Evans, Over, & Manktelow, 1993). Here individuals might rely on heuristics and intuitions. At the same time, in decision-making tasks individuals will have to evaluate the information available to make a conclusion about the choice they are given. For this, slow and deliberate logic processes are needed, yet they also might rely on heuristics and intuitions.

In sum, although theoretical reasoning and decision-making have been studied as separate fields, the idea of both processes sharing the same mechanisms has been and is being investigated (Evans, 2012; Evans et al., 1993; Johnson-Laird & Shafir, 1993). Based on the current philosophical considerations both reasoning and decision-making may rely on probabilities and at the bottom level both processes can be influenced by the same logic.

How are optimal decisions made?

Game theory is used in economics and some psychological research to analyse an individual's decision-making process. This theory is based on mathematical models predicting the behaviour/decision-making of two rational and intelligent players

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[2] Deontic tasks have a scenario telling what an individual must, should or should not do in a set of given circumstances. For example, in Wason's Selection Task participants are given a scenario that they are policemen on patrol and they have to check that if a person is drinking beer in the pub, they are over 21. On the table there are 4 double-sided cards with the following information provided on the face-up sides of the cards: 'age 18', 'age 22', 'beer' and 'coke'. Which card/cards need to be turned over to see if the law was not broken? The 'age 18' and 'beer' cards needs to be turned over.

(Myerson, 2013). In this theory, the term ‘game’ refers to any situation involving at least two individuals – the ‘players’. The first assumption of game theory, that players behave rationally, refers to the utility model, which assumes that individuals always act in their own self-interest, namely, maximizing gains and minimizing losses (Camerer, 1997). Although individuals are supposed to strive to maximise their utility worth in games this behavioural trend is not linear but depends on the value attached to items and perceived risk (Myerson, 2013). For example, £10 might be a significant amount of money for a very poor person, but for a richer person it is not even worth considering as the change in financial situation would not be significant. In addition, the utility model takes into account subjective probabilities as each player has to anticipate the possible behaviour of their opponent and act accordingly (Loewenstein, Thompson, & Bazerman, 1989; Messick, 1995). The second assumption about the player in game theory concerns his/her intelligence. Players have the same level of intelligence and knowledge as the experimenter. They can understand the game and make the inferences about it not any worse than the researcher (Myerson, 2013). Only in these conditions would experimenters be able to analyse the players’ behaviour and predict their choices accurately.

However the utility model received criticism as a number of studies showed evidence that individuals do not always make the most logical decisions to increase their wealth, and indeed their choices in most games are based on fairness that each player would receive the same payoff (De Cremer, Handgraaf, & Van Dijk, 2003; van Dijk & Vermunt, 2000). In addition, individuals are not driven only by self-interest and the fairness principle, but also take into consideration the outcomes for their partner, as is discussed in the social utility model (De Cremer et al., 2003; Loewenstein, Thompson, & Bazerman, 1989). This model is based on two concepts of how individuals make their decisions: absolute payoff value, and comparative payoff value (van Dijk & Vermunt, 2000). While the absolute payoff value is similar to the utility model meaning that the player is interested in gaining maximum payoff, the comparative payoff value means that individuals are interested in keeping their gains and losses similar to the other players or slightly better outcome for the individual player. Even players who are only be driven by self-interest, would still consider fairness as an important factor influencing the others’ choices as they are intelligent enough to predict such behaviour. However, various other effects such as descriptive framing (Camerer, 1997; De Martino, Kumaran, Seymour, & Dolan, 2006), fairness equilibrium (Camerer, 1997), consideration of the beliefs and desires of other players (Mellers, Haselhuhn, Tetlock, Silva, & Isen, 2010), perceived trustworthiness (King-Casas, 2005) are known to affect the decision-making process and, as emotions are particularly relevant when decision-making occurs in a social context (Reis & Collins, 2004), the role of emotions in that process need to be taken into consideration.

Thus, the focus of this thesis is not on optimal decision-making, but rather on decisions in a social context where the difference between normatively correct and incorrect answers is affected by social constructs and interactions. Consequently, the main attention here is upon emotions and their effect on human behaviour.

What is an emotion?

Although emotion has been an object of research in psychology and philosophy for a long time, there is no agreement on a single definition (Izard, 1992; Mulligan & Scherer, 2012; Rolls, 2000). In the affect literature, a few separate processes are used as synonyms to emotion such as affect, feeling, mood, and finally emotion itself (Scherer, 1982, 2005; Tooby & Cosmides, 1990).To start with, emotions have evolved over time as an adaptive mechanism of reacting to reappearing and structured situations to which psychological adaptation happened (Tooby & Cosmides, 1990).

Evolutionary perspective views emotions as serving an adaptive function in humans, yet currently there is an agreement that not only nature influences emotions, but also the social and cultural context helps to shape them (Nesse, 1990). Biologically, three systems influence emotions – visceral afferents (mechanisms providing with the feelings of hunger may also convey a sense of nausea during emotionally stressful situations; (Porges, 1997)), the sympathetic nervous system - fight or flight response (Cannon, 1928) and the parasympathetic nervous system (in particular vagal control of the heart) influences individual differences in emotion expression and regulation of emotion (Diamond, Hicks, & Otter-Henderson, 2011; Porges, Doussard-Roosevelt, & Maiti, 1994). The function of these biological concepts affecting how emotions arise is not only to help to survive and spread their genes, but to help humans to succeed in social relationships (Nesse, 1990). Yet, social emotions are not fixed responses but vary depending on individual and cultural differences - for example fear to snakes and darkness might be inborn (Öhman et al., 2001), but fear of knives and guns can be learned (Öhman, Dimberg, Öst, & others, 1985). Furthermore, according to (Scherer, 1982, 2005) emotions can have behavioural expression, induce arousal/bodily symptoms or be subjective experience. The subjective experiences are particularly important not only in physical form, but in a social and psychological context (Rolls, 2000). Emotions differ from feeling and moods in that feelings are just a single component (subjective experiences) while emotions are multicomponent constructs (Scherer, 2005). Finally, moods in everyday language and academic studies are considered to be longer lasting and of lower intensity than emotions (Beedie, Terry, & Lane, 2005).

Even though recent research investigated the influence of emotions on decision-making, the majority of such studies were interested in emotions associated with the reputation effect which arise in response to the partner's behaviours earlier in the interaction (e.g. Ben-Shakhar, Bornstein, Hopfensitz, & Van Winden, 2004; Bosman & Van Winden, 2002; Duersch & Servátka, 2007). Only a very few studies have looked into how emotions directed towards the other (i.e. partner-directed emotions) influence our social decision-making. The objective of this section is to review our current knowledge about how different types of emotion direction (i.e. displaced and direct sympathy and anger) influence decision-making. In addition, what are the aspects influencing emotion duration and strength that might affect decision making on the social exchange game due to the experimental design choice (blocked or event-related presentation of the emotion condition)?

This thesis focused on the effects of two partner-directed emotions which were predicted to influence social exchange decision-making – sympathy and anger. These two emotions were chosen for a number of reasons. First of all, sympathy and anger are social emotions and emerge in the interaction between individuals. Secondly, while one of these emotions induces altruistic behaviour, another triggers selfish choices. That is, both emotions not only have a measurable behavioural outcome, but they are also on opposite ends of the social behaviour continuum.

Sympathy is traditionally defined as an emotional response that results from the awareness of another persons' negative emotional state (Wispé, 1986). Its subjective experience consists of feelings of sorrow and concern for the other, although this may not always be an aversive experience for the individual themselves. It is also associated with heightened awareness of the plights of others, and a desire to help (Eisenberg & Strayer, 1987; Wispé, 1986). Empathy is associated with the emotional state of others and commonly defined as the ability to "put oneself in the other's shoes" rather than being an emotional experience itself (with resulting action tendencies; (Eisenberg &

Strayer, 1987). One might say that the ability for empathy is a precondition to feel sympathy.

Whereas the feeling of sympathy requires the feeling of need to help the other, anger is caused by frustrating events initiated by others or even oneself, and the responsibility of the frustration is held upon the others (Winterich, Han, & Lerner, 2010). Anger can be triggered by frustrating or provocative events (e.g. being stuck in traffic), the behaviour of others (critical, disrespectful comments), objects (a malfunctioning computer) or one's own behaviour or characteristics such as missing an important meeting (Deffenbacher, 2011). For the induction of anger, the provocation has to be unexpected, apparently real, and with a high degree of the agent's accountability for the behaviour induced (Stemmler, 1997). Lobbestael, Arntz and Wiers (2008) looked into anger induction techniques and found that only harassment caused significant reaction on all used physiological measures (blood pressure, heart rate and galvanic skin conductance). This demonstrates that in order for anger induction to be effective and cause a physiological response, a strong negative as well as personal stimulus is necessary.

In summary, for successful sympathy induction, past studies have shown that a subject must adopt the other's perspective or to place at least a moderate value on the welfare of the other (Lishner, Batson, & Huss, 2011; Smith, 1992). Anger-induction, on the other hand, requires unexpected and apparently real frustrating events (Clore & Centerbar, 2004; Deffenbacher, 2011; Stemmler, 1997; Winterich et al., 2010).

Direct and displaced emotions in socio-economic context

Although emotions can affect an individual’s choices, the extent of this impact can differ depending if the emotion is felt towards the opponent or is displaced from another subject/event. This section will discuss the empirical evidence showing how direct and displaced emotions influence an individual’s behaviour in a social and economic context.

Direct emotion is when one individual feels a particular emotion towards another individual and expresses those emotions directly to that person. On the other hand, emotion displacement is generally defined as an unconscious mechanism whereby the feeling towards one individual is redirected to another individual or object because the original target is unavailable, or the emotion expressed to it is dangerous or unacceptable, resulting in a redirection of emotion to a lower level target (Dollard, Miller, Doob, Mowrer, & Sears, 1939; Miller, 1941). A common example is when someone is angry with an employer, but cannot express the anger for fear of losing the job, so they take it out on their children, this way displacing their emotion. Incidental and displaced emotions in this thesis refer to the same type of emotion mechanisms and are used as synonyms.

It is well established that an individual's decisions during interaction with others are influenced by emotions felt towards the other person (Batson & Ahmad, 2001; Harmon-Jones, Peterson, & Vaughn, 2003; Harmon-Jones & Sigelman, 2001; Van Lange, 2008) or displaced from another person or event (DeWall, Twenge, Bushman, Im, & Williams, 2010; Marcus-Newhall, Pedersen, Carlson, & Miller, 2000; Reijntjes et al., 2013). Moreover, the decisions participants make may depend not only on whether they act under the influence of emotion, but also on the direction of that emotion. An individual might interact in one way while dealing with the subject of their emotion, but differently while displacing their emotion to another individual (Bartlett & DeSteno, 2006) or if they act under the influence of emotions felt due to reasons unrelated to the initial task; for example weather conditions having an effect on enrolment to college (Simonsohn, 2010) or watching video clips and then playing an economic game (Harlé & Sanfey, 2007).

Although direct and displaced emotions have been investigated separately in the context of decision-making, the nature of the relationship between direct and displaced emotion has been investigated only in a few studies and these two types of emotions in the socio-economic context did not yield consistent results (Bartlett & DeSteno, 2006; DeSteno, Bartlett, Baumann, Williams, & Dickens, 2010).

For example, direct sympathy has been found to induce helping behaviour in students who were sharing their lecture notes with another student whose eye infection prevented him from taking his own notes (Reisenzein, 1986) and also to promote willingness to help a family whose son has cancer (Harmon-Jones et al., 2003). Direct sympathy also led to more generous decisions towards the other person in economic decision-making games (Batson & Ahmad, 2001; Batson & Moran, 1999; Duersch & Servátka, 2007; Van Lange, 2008). In the Prisoner's Dilemma and the Ring Measure of

Social Values games[3], higher cooperation rates were promoted when participants perceived their opponent to be in need and when they adopted their opponent's feelings (Batson & Moran, 1999; Van Lange, 2008). Batson and Moran (1999) showed that relating to, and being aware of one's partner's current difficulties, results in higher cooperation in the Prisoner's Dilemma, compared to a neutral emotion. In a follow-up study by Batson and Ahmad (2001), this increased cooperation was apparent even when the opponent had made previous decisions in the game that were against the interests of the participant.

Similarly to direct emotion, early investigations of displaced positive emotions (feeling grateful) show that people in a positive emotion condition show more willingness to help others (donate to charity or agree to help with a tedious task), than individuals who were assigned to a neutral emotion condition (Batson, Coke, Chard, Smith, & Taliaferro, 1979; Isen & Levin, 1972; Isen & Simmonds, 1978; Levin & Isen, 1975). These studies commonly observed participants in their natural surroundings and a positive mood was induced by finding an experimenter's coin left in the telephone booth or being offered a cookie in the library. Although such field study set-ups allow the experiment to be as close to the real world as possible, they do not allow the strength of the emotion manipulation and the extent to which participants were affected by it to be measured directly.

A more recent experiment into displaced emotions that induced gratitude which was costly to the participant was carried out by (Schnall, Roper, & Fessler, 2010): participants viewed either videos with a person helping another individual or a control video with neutral content. Afterwards participants were asked to help with an unpaid experiment and those participants in the gratitude condition agreed to help more often than participants' in the neutral condition. Bartlett and DeSteno (2006) showed that displaced gratefulness resulted in more helping behaviour while interacting with strangers (Bartlett & DeSteno, 2006): following the induction of gratitude by receiving help from a confederate, the participant was approached by the experimenter asking for help with another experiment. The impact of the induced displaced helping behaviour was measured by how much time was spent on the other experiment. The displaced

[3] In this game participants have to make a choice regarding the distribution of wealth between themselves and the other player. For example, the participant is given an option to choose either (a) £14 for them and -£4 for the other, or (b) £13 for them and -£7 for the other. This game measures how an individual weighs their own personal gains versus the gains of another.

gratitude participants spent significantly more time than the control condition participants answering questions for the other experiment. However, this effect was eliminated when participants were made aware that they felt grateful for the person who helped in the first place. This suggests that conscious understanding of one's emotions helps to eliminate the possible affect it holds on decision-making.

In addition, other studies with positive incidental emotions (such as amusement (Harlé & Sanfey, 2007) or happiness (Andrade & Ariely, 2009) show contradicting results: in a study where amusement was induced by watching video clips followed by the Trust Game, the researcher did not find a significant difference in rejection of unfair offers compared to the neutral condition (rejection around 56% for both conditions; (Harlé & Sanfey, 2007). Yet when influenced by induced sadness, participants accepted a higher number of unfair offers compared to the neutral condition. Furthermore, in a similar study with induced incidental happiness (asking participants to describe a similar experience to the one presented in the video clip) followed by two trials of the Ultimatum Game (the first as receiver, and second as proposer) and finally by a trial of the Dictator Game, researchers found that incidental happiness actually triggered more selfish behaviour – participants accepted more unfair offers (first trial) but proposed more unfair offers (second trial), and then more often proposed an unfair/selfish deal (keeping all the money/most of the money to themselves) in the Dictator game (Andrade & Ariely, 2009). The authors explained the behaviour occurring in the second and third trials in terms of misattributing one's behaviour to stable preferences rather than to incidental affect. That is, if participants accepted unfair offers in the first interaction, they expected that others would accept unfair offers by them also.

In contrast, direct anger has been found to encourage higher defection rates in social-exchange games, even when such behaviour was costly to the decision-maker (Ben-Shakhar et al., 2004; Bosman & Van Winden, 2002; Duersch & Servátka, 2007). Moreover, the intensity of the anger felt is found to be positively related to defection rates (Bosman & Van Winden, 2002; de Quervain, 2004; Hopfensitz, 2006). Bosman and van Winden (2002) found that the more anger participants felt about their opponent's decision, the more often they destroyed income for both of them in the Power-to-Take Game. It has also been found that anger induced through perceptions of character elicits more violent behaviour towards the anger-inducing individual (Harmon-Jones & Sigelman, 2001).

In addition, a displaced aggression meta-analysis (analysing 49 studies from 1948-1997) showed that the effect of displaced anger is real and strong (Marcus-Newhall et al., 2000). Based on this analysis, several conclusions about displaced aggression were drawn: (1) the more negative the setting of the participant and aggressor interaction, the stronger the displaced aggression was; (2) the more similar the real aggressor was to the target of the displaced aggression, the stronger the displaced anger; and (3) the more intense the initial provocation, the smaller the displaced aggression; that is, the nastier the aggressor was the kinder the object of anger displacement appeared to be (Marcus-Newhall et al., 2000).

More recent findings by DeWall, Twenge, Bushman, Im, and Williams (2010) contradict the idea that the initial provocation is inversely related to the strength of the retaliation. A participant and four confederates took part in a game and at the end the confederates indicated if they would want to interact with the participant once again. With the increasing number of rejections the displaced aggression became stronger (as indicated by a spiciness of a drink mixed for the innocent other). In addition, the study by Reijntjes et al., (2013) on displaced aggression showed that when the initial anger was triggered by individuals of the same nationality, participants displaced their aggression towards people of another nationality. The authors suggested that the greater the difference between the target and the aggressor (in this case the participant) the more likely it is that he/she will displace their anger. This expands the results from Fitz and Stephan (1976) who showed that the strongest *displaced* aggression was towards people who shared most similarities with the aggressor, but not between the participant and the aggressor.

Yet, some studies with incidental anger in economic games show unexpected results. In the Stag Hunt Game[4] participants with induced anger made more low risk choices (55 % of the time). Although their risk attitude changed from the lottery game (choice between risky/high-payoff and safe/low-payoff options) to this socio-economic interaction game (they became comparatively more risk averse) their risk perception did not (assessed by a question asking how many individuals of every 100 would choose riskier options from the lottery; (Kugler, Connolly, & Ordóñez, 2012). Furthermore, in

[4] Two players have to decide whether to go stag hunting or rabbit hunting. Stag hunt has a high-payoff, but both players have to choose it otherwise they do not get anything. On the other hand, rabbit hunt has low-payoff, but doesn't require mutual agreement. Players during decision-making cannot communicate with each other.

the Ultimatum Game by Andrade and Ariely (2009) angry participants rejected more unfair offers but proposed more fair offers in the proposers role, and in the Dictator Game although they were proposing to keep more money to themselves, still gave more beneficial offers compared to the neutral condition. The same as with happiness, such behaviour in the anger condition in the second trial of the Ultimatum Game and the Dictator Game might have been attributed to stable preferences by participants, suggesting that incidental emotions affected the first trial only.

Taken together, displaced emotions, either induced by another person, or induced by a particular stimuli (e.g. viewing video clips) reveal contrasting behavioural results depending on particular emotions: positive emotions trigger gratefulness and helping behaviour, or can result in more selfish behaviour, while anger triggers aggressive behaviour, or it can result in more risk averse and fairer to others choices. Furthermore, although the effects of displaced/incidental emotions are inconsistent, a direct comparison between displaced and direct emotions might reveal dissimilarities especially in the context of socio-economic games when participants have to consider gains and losses. In Bartlett and DeSteno's study (2006) participants with induced gratefulness were more cooperative independently of whether they interacted with their benefactor (direct emotion) or a complete stranger (displaced emotion) compared to a neutral emotion condition in helping to fill in a questionnaire (Bartlett & DeSteno, 2006). Furthermore participants were more helpful to a benefactor than to a complete stranger. A follow-up study using the Give Some Dilemma Game[5] – economic decision-making game – however, did not show a difference in cooperation with a stranger versus a benefactor (DeSteno et al., 2010).

Emotion duration and strength

Studies investigating emotions in a social context tend to rely on between-subject designs where participants are exposed to a single emotion condition, preventing comparisons on a within-subject basis. However, even for within-subject designs, it remains to be clarified how long an emotion lasts and how to extend an emotion's

[5] In the Give Some Dilemma Game each player has 4 tokens which are worth £1 to them, but £2 to their opponents. The players have to decide on how many tokens they want to exchange. The game is similar to the Prisoner's Dilemma as mutual cooperation is more advantageous (gain of £8) than mutual defection (£4), but the highest gains are achieved for players who defect while the opponent cooperates (£12 vs. £0).

duration and strength depending on the choice of the experimental stimuli presentation (block or event-related design).

Emotions can last from a few seconds to a few hours and even a few days (Verduyn, Delvaux, Van Coillie, Tuerlinckx, & Van Mechelen, 2009; Verduyn, Van Mechelen, & Tuerlinckx, 2011). Although emotion duration is an important factor in experimental studies, little research has been done to identify what determines how long an emotion will last and how to maintain it, not to mention the implications different experimental designs have on the emotion duration. Currently it is common to predict emotion duration depending on three types of predictors; episodic, trait and moment.

Episodic predictors show that the importance and intensity of emotion eliciting event positively correlates with emotion duration. In the Sonnemans and Frijda (1994) study participants had to report their emotional experiences once a week during 6 weeks testing period. The correlation between anger, disappointment, positive emotion and sadness duration with intensity was positive, but fear duration and intensity correlated negatively (Sonnemans & Frijda, 1994). Furthermore, the importance of the event triggering emotions correlates positively with the intensity of emotion and as a result the duration of an emotion is increased for more important events. For example, happiness from winning the lottery will depend on the desire to win money and the amount won (Sonnemans & Frijda, 1995).

Trait predictors are personality traits that remain stable before and during an emotional event and influence how long one will experience the emotion. In the experience sampling study by Schimmack (2003) a negative correlation between unpleasant affect duration and extraversion, but a positive correlation with neuroticism was observed. In addition, the Sbarra (2006) study with couples who broke up showed that individuals who felt greater preoccupation with former partner (measured by the Relationship Styles Questionnaire) felt longer episodes of sadness, but individuals with greater secure relationship styles felt shorter periods of anger.

Finally, moments predictors are defined by the reappearance of the person who elicited emotional experience. Couples who broke up showed that being in contact with their former partner prolonged the duration of love and sadness (Sbarra & Emery, 2005). In a similar vein, Verduyn (2009) observed prolonged emotion duration following physical reappearance of the emotion-eliciting person (or event) in participants who were instructed to report their emotions every day for two weeks. These examples show that when individuals are constantly reminded of the cause of their emotion, the duration extends, as it is harder to forget the emotion eliciting experience.

The moment predictors are related to emotional rumination. Ruminating about emotion eliciting events/objects, can prolong the emotion. Although rumination is mostly associated with negative emotions, such as anger (Barber, Maltby, & Macaskill, 2005; Bushman, Bonacci, Pedersen, Vasquez, & Miller, 2005; Denson, Pedersen, Ronquillo, & Nandy, 2009; Peled & Moretti, 2007; Ray, Wilhelm, & Gross, 2008), it can also extend the duration of positive emotions such as gratitude (Verduyn et al., 2011). Interestingly, thinking about an emotion eliciting event in a certain way determines the emotional response. For example, thinking about an event eliciting negative emotions from the position of an impartial observer and finding something positive, can weaken anger and shorten the periods of time thinking about it (Ray et al., 2008).

In addition, thoughts unrelated to the eliciting event (distractions) also help to shorten emotion duration. Spielmann, MacDonald and Wilson (2009) found that individuals entering a new relationship before having fully recovered from a previous break-up, overcame attachment to the former romantic partner more quickly. Moreover, although positive distractors help to cope with negative emotions, negative distractors do not help to reduce the intensity of an initial negative emotion (Boden & Baumeister, 1997; Wenzlaff, Wegner, & Roper, 1988).

In sum, the present literature review serves multiple purposes. First of all, it has been shown that sympathy and anger emotions have differential impacts on an individual’s behaviour, however within subject comparison of these emotions is necessary in order to investigate their effect on socio-economic decision-making. Furthermore, the effect that partner-directed and displaced emotions have on decision making has been proven by previous studies separately, yet the comparison between displaced and direct emotions in social exchange games is inconsistent and yields contrasting results. Following on from this, experimental design might influence emotion strength and duration; therefore the success of inducing long lasting emotion might be affected by stimuli presentation (block or event-related design). This issue becomes even more important when conducting an imaging study, as block and event-related designs have their own flaws and benefits. Finally, these behavioural experiments aims at constructing a suitable basis to progressing to the fMRI investigation of emotion influence on decision-making in the social context. The following part of this chapter will discuss the more prominent and influential models in the literature used to explain the effect of emotion on decision-making in a social context.

2.1.2 Models of decision-making under emotion

The impact attributed to emotions on decision-making and reasoning processes changed over time, from early philosophers considering it to be harmful to later considerations by behavioural researchers, as well as modern philosophers, that they can be beneficial (Lewis et al., 2010). However, before starting to discuss emotion influence on socio-economic decision-making, it is important to consider theory of mind as individuals without it would not be affected by social emotions in their interactions.

Theory of mind

Theory of mind is an automatic and high level mechanism almost unique to humans which enables individuals to make predictions and inferences about the mental states and possible decisions of others (Premack & Woodruff, 1978). Evidence from studies with autism reveals that those individuals with an impaired mentalising ability suffer from more impaired socialization and communication. Theory of mind mechanisms rely on the individuals' beliefs about the world and about other individuals' beliefs (Leslie, 1987, 1994). Humans' understanding of reality depends upon their beliefs, and if they do not match, their understanding will be shaped by their beliefs rather than reality. In addition, people assume that others may have a different perception of reality from their own and by trying to recognize others' beliefs and goals try to understand what their reality perception is. Individuals might understand others' reality perception, yet although they can compare these perceptions, they do not merge them. Similar is the process of inferring other individuals' thoughts and feelings. The theory of mind mechanism is particularly important in social emotions – such as empathy where individuals need to understand another's feelings, but keep them separate from their own.

By having a mentalising ability, individuals are capable of social emotions and their interaction with other human beings are affected not only by logic, but on the emotions which are related to the decisions they are making. From a basic psychological perspective, decisions are made according to affect heuristics, but do not depend on rational thinking where one considers all positives and negatives of a decision (Evans, 1984; Evans, Barston, & Pollard, 1983; Tversky & Kahneman, 1981). Although rational thinking is considered more beneficial for the decision-maker, individuals do not seem to follow this approach. Indeed, some psychological theories suggest that during decision-making individuals drift away completely from logical thinking and base their choices on expected emotions and the framing effects of the choice – the emphasized possibility to gain or to lose during the instruction phase of the game (Loewenstein & Lerner, 2003; Pfister & Böhm, 2008). Given that some psychological researchers suggest that decision-making is far from rational, mechanisms were proposed for how emotions guide and bias individual’s choices (Damasio, 1994). This section of the chapter will discuss influential behavioural as well as neuroimaging models debating how individuals stray from rational thinking, and what neural mechanisms represent emotion effects on decision-making.

Loewenstein - Lerner classification

One of the earlier models of decision-making under emotion suggested that emotion acts as an information medium (Schwarz & Clore, 1983). Affective states provide information about the choice an individual is considering and the positive or negative valence of the affect changes the course of action respectively. However, this theory mostly focuses on incidental emotions. A different view was offered by the Decision Affect Theory proposed by Mellers, Schwartz, Ho, and Ritov (1997) who expected choices to be made depending on the interaction between anticipated and predicted emotions. In that sense the Decision Affect Theory is similar to the Regret Theory where an individual evaluates the anticipated emotions and chooses the course of action which would yield the best possible outcome in terms of its emotional consequences (Loomes & Sugden, 1982). These theories were the basis for Loewensteins and Lerner’s emotion classification (Loewenstein & Lerner, 2003).

The Loewenstein - Lerner classification categorises emotions according to their place in the time course of a decision-making process starting with deliberation, followed by making a choice and finally by experiencing the outcomes. In view of this classification, emotions that influence decisions can be categorised into expected or experienced emotions (Loewenstein & Lerner, 2003). Expected emotions are associated with the deliberation stage and direct the mind towards future experiences after the decision has been made (Loewenstein & Lerner, 2003; Rick & Loewenstein, 2008). For example, how good it will feel to lose a few pounds after starting to diet. On the other hand, experienced emotions are the ones the individual feels during the deliberation phase of the decision-making process. These emotions can be directly related to the decisions or they may be incidental/ displaced, caused by factors not related to the decision-making.

According to Loewenstein and Lerner's model, the decision-making process comprises six assumptions: (1) humans are always affected by the experienced emotions and do everything that needs to be done to feel better. (2) These emotions are either incidental or directly related to the decision-making process. In addition, (3) every decision comes with beliefs about the consequences of that decision (outcomes) which, as a result, (4) influence how individuals perceive their emotional response to these outcomes, consequently (5) affecting the decision. While considering expected outcomes and emotions produced by these outcomes, (6) experienced emotions are updated and changed depending on the expected outcomes (Figure 2.1).

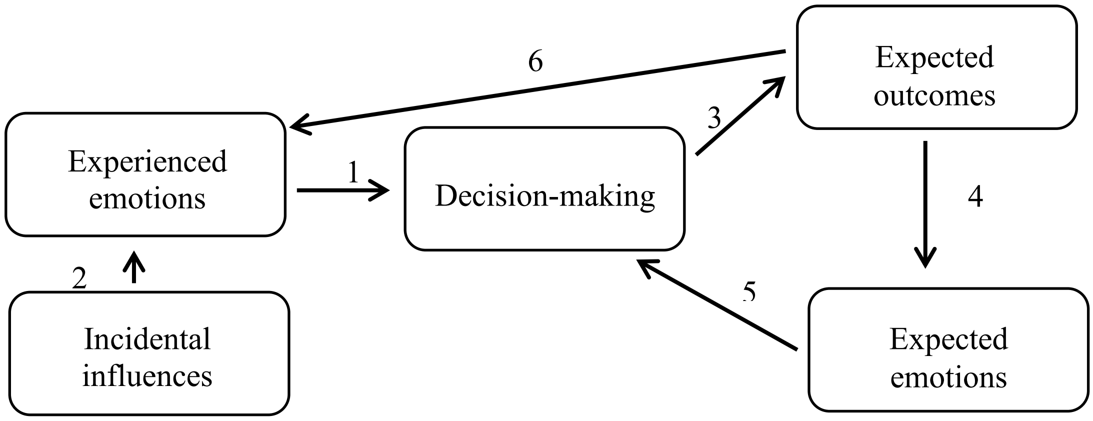

Figure 2.1: Loewenstein and Lerner emotion classification: This model outlines the role of anticipated and experienced emotions in human decision-making. The figure has been adapted from (Loewenstein & Lerner, 2003).

However, this model does not explain how to overcome experienced emotions to achieve goals that would be beneficial in the more distant future (Wenstøp, 2005). Furthermore, emotions should not be considered to be a homogenous category. Neurological, physiological and behavioural properties are not universal, or essential, to all emotions, and emotional expressions and meanings differ in different cultures (Griffiths, 1997). Also valance (positive vs. negative) is not the main aspect of emotion as not all emotions can be mapped on a one-dimensional scale. For example, what is good and beneficial is not always pleasurable, and what is harmful can give lots of satisfaction, or ambivalent emotions such as gloating (‘schadenfreude’; Pfister & Böhm, 2008).

The Pfister and Böhm framework

A more recent theory of emotion function in the decision-making process that tries to address the weaknesses of Loewenstein - Lerner’s classification is the Pfister and Böhm (2008) framework. This framework does not consider emotions to be irrational and simply influencing the decision-making process, but an integral part of it. According to this model, emotions hold four functions in the decision-making process. The first function is emotion as a source of information by flagging-up the course of action that will result in the biggest possible pleasure (not only monetary, but also social). Risky options are evaluated by relying on the liking or disliking of the outcome the decision would result in. The second function of emotions supports speedy decisions (speed function) by involving somatic markers in the process and triggers the fight or flight response. It relies on the notion that there is a class of bodily functions that direct behaviour without cognition. The third emotion function is indicating the relevance of a choice. In this context, emotions help individuals to decide which aspect of the decision-making is more personally important and base their choices depending on this aspect. For example, when individual considers investing their savings in a newly opened company, feelings of satisfaction and regret have to be weighted. On one hand, investing money and receiving the profit when the company prospers gives satisfaction. On the other hand, if after investment the company went bankrupt, regret would be unavoidable. Only by making the choice as to whether satisfaction or regret is more personally important, can individuals make an investment decision. Finally, emotion serves as a commitment function. Moral sentiments are an example of this function and relate to social relationships where sympathy and guilt signal reciprocation and support. For example, in a social context, over time two individuals benefit from mutual cooperation, however in the case of mutual defection they both lose. This function explains why individuals commit to decisions even if they are against their short-term self-interest.

This theory assumes that emotion is an inseparable part of the decision-making process which is however, at odds with the neuroimaging literature that found evidence for cognition and emotion being differential processes involved in decision-making (LeDoux, 1998). In addition, studies looking at emotion regulation strategies and cognitive control ability showed that individuals can control their behaviour by overriding their emotions (De Neys, 2006; De Neys, Novitskiy, Geeraerts, Ramautar, & Wagemans, 2011; Gross & John, 2003; Gross & Thompson, 2007). Although the above theories suggest possible mechanisms and roles that emotion plays in the decision-making process, models that incorporate neuroimaging evidence for the behavioural explanation and prediction of decisions under the influence of emotion take a further step forward into our knowledge about how rational thinking and emotions interact during social decision-making processes.

The Somatic Marker Hypothesis

The Somatic Marker Hypothesis (Bechara & Damasio, 2005; Damasio, 1994) is based on studies in brain-damaged patients who were impaired in decision-making tasks in the presence of a normal IQ but muted emotional responses. This theoretical approach shares similarities with the emotion as a speed function from the Pfister and Böhm (2008) model emphasizing the interactions of bodily signals with other information resulting in a modified intensity of emotions.

The evidence for this hypothesis comes from the studies with patients having lesions in the frontal cortex (in particular, the ventromedial prefrontal cortex and the amygdala) and experiencing muted or aberrant emotional reactions. Although their IQ was normal and comparable to healthy control participants', their responses on gambling and betting tasks consistently resulted in monetary loss (Bechara, 2000; Bechara & Damasio, 2005; Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Damasio, Tranel, & Anderson, 1998; Damasio, 1994). In addition, while healthy controls showed increased skin conductance rate (SCR) during trials with risky options compared to safe options, the SCR of the patients did not differ between risky and safe trials. The authors suggest that the decision-making of frontal lobe damaged patients was impaired due to impaired emotional processing. This theory - similarly to the previously discussed theories - assumes decision-making not to be rational, and states that emotions triggered by the somatic markers affect human behaviour. That is, somatic markers - bodily related responses such as emotions themselves (primary inducers) or thoughts/memories about primary inducers (secondary inducers) - were not triggered to signal the optimal choice.

Somatic markers, as mentioned previously, can arise from either primary or secondary inducers (bodily responses and thoughts/memories about bodily responses).

The primary inducers are responsible for the automatic and obligatory somatic markers. In most cases these inducers are fear and pain and the decisions should be made immediately, for example jumping to the side of the path if you think you heard a car approaching. Primary inducers are mostly involved in the Body Loop, which is a mechanism when brain gives boosts to physiological changes, which in turn are pre-processed again in the brain. In particular, when an individual needs to make an immediate decision about the possible options, information about these options is received through the ventromedial prefrontal cortex (vmPFC) to the amygdala which then generates somatic markers in form of emotion and physiological states. The somatic markers then send information to the insular system (Bechara & Damasio, 2005) followed by choosing one option or another according to one's gut feeling (Figure 2.2).

Secondary inducers are the result of thoughts about what a particular decision will lead to in the future. For example, an investor who notices that the value of certain shares increases on the stock market may consider buying more so that in the future he would feel happy in a stock market boom. This example represents the As If Loop of the somatic marker hypothesis. This loop is active when ventromedial prefrontal cortex activation is not strong enough to trigger somatic states, but changes in the neural level still occur. And in cases of high uncertainty, the As If Loop is more influential than the Body Loop (Bechara & Damasio, 2005).

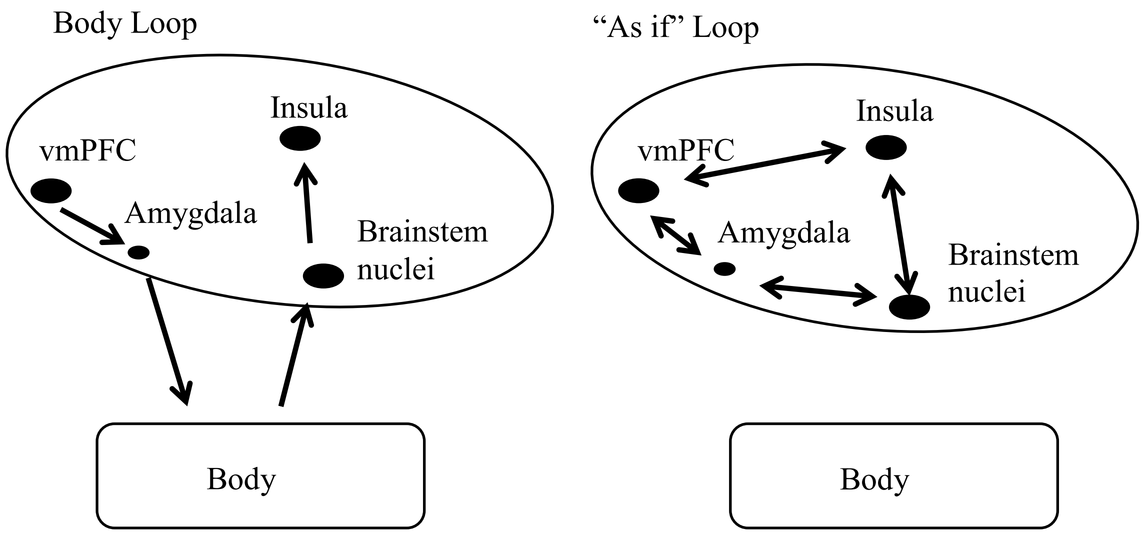

Figure 2.2: Somatic Marker Hypothesis model: ventromedial prefrontal cortex (PFC) and amygdala interactions in the Body Loop and "As If" Loop. Adapted from Bechara and Damasio (2005).

Although the somatic marker hypothesis remains influential in the decision-making and reasoning literature, it has also generated a large body of criticism. One of the critiques is directed towards the Iowa Gambling Task (IGT) from which the Somatic Marker Hypothesis and the majority of the supporting evidence for the theory is based on. It has been suggested that participants might have conceptual knowledge and be aware of the possible outcomes rather than respond according to their "gut feeling". The Iowa Gambling Task relies on the assumption that participants do not have a clear understanding about reward and punishment outcomes. However, in experiments where the healthy participants were given questions after every block of trials it was found that participants gained a clearer understanding of the likely monetary rewards they would receive and when they would get them (Maia & McClelland, 2004). This showed that players had a clearer anticipation of the possible outcomes than was previously expected (Maia & McClelland, 2004). This means that normal (without lesions) participants are aware of the possible outcomes and the anticipatory increase in SCR may be the result of conscious knowledge rather than of a casual involvement in the decision-making, suggesting that explicit knowledge might occur early in the process and direct the participant's behaviour as well as affect their SCR (Maia & McClelland, 2004). The physiological evidence from the SCR of anticipating a possible profit is considered important evidence in support of the theory. However, the difference in the skin conductance can also be explained by the variability of the reward and punishment (Tomb, Hauser, Deldin, & Caramazza, 2002) as well as a response to the outcome (Crone, Somsen, Beek, & Van Der Molena, 2004).

Another concern raised by critics of the theory is the interpretation of evidence from the patient studies. It is highly likely that patients with frontal lobe damage, instead of showing deficits in emotion processing, were impaired in switching between options in the IGT (Fellows & Farah, 2005). Following from the fact that ventromedial prefrontal cortex is involved in the learning process, these patients (with damaged vmPFC) might not be impaired on emotional processes but rather on learning from the previous trial (Fellows & Farah, 2003). In addition, poorer performance on the IGT might arise from working memory impairments. Working memory and decision-making are related and patients with lesions extending to the dorsolateral prefrontal cortex have problems with decision-making as well as with working memory (Bechara et al., 1998). However, patients with impaired working memory alone were not necessarily affected in decision-making (Bechara et al., 1998).

Despite the substantial amount of criticism aimed at the empirical foundations of the Somatic Marker Hypothesis, it has its merits in highlighting the role of emotions in the decision-making process by attempting to integrate the brain mechanisms involved. However, a different strand of decision-making research considers reasoning and decision-making to be a conscious and deliberative process, whereas emotion represents the automatic and unconscious part of the decision-making. This division between deliberative and intuitive, conscious and unconscious is the cornerstone of the dual-process theory.

Dual-process theory

Dual-process theory is an umbrella term for different theoretical approaches that have been used to explain the emotion-reason interaction such as the affect infusion model (Forgas, 1995) and moral reasoning (Greene, 2001; Greene & Haidt, 2002). Although the dual-process explanation is used by a number of theories, they should not be judged as one theory and all of them have their strengths and weaknesses (Evans & Stanovich, 2013). Evans and colleagues have investigated dual-process theory in general and not specifically to certain aspects of human behaviour (such as moral reasoning or social judgment), therefore, the dual-process theoretical approach discussed by them will be considered in this thesis (Evans, 2008; Evans & Stanovich, 2013; Stanovich & West, 2003). Evans and Stanovich (2013) suggest two basic processes with Type I being quick, automatic and unconscious and Type II being slow, conscious and deliberative. Although the majority of evidence for dual-process theories comes from the reasoning literature, they are also applicable to the decision-making processes as both rely on conscious and intuitive routes (Evans, 2012).

Type I is considered to be old in evolutionary terms, and is common to humans and animals and independent of individual differences and intelligence (Evans, 2006; Evans, 1984, 2003; Stanovich & West, 2003). It is not a single system, but a collection of autonomous sub-systems (Stanovich & West, 2003). Type I processes are triggered instantly by a stimulus, and they are based on bottom-up processes, implicit learning and automatic reactions to learned associations. These processes include behavioural control by emotions and heuristics (Evans, 1984; Evans, 2003; Slovic et al., 2007) and is associated with the ventromedial prefrontal cortex activity (Goel & Dolan, 2003).

Type II, on the other hand, is believed to have evolved more recently and is most often associated with human thinking. Characteristically Type II processes are associated with prefrontal cortex activity (Goel, Buchel, Frith, & Dolan, 2000). Despite taking more time and requiring higher working memory load, Type II is necessary for hypothetical and abstract thinking, and is not autonomous. Type II processing thus involves inhibitory mechanisms and is related to executive functioning (Evans, 2012). According to Evans, successful reasoning, decision-making and other complex behaviour depends on the interaction between Type I and Type II processes.

Evidence for the dual-process theory comes from bias effects. Belief-bias is a tendency to judge an argument according to its plausibility based on prior experience. For example, given that “Some apples are sweet fruit” followed by “All sweet fruit are grapes” the conclusion “Some grapes are apples” is unbelievable (we know that apples are not grapes), however the conclusion is normatively correct. Other common biases are the framing bias and conjunction fallacies. Framing biases occur when participant’s decisions depend on the presentation of the task; riskier choices are made in a possible loss presentation or risk averse choices in a possible gain presentation. In addition, conjunction fallacies happen when multiple conditions are chosen to be more plausible than single condition. For example, the Linda’s problem, “Linda is 31 years old philosophy major who as a student was concerned with social justice and discrimination issues”. Participants get asked what is more probable - that Linda is a bank teller or that she is a bank teller and the active in feminist movement. The common answer is that Linda is bank teller and active in feminist movement. In the reasoning processes if the syllogism is incongruent (incorrect but believable or correct but unbelievable), a normatively incorrect answer will be reached if decisions are based on Type I processes. However, if Type I does not interfere with Type II processes, a normatively correct answer is usually given (Evans, 1984; Evans, Barston, & Pollard, 1983).

The neuroimaging evidence for belief bias comes predominantly from fMRI studies. Goel and colleagues (Goel et al., 2000; Goel & Dolan, 2003) showed that Type I and Type II are anatomically associated with activity in different brain areas with content based reasoning (Type I) based in left temporal areas, while syllogisms with no content activated parietal areas (Goel et al., 2000). In addition, a follow-up study observed prefrontal cortex (in particular BA 45) activity during the detecting and overcoming of conflicts (Type II process), while the ventromedial prefrontal cortex was activated during decisions based on intuition and heuristics (Type I; Goel & Dolan, 2003). Furthermore, the right inferior frontal gyrus (IFG) has also been identified as being involved in conflict detection while solving incongruent syllogisms (Type II).

Tsujii and Watanabe (2009) used near-infrared spectroscopy (NIRS) and showed that the right IFG is active when participants solve incongruent trials correctly; however when this area is impaired by the 2-back task the accuracy in reasoning tasks decreases, as this area is kept busy by higher a working memory load due to 2-back task. Even though dual-process theories have been supported by neuroimaging experiments, they have not avoided criticism. Evans outlines major issues and fallacies related to the dual-process theory (Evans, 2006; Evans, 2012; Evans & Stanovich, 2013).

Critics argue that it is not clear whether there are two systems or multiple systems to account for human behaviour. Moshman (2000), for example, suggested 4 different types of processing as an alternative to the dual-process theory: (1) automatic heuristic processing that is equivalent to Type I, (2) automatic rule-based processing, (3) explicit heuristic processing and (4) explicit rule-based processing (Type II). On the other end of the theoretical spectrum, some researchers argue that if both Type I and Type II processes are considered computational in nature, the same rules can be applied in both deliberative (Type II) and intuitive (Type I) decisions (Kruglanski & Gigerenzer, 2011) requiring only one system.

In addition, the dual-processing theory's dichotomy between Type I processes being responsible for cognitive bias and Type II for achieving normative correct answers is not absolute. Both types can lead to normative answers and in some cases can be affected by cognitive bias (Stanovich, West, & Toplak, 2011). Moreover, unconscious or belief biased decisions were observed to be more effective and superior to the conscious/deliberative approach in generating normative correct answers (Dijksterhuis & Nordgren, 2006; Reyna, 2004). Analytical decisions, on the other hand, may lead to normatively incorrect answers (Wilson & Schooler, 1991).

Finally, the experimental evidence for the theory is not always supportive. Working memory is a necessary requirement for all Type II processing, however research shows that reasoning does not always depend on working memory (Reyna & Brainerd, 1995; Shafir & LeBoeuf, 2002). Moreover, quicker responses which are commonly associated with Type I processes, do not necessarily mean that the individual is engaging in Type I processing as experience and heuristics can speed up Type II processes to be quicker (Evans, 2012; Holyoak & Morrison, 2012).

Summary:

The investigation of reasoning in everyday situations which are risky, require quick answers, and are uncertain, shows that individuals do not always base their decisions on logic. The emotion and decision-making models presented in this chapter illustrate how emotions interact with the decision-making and influence human behaviour. According to Pfister and Böhm's model, individuals act depending on what emotions they are experiencing and expect, or want, to experience. Their choices are driven in order to regulate emotional experiences. The Loewenstein and Lerner model suggests that different emotions have different functions and depending on that affect behaviour. Furthermore, the Somatic Marker Hypothesis states that emotions, or thoughts and memories of emotional situations, induce a physiological response which in turn affects our behaviour. Finally, the Dual-Process theory suggest that human behaviour can be affected either by Type I processes (unconscious, fast, emotional, etc.) or Type II processes (slow, deliberate, based on logic, etc.).

Although the Pfister and Böhm classification suggests that emotion is an integral part of the decision-making process, and that different emotions have separate roles in decision-making, neuroimaging studies suggest that logical reasoning and emotion have different neural networks, and are possible separate processes that may interact. This is also what the dual system and Somatic Marker hypothesis agree upon. Further, comparing and contrasting the studies it is evident that the Loewenstein and Lerner model is similar to the dual-process theory as experienced emotions are based on affect (Type I process), and the experienced emotions try to cognitively predict the emotion the decision will bring (Type II process). Furthermore, the Loewenstein and Lerner theory has resemblance to the SMH. In this model experienced emotions are generated in the body loop as emotions arising from somatic markers, while expected/anticipatory emotions are formed in the 'As if' Loop.

Even though SMH has been criticized for methodological issues and that the emotion influence on decision making might actually reflect cognitive inflexibility and learning impairment, it highlights the importance of emotion in decision-making and emphasizes the possible neural mechanisms for how emotions are processed in the brain during decision-making. Another model that proposes that emotions can be of benefit in decision-making is the dual-process model, suggesting that successful decisions are made while engaging in Type II processes and suppressing Type I, and in combination with the Affect Infusion Model (AIM; Forgas, 1995) it can account for situations where emotional content helps to achieve normatively correct answers, where participants deliberate longer. AIM suggests that emotions draw an individual’s attention to inconsistencies, and as a result more time is spend processing incongruent emotional syllogisms and then manages to solve them correctly. In spite of a number of criticisms, the dual-process theory integrates a large body of behavioural and neuroimaging evidence providing a mechanism for how emotions and logic affect reasoning, and accounts for wider range of reasoning and decision-making tasks as well as wider range of influencing factors.

These and other theories concerning decision-making under the influence of emotion can explain many behavioural observations of human behaviour, yet they do not include individual differences in a socio-economic context. Although these models are a useful way to test these theories and make predictions on human decision-making, the limitations of the discussed models lies in individual differences affecting decision-making under emotion and the involvement of the social exchange context in the competitive interaction between participants.

2.2 Cognitive control and emotion regulation in decision-making

Behavioural decision-making as investigated in economic and gambling tasks is affected by socio-economic backgrounds, age, brain lesions (Bechara, 2000; Clark et al., 2007), personality disorders (Bazanis et al., 2002; Mazas, Finn, & Steinmetz, 2000) and drug addiction (Bechara, 2003; Bolla et al., 2003; Schoenbaum, Roesch, & Stalnaker, 2006). The research shows that older people perform worse on decision-making tasks than young adults (Finucane et al., 2002) and people from poorer economic background make worse choices in economic reasoning tasks (Larrick, Nisbett, & Morgan, 1993). In addition, individual character traits such as a tendency to narcissism (Martinez, Zeichner, Reidy, & Miller, 2008; Twenge & Campbell, 2003) or egoism (Bushman & Baumeister, 1998) can negatively affect decision making in these tasks. Yet, relatively little investigation has been done into how individual cognitive differences affect social decision-making. Researchers are mainly using game theory to analyse decision-making, and this analysis does not always include other factors such as individual differences. However, an individual’s cognitive and emotion regulation abilities might determine their choices and this section will discuss how these influences can affect an individual's decision-making.

To start with, working memory has been positively correlated with the ability to solve syllogisms correctly (Copeland & Radvansky, 2004). De Neys (2006) showed that performance on incongruent syllogistic trials, where plausibility is in conflict with validity (Type II processing), can be impaired by a dot memory task inducing working memory load by asking participants to remember and reproduce a 3-4 dot pattern. Conversely the performance on congruent trials (Type I processing) was not affected by the distractor task. Working memory capacity is a positive predictor of an individual's cognitive capabilities (Engle & Kane, 2004), and in fact, research shows that individuals with higher cognitive ability and IQ are able to overcome belief biases and are better at engaging in Type II processes (Evans, 2003; Kokis et al., 2002). Higher cognitive abilities as measured by the Scholastic Aptitude Test (SAT) enabled participants to avoid the framing bias (make decisions depending on the presentation; riskier choices in a possible gain presentation or risk averse in possible loss) and conjunction fallacies (assumption that multiple conditions are more plausible than a single condition, i.e. Linda's problem) in reasoning tasks compared to low SAT score participants (Stanovich & West, 1998). They also performed better in abstract reasoning questions, although the reasoning on the deontic tasks was not affected by cognitive ability.

In addition, a scale for measuring individuals differences on the tendency to engage and enjoy thinking about reasoning tasks - "need for cognition" (Cacioppo & Petty, 1982) - was associated with individuals being affected by framing effects less in the choice problem (the choice between paying again for a theatre ticket after discovering its loss and losing a banknote; Smith & Levin, 1996). Later studies, however, were unable to replicate this effect with the attribute[6], goal[7] and risky choice[8] framing effects (Levin, Gaeth, Schreiber, & Lauriola, 2002). McElroy and Seta (2003) manipulated the task content to induce different processing styles; personally relevant – analytical – and personally irrelevant – holistic – styles. The researchers found less framing bias when individuals were manipulated to engage in analytical processing

[6] Evaluations of object/event depend if the key attribute is presented in positive vs. negative terms, such as the chees is either 80% lean or 20% fat

[7] Persuasive message is evaluated differently depending if the message describe either the risks of not doing something, or the positive effects of doing something

[8] Individuals willingness to take the risks depending if the outcome is positively framed or negatively framed

style (equivalent to Type II process), than when they engaged in holistic processing style (Type I process). The same pattern was observed without content manipulation for participants showing a natural predisposition towards either analytical or holistic processing styles.

Analytical thinking style that depends on Type II processes is slower, and requires higher cognitive control not to act on impulses. Conversely, holistic thinking style (Type I) is faster and individuals depend more on intuition, biases and emotions and require less cognitive control. Following this, it is possible that individual differences in cognitive control would affect behaviour. In fact, low cognitive control was found to induce higher rejection rates in the Ultimatum game (De Neys et al., 2011). The optimal choice in this game is to accept any offer greater than 0 (in comparison when rejecting the participant would not receive anything). In De Neys et al.'s study performance on the Go/no-Go task was compared between individual groups who rejected the highest number of unfair offers in this game with those who rejected the lowest number of unfair offers (individuals with intermediate rejections on the Ultimatum Game were not tested on the Go/no-Go task). The results showed that those who rejected the least number of unfair offers had higher cognitive control than those who rejected most, suggesting that judgements of fairness have a greater effect on choice behaviour when cognitive control is low. Cognitive control also impacts also on logical reasoning, as individuals with higher cognitive control were found to reason in line with logic while low cognitive control participants tend to make their choices more intuitively (Stanovich & West, 2000). These findings fit the results of, an imaging study using the Ultimatum Game where recipients of unfair offers had a higher activation in brain areas related to cognitive control (dorsolateral prefrontal cortex) and emotional processing (anterior insula; Sanfey (2003)) suggesting that both cognitive control and emotion processing are involved in making decisions in economic games.

Even though cognitive control has been identified as a predictor for how well an individual will perform in reasoning/decision-making, another aspect of emotional influence -emotion regulation ability - may also need to be considered to gain a more complete picture of the process. Emotion regulation changes the degree to which an individual expresses an emotion and is affected by it. By using emotion regulation an individual can dampen, intensify, or maintain an emotion depending on the personal goals. Gross and colleagues (Gross, 2002; Gross & John, 2003) suggested a dual component emotion regulation concept consisting of cognitive reappraisal and expressive suppression. Cognitive reappraisal is based on a cognitive way of reducing the emotion (Sheppes & Gross, 2011), and this makes a person more capable of lowering their emotional experiences, so they are more socially acceptable (Extremera & Fernández-Berrocal, 2006; Gross, 2002; Gross & John, 2003). On the other hand, expressive suppression relies on a behavioural way of regulating emotion (Sheppes & Gross, 2011) and this can result in a less effective way of controlling the emotions, which might result in less socially acceptable behaviour, and sometimes even lead to some mental health issues (Butler et al., 2003; McLean, Miller, & Hope, 2007; Moore et al., 2008). An individual's behaviour is a reflection of either strategy or a combination of both. In general the use of one or another form of emotion regulation is highly dependent on individual preferences and situational context. However, from past research it is clear that when participants were required to actively adapt either reappraisal or suppressive emotion regulation strategies, reappraisal was more effective (Cutuli, 2014; Ehring, Tuschen-Caffier, Schnülle, Fischer, & Gross, 2010; Gross, 2002; Moore, Zoellner, & Mollenholt, 2008).

Typically, decision-making processes were investigated in isolation of other processes; but as this field of study is expanding, it is becoming clear that not only various external variables such as emotions, framing effects, bias etc. affect an individual's behaviour, but also individual differences can affect the outcome of the reasoning/decision-making task. Cognitive control and emotion regulation abilities influence human actions in a social context, and the investigation of their role and interaction with emotional influences is necessary in order to understand what mechanisms determine human decisions and how.

2.3 Emotion and decision-making in the brain

Returning to the main question of what are the neural correlates of decision-making under emotion, and is it possible to predict human behaviour, the theoretical models presented previously might imply how behaviour is affected by emotion. However, only predictions incorporating a combination of theoretical models, behavioural, neuropsychological and the neuroimaging data allow the possibility to predict the complex processes of the brain when decisions are made in a social context. Social situations imply not only the direct involvement of emotion between two interacting individuals, but also emotions triggered by human interactions in the context of competition, cooperation and their outcomes. These interactions requiring theory of mind and strategic thinking are an inseparable part of social exchange games. In this section, neuropsychological and neuroimaging evidence of the neural networks responsible for the emotion processing and decision-making in the social context will be presented.

Neuroanatomy of emotional decision-making

Earlier investigations of brain areas associated with emotional processes during decision making used lesion studies where neurological patients performed on reasoning and gambling tasks. Lesions resulting in specific behavioural impairments were used to classify brain regions involved in emotional and rational processes. With the advance of neuroimaging techniques and the emergence of neuroeconomics, the investigation into the anatomical correlates of decision-making became more sophisticated. These studies yielded three brain regions in particular as important to the decision-making process under the influence of emotion: the bilateral ventromedial prefrontal cortex (vmPFC), the orbitofrontal cortex (OFC) and the amygdala.

Lesion overlap studies in brain damaged patients show that a balance between emotions and reasoning is a prerequisite for successful problem solving and decision-making. Lesions to the bilateral ventromedial prefrontal cortex (vmPFC), including bilateral orbitofrontal cortex (OFC) and/or lesions to the bilateral amygdala, seem to disrupt the balance between emotions and reasoning: emotional responses tend to be muted or aberrant, resulting in ineffective decisions in life, without cognitive abilities being necessarily affected (Anderson, Damasio, Tranel, & Damasio, 2000; Bechara, 2000; Bechara & Damasio, 2005; Bechara, Damasio, Damasio, & Lee, 1999; Damasio, 1994; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). In addition, patients with lesions to the OFC have been observed to be impaired in regret processing (not experiencing regret when they lose) in a gambling task when they were provided with the outcome of the possible gamble they could have won, but decided not to risk. However, they were experiencing the same happiness and disappointment at winning and losing as healthy controls (Camille et al., 2004). This finding was supported by fMRI studies on healthy controls (Coricelli et al., 2005): the study paradigm was similar to Camille et al. (2004) and the regret strength was positively correlated with increased relative BOLD signal change in the left OFC, anterior cingulate cortex and the amygdala. Coricelli et al. (2005) interpret these findings as the OFC and the amygdala being responsible for reversal learning in order to change behavioural strategies which are not advantageous and would cause regret (Figure 2.3).

Functional anatomical studies investigating syllogistic reasoning with emotional and neutral content identified a differential role for the ventromedial and dorsolateral prefrontal cortices (Goel & Dolan, 2003). The vmPFC showed stronger activation during emotional reasoning trials, while increased lateral/dorsolateral prefrontal cortex (l/dlPFC) activity was related to successful reasoning with neutral content. It is evident from these anatomical and functional imaging findings that there exist distinct brain mechanisms underlying the emotion and reason interaction that enable humans to make successful decisions in economic games.

Economic gains and losses are a common cause of emotion; nevertheless, social interactions depend not only on winning or losing money. Cooperation for example, whether reciprocated or not, leads to changes in reputation and social status, which are important in a social environment.

Neuroanatomy of social decision-making

Neuroscience is investigating not only how emotions affect the decision-making process but also how our perception of the outcome influences our decisions. After all, emotions emerge not only from the direct interaction between individuals, but also depend on the perception of the outcome not only in monetary but also in social terms (King-Casas, 2005; McCabe, Houser, Ryan, Smith, & Trouard, 2001; Sanfey et al., 2003).

Interactions between individuals in economic games are characterised by differential striatal activations: in the Trust Game where one of two players has the option to share their stake with the other in the hope that the other will reciprocate it, increased dorsal striatum activation is evident during the costly monetary versus the symbolic punishment of the other player who did not reciprocate (de Quervain, 2004). In fact, the strength of the activation correlated with the players desire to punish the other. In addition, the ventral striatum was also activated in decision-making tasks when participants choose immediate reward over a higher but delayed reward (McCabe et al., 2001; Rilling et al., 2002). Rilling et al., (2002) found activation in the ventral striatum along with OFC associated with mutual cooperation in the Prisoner’s Dilemma game. Interestingly, the defection-cooperation decision was associated with deactivation of the striatum – possibly reflecting regret and guilt. In addition to the striatum, caudate activation has been shown to be associated with anticipated reciprocated cooperation in the Trust Game (King-Casas, 2005) and the Prisoner’s Dilemma (Rilling et al., 2002).

Not only monetary expressions of the possible gains and losses are important, as in many social interactions the outcome affects the position of the individuals social status and reputation (Izuma, Saito, & Sadato, 2008; Zink et al., 2008). Interestingly, imaging studies have found striatum activation during such social decision-making processes, suggesting its involvement in processing the information of both monetary and social losses and rewards (Izuma et al., 2008). In particular, the putamen and caudate nucleus were activated while participants were gaining monetary reward and social reward in the form of praise. Furthermore, the ventral striatum was found to be involved in the comparison of one's own performance with individuals of higher or lower status to oneself (Zink et al., 2008). In Zink et al.'s study participants were engaged in a reaction time game and although they did not compete with each other, their performance was compared in each trial. A participant and two confederates had their social status predetermined before the game, but their status could change depending on their performance. Increased ventral striatum activity was associated with performing worse than socially inferiors, but the dorsal striatum was activated when participants were performing better than a socially superior player.

In addition, striatum activation has been observed during altruistic giving tasks (Harbaugh, Mayr, & Burghart, 2007; Hare, Camerer, Knoepfle, O'Doherty, & Rangel, 2010; Moll et al., 2006). Participants donations to charity organisations were marked by increased activity in the striatum despite the fact that the donations would result in losing money for the participant himself/herself (Moll et al., 2006).This effect, however, disappeared when the donation stopped being voluntary and participants had to transfer a certain amount of money to the charity (Harbaugh et al., 2007). A study by Hare and colleagues found that the vmPFC is integrating inputs from the striatum as signals about value when participants have a choice to donate or not (Hare et al., 2010). This shows a connection between areas processing the emotional component in decision-making and reward related areas.

While in many cases the striatum is associated with positive reward value during social exchange in economic and social contexts, the insula has been found to be involved in loss prediction during monetary exchange games (Knutson, Rick, Wimmer, Prelec, & Loewenstein, 2007; Kuhnen & Knutson, 2005) and during increased risk choices (Paulus, Rogalsky, Simmons, Feinstein, & Stein, 2003). In tasks where participants had to shop for various items, correlation between insula activation and anticipated greater loss caused by excessive prices was observed (Knutson et al., 2007).

Furthermore, increased insula activation was seen following interactions with individuals who defected in the Prisoner's Dilemma (Rilling et al., 2002) and predicted mistakes due to risk aversion in the Behavioural Investment Allocation Strategy game where participants were instructed to buy stocks (Kuhnen & Knutson, 2005). Correspondingly, a lesion study by (Clark et al., 2007) showed that patients with lesions to the bilateral insular cortex exhibited a different gambling pattern from healthy controls in the Cambridge Gamble task - they did not adjust their betting according to the possibility to lose and betted higher stakes. In contrast, vmPFC, striatum, medial OFC and ACC – areas associated with emotional processing - have also been found to increase their activity during economic gains, but during losing trials activity in these areas decreased (Tom, Fox, Trepel, & Poldrack, 2007).

Insula activity is not only known as a predictor of risk aversion, but this area is also activated when negative emotions occur (Decety, 2010). During game play emotions may arise from the interaction between participants, for example, unfair offers and defection trigger negative emotional states. In fact, irrational decision-making in economic games has been found to be positively correlated with anger in cases where an individual intends to retaliate against anger induced by the other player (Pillutla & Murnighan, 1996). Accordingly, the anterior insula was found to be associated with perceived unfairness in the Ultimatum Game and the iterated Prisoner's Dilemma as anterior insula activation increased the less fair an offer was (Rilling, Sanfey, Aronson, Nystrom, & Cohen, 2004; Sanfey et al., 2003). On the other hand, Singer and colleagues (2006) found that the insula was associated with sympathetic feelings towards the other. In their fMRI study, participants had to witness how cooperative players were being unfairly punished in the Prisoner's Dilemma and during these trials the participants showed an increased activity in the bilateral fronto-insular regions (Singer et al., 2006).

To sum up, social interactions represented by activity in the human striatum (putamen and caudate) involves social interactions with monetary and social gains and losses. In particular the dorsal striatum showed increased activation in costly punishment by non-cooperative players, while the ventral striatum was found to be active during social status comparison and while choosing immediate reward. In addition to the striatum, the insular cortex shows activation in response to loss aversion in economic games (when the choice is of increased risk or expected loss). In addition, the insular cortex is involved in processing negative emotions such as anger due to perceived unfair outcomes of the socio-economic games (Figure 2.3).

Social interactions are one of the most complicated of human behaviours. They are driven not only by logic and incidental emotions, but also emotions that emerge from the interaction between the individuals. In addition, social status changes, and expected or received reward and punishment affect decision-making and influence individuals' strategical thinking by attempting to predict the next move of the other person.

Neuroanatomy of strategic decision-making

In order to be able to predict possible rewards, it is necessary to predict the choices the other individual will make. Theory of Mind investigates how humans make predictions about the thoughts and intentions of the other by forming second order beliefs about what the opponent thinks the thinker will do (Camerer, 2003). This strategic thinking is an important factor when two individuals are making their decisions simultaneously, and is represented by activations in the medial prefrontal cortex, insula, paracingulate cortex and superior temporal sulcus (Decety, Jackson, Sommerville, Chaminade, & Meltzoff, 2004; Frith & Frith, 1999; Frith, 2001; Fukui et al., 2006; Gallagher, Jack, Roepstorff, & Frith, 2002; McCabe, Houser, Ryan, Smith, & Trouard, 2001; Rilling, Sanfey, Aronson, Nystrom, & Cohen, 2004).

The insula and paracingulate cortex were found to be activated when participants have to make decisions about another individual's intentions in Theory of Mind tasks. In the (Bhatt & Camerer, 2005) study participants played various economic interaction games and in addition to making their own choices they had to predict the future choices of the other player (first order predictions), and also what the other player thought the participant would choose (second order predictions). While second order predictions activated the anterior insula, the posterior and anterior paracingulate cortex was involved in both first and second order predictions. Similar findings were reported by Gallagher, Jack, Roepstorff and Frith (2002) where participants had to predict the choices of their opponent during a game of 'Rock Paper Scissors'. The bilateral anterior paracingulate cortex was activated when predictions about the behaviour of the other were made.

In addition, Rilling et al. (2004) carried out a study where participants played the Prisoner's Dilemma and the Trust Game interacting with another participant as well as a computer program. Although the anterior paracingulate cortex and posterior superior temporal sulcus (STS) were activated in both games, both areas showed stronger activation during playing with human opponents than the computer during the time of receiving the feedback of the interaction. A study by Fukui et al. (2006) examined neural networks when participants were playing the Chicken Game[9]. They confirmed the results of Rilling et al. (2004), and concluded that the posterior STS is involved in general mentalising during social interaction tasks as the STS showed similar levels of activation during risky and safe choice conditions. In contrast, the anterior paracingulate cortex was found to be involved only during risky decision-making.

Tasks in which participants have to consider another individual's thoughts, beliefs and feelings and predict their choices involve the processes of Theory of Mind. In addition, typical Theory of Mind brain areas are expected to be active during socio-economic decision-making tasks with strategic thinking. High co-operators in the Trust Game showed stronger medial prefrontal cortex activation whilst interacting with human opponents compared to the interaction with a computer, yet for high defectors activation of this region did not depend on the type of the opponent (McCabe et al., 2001). Furthermore, in the Token Game, participants in the condition where they had to compete between each other indicated medial prefrontal cortex activation (Decety et al., 2004). Also, medial prefrontal areas were activated in solving moral dilemmas with personal content (push a man under the train to save 5 people) as opposed to non-personal (to press the lever to redirect the train to kill just one person instead of 5) or neutral dilemmas (Greene, 2001). It was also observed that the reaction times were longer for personal moral dilemmas, compared to the impersonal ones, in what the researchers interpreted as a result of emotion and abstract thinking interaction. In these tasks it was essential for participants to consider the point of view of the other individual and the emerged activation of the medial prefrontal cortex suggest that this areas is necessary while thinking from the 'others' point of view.

[9] In this game two players attempt to maximize their gains while trying to predict their opponent's behaviour. Each player can choose one of two options - either reconcile or aggress – providing the game with four possible outcomes. The outcomes for the participant would be best if he/she would aggress while player B reconciles. Less advantageous is when both players reconcile followed by player A's reconciliation and player B's aggression. And the least advantageous option is when both of the players aggress. The most common to imagine scenario is when two drivers are in front of each other on a straight road and driving towards each other. The one which turns to aside first loses, however the worst outcome for both is if no one turns aside and they both crash.

The results from these studies show activation under competitive game play conditions in the typical Theory of Mind areas - the anterior paracingulate cortex, posterior STS, insula and medial prefrontal cortex. This indicates that participants consider not only the optimal choice to make, but also whether to alter those choices depending on potential moves by the opponent. While the STS seems to be, in general, involved in the mentalizing process (when the participant has to predict what other individual's thinking and their course of action, for example Chicken Game), the anterior paracingulate cortex shows activation in predicting opponents' moves and making predictions about what the opponent expects from the participant (the Prisoner's Dilemma, the Trust Game and the 'Rock Paper Scissors' game). Finally, the medial prefrontal cortex was involved in competitive gameplay while interacting with human opponents vs. a computer. This indicates that the medial prefrontal cortex helps to distinguish when an individual is involved in social interactions with another human (vs. computer gameplay), and is involved in human strategic thinking (Figure 2.3).

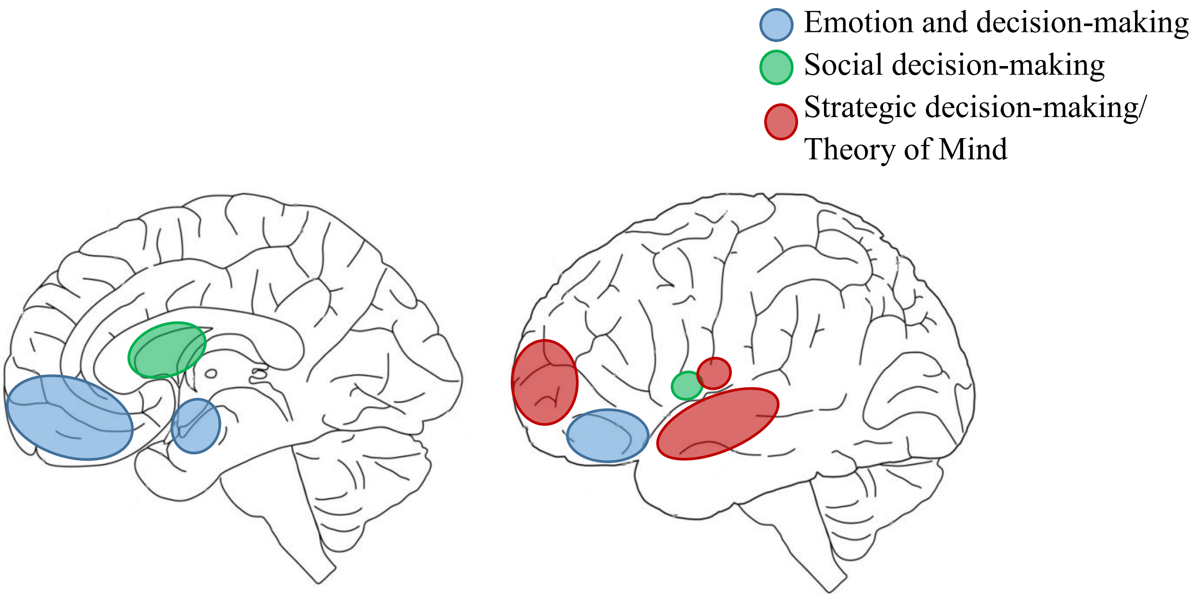

Figure 2.3: Summary of brain areas activated during emotional, social and strategic decision-making gameplay.

2.4 Summary and conclusion

The aim of this review was to explore what is currently understood about the role of emotion during social exchange interactions. The studies investigating emotion in general in social economic decision-making games have been explored, with a specific focus on behavioural and neuroimaging models of decision-making. The amygdala and prefrontal cortex have been identified as key regions involved in emotional as well as the decision-making processes in the neuropsychological literature. The superior temporal sulcus, medial prefrontal cortex and anterior prefrontal cortex are involved in the decision-making under emotion network when an individual starts predicting choices while engaging in competitive gameplay. Also, insula and striatum activity stretch from being activated during social interaction between two individuals and making risky decisions to predicting loss and receiving monetary and non-monetary rewards. Neuroimaging evidence for the possible neuro correlates of the mechanisms responsible for decision-making under the influence of emotion has also been reviewed.

2.4.1 Key points

- Contrary to popular belief, emotions do not always hinder decision-making, but can be beneficial which is taken into account by more recent decision-making models.
- Dual Process theories have an advantage compared to Somatic Marker Hypothesis, Loewenstein - Lerner classification and Pfister and Böhm framework, as this theory integrates neuroimaging evidence for dual processes in the brain and has been supported by a vast literature in the reasoning field showing separate systems for emotional and logical processes.
- Although there is convincing evidence showing that both partner-directed and displaced emotions affect behaviour, there is a lack of information on how these two types of emotion differ on their impact on an individual’s decision-making and what impact they might have on choices during social exchange tasks.
- Following on from the previous point, although emotions in the decision-making context have been of interest in some psychological research, most studies used between-subject differences in exploring emotional effects where individual differences might have influenced the outcome. Consequently, some aspects of particular emotional impact might have been unnoticed. In addition, the choice of the experimental design, as well as how the emotions are induced could have an influence on participants’ behaviour in social exchange games.

- Behavioural results of decision-making in neutral emotion conditions show that behaviour can be affected by individual cognitive and emotion regulation abilities: individuals with higher cognitive- or emotion regulation abilities tend to show better performance on decision-making tasks and more success in daily-life.
- Emotion and social exchange decision-making are represented in the brain by a complex neuronal network comprising the core areas – vmPFC and amygdala. However, depending on the context, if the task involves the participant's consideration of monetary and symbolic rewards, losses and risks, striatum and insula activation would be evident. In addition, strategic thinking and prediction of the opponent's thoughts and choices as well as feelings are represented with the increased activation in the superior temporal sulcus, medial prefrontal cortex and striatum.

2.4.2 Research questions

Based on the evidence presented in this review, it seems that the specific role of emotion in social decision-making is yet to be defined. The evidence from the reasoning literature suggests that emotion can both hinder and help decision-making. In a social context, however, not all decisions are characterised by normatively correct or incorrect answers, as social context and emotions influence the goals of an interaction. Furthermore, not all behaviour during decision-making can be explained by the presence of emotions, as decision-making has been shown to depend also on cognitive and emotion regulation abilities. Taken together, there is a need for clarifying not only the specific role of emotions during decision making in a social context by taking into account individual differences in cognitive and regulation abilities, but also for disentangling the functional anatomy of choice making in a social context.

The specific research questions that will be addressed by this thesis are:

(1) How do two particular emotions (sympathy and anger) affect individual's decisions to cooperate or to defect in social exchange decision-making? As discussed in the 2.1.1 "What is an emotion?" section, sympathy and anger emotions were chosen as they are social emotions and their behavioural impact is on opposite ends of the social behaviour spectrum. Furthermore, the majority of studies investigate emotions in an economic context using between subject designs but a within-subject design is needed

to investigate these two emotions while controlling for individual differences. In addition, the section "Direct and displaced emotions in socio-economic context" revealed that displaced and direct emotions in socio-economic exchange games might differ on the extent they affect an individual's behaviour and a direct comparison with the same experimental paradigm might bring more light to this question.

(2) Does cognitive control and emotion regulation ability modulate the effect of emotion on social exchange decision making? As discussed in section 2.2, although game theory does not elaborate on the possible individual differences affecting decision-making, cognitive control and emotion regulation strategies can influence how much emotions will affect individuals' choices.

(3) What are the neural pathways involved in social exchange decision-making under the influence of sympathy and anger emotions? Is it possible to predict participants' choices based on the observed neural correlates?

(4) What is the role of the ventromedial prefrontal cortex in reasoning with emotional context?

Questions (3) and (4) relate to the literature review in section 2.4 discussing the neuroanatomy of emotional, social and strategic decision-making.

2.4.3 Overview of the experiments

To achieve the aims and answer the questions of the thesis the following experiments were conducted:

Experiment 1 explored the differences between behavioural responses under the partner-directed emotions (sympathy, anger and neutral) in the Prisoner's Dilemma and the Trust Game. In addition, the study included a cognitive inhibition measure to investigate emotion and cognitive inhibition interactions in the social exchange games. This experiment related to the research questions 1 and 2. Experiment 2 further explored the research questions 1 and 2 with the aim of exploring differences between event-related and blocked design on the decision-making under sympathy and anger emotions in the Prisoner's Dilemma. In addition to the cognitive inhibition measure, the Emotion Regulation Questionnaire (Gross & John, 2003) was added to investigate the individual differences in the participants behavioural response. The third and final behavioural experiment was designed to further investigate question 2 and compared what behavioural effect displaced and partner-directed emotions have in the Prisoner's

Dilemma. A cognitive flexibility measure was included to explore if, and how, different types of cognitive control affect human social interactions.

Following the behavioural studies, an fMRI experiment using the iterated Prisoner's Dilemma under sympathy, anger and neutral emotion conditions was conducted. The aim of the study was to investigate the neural correlates of decision-making under emotion, aiming to answer question 3. Finally, to investigate the role of the ventromedial prefrontal cortex in emotional reasoning, patients' lesion data was analysed with the exclusive disjunction studies covering research question 4.

Chapter 3 Experiment 1: Do Emotions affect Performance on the Prisoner's Dilemma and the Trust Game Differently?

3.1 Overview

This chapter reports the first behavioural experiment leading to the experimental paradigm for the functional magnetic resonance (fMRI) study. Experiment 1 explored the differences in behavioural responses to partner-directed emotions between the Prisoner's Dilemma and the Trust Game. In addition, the study included cognitive inhibition measures to investigate emotion and cognitive inhibition interactions in both social exchange games.

3.2 Introduction

Experiment 1 aimed at measuring the differential impact of sympathy and anger behaviour in two commonly used social exchange games -the Prisoner's Dilemma and the Trust Game. In these games participants must decide between cooperating with their partner or betraying them for their own personal gain (i.e. defecting). The Prisoner's Dilemma was devised and discussed by Flood and Dresher in 1950 (Kuhn, 2009) and the 'rational' choice in a one shot of this game (i.e. the choice that maximises payoff) is to defect. In the Trust Game (Berg, Dickhaut, & McCabe, 1995) the rational choice for either player is to keep the money, since this choice minimises any losses (Burks, Carpenter, & Verhoogen, 2003).

The fact that the Prisoner's Dilemma involves simultaneous interaction, while the Trust Game involves sequential choices, may result in the two games loading differently on the decision-makers' cognitive resources. More specifically, players of the Prisoners Dilemma must keep in mind four possible outcomes of the interaction and have to anticipate their opponent's choice, while players of the Trust Game must consider only two possible options and (because the decision is sequential) this means that participants can more easily predict the outcome of the interaction (i.e. being Player A or B and keeping all the money). Cognitive load is known to influence the level of cooperation in such socially-interactive decision games. For example, when participants memorize 7 digits (high- cognitive load) instead of 2 digits (low load), they are found to cooperate more in the Prisoner's Dilemma, particularly toward the end of the game (Duffy & Smith, 2012).

The influence of emotion on social decision-making may also depend upon the extent to which the decision-maker is able to control their responses. For example, De Neys, Novitskiy, Geeraerts, Ramautar and Wagemans (2011) found that participants who made irrational decisions (manifest as highest rejection rates) in the Ultimatum game also made more mistakes in the Go/no-Go task, a task in which good performance relies on the ability to control impulsive responses. Also, in neuropsychological studies, lesions the right dlPFC resulted in the impaired ability to override selfish impulses in order to reject offers perceived as unfair, showing that cognitive control can modulate emotional impulses (Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006).

To test the efficacy of the emotion manipulations galvanic skin conductance measures and subjective reports were used. Skin conductance response (SCR) is commonly used as an indication of physiological and psychological arousal. This indirect measure of psychological and emotional arousal is observed by electrical conductivity responses in the skin (Bach, Flandin, Friston, & Dolan, 2009). This measure is considered to be objective, and participants cannot regulate it as it is unaffected by top-down control. However, a drawback of SCR is that it cannot indicate the subjective content and direction of the emotional experience and, as such, a self-report questionnaire was also included in this study.

The aim of the experiment was to test which game of the two chosen – the Prisoner's Dilemma or the Trust Game – provides a more sensitive measure of the influence of sympathy and anger emotions on decision-making. Given the possibility that the two games require different cognitive loads, individual differences in cognitive control and their influence on how emotion affects decision-making in the Prisoner's Dilemma and the Trust Game was also explored. The second aim was to test the influence of cognitive control on the emotion effect of decision-making. Participants with lower cognitive control were expected to have different defection rates than those with higher cognitive control. In addition, the current study explored how the emotions of sympathy and anger affect decision-making in the Prisoner's Dilemma and the Trust Game in a within-subject design. Sympathy and anger were hypothesised to have different effects on social decision-making, such that sympathy would reduce defection rates and anger would increase defection rates, compared to a neutral emotion condition. And finally, to evaluate whether the emotion manipulations were effective galvanic skin conductance was recorded throughout the experiment. In accordance with past literature, higher skin conductance levels were expected to be associated with anger and sympathy emotion-induction conditions compared to a neutral emotion condition (Ben-Shakhar et al., 2004; Hein, Lamm, Brodbeck, & Singer, 2011; Rustichini, 2005).

3.3 Methods

3.3.1 Participants

Thirty-eight participants took part in the study. All participants had normal or corrected-to-normal vision and were not undergoing any psychopharmacological treatment (one participant was removed after self-declaring an anxiety disorder). Another eight participants were removed after declaring that they were aware of the deception, leaving 29 participants for the final analysis (14 females) (Mean age = 23 years, SD = 4.4). The study was approved by the Department of Psychology ethics committee, University of Hull, and was carried out in accordance with the ethical guidelines published by the British Psychological Society, the American Psychological Association and the Declaration of Helsinki 2.

3.3.2 Stimuli

The emotion manipulation was achieved by presenting participants with pre-constructed essays (one page, 200-250 words), which they believed were written by their partner participants, and with subsequent evaluations of the participant's own essays, which they believed were also written by their partners. The evaluation forms consisted of ratings of the essays on six 9-point bipolar scales (unintelligent - intelligent; thought provoking - boring; friendly – unfriendly; illogical – logical; respectable – unrespectable; irrational – rational), along with a space for free comments.

In the sympathy condition the essay was used to induce sympathy emotion and was modified from Harmon-Jones, Peterson and Vaughn (2003) and concerned a young person coping with cancer. After reading this essay, the participant received a neutral evaluation of their own essay, consisting of neutral ratings (between 4 and 7 on the evaluation scales) and a hand-written positive comment "I can understand why a person would think like this". The condition to induce anger consisted of a poorly written essay (one page long, 210 words) with neutral content writing about travelling (grammatical mistakes, badly structured arguments), and a negative evaluation of their own essay

(Harmon-Jones & Sigelman, 2001) with ratings weighted towards negative words (e.g. illogical or unacceptable) and an insulting hand-written comment underneath the evaluation ("This is the stupidest thing I have ever read"). In the neutral condition, participants received an emotionally neutral essay about ecology (grammatically correct, structured arguments), and a neutral evaluation of their own essay (consisting of neutral evaluations with ratings between 4 and 6, and no additional hand-written comments; Appendix A on page 212).

The three essays/evaluations were written in clearly differentiable handwriting, and were piloted before the study to ensure that they triggered the targeted emotion (SCR was recorded in 15 participants while they were reading essays and evaluations and who later self-reported what emotions the essays triggered). Galvanic skin conductance serves as an objective measure of emotional arousal (Ben-Shakhar et al., 2004; Lin, Omata, Hu, & Imamiya, 2005). Yet as this measure does not allow one to address the subjective content and direction of the emotional experience, a self-report emotion questionnaire was included which participants completed at the end of the experiment.

3.3.3 Tasks

Self-report emotion questionnaire

Here participants were presented with a list of 36 emotion words (Harmon-Jones et al., 2003; Harmon-Jones & Sigelman, 2001) and, indicated for each word, which (if any) "other participant" they had felt it towards (see Appendix B on page 218). The questionnaire was analysed with hierarchical and k means cluster analysis.

Galvanic skin conductance

Galvanic skin conductance was continuously recorded throughout the experiment using a second computer, connected to a Biopack MP100A digital skin conductance amplifier with a constant voltage of 0.5V. Electrodes were placed on the non-dominant hand and attached to the medial phalanx surfaces of the middle and index finger. An electrodermal gel (GEL101) was used as an electrolyte for conductance.

Galvanic skin conductance level (SCL) was calculated individually for each emotion-inducing condition. The skin conductance measurements were analysed from the time when participants received the essays and evaluations (with baselines collected at rest periods before each of these critical time windows). That is for the sympathy condition, SCL was analysed while participants read the sympathetic essay and for the anger condition while reading the negative evaluation on the participant's own essay. For the neutral condition, galvanic skin conductance was averaged from reading the neutral essay and receiving the neutral evaluation on the participant's own essay. The mean SCLs were computed for each condition, using Acknowledge 3.9.1 for Windows.

Decision-making Tasks

The following tasks were completed by participants separately for each emotion condition (with three repetitions of each task per fictional partner). The tasks were presented via a computer, using Cogent 2000v1.32 (www.vislab.ucl.ac.uk) on a Matlab platform (version R2011.a). Participants were guided through the rules of these games, and the experimenter asked questions to make sure that the participants understood the game. To reduce participants' expectations and any reputation effects in the games, participants were told that they may or may not play some games more than once.

Prisoner's Dilemma

The task was developed by Flood and Dresher in 1950 (Kuhn, 2009). Participants are asked to imagine that they are two criminals who are hiding money. They have been caught by the police, separated, and each given two options: betray/defect or keep silent/cooperate. If one cooperates and the other one defects, the defector is able to keep all the money, while the cooperating player must pay a fine. If both remain silent, however, they both receive half of the money. If both choose to defect, they will both have to pay half of the fine (Figure 3.1 C). There is no optimal outcome in this game, as the outcome of the decision depends on the interaction between two players. However, the general tendency for defection in the Prisoner's Dilemma game without emotion manipulation is around 50-60 % (Oskamp & Perlman, 1965)

Trust Game

In the Trust Game (Berg, Dickhaut, & McCabe, 1995) participants can be either player A or player B. Player A has an amount of money and may decide to either pass it to player B or to keep it all for himself/herself. If the money is sent to player B, the total is multiplied by four and then player B must choose to either send half back to player A or keep it all. During this experiment participants had to play both roles with player A and B counterbalanced between the runs of the game and the optimal choice for either player is to defect- keep the money (Figure 3.1 B).

Cognitive control task

Participants also completed a Go/no-Go task to measure cognitive control abilities (see De Neys et al. (2011)). This task was administered once at the start of the experiment (i.e. prior to any essay reading/evaluation). At trial onset, a central fixation point was shown for 500ms followed by a single letter either “M” or “W” for 500 ms with an inter-trial interval of 1 s. Participants were instructed to respond as fast and as accurately as possible to the target letter (either “W” or “M” instructed before the task started, counterbalanced across participants) with a spacebar press whenever the target letter was present. A warning message appeared if they took longer than 500 ms or the response was incorrect. In total 100 trials were presented with 80% of the trials showing the target. The number of correct responses to target and non-target letter was recorded.

3.3.4 Procedure

Participants were asked to come to the experiment with an essay they had written about anything that was important to them. They also believed that three “other participants” had done the same and would be participating in the experiment at the same time, though the participant never met these other individuals and, indeed, they were not real. Participants were told that, for reasons of anonymity, everyone would complete the experiment in separate rooms. During the experiment each participant was required to read all the other participants’ essays (N = 3) and to evaluate them one by one (while they were led to believe that their own essay was also being evaluated by each other participant).

Participants always began the experiment by completing the Go/no-Go task as a one-off. Following this, they were presented with their first opponent’s essay to read and evaluate. After the first essay was evaluated, participants played two self-paced distractor games while the experimenter left the room and returned after 6 min (participants believed that the experimenter was collecting the next opponents’ evaluations). The Wason’s Card Selection task (Wason, 1968) and the THOG task (Wason & Brooks, 1979) were used as distractors in order to make the aims of the study less obvious to the participants. Performance in these tasks was not analysed further. The participant then received his first opponent’s evaluation of his own essay, and then immediately played three rounds of the Prisoner's Dilemma and three of the Trust Game with this same opponent. This was followed by new parallel versions of each distractor task. This procedure of essay reading/evaluation, distractor tasks, receipt of one's own evaluation and social-exchange game playing was then repeated for the remaining two emotion conditions (i.e. with the remaining two other "participants"). The essays and evaluations were constructed to induce sympathy, anger and neutral emotions. The order of emotion conditions (sympathy, anger and neutral) and the order of the social decision-making tasks were counterbalanced between subjects to avoid order effects (Figure 3.1 A). The galvanic skin conductance was recorded continuously from the time participant finished their own essay till the interaction with the third "other participant" has ended. At the end of the experiment, participants completed the emotion questionnaire (see below). Finally, the experimenter asked questions to determine whether the participant suspected deceit or the aim of the experiment. While deception/harm to the participant was transitory, full debriefing and contact details for a university counsellor were given to participants at the end of the experiment.

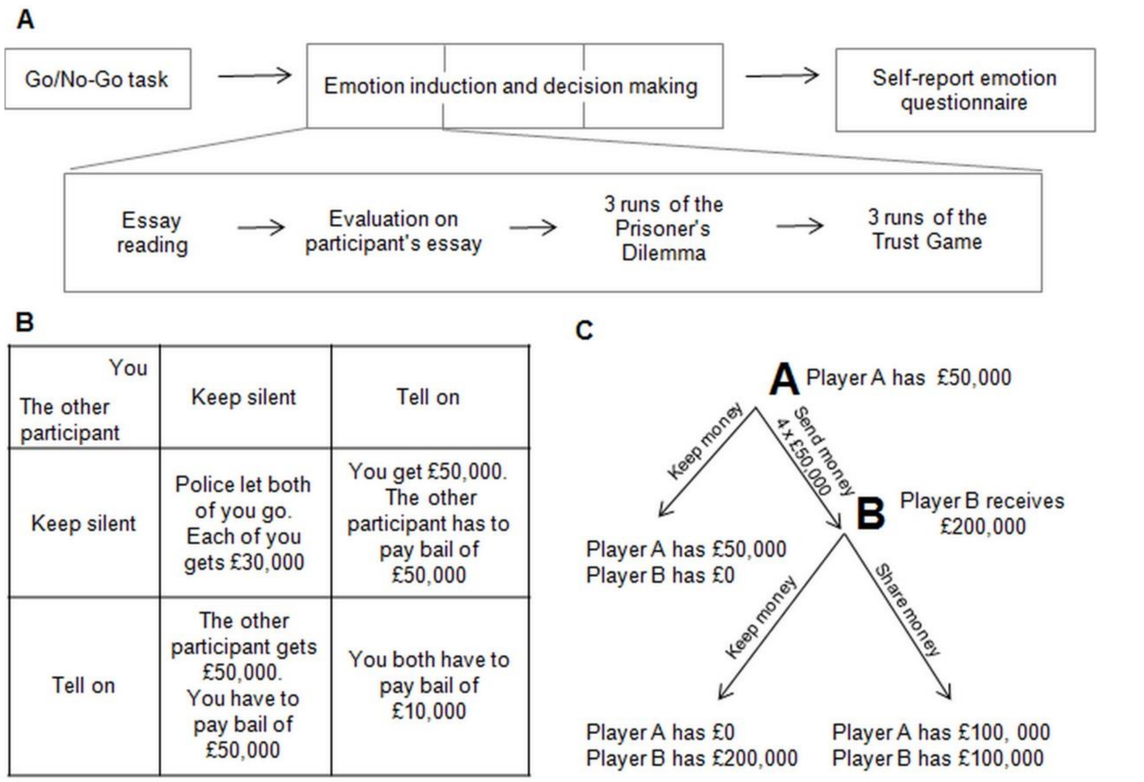

Figure 3.1: Experimental procedure for comparing emotional impact on individuals' behaviour in the Prisoner's Dilemma and the Trust Game on: (*A*) *Experimental timeline for an example participant. The order of the three emotion induction conditions* (*sympathy, anger and neutral*), *and of the two social exchange games* (*the Prisoner's Dilemma and the Trust Game*), *were counterbalanced across participants;* (*B*) *graphic outline of the Prisoner's Dilemma;* (*C*) *graphic outline of the Trust Game*

3.3.5 Analysis

The key dependent measures in this study were mean defection rates in the Prisoner's Dilemma and the Trust Game (for each game, participants could defect a total of 0, 1, 2 or 3 times per emotion-induction condition). These dependent measures were ordinal, and Kolmogorov-Smirnov and Shapiro-Wilk tests showed that the data were not normally distributed. Consequently, non-parametric statistical tests were used (as has been done previously by Brosig, (2002), Falk, Fehr, and Fischbacher (2005)). The data was analysed using a 2 x 3 mixed non-parametric Friedman's ANOVA with 2 Cognitive Control groups (high and low) and 3 Emotion Conditions (sympathy, anger and neutral), defection rate was the dependent variable (Field, Miles, & Field, 2012).

This analysis was performed separately for the Prisoner's Dilemma and the Trust Game. Post-hoc comparisons were carried out using Bonferroni-corrected Wilcoxon Signed-Rank tests (two-tailed, alpha = .017) to explore any differences further.

The number of errors in the Go/no-Go task was used to calculate d' for each participant as a measure of cognitive control ability. Using a median split, participants were divided into two groups according to this measure; a low (d' = 2.21 - 3.03, N = 14) and a high cognitive control group (d' = 3.24 – 4.46, N = 15). The difference between high and low cognitive control groups was significant ($t(27) = 5.76$, $p < .001$). Planned Mann-Whitney U tests were then used to analyse whether the effect of emotion on social-exchange decision-making depended on between-subject differences in cognitive control, as measured by the Go/no-Go task. Within each cognitive control group, a Wilcoxon Signed-Rank test for two related samples was used to test for within-subject differences between the effects of the emotion-inducing conditions on defection rates (Bonferroni-corrected alpha = .017, two-tailed).

Individual SCL scores were z-transformed for subsequent analyses with a 2 x 3 mixed design ANOVA with the between subject factor Cognitive Control (high, low) and the within-subject factor Emotion Condition (anger, sympathy, neutral. *Post-hoc* comparisons were performed using paired t-tests with Bonferroni-corrected alpha (two-tailed, $p = .017$).

3.4 Results

3.4.1 Emotional manipulation - Galvanic skin conductance

A significant main effect of Emotion Condition on the z-scored galvanic skin conductance level (zSCL) was found ($F(2, 50) = 6.13$, $p = .004$). However, there was no main effect of Cognitive Control and there was no Emotion Condition × Cognitive Control group interaction ($F(2, 50) \leq 0.49$, $p \geq .616$). Post-hoc analyses with paired t-test revealed that zSCL during the sympathy condition did not differ significantly from the neutral condition ($t(28) = 0.65$, $p = .520$). However, in the anger condition zSCL was significantly higher compared to the sympathy condition and the neutral condition ($t(28) = 2.63$, $p = .014$, and $t(28) = 4.12$, $p \leq .001$, respectively, Bonferroni-corrected). These findings show that anger induction, but not sympathy, increased zSCL compared to the neutral emotion- inducing condition (Figure 3.2).

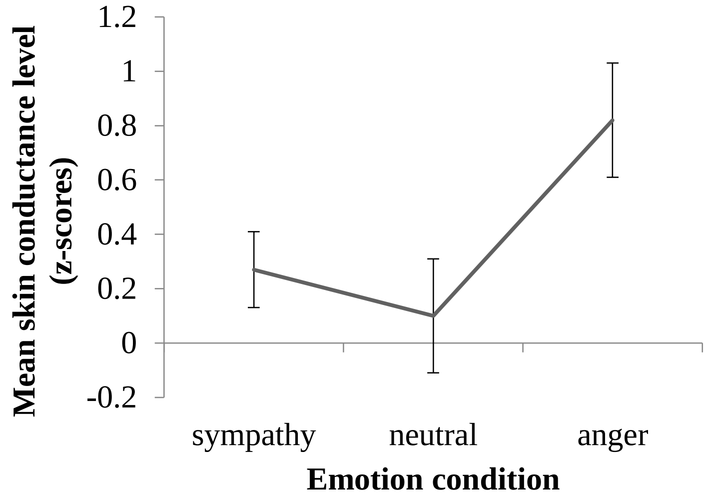

Figure 3.2: Z-scores of mean skin conductance level (zSCL) as a function of emotion condition (+/- 1 SEM). The mean zSCL in the anger condition was significantly higher compared to the neutral and sympathy conditions. The zSCL was similar for the sympathy and neutral conditions.

In order to evaluate whether zSCL was related to the effect of cognitive control on defection rate, Spearman's correlation analyses were performed separately for low and high cognitive control individuals. There were no significant correlations between defection rates in three emotion conditions and zSCL neither for high (Spearman's rho ≤ -.35, $p \geq .201$) nor low cognitive control participants (Spearman's rho ≤ -.37, $p \geq .196$).

3.4.2 Emotional manipulation - Self-report questionnaire

A hierarchical cluster analysis procedure was used to determine the number of clusters that could be extracted from participants' responses on the self-report emotion questionnaire. This analysis was based on Ward's Squared-Euclidian distance method (Bigné & Andreu, 2004; Willebrand, Andersson, Kildal, & Ekselius, 2002) and was used to determine the number of clusters according to an agglomeration schedule as suggested by Burns and Burns (2008). A three cluster solution was selected, on the basis that adding further clusters had minimal additional effect on the agglomeration coefficient. Accordingly, a three cluster analysis was performed using a k means approach, which grouped the self-report emotion questionnaire items according to their similarity across participant ratings (Bigné & Andreu, 2004). The words found to be associated with each cluster are presented in Figure 3.3 (A), along with each cluster's Cronbach's alpha. Figure 3.3 (B) illustrates these clusters according to the number of participants reporting words specific to each cluster in each emotion condition. T-tests showed that words from cluster 1 were more often reported to be experienced during the neutral- than the anger- ($t(11) = 7.18$, $p = .015$, Bonferroni-corrected) or sympathy conditions ($t(11) = 2.89$, $p \leq .001$). In contrast, words from cluster 2 were more often experienced during the anger condition, compared to the sympathy and neutral conditions ($t(14) = 4.38$, $p = .001$ vs. $t(14) = 6.94$, $p \leq .001$). Conversely, cluster 3 words were more often reported in the sympathy condition than in the anger ($t(8) = 3.07$, $p = .015$, Bonferroni-corrected) or neutral condition ($t(8) = 4.06$, $p = .004$).

A

	Cluster		
	1	2	3
Questionnaire words	active	scared	upset
	calm	nervous	strong
	content	mad	proud
	enthusiastic	jittery	interested
	excited	irritable	inspired
	glad	hostile	guilty
	good mood	furious	determined
	happy	frustrated	attentive
	joyful	enraged	alert
	pleased	distressed	
	satisfied	disgusted	
	tranquil	ashamed	
		angry	
		agitated	
		afraid	
Cronbach's alpha	0.972	0.967	0.907

B

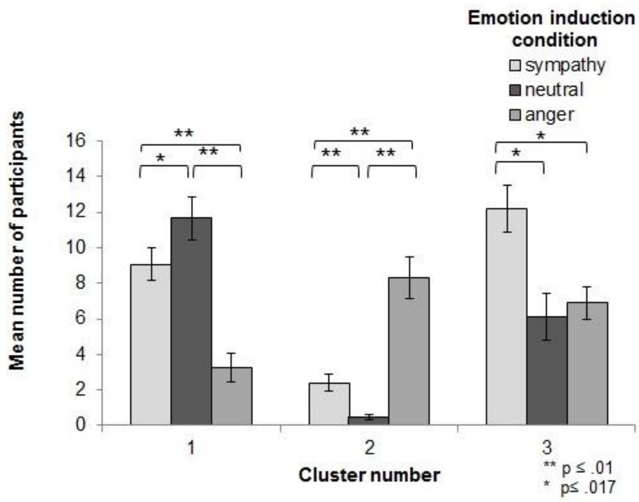

Figure 3.3: Emotion manipulation assessment: (A) The table shows words grouped into three different clusters identified by the results of the cluster analysis, along with each cluster's associated Cronbach's alpha. (B) Mean number of participants who reported experiencing those words during the sympathy, anger and neutral emotion conditions as a function of word cluster. Error bars represent +/-1 SEM.

3.4.3 Social exchange tasks

The Trust Game

The same non-parametric mixed design analysis was performed for the Trust Game. The results showed a significant main effect of emotion ($Q = 9.10$, $p = .001$), but no main effect of Cognitive Control and no significant Cognitive Control × Emotion Condition interaction ($Q \leq 0.95$, $p \geq .402$). Post-hoc comparisons with Wilcoxon Signed-Rank tests yielded a significantly higher defection rate in the neutral condition compared to sympathy induction (Z = -2.45, p = .014, Bonferroni-corrected) and a significantly higher defection rate after anger induction compared to sympathy induction (Z = -3.36, p = .001, Bonferroni-corrected). The difference in defection rates between the neutral and anger conditions was not significant (Z = -1.82, p = .068) (Figure 3.4).

The Prisoner's Dilemma

The 2 (high and low Cognitive Control) × 3 (anger, sympathy and neutral Emotion Conditions) mixed design non-parametric analysis yielded a significant main effect of Emotion Condition (Q = 0.454, p = .002) and a significant interaction between Cognitive Control and Emotion Condition (Q = 5.06, p = .01). The main effect of Cognitive Control was not significant (Q = 0.58, p = .454). Post-hoc Wilcoxon Signed-Rank tests showed a significantly higher defection rate after anger induction compared to sympathy induction (Z = -3.21, p = .001, Bonferroni-corrected). In contrast, there was no significant difference between the defection rates following neutral and sympathy induction (Z = -1.52, p = .128), the anger induction resulted in higher defection rates compared to the neutral induction (Z = -2.84, p = .004, Bonferroni-corrected; Figure 3.4).

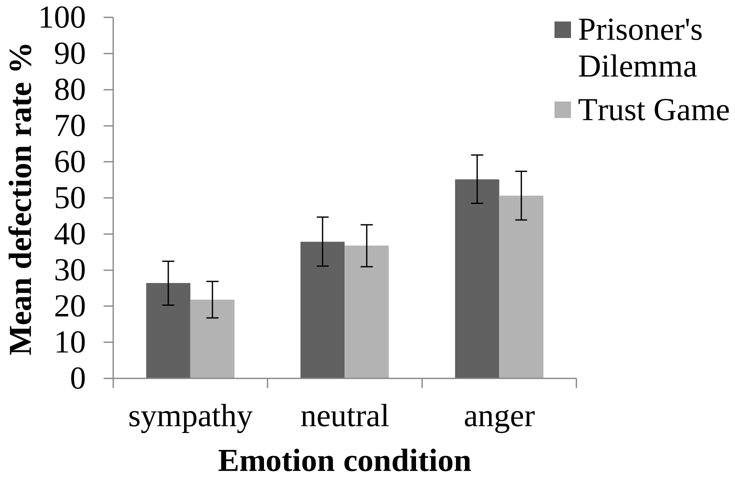

Figure 3.4: Mean percentage defection rates (*+/-1 SEM*) *in the Prisoner's Dilemma and the Trust Game as a function of emotion condition.*

The interaction effect was further explored using within-subject comparisons with Wilcoxon Signed-Rank tests were performed for each cognitive control group separately. The defection rates of high cognitive control participants did not differ significantly between emotion conditions ($Z \leq 0.97$, $p \geq .331$). In contrast, low cognitive control participants showed a significantly higher defection rate in the anger condition, compared to both neutral and sympathy inductions ($Z = -2.98$, $p = .003$ and $Z = -2.90$, $p = .005$, respectively, Bonferroni-corrected). The increased defection rate for the neutral, compared to the sympathy condition, was not significant ($Z = -1.64$, $p = .101$) (Figure 3.5).

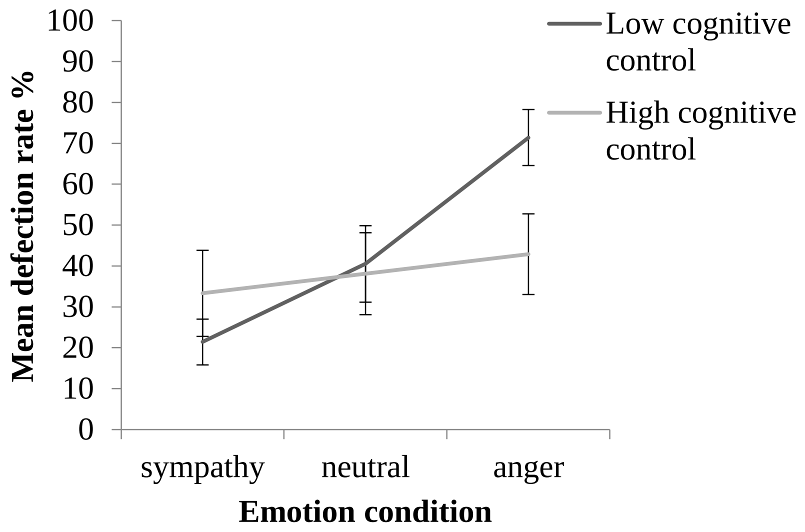

Figure 3.5: Mean defection rates in the high- and low cognitive control groups as function of emotion condition in the Prisoner's Dilemma (*+/-1 SEM*)

Reaction times

In order to find out whether participants were quicker to choose cooperation or defection depending on the emotion condition, the mean reactions times were analysed with independent t-tests for each game separately. Only the data of participants' who chose to defect and to cooperate at least once per emotion condition per game were used in this analysis. Due to a small number of trials (N = 3), only 7 participants in the Prisoner's Dilemma and only 5 participants in the Trust Game had chosen both cooperation and defection in all three emotion conditions.

A 2 (Response: cooperation vs. defection) x 2 (Cognitive Control: high vs. low) x 3 (Emotion Condition: sympathy vs. anger vs. neutral) ANOVA for the Prisoner's Dilemma showed that only Response x Cognitive Control interaction was a trend (*F*(1,

6) = 6.68, p = .081), the main effects of Response, Emotion Condition and Cognitive Control were not significant ($F(1, 6) \leq 2.41$, $p \geq .170$). The same ANOVA for the Trust game showed the Response x Cognitive Control x Emotion Condition interaction to be significant ($F(2, 6) = 9.40$, $p = .014$), yet the main effects and the rest of interactions were not significant ($F(2, 6) \leq 3.09$, $p \geq .119$; Table 3.1). Yet, due to low number of participants, future studies should investigate the reaction times more in depth.

Table 3.1: Mean reaction times in ms (*SD*) *in the Prisoner's Dilemma and the Trust Game across the three emotion conditions as a function of response* (*cooperation, defection*) *and participants' cognitive control* (*c.c.*)

		Prisoner's Dilemma		Trust Game	
		low c.c.	high c.c.	low c.c.	high c.c.
Sympathy	cooperation	2190 (1627)	2206 (417)	2028 (523)	4931 (2818)
	defection	6252 (3151)	2720 (784)	3868 (2487)	2966 (2512)
Anger	cooperation	5465 (3075)	4581 (1530)	8377 (2743)	2664 (443)
	defection	2894 (518)	3123 (889)	3391 (808)	5012 (1913)
Neutral	cooperation	2981 (1180)	4511 (3132)	5294 (3969)	6216 (5269)
	defection	2979 (1526)	3944 (2589)	2355 (324)	2474 (1727)

3.5 Discussion

This study investigated the influence of partner-directed emotions on social decision-making. The experiment compared the effects of two induced emotion (anger and sympathy) and one baseline (neutral) emotional condition, and assessed their differential impacts on decision-making in two social-exchange games - the Prisoner's Dilemma and the Trust Game. In addition, only the defection rates in sympathy and anger conditions in the Prisoner's Dilemma were modulated by participants cognitive control – low cognitive control participants defected more in the anger condition compared to neutral and less (though not significant) in sympathy condition. High cognitive control participants' defection rates over three emotion conditions were similar.

The results of the self-report questionnaire indicated that the three emotion induction conditions were associated with distinct affective experiences. The feelings most associated with the anger induction were all negative and in keeping with common definitions of anger (see Figure 3.3). The cluster most associated with sympathy induction included a mix of positive and negative feelings, suggesting that sympathy may be a more complex (or mixed) emotional experience. Specifically, some aspects of sympathy feelings seem to be associated with the empathic understanding of others (e.g. feeling upset and also feeling strength in the knowledge that people can cope with a disease), while others may be more linked to heightened concern for others (e.g. feeling attentive and alert), or with the effect the other person's perceived psychological state has on oneself (e.g. feeling inspired and interested). The cluster of feelings most strongly associated with the neutral condition was positive and relatively placid, which was also in keeping with the experiment's expectations. While this cluster was significantly more associated with the neutral condition than both emotional conditions, the sympathy condition did also load somewhat onto this cluster (clearly more so than the anger condition), suggesting that there may be a certain level of overlap between the neutral and sympathy conditions in this study. It is worth noting, however, that the neutral condition showed no closer relationship than the anger condition with the cluster that was most associated with sympathy.

The skin conductance findings show clear evidence for a certain degree of overlap between the sympathy and neutral emotions; in so far as only anger induction was associated with increased SCL, while the SCL for sympathy induction was very similar to the neutral emotion condition. This result is consistent with findings by (Frodi & Lamb, 1980; Frodi, Lamb, Leavitt, & Donovan, 1978), who showed that sympathy-related emotions had no significant impact on physiological responses (skin conductance and systolic and diastolic blood pressure). On the other hand, threat related stimuli such as angry faces, spiders or snakes are detected faster possibly due to evolutionary reasons thus increasing blood pressure and causing higher skin conductance level (Öhman et al., 2001; Öhman & Mineka, 2001). This idea has received criticism, however, by those who suggest that the speeded responses to fearful or threatening stimuli depend on the relevance of stimulus to the individual rather than its negative valence per se (Brosch, Pourtois, & Sander, 2010; Brosch, Sander, Pourtois, & Scherer, 2008; Brosch, Sander, & Scherer, 2007; Sander, Grafman, & Zalla, 2003). In the context of this study, it is possible that participants perceived the anger induction condition to be more relevant to their current situation, which resulted in a stronger emotional response and induced a desire in participants to do something to change their feelings. In contrast, induced sympathy may not always promote such strong action tendencies especially when other emotions (or distractors) are involved (Dickert & Slovic, 2009). Accordingly, anger may result in higher arousal, while sympathy is more neutral in terms of the evoked physiological response. Another explanation may be that sympathy does have a physiological impact, but that this was simply not measurable through SCL in the experiment.

The results of the social-exchange games indicated that, although the sympathy and neutral conditions did not differ noticeably in their effects on physiological arousal, both the anger and the sympathy inductions had significant (and opposing) behavioural effects on participants' social decision-making. The direction of these effects was consistent with past findings: sympathy was observed to trigger lower defection rates and anger to trigger higher defection rates compared to neutral emotion conditions (Batson, Engel, & Fridell, 1999; Ben-Shakhar et al., 2004; Bosman & Van Winden, 2002; Duersch & Servátka, 2007; Van Lange, 2008). Although, the analyses of defection rates tended to yield a similar pattern of a decrease from neutral to sympathy and an increase from neutral to anger in both games, there were subtle differences between the two games: in the Prisoner's Dilemma significant differences were found between anger and neutral, and in the Trust Game between sympathy and neutral. Therefore, both games were affected by the emotion manipulations, but in slightly different ways. One possible explanation for this pattern of results could be the different framing of the choices in the games: the Prisoner's Dilemma holds a loss frame, because participants are told that in the beginning they already have the money (they have robbed a bank) and the game outcome might result in loosing that money. In contrast, the Trust Game holds a gain frame, since the participant can either gain money. Framing effects have yielded conflicting results in different studies. While there are a wide range of experiments showing that framing does influence individuals' decisions (De Dreu & McCusker, 1997; Frank & Claus, 2006; Tversky & Kahneman, 1981) other studies find that not all people are affected by the framing effect (Peters et al., 2006). The results of the current study hint that framing effects may interact with emotion in social decision games. In the Prisoner's Dilemma participants are driven to avoid loss, and the anger condition in this experiment may have increased the saliency of losses making the option to defect even more tempting. Conversely, the Trust Game rewards cooperation, and this may be further promoted by sympathy rather than anger.

A particularly interesting finding from this study is that the effect of anger on decision-making in the Prisoner's Dilemma depended on cognitive control ability – as determined by performance in the Go/no-Go task. The effect of anger on defection rates was driven almost exclusively by the low cognitive control group. This is consistent with De Neys et al., (2011) who found that participants showing high defection rates in the Ultimatum game also made more mistakes in the Go/no-Go task. The SCL analysis, however, did not indicate a difference in the intensity of experienced emotions between low and high cognitive control participants. Thus, it is possible that high cognitive control participants were better at focusing on the game itself, and were therefore less affected by their emotions. Kollock (1998) as well as Komorita and Parks (1999) note that, in the long term, cooperation can bring bigger benefits to the players than defection. Therefore, high cognitive control participants may be more likely to follow longer term goals while playing the game. On the other hand, low cognitive control participants may be relying more on intuition (Stanovich & West, 2000; Sunstein, 2005), and in particular an "outrage heuristic", which promotes a desire to punish others as retribution for their anger and satisfying a short term goal (Kahneman & Frederick, 2002).

Limitations

This study had some limitations that should be considered in future studies: first of all it is possible that reputation effects were induced through multiple repetitions of the games thus providing participants with their opponent's response. That is decisions may have been based not on the emotion condition and considerations what is the most optimal choice in the game, but arise in response to the partner's behaviours earlier in the interaction. Although the game order was counterbalanced, and attempts were made to control for reputation effects by giving a randomised outcome of participant's interaction with the "other participant", future studies might remove the outcome after each single trial and increase the number of trials and/or randomise the trials completely, such that participants play multiple games against several partners in a fully interleaved manner. Another limitation is the self-report emotion questionnaire used, where sympathy and anger conditions had different numbers of words representing the possible emotions. In this experiment this issue was compensated for by using a galvanic skin conductance measure showing participants physiological arousal level. However, in future experiments an improved version of the self-report emotion questionnaire, where participants are required to indicate the extent each emotion word was felt towards each of the “other participants” via a rating scale, would be sufficient enough to reflect the success of emotion induction.

In addition, although only a limited number of participants both defected and cooperated in all three conditions, their reaction time data shows an emerging pattern; in the Prisoner’s Dilemma in the sympathy condition low cognitive control participants spend more time deciding before defection and were quicker to cooperate, while high cognitive control participants showed barely any change between cooperation and defection options. In the anger emotion condition low cognitive control participants took longer to cooperate than to defect and for the high cognitive control participants this difference between two options was smaller. Finally, in the neutral condition both high and low cognitive control participants’ reaction time differences between cooperation and defection was similar. The same reaction time analysis in the Trust Game showed a similar pattern to the Prisoner’s Dilemma for low cognitive control participants, however high cognitive control participants showed almost a revered pattern – being quicker to defect than to cooperate in sympathy and deciding to cooperate quicker than to defect in anger condition. Overall this result suggests that participants with high cognitive control are considering the alternative options more closely, and according to AIM individuals spending more time on analysing a situation or reasoning task are able to overcome their biases and to respond in accordance to logic. Yet, as mentioned previously due to low numbers of participants it is impossible to draw clear conclusion and further investigations are needed.

This study leads to choosing the Prisoner’s Dilemma as the game of interest for the future studies. This game requires a higher cognitive load as participants make their choices simultaneously with “other participants” and have to hold in mind two possible outcomes. In addition, the Prisoner’s Dilemma design can be changed to eliminate the possible reputation effects by not providing participants with the outcome of each interaction. The behavioural responses showed an interaction between defection rates and participants’ cognitive control which needs to be explored further by eliminating the limitations of the current study.

Chapter 4 Experiment 2: The Impact of Experimental Design on Decision-Making under Emotion

4.1 Overview

Based on the findings of Experiment 1 the Prisoner's Dilemma has been chosen to explore differences between event-related and block designs on decision-making while experiencing sympathy and anger in the Prisoner's Dilemma. In addition to the cognitive inhibition measure, the Emotion Regulation Questionnaire (Gross & John, 2003) was added to investigate the potential impact of individual differences in emotion regulation on behavioural responses.

4.2 Introduction

The previous experiment found -as expected- that anger and sympathy have opposite effects on decision-making compared to neutral emotion and this differential effect of emotion type on decision-making was further modulated by the level of cognitive control. However, one of the limitations of that study was the sequential manner of interaction with the other "participants" which might have led to the reputation effects. To avoid this limitation only one game – the Prisoner's Dilemma- was chosen as it allows for being played over multiple trials without revealing the opponent's choice in every single trial and thereby possibly prevents the formation of reputation effects. Modifications of this kind were not possible by using the Trust Game.

In addition, the limitation of three trials per condition contributed to the data distribution being non-normal. Hence, to allow for normally distributed data more trials per emotion condition are necessary. Additionally, the question if emotion condition presentation has an effect on the defection rate had to be answered: emotion condition presentation in a completely randomised manner (event-related design) might be less effective than presenting conditions in blocks due to participants not being able to switch between emotions and reducing the duration of the triggered emotion. For this reason, the potential differences between event-related and block design will be investigated taking into account possible ways to prolong the emotion duration and intensity.

Emotion duration depends on various factors. Emotions last longer if the emotion eliciting event has reappearance and contains reminders of the event (Sbarra & Emery, 2005; Verduyn et al., 2009). Following this, the thoughts related to the emotion eliciting event also have an impact on how long the emotions are experienced. On the one hand, these event-related thoughts can prolong emotional experiences via ruminations (Barber et al., 2005; Bushman et al., 2005; Denson et al., 2009; Larsen & Prizmic, 2004; Martin & Tesser, 1996; Peled & Moretti, 2007; Ray et al., 2008; Verduyn et al., 2011), on the other hand, elicited emotions unrelated to the event, in the form of distractions may be used to overcome the original emotion (Boden & Baumeister, 1997; Spielmann et al., 2009; Wenzlaff et al., 1988). Finally, the more personally important the emotion triggering situation is, the stronger the emotion is felt and the longer its duration (Sonnemans & Frijda, 1995).

Overall, emotion duration can depend on any of these factors or a combination of them. However, looking deeper into what these factors involve it seems the main components are behavioural (avoiding or approaching the emotion eliciting person/situation physically) or cognitive (the direction of thoughts and the assigning of particular importance to an event). Both components are influenced by an individual's emotion regulation abilities (Gross, 1998, 2002; Gross & John, 2003; Gross & Thompson, 2007; Ochsner & Gross, 2005).

The previous study found an interaction between cognitive control and decision-making under emotion, however, there is evidence that decision-making is also influenced by an individual's emotion regulation strategies (Heilman, Crişan, Houser, Miclea, & Miu, 2010). In two of their experiments researchers showed that cognitive reappraisal from the Emotion Regulation Questionnaire for fear and disgust (exp. 1) and neutral affect (exp. 2) in the Balloon Analogue Risk Task (BART; a computer based task were participants earn money by pumping the balloon, but once it explodes the money is lost) and the Iowa Gambling Task encouraged more riskier decisions (more pumps to the balloon in BART/choices from higher wins and higher loses card piles in IGT) compared to a control condition. In general, emotion regulation is thought to facilitate the control of emotion intensity, duration and overall experience depending on personal goals. The emotion regulation concept comprises two mechanisms - cognitive reappraisal and expressive suppression (Gross, 2002; Gross & John, 2003). Reappraisal is defined as a cognitive way of reducing the strength of an emotion by changing the thoughts associated with that particular emotion (Sheppes & Gross, 2011) while expressive suppression relies on a behavioural way of regulating emotion, for example not crying when one feels sad (Sheppes & Gross, 2011). In general, cognitive reappraisal is thought to be a more effective strategy to regulate emotions, but it takes more time to come into effect (Extremera & Fernández-Berrocal, 2006; Gross, 2002; Gross & John, 2003). Although expressive suppression is a quicker way of regulating one’s emotions, it is not as effective as cognitive reappraisal and can lead to antisocial behaviour or mental health problems in the long term (McLean, Miller, & Hope, 2007; Moore, Zoellner, & Mollenholt, 2008).

The aim of the current experiment is not only to test which design -block or event-related- is more suited for investigating the impact of emotions on decision in social economic games, but also to evaluate how differential emotion regulation strategies influence decision-making. In Experiment 2 block and event-related designs were used to see if participants can switch between emotions felt to different people on a trial by trial basis, or whether having blocks of trials for a given emotion at a time is a better option as it allows participants more time before switching to another emotion. The hypothesis for the study was that a block-design will lead to more intense emotional experiences which will be measured in a clearer defection rate pattern compared to an event-related design. Under the sympathy emotion condition defection rates will decrease and under the anger emotion, defection rates will increase compared to a neutral emotion condition. Also, it is expected that participants that use predominantly cognitive reappraisal strategies will be less affected by emotion in the decision-making game than participants who typically engage in expressive suppression strategies, as cognitive reappraisal has been shown to be a more effective strategy at regulating emotions (Extremera & Fernández-Berrocal, 2006; Gross, 2002; Gross & John, 2003).

4.3 Methods

4.3.1 Participants

Initially 25 participants (seven males) took part in this study. Five participants were later removed from the study due to being aware of the deception. The mean age of the remaining 20 participants (five males) was 21.15 years (SD = 3.70). All of the participants were University of Hull undergraduate students who gained course credits for taking part in the experiment. All participants were native English speakers, or fluent in English language to successfully study at UK University level (IELTS score of 5.5 or above). Participants had normal or corrected-to-normal vision and were not undergoing any psychopharmacological treatment. The study was approved by the Departmental ethics committee.

4.3.2 Stimuli

To trigger emotions, essays and evaluations inducing sympathy, anger and neutral emotions were used. For a full description of the content of the essays and evaluations please refer to Methods section of Experiment 1.

Essays and evaluations were hand-written in a clear handwriting and on different coloured paper (light green, light blue, light purple). This was done in order for the participants to learn to associate particular colours with particular emotions. Given that emotion condition material was presented on a computer screen this allowed participants to remember the emotion triggering stimuli quicker. Colours were counter-balanced across participants. Participants wrote their essays and evaluations on light yellow coloured paper.

4.3.3 Tasks

The Prisoner's Dilemma

An iterated version of this game was used consisting of 21trials in a block design, and 21 trials presented in an event-related design. A single trial of the Prisoner's Dilemma would start with a presentation of a fixation cross (lasting on average for 2.5 seconds), followed by a photograph of the "other participants" essay (for up to 4 seconds but not less than 1second; the participant could press a button indicating that he/she remembered the essay and not wait until the end of the 4 seconds period) and then the photograph of the evaluation the participant received from the "other participant" (for up to 4 seconds but no less than 1second; the participant could press a button indicating that he/she remembered the evaluation; Figure 4.1B). It was explained to the participants that the reminders during the experiment serve as indicators that the next trial of the Prisoner's Dilemma would be played interacting with that particular "other participant" whose essay and evaluation they saw before the game trial. Participants were allowed 7 seconds to decide whether to keep silent (pressing the "M" button) or to tell on the "other participant" (pressing the "X") when the payoff matrix of the game appeared on the screen. The outcome of the game was presented after 21 trials.

The photographs of the emotional stimuli were shown again at the beginning of every trial of the decision-making game serving as a reminder of the induced emotion and as a method to prolong the emotion (Sbarra & Emery, 2005; Verduyn et al., 2009).

In addition, seven different payoff matrices were used in the game, where the proportion of money in different outcomes remained the same (3: 5: -5: -1), but the values changed e.g. in one matrix if both players cooperated they got £30,000 (3), if one participant defected and the other player cooperated, the participant got £50,000 (5) and the other player lost £50,000 (-5), and if both chose defection both lost £10,000 (-1); while in a second matrix the values might be £120,000, £200,000, -£200,000 and -£40,000 respectively.

The cognitive inhibition task

The Go/no-Go task was carried out in the same way as described in the Methods section of Experiment 1.

Self-Report Emotion Questionnaire

In this questionnaire participants were presented with a list of 54 emotion words assessing sympathy and compassion (compassionate, sympathetic, warm, tender, moved, soft-hearted; Cronbach's Alpha .918, n = 6), sadness for the other individual (sad, upset, feeling low, grieved, heavy-hearted, low spirited, sorrowful, guilty, troubled, worried, nervous, distressed; Cronbach's Alpha .942, n = 12), fear (afraid, jittery, scared, perturbed; Cronbach's Alpha .719, n = 4) and anger (agitated, irritable, angry, frustrated, hostile, furious, enraged, mad, alert, determined, bothered, alarmed, disgusted; Cronbach's Alpha .911, n = 13) and positive affect (good mood, happy, active, enthusiastic, excited, pleasant, inspired, interested, proud, attentive, pleased, strong, glad, joyful, pleased, satisfied, calm, content, tranquil; Cronbach's Alpha .898, n = 19; Harmon-Jones et al., 2003; Harmon-Jones, Vaughn-Scott, Mohr, Sigelman, & Harmon-Jones, 2004; Harmon-Jones & Sigelman, 2001). The increase in the number of words was due to the fact that in previous experiment the sympathy condition had a lower number of words to represent sympathy. In this Self-Report Emotion Questionnaire there were a similar number of words in all three conditions (sympathy N = 18, anger N = 17, neutral N = 19).

For each word, participants had to indicate how strongly they felt that emotion towards each of the three other "participants" on a scale from 1 (not at all) to 5 (very strong). This was an improvement from the previous study allowing a measure of the intensity at which the emotion word was felt. The mean rating for each emotion word was calculated for subsequent analysis (Appendix C on page 219).

Emotion Regulation Questionnaire

The questionnaire was designed and validated by Gross and John (2003) and comprises of 10 statements which are used to assess two emotion regulation strategies: expressive suppression and cognitive reappraisal (for example, "I keep my emotions to myself"). Participants were asked to indicate their agreement to each statement on a scale from 1 (strongly disagree), to 4 (neutral), to 7 (strongly agree). The Emotion Regulation Questionnaire was analysed by calculating expressive suppression (average of questions 1, 3, 5, 7 and 10) and cognitive reappraisal scores (average of questions 2, 4, 6, 8 and 9) for each participant.

4.3.4 Procedure

The general procedure was similar to the one used in experiment 1. Upon their arrival to the experiment participants were asked to write a short essay discussing something which was important to them. After explaining the instructions and procedure of the experiment, the experimenter left the room to take the essays and evaluation forms to the participant ("seated in separate rooms") as well as taking away the participants own evaluations on the "other participants'" essays. The order of emotion conditions (the essays and evaluations from the "other participant") was counterbalanced across participants.

Each time the experimenter brought in the "other participants" essay or evaluation, photographs of all the materials (essays and evaluations) were taken while the participant watched. After participants read and saw evaluations their own essay from all three emotion induction conditions, the photographs were uploaded onto the network while participants observed this. Then participants were reminded of the Go/no-Go and the Prisoner's Dilemma instructions by the experimenter and they also saw the instructions before each task on the screen. They always began with the Go/no-Go task, and then proceeded to the Prisoner's Dilemma where each trial started with emotion condition reminders (colour photos of essays and evaluations from the "other participant") followed by the Prisoner's Dilemma outcome table (A).

Finally, participants had to fill in the Emotion Regulation Questionnaire and the Self-Report Emotion Questionnaire. At the end of the session, questions establishing the participant's belief in the deception were asked. These questions were about the "other participants" age and gender and if the participants believed in the existence of the "other participant". Data from participants who were not deceived (i.e. did not believe in the other participant being a real person) was removed from the study.

Upon completion of the experiment, participants were fully debriefed and contact details of the university counsellor were given.

Design

Participants received both designs, and half of the trials for the experimental task (the Prisoner's Dilemma) were run in a block design and the other half as event-related (counterbalanced across participants). In the block design there were three runs comprising all 3 emotion conditions respectively: in each run, one emotion condition could appear eight, seven or six times in a sequence. The order of emotion conditions and the number of trials (six to eight) in a run was counterbalanced for each emotion. Thus each emotion condition consisted of 21 trials in total. In the event related design, the emotion conditions were pseudo-randomised that there were no more than three trials of the same emotion condition in a sequence (Figure 4.1 C). This resulted in 63 trials over three runs (21 per run, and 21 per each condition).

Overall, there were a total of 126 trials; after each set of 21 trials participants were given a short self-paced break and the outcome of the interaction in those 21 trials was given. The outcome did not identify the proportion of money gained or lost from the interaction with any particular "other participant", just an overall score. This prevented any reputation effect from forming. There were six different possible overall results after interacting for 21 trials, and their order was counterbalanced across participants.

The dependent variable was the defection rate and the independent variables were the design type (block and event related), emotion condition (sympathy, anger and neutral), the level of cognitive control (low and high), cognitive reappraisal (low and high) and expressive suppression (low and high) both from the Emotion Regulation Questionnaire.

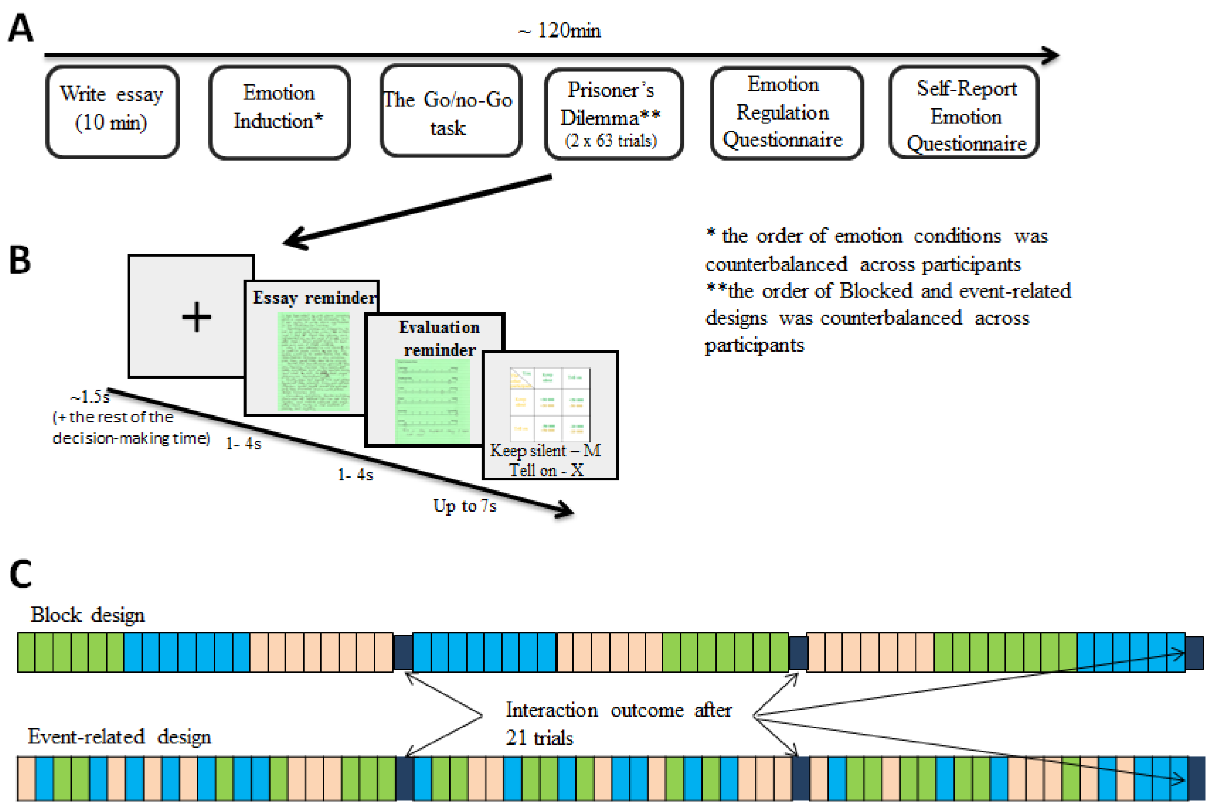

Figure 4.1: (*A*) *A general procedure of the experiment comparing block and event-related designs.* (*B*) *An example of a single trial of the Prisoner's Dilemma.*(*C*)*An example of trial order for block and event-related designs.*

4.3.5 Analysis

The main interest of this experiment was the defection rates in the three emotion conditions as a function of experimental design in the Prisoner's Dilemma task. A mixed design ANOVA with within-subject variables of Design Type (block and event-related), Emotion Condition (sympathy, anger and neutral) and between subject variables of Cognitive Inhibition (high and low) and from ERQ Expressive Suppression (high and low) and Cognitive Reappraisal (high and low) were used to explore the main effects and interactions between dependent and independent variables. Significant results were followed up with Bonferroni-corrected paired t-test (p = .017, two-tailed) or independent t-tests (alpha = .05, two-tailed, unless stated otherwise).

4.4 Results

4.4.1 Emotion manipulation

The ratings of the Self-Report Emotion Questionnaire were analysed to confirm if the emotion manipulation was effective, and the emotional stimuli triggered the targeted emotion. A Principal Components method with a Varimax (orthogonal) rotation analysis was used to evaluate whether the emotion manipulation was successful. Six emotion words (excited, jittery, guilty, disgusted, nervous, ashamed) that were rated as 1 (did not feel that emotion at all) across all conditions and participants were excluded from the analysis. Although the Kaiser-Meyer Olkin measure of sampling adequacy was medium (KMO = .61, N = 20), the Bartlett's test of Sphericity was significant, χ^2 (1128) = 3088.144, $p < 0.001$. The factor analysis identified three factors (each explaining at least 10% of variance) in total explaining 60% of variance (Table 4.1).

Following the factor analysis, the mean ratings of the emotion words in each factor were compared between each emotion condition. The first factor was felt significantly stronger in the sympathy emotion condition (Mean = 2.90, SD = 1.18) than in the anger condition (Mean = 1.56, SD = 0.79, $t(38) = 4.21$, $p < .001$) or neutral emotion condition (Mean = 1.59, SD = 0.52, $t(38) = 4.53$, $p < .001$). The second factor had significantly higher ratings in the anger emotion condition (Mean = 2.77, SD = 1.05) compared to the neutral (Mean = 1.52, SD = 0.54, $t(38) = 4.70$, $p < .001$) or the sympathy condition (Mean = 1.92, SD = 0.77, $t(38) = 2.93$, $p = .006$). The ratings for words comprising the third factor were significantly stronger in the neutral condition (Mean = 2.38, SD = 0.71) than in the anger emotion condition (Mean = 1.47, SD = 0.68, $t(38) = 4.1$, $p < .001$). There was also a slight trend for an increase compared to the sympathy emotion condition (Mean = 1.86, SD = 0.60, $t(38) = 1.88$, $p = .067$).

These results suggest that overall the target emotions were induced as expected. The first factor seems to relate to the sympathy condition in the experiment. The words that loaded onto the second factor seem to relate to the anger condition, while the third factor words seem to contain what we would expect from our neutral, but slightly positive condition (as the essay-evaluation was slightly positive).

Table 4.1: Overview over the results of the Factor analysis on the Self-Report Emotion Questionnaire: three factors accounting for 60 % of the total variance were identified.

	first factor (sympathy condition)	second factor (anger condition)	third factor (neutral condition)
	sympathy	furious	glad
	moved	mad	happy
	heavy hearted	angry	joyful
	grieved	agitated	pleased
	sad	irritable	good mood
	sorrowful	enraged	satisfied
	tender	hostile	warm
	compassionate	frustrated	tranquil
emotion words	worried	low spirited	content
	soft hearted	strong	enthusiastic
	distressed	bothered	active
	afraid	feeling low	pleasant
	troubled		calm
	scared		
	upset		
	feeling low		
	attentive		
% of variance explained	28%	22%	10%

4.4.2 Block- vs. Event-Related Designs in the Prisoner's Dilemma

Defection rates

As a first step, a 2 Design Type (block vs. event-related) x 3 Emotion (sympathy vs. neutral vs. anger) mixed design ANOVA was performed on the mean defection rates to verify whether there was any difference in decision-making under emotion depending on the Design Type. There was a significant main effect of Emotion Condition ($F(2, 38) = 15.95$, $p < .001$), but neither the main effect of Design nor the Emotion Condition x Design interaction were significant ($F(2, 38) \leq 1.48$, $p \geq .240$).

Given that the main effect of Design Type was not significant (Table 4.2) the mean defection rates were collapsed across block and event-related designs for comparison between each emotion condition.

The main effect of Emotion Condition indicated that participants' choices on the iterated Prisoner's Dilemma differed according to the emotion they felt towards the person they interacted with. The difference between sympathy, anger and neutral conditions defection rates were compared with Bonferroni-corrected paired sample t-tests (alpha = .017, two-tailed). This analysis revealed that defection rates significantly increased in the anger condition (Mean = 0.72, SD = 0.19) compared to sympathy (Mean = 0.39, SD = 0.24; $t(19) = -5.30$, $p < .001$) and neutral (Mean = 0.52, SD = 0.27; $t(19) = -3.68$, $p = .002$). The defection rate in the neutral condition was numerically higher than for sympathy and was approaching significance ($t(19) = 2.1$, $p = .05$; adjusted for multiple comparisons with Bonferroni correction, alpha = .017, two-tailed).

Table 4.2: Mean defection rates (*SD*) *in the three emotion conditions as a function of design type* (*block/ event-related*)

Design	Emotion Condition		
	Sympathy	Neutral	Anger
Block	0.36 (0.28)	0.51 (0.33)	0.76 (0.25)
Event-related	0.43 (0.30)	0.52 (0.30)	0.69 (0.27)

Cognitive Control

The Go/no-Go task was analysed by calculating individual d' scores which were used to divide the participants into high [2.72 - 4.46; N = 10] and low [0.76 – 2.49; N =

11] cognitive control groups (Eimontaite, Nicolle, Schindler, & Goel, 2013). High cognitive control participants had significantly higher d' scores compared to low cognitive control participants, $t(18) = 6.89$, $p < .001$.

To explore the effects of cognitive control on decision-making in the Prisoners Dilemma a mixed 2 x 3 x 2 ANOVA was performed with the within-subject factor Design Type (block and event-related) and Emotion Condition (sympathy, anger and neutral), and the between-subject factor Cognitive Control (high and low). There was a significant main effect of Emotion Condition ($F(2, 36) = 17.32$, $p < .001$), and a trend interaction between Emotion Condition and Cognitive Control ($F(2, 36) = 2.64$, $p = .085$). There were no other significant main effects or interactions ($F(2, 36) \leq 1.60$, $p \geq .215$).

Given the trend towards an interaction between Emotion Condition and Cognitive Control, and the hypothesis concerning the low and high cognitive control participants' this interaction was explored further. The between subject comparisons in three emotion conditions with independent t-test did not reveal any significant differences between low and high cognitive control participants (sympathy: $t(18) = 0.43$, $p = .67$; neutral $t(18) = 0.70$, $p = .495$; anger $t(18) = 1.92$, $p = .071$). Within subject comparisons for the low cognitive control group showed a significant decrease in defection rates from the sympathy to the anger condition, and an increase from the neutral to the anger conditions ($t(9) = -5.68$, $p < .001$ and $t(9) = -4.66$, $p < .001$, respectively). The difference between the sympathy and neutral condition was not significant ($t(9) = -2.11$, $p = .064$). The same analysis for the high cognitive control group, yielded no significant differences in defection rates between the emotion conditions ($t(9) \leq 2.50$, $p \geq .034$, multiple correction adjustment alpha = .017, two-tailed; Figure 4.2).

This result replicates finding from the previous study, showing that participants' performance on the Prisoner's Dilemma is modulated by their cognitive control, and the significant differences appeared between the anger and neutral and sympathy conditions. In addition, although the initial analysis did not reveal significant differences between block and event-related designs, a cognitive control effect was found only in the event – related design where low cognitive control participants' behaviour was more affected by the emotion condition.

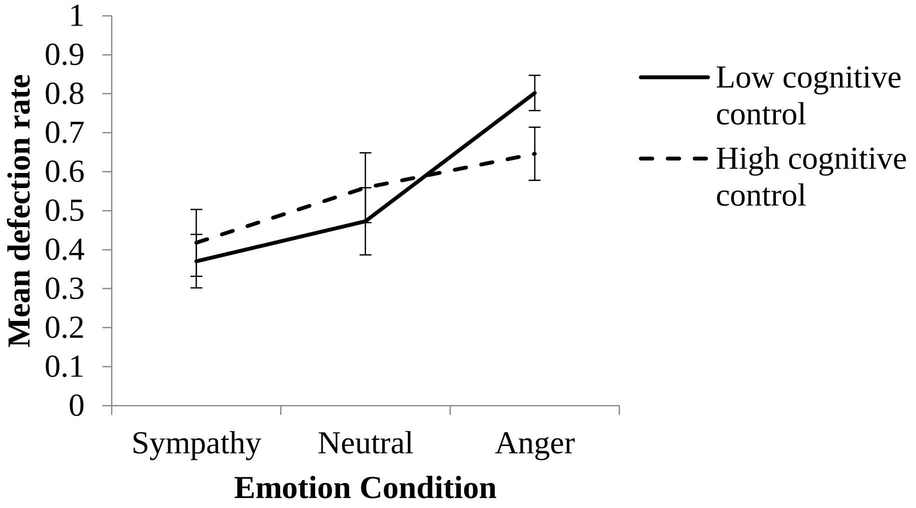

Figure 4.2: Mean defection rates (+/-1 SEM) in the high- and low cognitive control groups as function of emotion condition

Expressive Suppression

The Emotion Regulation Questionnaire (ERQ) was analysed by calculating expressive suppression (mean ratings for questions 1, 3, 5, 7 and 10) and cognitive reappraisal scores (mean ratings for questions 2, 4, 6, 8 and 9) for each participant. The comparison between reappraisal and suppression showed that the participants in this study had significantly higher reappraisal scores (Mean = 4.63, SD = 1.48) compared to expressive suppression (Mean = 3.50, SD = 1.02; $t(19) = 2.96$, $p = .008$). This suggests that participants in the current study had significantly more developed cognitive reappraisal skills compared to the expressive suppression. As a next step, participants were divided into two groups according to their score on the ERQ, separately for both high [4.83 – 7.00, N = 10, Mean = 3.43] or low [1.50 – 4.50, N = 10, Mean = 5.83] cognitive reappraisal and high [3.50 – 5.50, N = 9, Mean = 2.69] or low [1.25 – 3.25, N = 11, Mean = 4.16] expressive suppression. High and low scores differed significantly for cognitive reappraisal and expressive suppression ($t(18) = 6.37$, $p < .001$ and $t(18) = 4.61$, $p < .001$, respectively).

To check if defection in the Prisoner's Dilemma depends on the Expressive Suppression and Cognitive Reappraisal a mixed 2 x 3 x 2 x 2 ANOVA was done with the within-subject factors of Design Type (block and event-related) and Emotion Condition (sympathy, anger and neutral), and the between-subject factors Expressive Suppression (high and low) and Cognitive Reappraisal (high and low). There was a significant main effect of Emotion Condition ($F(2, 32) = 18.28$, $p < .001$) and a significant Emotion Condition x Expressive Suppression interaction ($F(2, 32) = 3.86$, $p = .032$, respectively). There were no other significant main effects or interactions ($F(2, 32) \leq 3.00$, $p \geq .102$).

To explore the interaction between Emotion Condition x Expressive Suppression the defection rates in the low and high Expressive Suppression groups were compared separately for each of the three emotion conditions. This analysis showed that defection rates differed only in the anger emotion condition where the low expressive suppression group defected more than the high expressive suppression group ($t(18) = 2.28$, $p = .035$). There were no group-differences in the sympathy and neutral conditions ($t(18) \leq 1.28$, $p \geq .216$). Following this, the defection rates between emotion conditions were compared separately for the low and high suppression groups. High expressive suppression participants showed increased defection rates in the anger condition compared to sympathy ($t(10) = -3.49$, $p = .006$), but there were no other differences in the remaining emotion conditions after correction for multiple comparisons ($t(10) \leq 2.26$, $p \geq .047$, Bonferroni-corrected two-tailed alpha = .017). For the low expressive suppression group the defection rates also significantly increased in the anger condition compared to sympathy ($t(8) = -5.25$, $p = .001$). This pattern was also observed when anger was compared to neutral albeit only approaching significance ($t(8) = -2.93$, $p = .019$, Bonferroni-corrected alpha = .017) whereas there was only a slight trend in the defection rate decrease between sympathy and neutral conditions ($t(8) = -2.10$, $p = .069$; Figure 4.3).

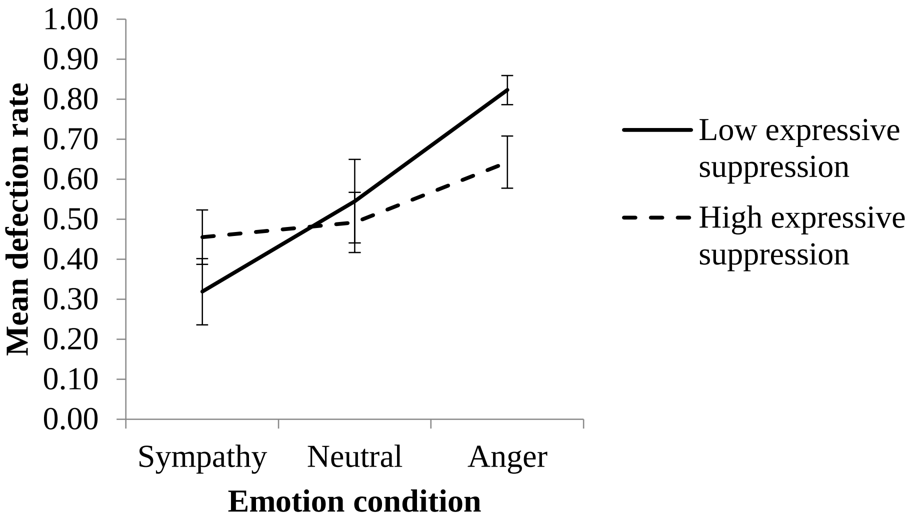

Figure 4.3: Mean defection rates (+/- 1SEM) in the high and low expressive suppression groups as a function of emotion condition.

4.4.3 Reaction times

In order to investigate if participants' reaction times were dependent on their response and emotion condition, a mixed design ANOVA with within-subject factors of Emotion Conditions (sympathy vs. neutral vs. anger), Responses (cooperation and defection) and between-subject factors of Cognitive Inhibition (high and low) and Expressive Suppression (high and low) on the overall defection rate was constructed. Although no significant main effects or interactions occurred ($F(2, 30) \leq 1.79$, $p \geq .185$) an interaction, Emotion Condition x Response x Expressive Suppression was a trend ($F(2,30) = 2.98$, $p = .066$). To explore the trend interaction Emotion Condition x Response x Expressive Suppression, a mixed design ANOVA excluding between-subject factor Cognitive Inhibition was performed. The interaction Emotion Condition x Response x Expressive Suppression was significant ($F(2, 34) = 4.17$, $p = .024$), but none of the main effects or other interactions were significant ($F(2, 34) \leq 1.77$, $p \geq .186$; Table 4.3).

Post hoc between subject analysis with independent t-test did not reveal any significant differences between low and high expressive suppression participants in three emotion conditions as a function of the participants choice ($t(18) \leq 1.62$, $p \geq .122$). The within-subject analysis with paired t-test revealed that low expressive suppression participants were at a trend difference at spending more time to deciding to cooperate in anger condition than to defect in the same condition ($t(8) = 2.86$, $p = .021$, Bonferroni-corrected alpha = .017 for multiple comparisons), sympathy and neutral emotion conditions as well as any conditions in the high expressive suppression group did not show significant result ($t(10) \leq 1.87$, $p \geq .091$).

Table 4.3: Mean reaction times in ms (*SD*) *for low and high expressive participants decisions over three emotion conditions as a function of their choice* (*defection and cooperation*)

	Decision	Emotion Condition		
		Sympathy	Neutral	Anger
Low Expressive Suppression	Cooperation	1855 (594)	2186 (768)	2320 (1059)
	Defection	2124 (756)	2202 (958)	1696 (677)
High Expressive Suppression	Cooperation	1875 (794)	1789 (1098)	1748 (814)
	Defection	1610 (633)	1464 (782)	1646 (688)

4.4.4 Additional analyses

Pearson correlation analysis was performed between the defection scores in the three emotion conditions, d' from the Go/no-Go task and Cognitive Reappraisal and Expressive Suppression scores from the Emotion Regulation Questionnaire. There was a significant correlation between defection rate in the event related anger condition and the false alarm rate from the Go/no-Go task, $r = .54$, $p = .015$. The correlation between other variables was not significant ($r \leq .41$, $p \geq .070$).

The follow up on the significant correlation between defection rate in the anger condition in the event-related design, with the false alarm rate from cognitive inhibition game, a simple linear regression was calculated to predict defection rates based on participant's false alarm score. A significant regression equation was found ($F(1, 19) = 7.27$, $p = .015$), with an R^2 of .29. Participant's predicted defection rate was = 0.538 + 0.789 (false alarm).

Defection over time

To check if the defection rates were changing over time, the 21 trials per emotion condition were divided into three sets (Runs) of 7 trials and a 3 x 3 x 2 repeated measures ANOVA was constructed with the within-subjects factors Run (1,2,3,), Emotion Condition (sympathy, anger and neutral) and Design (block and event-related). As shown in the previous section, the main effect of Emotion Condition and Run were significant ($F(2, 38) = 15.77$, $p < .001$ and $F(2, 38) = 6.37$, $p = .004$, respectively). The main effect of Design and the interactions were not significant, $F(2, 38) \leq 1.05$, $p \geq .387$.

The exploration of the main effect of run with paired t-test showed that overall participants defected least in the first run (Mean = 0.47, SD = 0.17) and this number significantly increased to the second run compared to the first (Mean = 0.59, SD = 0.18) and to the third compared to the first run (Mean = 0.58, SD = 0.24; $t(19) = -3.79$, $p = .001$ and $t(19) = -2.64$, $p = .016$, respectively). The difference between the second and third run was minimal ($t(19) = 0.061$, $p = .952$).

The Payoff Matrix x Defection analysis did not show that participants' responses would depend on the presented payoff matrix (see Appendix E on page 221).

4.5 Discussion

The current study explored if emotion condition presentation - in a sequential or completely interleaved way - has differential effects on decision-making in the Prisoner’s Dilemma game. No significant difference was found between the two designs. Overall sympathy and anger had opposite effects on defection in this game compared to the neutral emotion condition; in sympathy condition participants defected less and in anger condition they defected more than in the neutral condition. The significant difference between emotion conditions appeared between anger and neutral, but only at a trend level between sympathy and neutral. Furthermore, consistent with Experiment 1 results, the defection rate in sympathy and anger emotions was modulated by participants’ cognitive inhibition and also, surprisingly, by expressive suppression; low ability participants defected less in sympathy and more in anger compared to neutral emotion conditions.

These defection rate results for the significant increase in defection rates from neutral to anger, and non-significant decrease from neutral to sympathy are consistent with the results from Experiment 1. A possible explanation for this effect might be the loss frame the Prisoner’s Dilemma holds. In this game participants already have the money and they are threatened with losing it depending on the outcome. In addition to this, it is possible that as anger is the physiologically stronger emotion, it might also influence stronger behavioural responses – as threat related stimuli is processed quicker (Öhman et al., 2001; Öhman & Mineka, 2001). If participants recognise the “other participant” as being angry, they might have acted on this assumption by also defecting and not letting either of them win. On the other hand, sympathy has weaker action tendencies and does not trigger the ‘fight or flight’ response as anger does. And this is evident from behavioural and physiological response in Experiment 1 as well as defection rates in this study.

Looking at the interaction between cognitive control and defection rates in the Prisoner’s Dilemma it is evident that the higher defection rates in the anger condition were mainly driven by the low cognitive control group. The high cognitive control participants’ defection rate in anger condition was significantly higher compared to neutral, but the decrease in defection rate from the neutral to the sympathy condition was not significant. This result has replicated the Experiment 1 result. This pattern of behavioural responses suggests that higher cognitive control participants might have concentrated on long term goals, as cooperation over time is more beneficial then defection (Kollock, 1998; Komorita & Parks, 1999). Person-directed anger elicits less concession in the negotiating context; participants in the role of sellers or service providers (i.e. contractors) were less likely to negotiate the price, warranty and duration of a service provided to angry buyers (Kopelman, Rosette, & Thompson, 2006; Steinel, Van Kleef, & Harinck, 2008). In contrast, low cognitive control participants might have had another goal – retaliation as a way of coping with and reducing their feeling of anger (Kopelman et al., 2006; Schweitzer & Gibson, 2007)

The results from the Emotion Regulation Questionnaire show that overall participants scored significantly higher on the cognitive reappraisal part of the ERQ compared to expressive suppression. Moreover, after dividing participants into low or high groups according to their scores on expressive suppression and cognitive reappraisal, only the interaction between expressive suppression and emotion condition was significant. Here, a pattern for low and high expressive suppression participants emerged, similar to that found with cognitive inhibition, albeit weaker: the increase in defection from sympathy to neutral and from neutral to anger was only approaching significance. The only significant difference in defection rates was found for the anger condition where the low expressive suppression group showed higher defection rates compared to the high expressive suppression group. Overall this finding was unexpected, as cognitive reappraisal is considered to be a more effective emotion regulation strategy affecting individuals behaviour than expressive suppression (Butler et al., 2003; Ehring et al., 2010; Gross & John, 2003; Moore et al., 2008; Ray et al., 2008). However, participants overall had significantly higher cognitive reappraisal skills than expressive suppression as measured by ERQ, and it is therefore conceivable that individuals with less developed expressive suppression strategies were more affected by negative emotion in the Prisoner’s Dilemma. Expressive suppression is not an effective long term strategy in regulating emotional experiences as it may result in social, psychological and health issues (Butler et al., 2003; Ehring et al., 2010; McLean et al., 2007; Moore et al., 2008), but in the short-term this strategy can be as effective as cognitive reappraisal in reducing emotion experience (Gross, 1998).

Furthermore, the interaction between defection rate and expressive suppression is expanded upon by the reaction time data in this study; low expressive suppression participants in the anger condition were quicker to defect than to cooperate, but in the sympathy condition reaction times for both choices was very similar. No significant differences were found in high expressive suppression participants. It is possible that, according to the Affect Infusion Model, when participants in the anger condition were influenced by emotion (Type I process) they chose defection, but when they deliberated, they managed to overcome the emotion influence, engaged in Type II processes and chose cooperation instead. In the sympathy condition both reaction times were very similar, which in combination with the defection rate suggests that participants were already engaging in Type II processes and not acting on the sympathy emotional impulses (cooperation). On the other hand high expressive suppression participants might be used to controlling their emotional expressions (and behaviour) thus this difference was not evident with their reaction times.

Contrary to the prediction there was no significant difference between block and event related designs. In real life settings individuals experience a variety of emotions and they can occur at the same time – participants having to fill in an emotion report diary on a daily basis report a mixture of emotions and experiencing them simultaneously (Sbarra, 2006; Sbarra & Emery, 2005). In general emotion affected participants behaviour in *both* designs possibly because individuals can switch between emotions on demand depending on the reappearance of an emotion triggering subject/object (Sbarra & Emery, 2005; Verduyn et al., 2009). In this study each trial was preceded by a reminder about the emotion felt towards the “other participant” in the form of a colour-coded essay reminder, and the evaluation by the “other participant”. This could have recalled the experience of reading the essay or receiving the evaluation for the first time. Although the experiment was carried out in a laboratory environment it may have succeeded in simulating real-life conditions facilitating emotion duration. Reappearance of emotion eliciting stimuli, such as seeing the person who insulted you, or meeting up with a former partner with whom you just broke up, can bring back emotions and make them last longer (Sbarra & Emery, 2005; Verduyn, Delvaux, Van Coillie, Tuerlinckx, & Van Mechelen, 2009).

Moreover, a rumination effect could also have taken place. The presentation of the reminder stimuli may have induced anticipatory thoughts about the intentions or choices of the “other participant” in the Prisoner’s Dilemma game. This might have directed their thoughts on how they felt when reading the essay or receiving the evaluation form of the person with whom they were interacting, and this may have triggered them to respond in the Prisoner’s Dilemma according to their emotional state. In the Barber, Maltby and Macaskill (2005) study participants had to fill in the Anger

Rumination Scale and the Heartland Forgiveness Scale questionnaires. Thoughts of revenge and angry memory items negatively correlated with the forgiveness to self and others items, and further regression analysis revealed that the more people have angry memories the less likely they are to forgive. In addition, ruminating about negative events (induced by self-reflection with questions such as “why do people treat you the way they do” etc. at the start of the experiment and only selecting people who ruminated about negative events) and being exposed to an aggression triggering event (e.g. the experimenter reading trivia questions to be answered by the participants while mispronouncing words and mixing up multiple choice answers) increased the likelihood of aggression towards the experimenter and another participant/confederate (Bushman et al., 2005; Peled & Moretti, 2007). The aggression was measured by answering questions on how strongly they would recommend the experimenter for a paid position in the lab or how likable/intelligent/friendly/competent the confederate was. Triggered aggression participants answered these questions more negatively (they would recommend the experimenter less for the pair position and the confederate was less likable etc.) compared to not triggered rumination and neutral emotion conditions. This suggests that anger emotions and ruminating thoughts about anger triggering events/individuals gives rise to aggressive behaviour.

This experiment shows that block or event related design does not have a differential influence on defection rates in the Prisoner’s Dilemma task. Overall both designs replicated the findings of the previous experiment with the defection in the social exchange task increased from sympathy to neutral and from neutral to anger emotion induction conditions. In addition, the current experiment as well as Experiment 1were based on emotions felt directly towards the “other participant” while interacting in an economic decision-making task. Yet comparison between direct and displaced emotion in the socio economic games might yield different results. The few studies which have attempted to compare direct- and displaced emotions show inconsistent results: Bartlett and DeSteno (2006) found that participants in the induced gratefulness condition were more cooperative in helping to fill out a questionnaire independently of whether they interacted with their benefactor (i.e. direct emotion condition) or a complete stranger (i.e. displaced emotion condition) compared to a neutral emotion condition, although participants were overall more helpful to the benefactor than to the stranger. A follow-up study using the socio-economic Give Some Dilemma Game, however, did not show any difference in cooperation with a stranger versus a benefactor

(DeSteno et al., 2010). It is important to compare if and how displaced and direct emotion differ in their influence on choices during decision-making games.

Moreover, cognitive inhibition as measured with the Go/no-Go task showed the same pattern as previously - low cognitive inhibition participants were more affected by the emotion condition in the game. However, it is possible that not only cognitive inhibition can affect decision-making in economic games. Having high cognitive flexibility might influence participants defection rate either by showing a clear defection pattern in the Prisoner’s Dilemma modulated by emotion or not being affected by emotion condition at all (setting their mind only to the Prisoner’s Dilemma rules). In fact, neuroimaging studies found that regions in the dorsomedial prefrontal cortex are involved in task-set switching and also in switching between response rules (Crone, 2005; Dove, Pollmann, Schubert, Wiggins, & Yves von Cramon, 2000) making this speculation plausible and in need of further investigation.

Chapter 5 Experiment 3: Partner-Directed or Displaced Emotion: Does It Really Matter?

5.1 Overview

Based on the results from Experiments 1 and 2, this chapter reports the third behavioural experiment aiming to compare the effect that displaced and direct sympathy and anger have on socio-economic decision making. In addition, it further explores how cognitive control (cognitive inhibition and a new measure for this study – cognitive flexibility) and emotion regulation modulate the effects of direct and displaced emotions in the Prisoner's Dilemma game.

5.2 Introduction

Studies looking into direct emotion commonly found that sympathy encourages choices resulting in more generous outcomes for a stranger (Batson & Moran, 1999; Duersch & Servátka, 2007; Van Lange, 2008) sometimes even when it is costly for the participants themselves (Batson & Ahmad, 2001). Similarly, displaced emotions such as displaced gratitude and sympathetic emotions, seem in some studies to induce a similar pattern of encouraging helping behaviour (Batson, Coke, Chard, Smith, & Taliaferro, 1979; Levin & Isen, 1975) even if it requires additional resources (time or money from participant themselves (Bartlett & DeSteno, 2006; Schnall et al., 2010). In other studies induced displaced amusement and happiness either do not show behavioural effect in the Trust Game (Harlé & Sanfey, 2007) or exhibit selfish behaviour in the Ultimatum and the Dictator games (Andrade & Ariely, 2009). In other studies direct anger decreases help and increases aggressive behaviour (Ben-Shakhar et al., 2004; Duersch & Servátka, 2007; Harmon-Jones et al., 2004) or encourages participants to behave in a more aggressive way towards an innocent other (DeWall et al., 2010; Fitz, 1976; Reijntjes et al., 2013). Yet displaced anger has been observed to trigger more risk averse behaviour in the Stag Hunt game (Kugler et al., 2012) or encourage fair proposals in later interactions in the Ultimatum and Dictator games (Andrade & Ariely, 2009).

Bartlett and DeSteno (2006), using a real-life scenario to compare direct and displaced emotions, found that participants with induced gratefulness were more cooperative compared to a neutral emotion condition. However, they were more helpful to a benefactor (direct emotion condition) than to a complete stranger (displaced emotion condition). A follow-up study using the Give Some Dilemma Game, however, did not show a difference in cooperation with a stranger versus a benefactor (DeSteno et al., 2010). These conflicting findings may be explained by studies showing that emotional states do not exclusively influence human decision-making, but also economic background (Larrick et al., 1993), personality (Bushman & Baumeister, 1998) and cognitive control (De Neys et al., 2011).

For example, individuals with higher cognitive inhibition were found to reason in line with logic while low cognitive control participants make their choices more intuitively in a neutral emotion condition (De Neys et al., 2011) and low cognitive inhibitors defect more in anger and less in sympathy emotion conditions compared to a neutral one (Eimontaite et al., 2013). While inhibition represents an individual's ability to suppress the urge to respond in a certain way, flexibility reflects how quickly the individual can adapt to the new situation. In fact, in a cognitive flexibility task with negative emotional content (Emotional Card Sorting Task), where individuals have to sort cards into piles according to inferred rules, depressed patients make more errors compared to healthy controls (Deveney & Deldin, 2006). Furthermore, a study found that patients with impairment on emotion recognition and social interactions (Theory of Mind) after a Traumatic Brain Injury, also showed deficits in cognitive flexibility compared to healthy controls (Milders, Ietswaart, Crawford, & Currie, 2008). Taken together, these studies show that cognitive flexibility and emotion processing are connected, which suggests that performance in a social exchange tasks depends not only on cognitive inhibition but also on cognitive flexibility.

This study investigates the difference between displaced and direct emotion on a socio-economic decision-making game - the Prisoner's Dilemma - under the influence of three emotion conditions: sympathy, anger and neutral. It was predicted that the defection rates in the Prisoner's Dilemma would decrease from the neutral to the sympathy emotion condition and increase from neutral to anger. This increase was expected to be stronger in the direct emotion group, than in the displaced emotion group. In addition, cognitive control and emotion regulation were anticipated to interact with the sympathy and anger emotion conditions. Participants with low cognitive control (inhibition and flexibility) and low expressive suppression (determined by the Emotion Regulation Questionnaire) were anticipated to defect more in anger and defect less in sympathy compared to neutral emotion condition. High cognitive control and high expressive suppression participants were expected to show similar defection rate in the anger-, sympathy- and neutral emotion conditions.

5.3 Methods

5.3.1 Participants

In total, 55 participants took part in this study. Nine participants were removed due to suspecting the deception resulting in 23 participants per group for the final analysis. The mean age in the direct emotion group was 21.05 years (SD = 3.98) (8 males), and 20.31 years (SD = 3.57) in the displaced emotion group (7 males). All participants were native English speakers, or fluent in English (minimum IELTS score of 5.5). The study was approved by the Department of Psychology ethics committee, University of Hull.

5.3.2 Stimuli

To trigger emotions, essays and evaluations inducing sympathy, anger and neutral emotions were used. For a full description of the content of the essays and evaluations please refer to the Methods section of Experiment 1.

Essays and evaluations were hand-written in a clear handwriting and on different colour paper (light green, light blue, light purple). As the emotion condition stimuli were presented on a computer screen, having particular colours associated with particular emotional stimuli allowed participants to remember the emotion triggering stimuli quicker. Colours were counter-balanced across participants. Participants themselves were writing essays and evaluations on light yellow coloured paper.

5.3.3 Tasks

The Prisoner's Dilemma

An iterated version of this task (24 trials per emotion condition) was used in the current experiment. Each individual trial of the game would start with a fixation cross remaining on screen for 3.4 s on average (range: 1.2 s to 9.0 s) followed by the scanned essay from the emotion induction, and the evaluation. The images would stay on screen for 4 s each. Finally, the Prisoner's Dilemma payoff matrix was presented and participants were allowed 7 s to make their decision on whether to keep silent/cooperate, or tell on/defect. The pre-determined outcome of the interaction ('You get £315,500 out of £730,000 possible', 'You get £396,000 out of £849,000 possible' or 'You get £745,000 out of £900,000 possible') was shown only after 24 trials and was counterbalanced across emotion conditions to control for emotion effects due to wins/losses (Figure 5.1).

Cognitive inhibition task (the Go/no-Go). The Go/no-Go task was carried out in the same way as described in the Methods section of Experiment 1.

Emotion Regulation Questionnaire. This questionnaire was designed and validated by Gross and John (2003) and was described in detail in the Methods section Experiment 2.

Self-Report Emotion Questionnaire. Questionnaire was carried out as described in detail in the Methods section Experiment 2.

The Switch Task

This task measured cognitive flexibility for switching attention between different task rules (Ophir, Nass, & Wagner, 2009). A single trial starts with a presentation of a rule ("LETTER" or "NUMBER") followed by a letter and a single digit number combination, for example "3a", "2p", etc. Following the LETTER rule participants had to pay attention to the letter from the letter-number combination and press the left arrow key for consonants and the right arrow key for vowels. Similarly, for the NUMBER rule a left/right arrow key press was required for even/odd numbers.

This task consisted of 80 trials overall, with 40 NUMBER and LETTER trials respectively. Each of the LETTER and NUMBER trials were put in blocks of 1, 2, 3, and 4 trials. The reaction times and correct responses were recorded.

5.3.4 Procedure

Deception. Upon arrival at the experiment, participants were led to believe that they would interact via a computer network with students from another university. It was emphasized that participants from the same university would not interact with each other.

The experimenter carried on the deception by explaining that in the experiment there could be up to 4 participants from each university at the same time. Participants were told that all of them would perform various tasks measuring their cognitive abilities, and that some tasks might be repeated. Also, the Prisoner's Dilemma task would be repeated as many times as there were participants in the other university (once with each student from the other university).

In the testing room there were four desks with computers for the participants. The desks were separated by dividers giving some privacy to the participants during the experiment. In front of each computer was plain lightly coloured paper (yellow, purple, green or grey) for the participants to write their essay on, and the same colour evaluation sheets. It was explained that the students from the other university were also writing their essays on the coloured sheets, and that during the interaction tasks the colour of the sheet would help to identify the other participants they were paired with.

Experimental Design. The main task of interest was the Prisoner's Dilemma with the dependent measure of defection rate in a mixed design experiment. Independent variables were Emotion Group (direct- and displaced), Emotion Condition (sympathy, anger and neutral), Cognitive Inhibition from the Go/No-Go (high and low), Cognitive Flexibility from the Switch Task (high and low), and Expressive Suppression (high and low) and Cognitive Reappraisal (high and low) from the Emotion Regulation Questionnaire.

Procedure. In contrast to Experiment 1 and Experiment 2, participants in this experiment were tested in groups of between 2 and 4. The general procedure started with deception and asked participants to write a page long essay in 10 minutes by hand on any topic that was important to them. Upon completion, the essay was handed to the experimenter who scanned it and put it on the computer network. While the essays were being scanned, participants performed the Go/No-Go and the Switch Tasks in counterbalanced order. This was followed by the first emotion induction procedure: participants were presented with another participant's essay (on green, purple, or yellow lined paper with colours counterbalanced across the emotion conditions) on the computer screen and had to read it and fill in an evaluation form by hand (self-paced, up to 4 min). After completion the form was passed on to the experimenter to be scanned, and upon pressing the spacebar on-screen instructions informed participants to wait for the other person to complete the task, followed by the presentation of the evaluation of their own essay. The spacebar had to be pressed indicating that they had read the evaluation, and were ready to carry on with the experiment (self-paced, up to 4 min, Figure 5.1B).

Following this, the Prisoner's Dilemma instructions were presented to the participants. Displaced- and direct emotion group instructions differed. In the direct emotion group participants were informed that they will play the game with the other university's students whose essays they just read and received evaluations from, while instructions for the displaced emotion group emphasized the absence of any direct interaction with the individual whose essay they just read and received an evaluation from. After pressing the spacebar to indicate that they remembered the instructions (no time limit, self-paced) the participant played 24 trials of the Prisoner's Dilemma (Figure 5.1C). The same procedure of emotion induction followed by the Prisoner's Dilemma task was repeated two more times covering each emotion condition. Each group received all emotion conditions (sympathy, anger, and neutral, counterbalanced across participants), however they had to write only one essay at the beginning of the experiment which was consequently used in all the emotion induction steps.

When participants had completed all trials of the Prisoner's Dilemma in all three emotion conditions, they performed the cognitive control tasks (order counterbalanced between participants) to maintain the deception until the experiment ended. The last task for the participants was to fill in the Emotion Regulation Questionnaire followed by the Self-Report Emotion Questionnaire.

Finally, the experimenter asked questions about the "participants" from the other university (age, gender, education, etc.,) and whether the participants suspected they were being deceived in order to confirm the success of the deception. This was followed by a full debriefing.

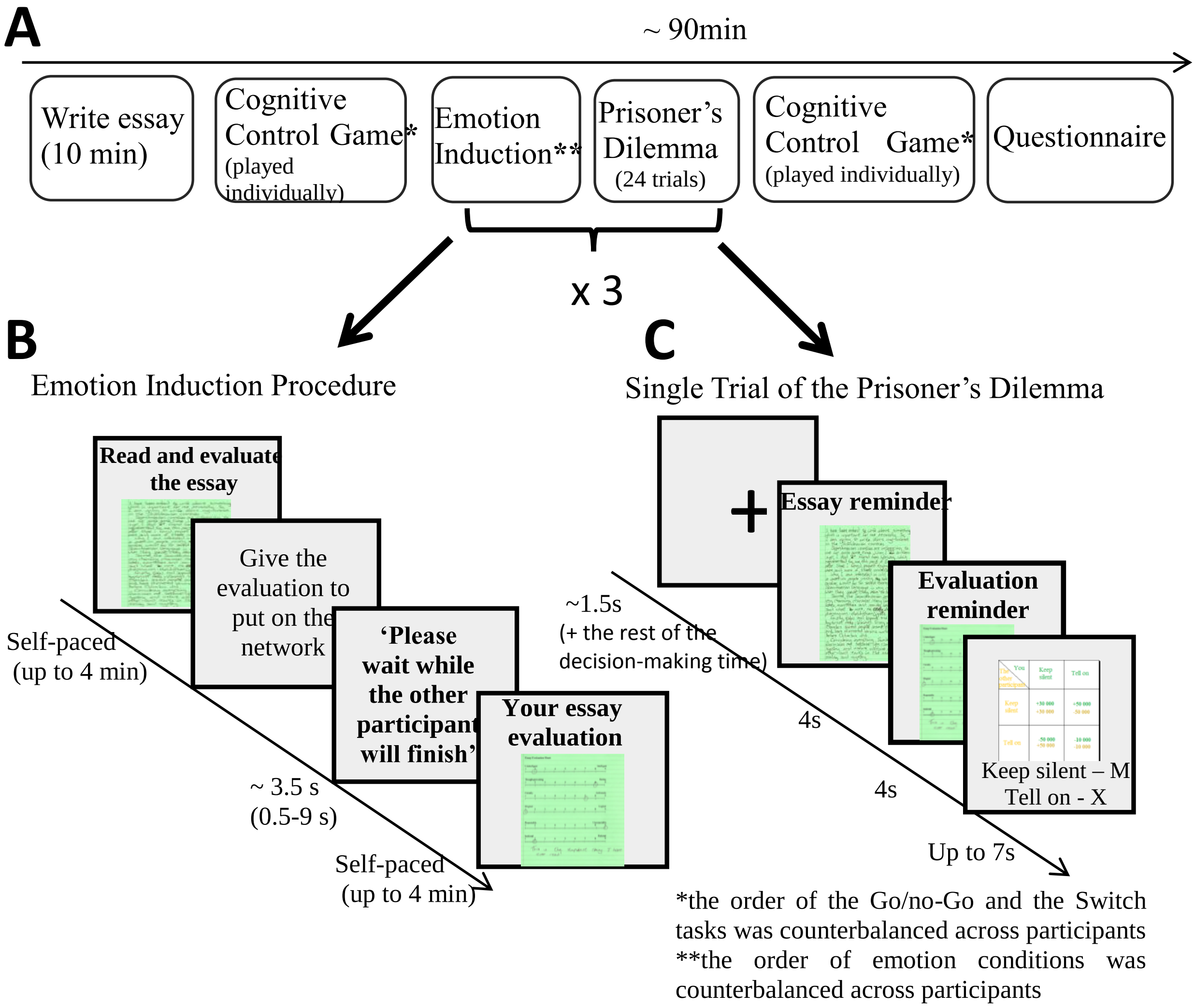

Figure 5.1: (*A*) *General experimental procedure for comparing displaced and direct emotions.* (*B*) *Emotion induction procedure.* (*C*) *An example of a single trial of the Prisoner's Dilemma.*

5.3.5 Analysis

The main interest of the experiment was the Prisoner's Dilemma. The dependent variable was defection in this task, and the independent variable was the emotion condition (sympathy, anger and neutral), emotion direction (direct or displaced emotion), low and high cognitive control, low and high cognitive reappraisal and expressive suppression from the Emotion Regulation Questionnaire. A mixed design ANOVA was used to explore the main effects and interactions between dependent and independent variables. The follow up post hoc within- subject analysis was performed with a paired t-test (with Bonferroni adjustment for multiple comparisons, $p<.017$, two-tailed). Between-subject differences were analysed with independent t-test (two-tailed).

5.4 Results

5.4.1 Evaluating Emotion manipulation

The Self-Report Emotion Questionnaire was used to confirm that the emotion manipulation was successful and the targeted emotions were induced. The analysis was done separately for the displaced and direct emotion groups. Emotion words which averaged at around 1 (indicating that participants did not feel the emotion at all) across all participants were removed (excited, jittery, nervous, ashamed), leaving 50 emotion words in the final analysis. A Principal Components method with a Varimax (orthogonal) rotation loaded mainly on three factors explaining more than 50% of variance. The factor analysis statistics suggest this analysis was appropriate (direct emotion group: KMO = .632, N = 23; Bartlett's test of Sphericity, $\chi^2(1225) = 3346.87$, $p < .001$; displaced emotion group: KMO = .665, N = 23; Bartlett's test of Sphericity, $\chi^2(1225) = 3278.30$, $p < .001$;)

The results from the factor analysis indicated that sympathy and anger emotions were triggered in the direct- and displaced emotion groups. Factor analysis for both groups indicated three main loadings representing the three emotion conditions and the words loaded in each factor were similar for direct- and displaced emotion (Table 5.1).

Table 5.1: Overview of the results of the Factor analysis on the Self-Report Emotion Questionnaire in the displaced and direct emotion groups: three factors accounting for more than 50 % of the total variance were identified.

	Direct Emotion			Displaced Emotion		
	1st factor (sympathy)	2nd factor (anger)	3rd factor (neutral)	1st factor (anger)	2nd factor (sympathy)	3rd factor (neutral)
Emotion words	sorrowful	furious	glad	furious	sympathetic	happy
	sad	irritable	happy	mad	moved	good mood
	grieved	agitated	good mood	angry	tender	pleasant
	upset	hostile	pleased	irritable	sad	glad
	distressed	enraged	joyful	hostile	compassionate	pleased
	sympathetic	mad	warm	frustrated	soft hearted	satisfied
	worried	disgusted	satisfied	scared	upset	joyful
	tender	angry	pleasant	disgusted	grieved	tranquil
	heavy hearted	perturbed	calm	troubled	interested	warm
	feeling low	frustrated	active	enraged	worried	content
	moved		enthusiastic	afraid	inspired	enthusiastic
	bothered		tranquil	agitated	proud	calm
	troubled		content	perturbed	sorrowful	
	compassionate				feeling low	
Variance explained	25%	20%	11%	27%	17%	9%

In a second step, the mean intensity ratings between each factor were compared separately for the direct- and displaced emotion groups, and the comparisons between the three emotion conditions were corrected for multiple comparisons (Bonferroni-corrected two-tailed alpha = .017). In the direct emotion group, the mean rating for the first factor loadings was significantly higher in the sympathy condition (Mean = 2.61, SD = 1.16) than in the anger (Mean = 1.49, SD = 1.07, $t(33.82) = 4.08$, $p < .001$) or neutral condition (Mean = 1.69, SD = 0.73, $t(38.1) = 3.12$, $p = .003$). The second factor showed significantly higher ratings in the anger (Mean = 2.04, SD = 1.02) than in neutral condition (Mean = 1.16, SD = 0.37, $t(27.55) = 3.91$, $p = .001$) and was approaching significance compared to sympathy (Mean = 1.44, SD = 0.74, $t(44) = 2.28$,

p = .028). The third factor was approaching significantly higher ratings in the neutral (Mean = 2.28, SD = 0.73) compared to the anger condition (Mean = 1.73, SD = 0.81, $t(44) = 2.44$, $p = .019$) and there was a similar trend with respect to the sympathy condition (Mean = 1.84, SD = 0.86, $t(44) = 1.93$, $p = .06$).

The same was done with the displaced emotion group. Here, however, for the first factor a trend towards higher mean ratings in the anger condition (Mean = 1.75, SD = 0.92) compared to the neutral condition (mean = 1.30, SD = 0.57, $t(36.67) = 1.99$, $p = .054$) was found. There was no difference between the mean ratings in the anger- and sympathy conditions (Mean = 1.50, SD = 0.61, $t(44) = 1.08$, $p = .287$). The second factor showed significantly higher ratings in the sympathy condition (Mean = 3.29, SD = 0.80) than in the anger- (Mean = 1.49, SD = 0.47, $t(35.27) = 9.27$, $p < .001$) or the neutral condition (Mean = 1.71, SD = 0.51, $t(37.17) = 7.929$, $p < .001$). Finally, the last factor, although showing numerically the highest ratings in the neutral condition (Mean = 2.38, SD = 0.81), did not significantly differ from the sympathy condition (Mean = 2.03, SD = 0.89, $t(44) = 1.22$, $p = .229$) or the anger condition (Mean = 1.99, SD = 0.80, $t(44) = 1.65$, $p = .106$).

A between-group comparison of factors representing sympathy, anger and neutral emotions did not show any significant differences ($t(44) \leq 1.64$, $p \geq .108$).

This analysis showed that for participants in the direct emotion group the mean intensity rating for every factor related to a particular emotion was significantly higher in the matching emotion condition compared to the other two factors (for example, the factors representing sympathy had an overall higher rating in the sympathy condition, compared to the anger or neutral conditions, whereas the neutral and anger conditions' mean intensity ratings for this factor did not differ). On the other hand, although an identical pattern was numerically evident in the displaced emotion group, significantly higher intensity ratings were only found for the factor representing sympathy emotion words in the sympathy condition but not in the other two conditions. This suggests that emotions were felt stronger in the direct emotion group than in the displaced emotion group.

5.4.2 Direct- vs. Displaced Emotion in the Prisoner's Dilemma

A 3 x 2 mixed design ANOVA with the within-subject factor Emotion Condition (sympathy, anger, and neutral) and the between-subject factor Group (displaced- or direct emotion) was designed to check for differences in defection rates in the Prisoner's Dilemma. The main effect of Emotion Condition was significant ($F(2, 88) = 15.48$, $p < .001$), as well as the Emotion Condition x Group interaction ($F(2, 88) = 4.98$, $p = .009$). There was no significant main effect of Group ($F(1,44) = 0.53$, $p = .471$).

The main effect of Emotion Condition was analysed further with paired t-tests (Bonferroni-corrected two tailed alpha = .017). Overall defection rates significantly increased from the neutral (Mean = 0.46, SD = 0.28) to the anger condition (Mean = 0.59, SD = 0.29) and from the sympathy (Mean = 0.37, SD = 0.29) to the anger condition ($t(45) = -4.68$, $p < .001$ and $t(45) = -3.18$, $p = .003$). The decrease from the neutral to the sympathy emotion condition was approaching significance ($t(45) = -2.46$, $p = .018$).

Independent t-tests showed that the defection rate in the direct emotion group was significantly lower than for the displaced emotion group in the sympathy condition (Mean = 0.29, SD = 0.31 vs. Mean = 0.47, SD = 0.25; $t(44) = -2.13$, $p = .039$). There were no group differences in the neutral and anger conditions ($t(44) \leq 0.583$, $p \geq .408$).

Within-subject comparisons showed that in the direct emotion group the differences in defection rate between sympathy and neutral, neutral and anger and sympathy and anger conditions were all significant ($t(22) = -2.91$, $p = .008$ vs $t(22) = -2.91$, $p = .008$ vs $t(22) = -5.03$, $p < 0.001$, respectively). The average defection rate in the sympathy condition was 0.29 (SD = 0.31), 0.63 (SD = 0.34) for anger and 0.44 (SD = 0.33) for neutral. There was no significant difference between the emotion conditions in the displaced emotion group ($t(22) \leq 1.75$, $p \geq .095$; Figure 5.2).

As the Emotion Condition x Group interaction was significant, all subsequent analyses were performed separately for the direct- and displaced emotion groups.

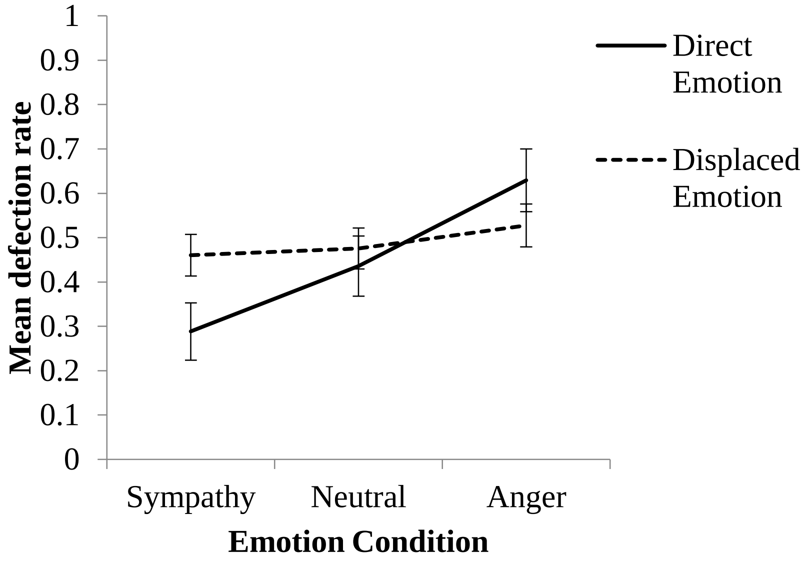

Figure 5.2: Mean defection rates (+/- 1SEM) in the displaced and direct emotion groups as a function of emotion condition

5.4.3 Cognitive Control in the Prisoner's Dilemma task

Cognitive Inhibition

The Go/No-Go task was analysed by calculating d' scores from the data collected before emotion induction. There was no significant difference in d' between displaced- and direct emotion groups ($t(44) = -1.07$, $p = .292$). After this, participants were divided into high [3.28 – 4.46] and low [1.61 – 3.24] cognitive inhibition groups according to d' averages (low/ high cognitive inhibition in the direct group N = 13/10 and low/high inhibition in the displaced emotion group N = 12/11). Low inhibition participants had significantly lower d' than high inhibition in both direct and displaced emotion groups, $t(21) = 5.83$, $p < .001$ and $t(21) = 7.83$, $p < .001$, respectively.

Displaced Emotion Group. To test the hypothesis about the interaction between Emotion Condition and Cognitive Inhibition, a 3 x 2 mixed design ANOVA with the within-subject factor Emotion Condition (sympathy, anger, neutral) and the between-subject factor Cognitive Inhibition (low, high) was performed on the defection rate in the Prisoner's Dilemma. The results did not show any significant main effects or interaction ($F(2, 42) \leq 2.11$, $p \geq .135$).

Direct Emotion Group. A similar 3 x 2 mixed design ANOVA yielded a significant main effect of Emotion Condition ($F(2, 42) = 14.69$, $p < .001$) and a trend towards an interaction between Emotion Condition and Cognitive Inhibition ($F(2, 42) =$

2.61, p = .086). The main effect of Cognitive Inhibition was, however, not significant ($F(1, 21) = 0.96$, p = .337).

The post-hoc results for the main effect of Emotion Condition are presented in the section above (Direct- versus Displaced Emotion in the Prisoner's Dilemma).

Having a hypothesis about cognitive inhibition and given the trend towards a significant interaction, the difference in defection rates between participants with high- versus low cognitive inhibition was investigated. Although there was no significant overall difference between the low and high cognitive inhibition groups ($t(21) \leq 1.67$, $p \geq .109$), a significantly decreased defection rate from the neutral to the sympathy condition and increased defection rates from the neutral to the anger condition as well as from the sympathy to the anger condition in the low cognitive inhibition participants was evident ($t(12) = -2.90$, p = .013, $t(12) = -3.04$, p = .010 and $t(12) = -4.47$, p = .001, respectively; Bonferroni-corrected two-tailed alpha = .017). The mean defection rate in the sympathy emotion condition was 0.22 (SD = 0.24), for neutral it was 0.34 (SD = 0.27) and for anger 0.65 (SD = 0.32). There was no significant change in the defection rates in high cognitive inhibitors following Bonferroni correction ($t(10) \leq 2.67$, $p \geq .025$, Figure 5.3 A).

Cognitive Flexibility

The Switch task was analysed by calculating a switch cost for each participant from the data collected before emotion induction: the mean reaction times (ms) for correct switch trials were subtracted from the mean reaction times of the correct non-switch trials. The displaced- and direct emotion group performances did not differ in this task ($t(44) = 0.101$, p = .244). Therefore all participants were divided into high [286.75 ms – 1701.51 ms] and low [-275.66 ms – 277.61 ms] cognitive flexibility (direct emotion: low/high cognitive flexibility N = 10/13, displaced emotion: low/high cognitive flexibility N = 12/11). There was a significant difference between low and high flexibility participants in the direct emotion group ($t(15.99) = 4.92$, $p < .001$) and in the displaced emotion group ($t(21) = 3.01$, p = .007).

Displaced Emotion Group. In order to explore if cognitive flexibility interacted with the type of emotion on the decision-making task in the displaced emotion group, a 3 x 2 mixed design ANOVA was performed on the defection rate in the Prisoner's Dilemma with the within-subject factor of Emotion Condition (sympathy, anger, neutral) and the between- subject factor Cognitive Flexibility (high, low). There were no significant main effects or interactions ($F(2, 42) \leq 2.01$, $p \geq .147$).

Direct Emotion Group. The same analysis performed for the direct emotion group yielded a significant main effect of Emotion Condition ($F(2, 42) = 15.42$, $p < .001$) but no other significant main effects or interactions ($F(1, 21) = 0.56$, $p = .462$ and $F(2, 42) = 2.16$, $p = .127$, respectively).

The post-hoc analysis of the main effect of Emotion Condition is presented in the section above (Direct- versus Displaced Emotion in the Prisoner's Dilemma).

5.4.4 Emotion regulation in the Prisoner's Dilemma task

The comparison between cognitive reappraisal and expressive suppression mean scores showed that the participants in the direct- and displaced emotion groups did not differ significantly ($t(44) \leq 0.36$, $p \geq .720$). Overall participants had significantly higher reappraisal scores compared to expressive suppression (direct emotion: $t(22) = 2.40$, $p = .026$, reappraisal Mean = 4.67 (SD = 1.45); suppression Mean = 3.59 (SD = 1.11); displaced emotion: $t(22) = 2.62$, $p = .016$, reappraisal Mean = 4.53 (SD = 1.24); suppression Mean = 3.47 (SD = 1.25)). As a next step, participants were divided into two groups according to their scores into high [3.75 – 6.00] and low [1.25 –3.25] expressive suppression and high [4.80 – 7.00] and low [1.00 – 4.60] cognitive reappraisal (direct emotion low reappraisal N = 11 and suppression N = 10, high reappraisal N = 12 and suppression N = 13; displaced emotion low reappraisal N = 12 and suppression N = 10, high reappraisal N = 11 and suppression N = 13). High and low cognitive reappraisers and expressive suppressors differed significantly from each other in direct and displaced emotion groups (direct emotion group: $t(21) = 5.97$, $p < .001$ and $t(21) = 2.74$, $p = .012$; displaced emotion group: $t(21) = 7.32$, $p < .001$ and $t(21) = 6.79$, $p < .001$).

Displaced Emotion Group. The possible interaction between Emotion Condition and high and low Expressive Suppression and Cognitive Reappraisal was explored with a 3 x 2 x 2 mixed design ANOVA with the within-subject factor Emotion Condition, and the between-subject factors Expressive Suppression (high, low) and Cognitive Reappraisal (high, low). There were no significant main effects or interactions ($F(2, 38) \leq 1.76$, $p \geq .186$).

Direct Emotion Group. An identical ANOVA for the direct emotion group yielded a significant main effect of Emotion Condition ($F(2, 38) = 17.96$, $p < .001$), as well as a significant Emotion Condition x Expressive Suppression interaction ($F(2,38) = 3.92$, $p = .028$). The main effects of Expressive Suppression, Cognitive Reappraisal, and all remaining interactions were not significant ($F(2, 38) \leq 0.751$, $p \geq .397$).

The defection rate of participants with high Expressive Suppression differed only significantly between the sympathy and anger conditions ($t(12) = -2.89$, $p = .014$) showing that participants defected more in the anger than the sympathy condition (anger: Mean = 0.54, SD = 0.39 and sympathy: Mean = 0.35, SD = 0.35). However, the differences between the anger and neutral emotion conditions and between neutral and sympathy were not significant ($t(12) \leq 1.35$, $p \geq .089$). Low suppression participants' defection increased from the sympathy (Mean = 0.21, SD = 0.24) to the anger condition (Mean = 0.74, SD = 0.24; $t(9) = -5.09$, $p = .001$), and the decrease in defection from neutral (Mean = 0.48, SD = 0.31) to sympathy was close to significance ($t(9) = -2.87$, $p = .018$, Bonferroni-corrected two tailed alpha .017). The difference between neutral and anger conditions was not significant ($t(9) = -2.23$, $p = .052$; Figure 5.3 B).

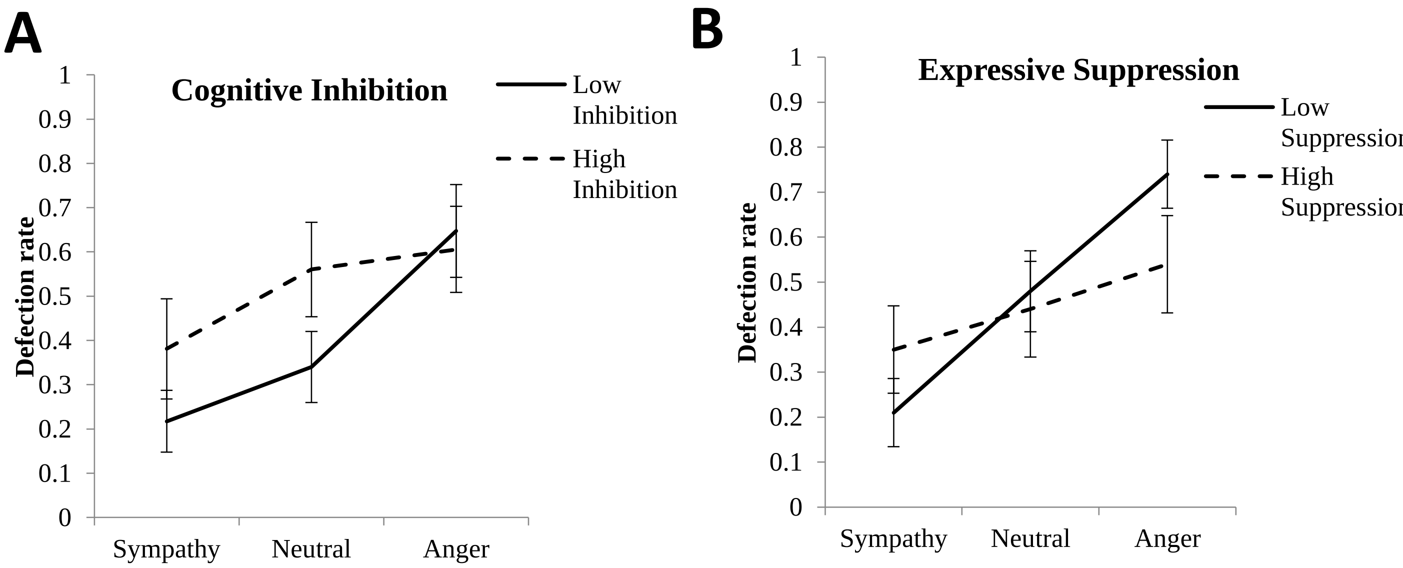

Figure 5.3: Mean defection rates (+/- 1SEM) in the direct emotion group as a function of (A) Cognitive Inhibition and (B) Expressive Suppression as a function of emotion conditions.

5.4.5 Reaction Times

Three 3 x 2 x 2 mixed design ANOVA's with the within-subject factors of Emotion Condition (sympathy, anger, neutral) and Choice (defection, cooperation) for each of the between-subject factors of Group (direct and displaced emotion), Cognitive

Inhibition (high, low), and Expressive Suppression (high, low) were performed separately to investigate whether the reaction times in the emotion groups differed depending on whether they chose to defect or cooperate in a specific Emotion Condition. However, only the main effect of Group was at a trend significance ($F(1, 23) = 3.51$, $p = .074$). No other main effects nor interactions were significant ($F(2, 46) \leq 1.67$, $p \geq .200$; Table 5.2).

Table 5.2: Mean reaction times in ms (SD) of the displaced and direct emotion groups as a function of Emotion Condition and Choice

		Direct Group	Displaced Group
Sympathy	Cooperation	1297 (137)	2041 (219)
	Defection	1274 (168)	2149 (253)
Anger	Cooperation	1348 (210)	2048 (170)
	Defection	1309 (187)	1873 (210)
Neutral	Cooperation	1472 (208)	1899 (219)
	Defection	1550 (246)	1873 (210)

5.4.6 Additional analysis

Pearson correlation analyses were performed between the defection scores in the three emotion conditions, d' and false alarms from the Go/no-Go task, switch cost from cognitive flexibility, and Cognitive Reappraisal and Expressive Suppression scores from the Emotion Regulation Questionnaire. There was a significant correlation only between switch cost and defection for the displaced emotion group in the sympathy condition ($r = -.43$, $p = .039$). The correlations between other variables were not significant ($r \leq .36$, $p \geq .092$).

Defection over time

A mixed design 3 x 3 x 2 ANOVA (within-subject factors of Emotion Conditions (sympathy, anger and neutral) and Run (run1, run2, run3) and a between-group factor of Group (displaced and direct emotion)) for the defection rate over time analysis was conducted. The main effect of Emotion Condition, and the interaction Emotion Condition x Group were significant, $F(2,88) = 10.20$, $p < .001$ and $F(2, 88) =$

4.17, $p = .019$. The main effect of Run, Group, and interactions Run x Group, Emotion Condition x Run, Emotion Condition x Run x Group were not significant, $F(2, 88) \leq 1.80$, $p \geq .179$.

The main effect of emotion as well as interaction emotion by group was described previously in this section. However, as there was no significant main effect, or interaction, with Run, it can be assumed that defection did not differ over time comparing the first, second and third parts of the trials.

Payoff Matrix x Defection analysis did not show that participants' responses would depend on the presented payoff matrix (see Appendix E on page 221).

5.5 Discussion

The current study investigated the effects of direct- and displaced sympathy, anger and neutral emotions on decision-making in the Prisoner's Dilemma. In addition, the potentially mediating effects of cognitive control (inhibition and flexibility) and emotion regulation (expressive suppression and cognitive reappraisal) were examined.

The main finding is that only the defection rate in the direct emotion group significantly differed between each emotion condition: compared to the neutral emotion condition the defection rate decreased in the sympathy condition and increased in the anger condition. This result is consistent with Experiment 1 and Experiment 2. However, the same defection rate pattern was not evident in the displaced emotion group where the defection rate across all three emotion conditions was similar. Comparing defection rates between the direct- and displaced emotion groups, a significant difference emerged only for the sympathy condition where the direct emotion group showed significantly lower defection rates. Participants' defection in the anger and neutral conditions was similar. Although the direct emotion group showed the clearest defection pattern in relation to the induced emotions, the effects were modulated by the level of cognitive inhibition and expressive suppression as participants with lower cognitive inhibition and expressive suppression showed the clearest differences in defection rates between the emotion conditions. On the other hand, the level of cognitive flexibility and cognitive reappraisal did not impact on emotion induced defection rates.

The finding of a differential effect in defection rate between direct- and displaced emotion contrasts with the results of previous studies showing similar behavioural effects for both types of emotion (Bartlett & DeSteno, 2006; Marcus-Newhall et al., 2000). This can be explained by a number of factors: firstly the type of social interaction in this study was different. In the majority of past studies displaced emotion was used to investigate effects on inducing helping/punishing behaviour, which did not involve any cost to the participant (DeWall et al., 2010; Reijntjes et al., 2013; Lewin & Isen, 1975). However, interactions in the economic exchange context might encourage participants to be more competitive and think more strategically while trying to increase gains and minimise losses. In addition studies in the economic game context with emotions triggered by unrelated tasks (i.e. watching video clips) before the experimental task are consistent with the current finding: the displaced amusement condition in the Trust Game produced the same unfair offer rejection as the neutral condition (Harlé & Sanfey, 2007), and the displaced anger condition in the Stag Hunt game led participants to choose safer options more than on the task with no social interactions – Lottery task (Kugler et al., 2012).

In fact, the general tendency for defection in the Prisoner's Dilemma game without emotion manipulation ranges between 50% and 60 % (Oskamp & Perlman, 1965). Here, a similar defection pattern was found in the neutral emotion manipulation in both the displaced- and direct emotion conditions (48% and 44%, respectively). Furthermore, in the displaced sympathy and displaced anger emotion conditions the level of defection stays within the normal range for the Prisoner's Dilemma game, 47% and 56% of the time. The findings also suggest that direct emotion encouraged less strategical thinking as indicated by the lower defection rates in the sympathy and higher in the anger manipulation conditions. The same –albeit not significant– pattern was observed for the displaced emotion condition.

Secondly, another factor explaining the differences between the current study and past studies is the experimental design. One study comparing the effect of displaced emotion in economic decision-making found an effect of displaced gratitude in inducing more cooperative behaviour compared to a neutral condition (DeSteno et al., 2010). The experimental design, however, was between-subjects and involved only one trial of the economic game Give Some Dilemma. Consequently, it cannot be ruled out that the differential effects on cooperative behaviour in the neutral and gratitude emotion conditions might have been a reflection of individual differences rather than emotion effects. The current study attempted to take into account individual differences by using a within-subject design which allowed for a direct comparison of the same participant's behaviour on sympathy, anger and neutral emotion conditions based on 24 trials per emotion condition. This allowed us also to investigate an individual's behavioural changes more reliably over a longer period of time.

Finally, a possible cause for the behavioural differences in the direct- and displaced emotion groups could be that the strength of the experienced emotion in these two groups was different. Generally the behavioural effect of direct emotion is stronger than displaced emotion (Bartlett & DeSteno, 2006) and they do not have a long term effect on individuals behaviour unless the emotion was triggered (Pocheptsova & Novemsky, 2010). Yet in this study every trial of the game started with a reminder of the emotional stimuli (picture of essay and evaluation participants read before the Prisoner's Dilemma). A similar method (a reminder of emotion inducing stimuli) was used in the Pocheptsove and Novemsky (2010) study to measure the effects of induced negative affect on picture rating after 5 days. This suggests that the reminder method is effective for as much as a 5 day interval and therefore should be enough to measure an almost immediate effect. In addition, a direct between-group comparison of the averaged intensity ratings of words loaded into the factors representing the three emotion conditions showed that the ratings for factors representing sympathy, anger, and neutral emotions were of similar intensity for the two groups. Yet in the direct emotion group, factors representing sympathy or anger had significantly stronger emotion ratings for that condition compared to the other two. In the displaced emotion group only the factor representing sympathy was reported to be significantly stronger in the sympathy emotion condition compared to the anger and neutral emotion conditions. This shows that although the overall intensity of the emotion in the direct emotion group was similar to the displaced emotion group, feelings in the displaced emotion group were less clear cut with the exception of sympathy.

The results show that partner-directed sympathy in the direct emotion group triggered more cooperation whereas partner-directed anger encouraged more defection compared to the neutral condition. As in Experiment 1 and 2 this basic pattern was further modulated by cognitive inhibition. Even though preliminary analysis suggested only a trend towards an interaction with the cognitive inhibition task, further investigation yielded the predicted pattern, namely that the defection rate in sympathy and anger conditions significantly differed from the neutral condition in low cognitive inhibition participants. This was specific to the direct emotion group whereas no significant results were found for the displaced emotion group.

In contrast, the observed defection pattern was not modulated by cognitive flexibility. According to the reinforcement learning theory (Sutton & Barto, 1998), cognitive flexibility and reversal learning are driven by the inconsistency between reward prediction and the actual reward. In the current study the outcome of the interaction was not presented after each trial, but only at the end of 24 trials to avoid learning effects. As a result, it is possible that participants did not have to depend on their cognitive flexibility as their view on the situation did not change. In other words, for the cognitive flexibility to be effective, feedback of the interaction outcome is necessary, but in the absence of the former, cognitive flexibility does not play a modulating role.

The results from the Emotion Regulation Questionnaire replicates the findings from Experiment 2; overall participants scored significantly higher on cognitive reappraisal than on expressive suppression and only the interaction between suppression and emotion condition was significant: low expressive suppression participants were defecting more in the anger condition, and less in the sympathy condition compared to neutral. On the other hand, the defection rate of individuals showing high expressive suppression did not depend on the emotion condition.

The main results of this study suggest that direct emotions have a much bigger impact on defection rates in the Prisoner's Dilemma game than displaced emotions. Furthermore, the direct emotional influence on defection rates depends on one's cognitive inhibition and emotion regulation, but not cognitive flexibility. Yet, these factors had no impact on the defection rates in the displaced emotion condition. These findings emphasize the differential role of direct- and displaced emotions on an individual's decision-making especially in a monetary exchange context where individuals may incur losses and are encouraged to think strategically.

Chapter 6 Experiment 4: Functional Anatomical Correlates of Emotion Processing Associated with Social Exchange Decision-Making

6.1 Overview

This chapter introduces functional magnetic resonance imaging (fMRI) as a technique for studying emotional and cognitive processes in the brain and follows on to report an fMRI study using the iterated Prisoner's Dilemma under sympathy, anger, and neutral emotion conditions. The aim of this study was to investigate the neural correlates of decision-making under emotion.

6.2 Introduction to functional magnetic resonance imaging

fMRI is a popular, non-invasive method for identifying in-vivo neural mechanisms underlying human behaviour and subjective experiences. With good spatial resolution, though limited temporal resolution (compared to MEG/EEG), fMRI is a useful method for identifying neural networks associated with decision-making.

How is the MR signal recorded?

In order to understand how fMRI works, at first the working principles of MRI should be considered. When an individual is placed in the MRI scanner, the hydrogen atoms within the body which are normally randomly oriented become aligned with the magnetic field reaching an equilibrium state (excitation; Huettel, Song, and McCarthy (2004)). Then an electromagnetic wave is pushed through the system to set up a resonance, flipping the alignment axis of the magnetic field. Each slice has its magnetic field flipped and then it is timed returning to the original alignment. The return of the magnetic field to its original alignment is called T1 relaxation. This fluctuating process of excitation and relaxation creates an electromagnetic pulse which is the raw MR signal (Huettel, Song, et al., 2004). The contrast between different tissues in the brain depends on the signal strength that in turn is determined by matter density. This provides the possibility to discriminate between white and grey matter and cerebral spinal fluid in structural MRI images.

A T2 relaxation happens after a radiofrequency signal forces neighbouring molecules to spin that are all in phase and as a response these molecules diphase from each other decreasing the MR signal. The decreased speed of the MR is unique to the tissue type and allows differentiation between them. The T2 signal is also affected by faster decay (T2*) due to inhomogeneities in the magnetic field caused by the deoxygenated blood in particular brain regions. T1 weighted scans are very useful for anatomical images as they show clear differences between grey and white matter, and also fat, while T2 images are better for seeing neurological pathologies such as tumours and oedema.

How is the fMRI signal recorded?

fMRI signal recording is based on the ratio between deoxygenated and oxygenated blood. Oxygen is delivered by haemoglobin through red blood cells and with increasing neural activity in particular brain areas, the oxygen usage of these areas increases resulting in increased blood flow. Haemoglobin is diamagnetic (having a weak repulsion from a magnetic field) when it is oxygenated (with attached oxygen), but after becoming deoxygenated it becomes paramagnetic (attracted to a magnetic field). This leads to the speed up of the T2 decay where the ratio of deoxygenated blood to oxygenated blood is higher. This is called Blood Oxygenation Level Dependent (BOLD) and is measured by fMRI. As active brain areas require higher quantity of the oxygenated blood, this allows for detecting changes in BOLD as a correlate of brain activity (Huettel, Song, et al., 2004).

Conversely to the expectation that oxygenation decreases with increasing activation, in reality there is only a momentary decrease in blood oxygenation immediately after increased brain activity. This results in the overcompensation of the oxygenation which peaks after around six seconds, then decreases below the baseline and finally returns back to the original level (Huettel, Song, et al., 2004).

The fMRI can present the result of the brain activity graphically by colour mapping these BOLD changes onto the structural MRI scan. Even though it has an advantage of good localization of the activated areas, its temporal resolution is limited to a few seconds.

Spatial resolution

As mentioned previously, the relatively high spatial resolution is one of the main advantages of fMRI. It determines how well the technique can discriminate between nearby locations, and is measured in voxels. A voxel is a three dimensional cube with dimensions ranging from a few mm to 1 mm depending on the slice thickness and scanner properties, such as the strength of the magnetic field (measured in Teslas). Smaller voxels have less neurons resulting in less blood flow, generating a weaker signal than larger voxels. In addition, scanning time is increased as it is directly related to the number of voxels and slices.

A good spatial resolution depends not only on deoxygenated haemoglobin in the capillaries near the activated area but also on larger vessels further away from the area – these need to be supressed. To achieve this researchers use a combination of strong magnetic fields and specific spin-echo pulse sequences (Huettel, Song, et al., 2004).

Temporal resolution

Temporal resolution (TR) is the ability to observe the changes in a signal across time and is usually measured in seconds. Although fMRI images can be acquired in a very short time, the limiting factor of this technique is temporal resolution, the smallest time period where neural activity can be reliably separated out by MRI. TR determines the time between excitation and reception and varies on average from 500 ms to 3 seconds (Huettel, Song, et al., 2004; Kim, Richter, & Uğurbil, 1997). The hemodynamic response in fMRI lasts around 10 seconds. This time is necessary for the blood flow to peak and then to return to baseline (Huettel, Song, et al., 2004). The simple solution of sampling faster TR’s actually just gives more points on the response curve, which would be sampled either way and does not improve temporal resolution.

Linear addition from multiple activations

If the same brain region is active twice in a rapid session, within an interval of about 6 seconds, the hemodynamic response (HDR) to the second event is reduced in amplitude compared to the signal evoked by a single (first) event. This refractory period during stimulus presentation means that the stimulus evokes a reduced response over time. Early studies investigating the refractory period have found that better scaling is recorded for the stimulus presentation lasting at least 6 seconds. This was confirmed for blocked design (Burton, Watson, Thacker, & Jackson, 1998; Robson, Dorosz, & Gore,

1998) and event-related studies (Dale & Buckner, 1997). Although the refractory period was found to be independent of age (Huettel, Singerman, & McCarthy, 2001) or mental health disorders (Barch et al., 2003), it is shorter in some brain areas (around 4 seconds) such as primary motor and sensory regions (Birn, Saad, & Bandettini, 2001) or the primary visual cortex during the processing of incongruent motion stimuli (Huettel, Obembe, Song, & Woldorff, 2004).

6.2.1 Introduction to fMRI analysis

The response from a single voxel over time is affected by various unwanted sources of noise such as signals from the scanner, random brain activity etc. These unwanted artefacts need to be eliminated in processing steps using appropriate statistical methods (Ashburner et al., 2012).

Sources of noise

Noise artefacts interfere with neural activity and affect the quality of data. These artefacts can happen through various means – physiological noise, scanner noise and drift, field distortions and inappropriate experimental designs. To increase the signal-to-noise ratio, careful planning of the design, and preprocessing the scans is necessary. While some artefacts such as head movements can be controlled, others cannot be avoided (e.g. thoughts unrelated to the experimental task, scanner noise). However, the signal-to-noise ratio in the data can be improved by applying preprocessing steps prior to the data analysis.

Pre-processing is aimed at correcting temporal and spatial distortions. Slice timing correction is one method of temporal pre-processing and is used for correcting differences in slice acquisition time resulting from the staggered order of slice acquisition (Ashburner et al., 2012). Without this correction one slice can be as far in time from the adjacent slice as half of the TR. An alternative to using slice time correction is to include temporal derivatives in the first level preprocessing instead. These derivatives can account for up to +/- one second changes in timing.

Spatial correction includes realignment, coregistration, segmentation, normalisation and smoothing. Realignment, also referred to as head motion correction, corrects for the timecourse distortions from one voxel to another due to the neurons in a particular voxel shifting as a result of head motion. Before the data analysis stage, all the scans of an individual need to be realigned to a specified time point volume. This procedure applies a six parameter (rigid-body) transformation to the volume, shifting and rotating the data to account for motion and in this way removing movement artefacts (Ashburner et al., 2012; Huettel, Song, et al., 2004).

To correct for field non-uniformities of the scanner there are two options: shimming coils inserted in the participants' mouth during the scan, or acquiring a fieldmap with two different echo times (short TE and long TE) used during data preprocessing steps to account for B0 inhomogeneities. In addition, the scanner acquires many functional images and a 3-D structural MRI image of the brain. However, both types of images have different spatial resolutions. To account for this, coregistration is performed where the structural images (T1) are aligned with the functional images. This is similar to the motion correction procedure, except that coregistration deals with different resolutions. Following this the anatomical image (T1) has to be segmented into cerebro-spinal fluid, white matter and grey matter.

As most imaging studies use several participants, their brains have to be normalised to a standard template allowing for a single group analysis. The two most common templates are the Talairach brain (based on a single brain from an elderly woman), and the MNI (Montreal Neurological Institute) brain created by combining the anatomical data of more than a hundred individuals. The normalization involves the manipulation of individual images (stretching, squeezing, warping) to fit the template brain, thereby reducing individual differences.

The final step of spatial data preprocessing is smoothing. In addition to suppressing the noise, smoothing also reduces residual effects in functional and gyral anatomy between the subjects producing a smooth spatial map across the brain. This process is achieved by applying a Gaussian filter, and if the spread of the active cluster of voxels is equivalent to the width of the filter used, this results in an increased signal-to-noise ratio (Ashburner et al., 2012).

Statistical analysis

Following preprocessing, the statistical analysis is performed. The common approach is to consider every voxel in the brain separately within the framework of the general linear model. Extracting the average activation in the activated voxel while the participant is performing the task of interest is one of the simplest analyses. However, as the task will engage most of the brain, the researchers focus on contrasts, comparing activation of the task of interest with a baseline task (Ashburner et al., 2012; Huettel, Song, et al., 2004). Unfortunately, contrast analyses can be problematic. As the cost of fMRI is high, most studies use small sample sizes leading to a decrease in statistical power leading to a higher risk of type I errors. In the fMRI analysis all voxels in the brain are considered and therefore it is necessary to apply a multi comparison correction to the results. Behavioural studies consider alpha values of 0.05 (and corrected for multiple comparisons) to be the appropriate standard. Although earlier neuroimaging studies tended to follow this threshold standard, a high number of more recent studies reported results based on a corrected alpha level of 0.01 (Bradley et al., 2015). Rising concerns about false positive results have pushed researchers to choose even stricter thresholds such as 0.001, as an alpha level of 0.01 would still produce 100 false alarms if 100 000 voxels are tested at once (whole brain analysis). The current most commonly taken approaches for correction of multiple comparisons is to use Familywise Error (FWE) or False Discovery Rate (FDR) correction (Genovese, Lazar, & Nichols, 2002). However, as Lieberman points out, both methods can lead to an increase of Type II errors of missing an existing effect. In addition, fMRI based research risks becoming biased towards publishing large and obvious effects, while missing more subtle and complex cognitive and affective processes (Lieberman & Cunningham, 2009). A combination of extent (how many voxels are activated) and intensity (the strength of activation, p-value) thresholds, as suggested by Lieberman and Cunningham, would be more effective in the studies of complex social neuroscience by balancing the risks of Type I and II errors. They suggest that having a combination of a $p < 0.05$ and a value of k = 10 voxels is more effective than having just $p < 0.01$ alone. Furthermore, they propose that a cluster size of 20 and a $p < 0.005$ is the same as FDR 0.05 (Lieberman & Cunningham, 2009). While comparing contrasts only the areas which show activation stronger than the set intensity threshold and over a larger area than the set extent threshold are shown.

However these and similar approaches have been questioned by other researchers suggesting that this type of analysis is incorrect. Vul, Harris, Winkielman, and Pashler (2009) for example, argued that very high correlations between fMRI data and personality questionnaires are due to false non-independent statistics (when the final measure is non-independent from the selection criteria – observing an activated number of voxels from functional analysis and then reporting the results of the same analysis and functional data from just those selected voxels). Their arguments have in turn been questioned by (Lieberman, Berkman, & Wager, 2009).

In summary, as fMRI includes multiple comparisons, the appropriate corrections for statistical comparisons are needed. The challenge lies in finding the balance between Type I and Type II error as it is extremely important in studying more subtle cognitive and affective processes. A combination of extent and intensity thresholds is a good place to start as it gives a good balance between both types of errors and false positives would be eliminated by future meta-analysis.

6.2.2 Advantages and limitations compared to other techniques

fMRI has many advantages over other neuroimaging and neurological techniques. To start with, what is common to all neuroimaging techniques compared to neurological studies is that neuroimaging studies do not rely on observing the behaviour and in this way making the associations between neuroimaging and behavioural results (Bunge & Kahn, 2009). It can investigate covert cognitive processes occurring before overt behaviour or even processes not related to that behaviour, for example, identifying brain regions necessary for memory retrieval separately from brain regions involved in memory encoding. In addition, neuroimaging studies allow the exploration of whole neural circuits associated with a particular behaviour/task, while neuropsychological studies are prone to overestimate or overlook the function of a particular brain region (Rorden & Karnath, 2004). This problem relates to very few patients showing specific injury to a single brain area due to e.g. cerebrovascular anatomy, resulting in damage beyond areas of interest (Bunge & Kahn, 2009; Rorden & Karnath, 2004). Another issue is diaschisis – when the damaged area has a negative effect on other areas that rely on it being intact. For example, damage to the left Broca’s area results in abnormal activity in the left posterior inferior temporal cortex in a semantic comprehension task (Price, Warburton, Moore, Frackowiak, & Friston, 2002).

In comparison with other imaging techniques, fMRI has a very good spatial resolution compared with MEG/EEG, and can investigate deeper areas of the brain compared to near-infrared spectroscopy (NIRS) or event-related optical signal (EROS; (Bunge & Kahn, 2009). Furthermore, as it is non-invasive, fMRI is more attractive to investigators compared to Positron Emission Tomography (PET) studies where participants have to be injected with radioactive tracers (Huettel, Song, et al., 2004). Combined with lower cost and better spatial and temporal resolution fMRI is generally found more advantageous for behavioural studies compared to PET.

However, fMRI also has some important limitations. One major drawback is that it only provides an indirect recording of neural activity via measuring changes in blood flow. Blood constantly flows to vessels and cells and also spreads to neighbouring neurons, which means that any scan represents only the summed version of a regions activity and researchers are not able to identify the precise neurons involved. In addition, the understanding of mental processes depends on understanding what function each brain area has, however, it is hard to interpret due to mental tasks involving a variety of different functions. For example, emotional tasks do not only involve emotion related areas such as the amygdala, but at the same time can show activation in reward processing and strategic thinking related regions (Gupta, Koscik, Bechara, & Tranel, 2011; Phan, Wager, Taylor, & Liberzon, 2002; Schaefer et al., 2002).

Furthermore, the amplitude of the BOLD signal does not reflect the level of neuronal activity and does not always reflect behavioural performance. With practice even difficult cognitive tasks become easier over time, and the mental efforts as well as neural processes required for the task completion become more effective. This implies that the amplitude of the BOLD signal decreases over time, although the behavioural result stays the same. In addition, as fMRI relies on correlation but not causation, it once again complicates the interpretation of the results; does a worse performance on the task reflect a neural dysfunction, or reversed, a neural dysfunction affects the performance? Also, fMRI cannot answer the question of whether an area is necessary for a specific task or is just co-activated as part of a network.

Another potential problem for fMRI experiments is design related. Both blocked and event-related designs have their advantages and disadvantages, and they impact not only on the quality of the behavioural data, but also on the quality of the acquired imaging scans.

Blocked designs use blocks of stimuli in one condition at a time. This design is best at detecting BOLD signal amplitude differences between conditions. In addition, timewise it is more efficient, as more scans can be obtained in less time compared to event-related designs. On the other hand, this design is unable to identify a single event within the blocks. Block designs also have implications for the behavioural part of psychology experiments. As the stimulus is presented in blocks, participants build anticipations and may predict accurately what the next trial will be like. It also raises the question of whether BOLD is reflecting this anticipation and prediction rather than task related activity.

Event-related designs are commonly used as an alternative to block designs. Here, the different stimulus conditions are presented in an interleaved manner and therefore at larger temporal intervals than in block designs. Researchers commonly use randomised inter-trial interval durations so that on average the stimulus presentation would leave enough time for the hemodynamic response function (sufficient time for the BOLD response to build up). These benefits eliminate some of the disadvantages of the blocked design. First of all, this design is best at estimating the hemodynamic response function shape as well as providing the means of estimating the response to a single event in the experiment (Huettel, Song, et al., 2004). As a result, this allows a broader variety of research questions and more complicated experiments, as well as a more flexible analysis of the BOLD signal in conjunction with behavioral responses. However, the main drawback of this design is the increased cost of the experiment requiring many more trials to ensure a robust average between trials.

To sum up, fMRI can be considered an appropriate technique for identifying the neural activity of areas involved in social decision-making tasks under emotion. Another advantage in terms of this particular study, fMRI is particularly good at event-related designs. As has been shown in Experiment 2, stimuli presentation in block or event-related designs resulted in a similar defection rates in the Prisoner’s Dilemma. Therefore, this design type can produce a more realistic set up for the participants to measure their behavioural responses and explore neural correlates of decision-making under emotion in social context with fMRI.

6.3 fMRI experiment

Based on the methods and findings of Experiments 1, 2, and 3, an fMRI study on decision making under emotion will be presented. The design has been in part determined by the results of the behavioural studies – from selecting the game of interest to choosing the stimuli presentation order. In this study, the interaction between emotion and choice was expected to show activation in frontal brain areas previously identified to be involved in emotional stimuli processing, namely the orbitofrontal cortex and the amygdala. In addition, as cognitive control is known to influence decision making under emotion (De Neys, Novitskiy, Geeraerts, Ramautar, & Wagemans, 2011) higher cognitive control participants were expected to engage in strategic thinking triggering increased activation in the striatum and medial prefrontal areas.

The previous behavioural experiments showed that emotions affect decision-making in the Prisoner's Dilemma task resulting in a consistent pattern: the defection rates increased from sympathy to neutral and from neutral to anger. In addition, the defection rates were different with respect to cognitive inhibition: low cognitive inhibition participants acted according to their negative emotion impulses stronger than high cognitive control participants. Furthermore, Experiment 3 showed that in a social economic context only direct emotion successfully affects decision-making, while displaced emotion has no impact. Also, by having participants interact in the event-related experimental design on the iterated Prisoner's Dilemma it was possible to avoid learning effects by not giving the outcome of the interaction after every single trial.

The clear pattern at the behavioural level allows some predictions about brain activity during these processes. The emotional part of the task is expected to show activation in the amygdala and the ventromedial prefrontal cortex as suggested by the Somatic Marker Hypothesis (Bechara & Damasio, 2005; Bechara, Damasio, Damasio, & Lee, 1999) and reasoning with emotional content studies (Blanchette et al., 2007; Goel & Vartanian, 2011). In addition, reward expectations and experience also affect the decision-making process and are marked by striatum activation (including the putamen and caudate nucleus) and an increase in activity in these areas is observed with gains (both monetary and symbolic; Elliott, Newman, Longe, and Deakin (2003), Haruno (2005); Hsu, Anen, and Quartz (2008); Siep et al. (2009)), but decreases are associated with losses (Bjork, 2004; Verney, Brown, Frank, & Paulus, 2003).

These studies suggest that the striatum is critically involved in monetary and symbolic reward processing. However, in order to predict what reward they may receive it is necessary to anticipate the choices of the other player. This requires theory of mind processes which are represented by medial prefrontal cortex activation (Decety, Jackson, Sommerville, Chaminade, & Meltzoff, 2004; Frith & Frith, 1999; Frith, 2001; McCabe et al., 2001). High co-operators in the Trust Game showed stronger medial prefrontal cortex activation whilst interacting with human opponents as opposed to interaction with a computer, yet for high defectors activation of this region did not depend on the type of opponent (McCabe et al., 2001). Furthermore, medial prefrontal areas were activated when solving personal versus non-personal moral dilemmas (Greene, 2001). In the same Greene (2001) study, the reaction times were longer for personal moral dilemmas, compared to impersonal ones (where participants instead of pushing a person (personal dilemma) pushed a lever (impersonal) to redirect a train and save three individuals by letting one die). This pattern has been interpreted as a result of emotions interacting with abstract thinking.

Following on from the previous experiments in this thesis, high cognitive control individuals are known to be more engaged in abstract thinking (Evans, 2008; Kahneman & Frederick, 2002) and they would also try to predict the other player’s choices as well as their reward/gains and losses during the game. If this is the case, one would expect medial prefrontal cortex and striatum activation during decision-making – when participants have to decide either to cooperate or defect. Also increased activation in the OFC and amygdala would be seen during the time point when participants have to make their choice in the sympathy and anger conditions, but not neutral. Finally, participants are predicted to defect less in the Prisoner’s Dilemma in the sympathy compared to the neutral emotion condition, whereas the defection rates in the anger condition were expected to increase compared to the neutral emotion condition as has been seen in Experiments 1-3. It was also expected that choices based on abstract thinking and controlled by cognitive control (e.g. cooperation in the anger condition/defection in sympathy) would result in longer reaction times and activate the middle frontal gyrus and parietal lobe, while choices based on intuition would show activation in the medial prefrontal areas (BA 9 and 10) and posterior cingulate (defection in anger/cooperation in sympathy; Greene, 2001).

6.4 Methods

6.4.1 Participants

Twenty-two participants (15 females) took part in the study. Two participants were removed from the analysis due to being aware of the deception or extensive head movement in the scanner, leaving 20 participants (14 females) for the final analysis. The mean age of the participants was 29 years (SD = 5.68), and their mean education was 16.4 years (SD = 3.54). All participants were native Italian speakers, and had normal or corrected to normal vision. 18 were right-handed and two left-handed. Participants did not have any neurological or psychiatric disorders and did not use any psychoactive medications, and all participants were pre-screened for fMRI exclusion criteria. All participants in this study were health-care professionals recruited from the IRCCS San Camillo hospital and voluntarily agreed to take part in the experiment. The study was approved by the University of Hull Ethics Committee and the ethics committee of the IRCCS San Camillo, Venice, Italy.

6.4.2 Stimuli

The emotion stimuli for this experiment were used as described in Chapter 4, except that they were translated into Italian. The essays and evaluations were hand-written on different colour paper (light blue, light purple and light green) so that participants would learn to associate a colour with a particular "participant". The colours were counterbalanced across participants.

6.4.3 Tasks

The Prisoners Dilemma and Cognitive Inhibition tasks (the Go/no-Go) were used as described in Chapter 4. Italian versions of the Emotion Regulation Questionnaire and the Self-Report Emotion Questionnaire were used.

6.4.4 Procedure

Upon arrival at the experiment, participants were encouraged to believe that three "other participants" were taking part in the same session, though the participant never met these other participants and, indeed, they were not real. They were told that all the participants in the same experimental session would interact on some tasks, however due to anonymity and confidentiality all the participants were seated in individual rooms.

The emotion deception procedure was as described in Experiment 2. The participant would write a short essay, which was later taken from the room and after a few minutes the “other participant’s” essay was brought in for the participants to read and evaluate. Following this, the participants own essay and evaluation from the “other participant” was brought in for the participant to read. This procedure was repeated three times overall, once for each emotion condition. Every time a new essay/evaluation would be brought in, the experimenter would take photographs of it and then upload the images onto a computer. Following emotion induction, participants previewed the uploaded images of the other “individuals’” essays and the evaluations they received on their own essays. This was done to allow participants familiarization with the digital versions of the stimuli. Afterwards, they completed the Go/no-Go task.

After the emotion induction, participants were taken to the fMRI room. They were reminded of the rules of the Prisoner’s Dilemma and put into the scanner to play this game. The experiment consisted of three runs and each run had 12 trials per emotion condition (36 trials overall) Each run lasted for 11.5 minutes, resulting in an overall scanning duration of approximately 35 minutes per individual, and overall in the experiment there were 108 trials.

Similarly to Experiments 2 and 3, a trial of the Prisoner’s Dilemma would start with a fixation cross for an average of 1.5s followed by a reminder of the other “individual’s” essay (the photograph from emotion induction), and then the reminder of the evaluation (photograph from emotion induction). The images would stay on screen for 4s each and they served as an indicator of with whom the participants were interacting. After this, the Prisoner’s Dilemma payoff matrix was presented and participants had 7 seconds to make their decision. They were required to press the button under the index finger of their right hand on the fMRI compatible keypad in the scanner to keep silent/cooperate and to press a button under their middle finger for choosing to tell on/defect. The response button mapping was not counterbalanced across participants. In trials where responses were shorter than 7 s, the remaining time was added to the fixation period of the next trial. The order of emotion conditions was pseudo-randomised across individuals, allowing for a maximum of three consecutive trials of the same emotion. The outcome of the players’ interaction was presented at the end of each run (after 36 trials) and was pre-determined before the experiment (Figure 6.1).

After the three runs (the full scanning procedure), participants were instructed to fill in the Emotion Regulation Questionnaire and the Self-Report Emotion Questionnaire. Following this, questions establishing the participant's belief in the deception were asked. Questions at first were about the other "individuals'" age and gender, etc., and the final question was if participants believed in the existence of the other "individuals". Finally, the full debrief was given providing the true aims of the experiment.

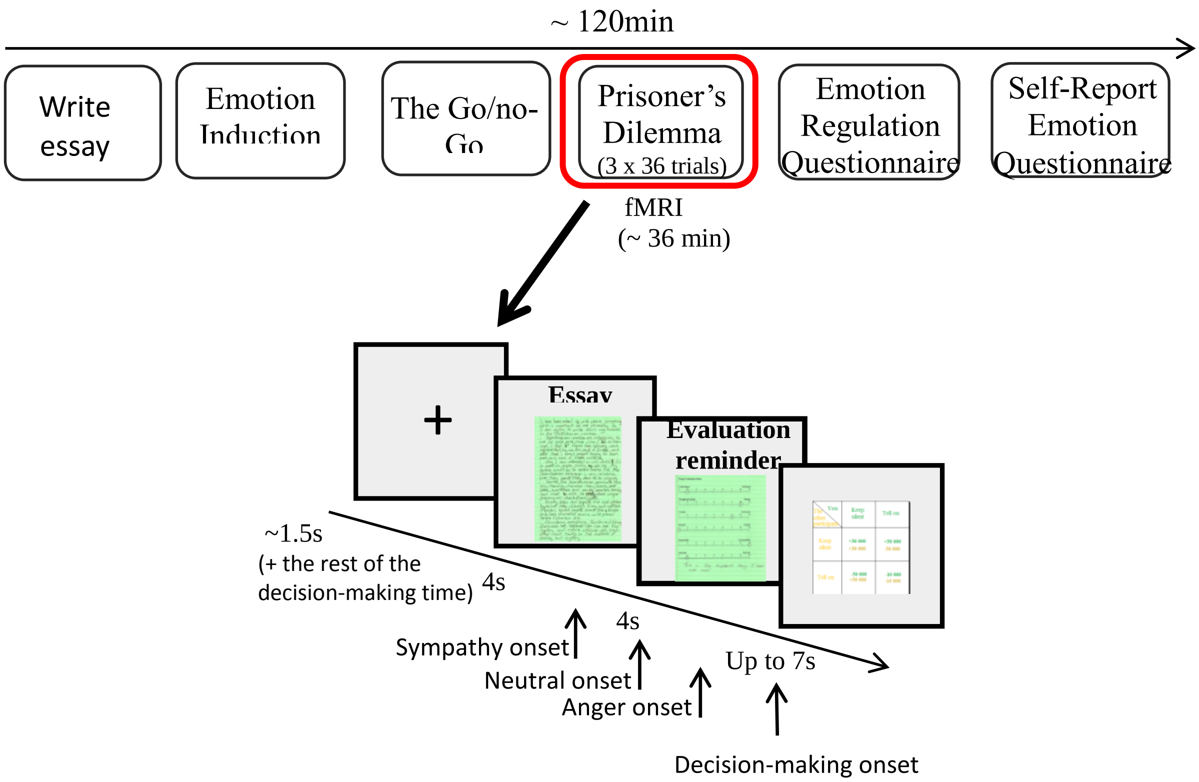

Figure 6.1: (A) A general procedure of the experiment. (B) An example of a single trial of the Prisoner's Dilemma. Each trial began with a fixation cross (1.5 s), followed by a reminder of the other "participant's" essay and the evaluation (each for 4s). In the end the participant would make a choice (within 7s) on the Prisoner's Dilemma outcome table by pressing a response key under the index finger to cooperate or response key under the middle finger to defect.

6.4.5 fMRI acquisition

Scanning was performed at IRCCS San Camillo, Venice, Italy using a 1.5T Phillips Achieva MRI scanner operated with a Sense 8 channel head coil. The experiment was divided into three functional runs, with a rest-period between runs. Functional scans were acquired by using a standard single shot EPI sequence (TR = 2060 ms, echo time (TE) = 45 ms, flip angle = 90°, 25 slices, slice thickness = 5 mm, no gap, matrix size 80 × 80, voxel size 2.88 × 2.88 × 5 mm, FOV = 230 × 230 mm). At the start of the scanning each participants' fieldmap was acquired (T1-weighted fast field echo sequence, TE long = 7.6 ms, TE short 4.9 ms, slice thickness 5 mm, matrix size 72 × 60, no gap, voxel size 0.8 × 0.8 × 5 mm). Fieldmaps were used for correcting EPI images for static geometric distortions caused by susceptibility-induced field inhomogeneities and head movement (Andersson, Hutton, Ashburner, Turner, & Friston, 2001; Hutton, 2002). To aid the inter-subject registration, at the end of each scanning session a T1-weighted structural scan was acquired for each participant (fast field gradient echo sequence, TR = 7.4 ms, TE = 3.4 ms, 280 slices, slice thickness = 0.6 mm, matrix 240 × 240, voxel size 1.04 × 1.06).

6.4.6 Behavioural analysis

The dependent measure of the behavioural analysis was the defection rate in the Prisoner's Dilemma, and the independent within-subject variable was the emotion condition (sympathy, anger and neutral). A series of mixed ANOVA identical to Experiments 2 and 3 were used to explore the main effects and interactions between defection rate in three emotion conditions with cognitive control and emotion regulation. Post hoc within-subject analysis was performed with a paired t-test and between-subject with an independent t-test (two-tailed). The Bonferroni correction was used for the multiple comparisons (alpha = .017, two-tailed).

6.4.7 fMRI analysis

Image pre-processing and data analysis were performed using Statistical Parametric Mapping (SPM8; Wellcome Trust Centre for Neuroimaging at UCL) software on a Matlab 2011a platform. The first six dummy volumes of each run were discarded to allow for T1 equilibration, and then the EPI images were corrected for geometric distortions caused by susceptibility-induced field inhomogeneities. Field maps were first brain extracted using FSL BET (Smith, 2002) and then processed for each participant using the FieldMap toolbox in SPM (Hutton, Deichmann, Turner, & Andersson, 2004). The EPI images were then realigned and unwarped (Andersson et al., 2001). Each participant's structural image was then coregistered to the mean of the motion-corrected functional images using a 12-parameter affine transformation, and segmented according to the default procedure in SPM8 (Ashburner & Friston, 2005). Subsequently, the spatial normalisation parameters resulting from the previous step were applied to the functional images to allow for inter-subject analysis. Finally, these images were smoothed using a 6 mm full width at half maximum Gaussian kernel.

For each participant, an event-related general linear model (GLM) was designed. The GLM consisted of five regressors of interest: the onset of all three emotion conditions (sympathy - halftime between the essay reminder appearing on screen and the evaluation reminder appearing; anger - halftime between the evaluation reminder appearing on screen and the decision matrix; neutral - at the time when the evaluation reminder appeared on the screen; each duration was set for 2 seconds), and the onsets of the Prisoner's Dilemma payoff matrix separately for cooperation and defection in each emotion condition (sympathy, anger and neutral). The onset for the latter was set at the time when the payoff matrix appeared on the screen until participants made their choice and pressed the button, on average 1.96 seconds (SD = 1.22). Motion parameters defined by the realignment procedure were entered as six regressors of no interest, separately for each run.

Time derivatives were used instead of slice timing correction, and runs where any one of the emotion conditions did not have a single defection or cooperation were removed (1 run for 6 participants). Statistical parametric maps were generated from contrasts of interest. These included the main effects of emotion (sympathy vs. anger, sympathy vs. neutral, anger vs. neutral), and the main effect of choice (cooperation vs. defection). However the main interest of the analysis were the interactions of [sympathy (defection – cooperation) vs. neutral (defection – cooperation)], [anger (defection – cooperation) vs. neutral (defection – cooperation)] and [sympathy (defection – cooperation) vs. anger (defection – cooperation)].

A random-effects group-level analysis using one-sample t-tests on the contrast images obtained from each contrast of interest for each participant was used. To avoid a Type I error, Monte Carlo simulations were performed using the REST AlphaSim toolbox with individual voxel *p*-values set at 0.005. The toolbox performed 5000 simulations with a cluster connection set to radius of 6 mm and Smoothing kernel set to 6mm (Dannlowski et al., 2013; Jiao et al., 2011; Song et al., 2011; Yan, 2010). A minimum cluster extent (KE) of 32 voxels was estimated to satisfy a $P_{FWE} < .05$ for all contrasts, except [sympathy (defection – cooperation) – anger (defection – cooperation)] where KE was 20 voxels.

6.5 Results

6.5.1 Behavioural results

Emotion manipulation

The Self-Report Emotion Questionnaire was analysed with a factor analysis and paired t-test to check if the emotion manipulation was successful, as was done in Experiments 2 and 3. Emotion words that did not vary in answers and were identified as 1 (did not feel emotion at all) across conditions and participants were removed (excited, pleased, heavy-hearted, afraid, jittery, and enthusiastic), leaving 48 emotion words in the final analysis.

A Principal Components method with a Varimax (orthogonal) rotation showed that the Kaiser-Meyer Olkin measure of sampling adequacy was medium (KMO = .638, N = 21), but Bartlett's test of Sphericity, $\chi^2(1081) = 2737.97$, $p < 0.001$ indicated that factor analysis is appropriate. Analysis loaded mainly on three factors (each explaining more than 10% of variance) in total explaining 52% of variance (Table 6.1).

Table 6.1: Emotion manipulation assessment in the fMRI study: three factors loadings from the factor analysis on the Self-Report Emotion Questionnaires with the percent of the variance they explain

	first factor (sympathy condition)	second factor (anger condition)	third factor (neutral condition)
Emotion words	compassionate	angry	happy
	upset	mad	glad
	feeling low	enraged	joyful
	sorrowful	furious	pleasant
	guilty	bothered	content
	soft hearted	nervous	satisfied
	moved	irritable	good mood
	sad	hostile	active
	grieved	perturbed	tranquil
	distressed	agitated	interested
	tender	determined	alert
	alarmed	frustrated	
	worried		
	troubled		
Variance explained	22%	18%	12%

To analyse emotion manipulation further, scores for words identified by each factor were averaged into new variables representing the first, second, and third factor. These variables were compared between emotion conditions using a one-way ANOVA (within-subject factor of emotion condition (sympathy, anger, neutral)) separately for each emotion condition. ANOVA for the first factor was significant ($F(2, 62) = 16.17$, $p < .001$). Post hoc analysis with paired t-test showed the first factor was significantly higher in the sympathy condition (mean = 2.29, SD = 0.87), than in the neutral (mean = 1.33, SD = 0.43), or anger (mean = 1.34, SD = 0.48) emotion conditions ($t(29.38) = 4.50$, $p < .001$ and $t(31.11) = 4.38$, $p < .001$, respectively). The first factor scores between anger and neutral conditions was not significant, $t(40) = 0.05$, $p = .962$.

ANOVA for the second factor was also significant, $F(2, 62) = 8.91$, $p < .001$. Post hoc analysis showed that the scores from the second factor were significantly higher in the anger condition (mean = 1.83, SD = 0.78), than in the neutral (mean = 1.22, SD = 0.32) or sympathy (mean = 1.29, SD = 0.30) emotion conditions ($t(26.54) = 3.34$, $p = .002$ and $t(25.95) = 3.00$, $p = .006$, respectively). The scores between sympathy and neutral conditions was not significant, $t(40) = 0.70$, $p = .488$. Finally, ANOVA for the third factor was not significant ($F(2, 62) = 1.12$, $p = .333$) suggesting that emotion ratings across three emotion conditions did not differ significantly.

As can be seen from the analysis above and Table 6.1, the first factor seems to represent the sympathy condition in the experiment. The second factor loadings combined with ANOVA results describe the anger emotion, while the third factor loadings contain what would be expected from the neutral, but slightly positive condition and even though there was no significant difference the score from this factor was highest in the neutral condition.

Emotion impact on social decision-making

To investigate the interaction between the defection rate in the Prisoner's Dilemma with participants' cognitive control and emotion regulation, the data from the Go/no-Go tasks and the Emotion Regulation Questionnaire were investigated.

The false alarms and the hit rate in the Go/no-Go task were used to calculate d' for each participant as a measure of cognitive control ability. Using a median split, participants were divided into two groups according to this measure; a low (d' = 3.00 – 3.87, Mean = 3.46 N = 10) and a high cognitive control group (d' = 3.91 – 4.46, Mean = 4.14, N = 10). High cognitive inhibition participants had significantly higher cognitive inhibition than low cognitive inhibition participants, $t(18) = 5.31$, $p < .001$.

Furthermore, the Emotion Regulation Questionnaire was analysed by calculating expressive suppression (average of questions 1, 3, 5, 7 and 10) and cognitive reappraisal scores (average of questions 2, 4, 6, 8 and 9) for each participant. The comparison between reappraisal and suppression showed no significant difference ($t(19) = .99$, $p = .336$, reappraisal mean 4.47 (.85), suppression mean 4.18 (1.12)). In the next step, according to their score participants were divided into high [4.50 – 6.00, Mean = 3.33, N = 10] and low [3.17 – 4.33, Mean = 5.02, N = 10] expressive suppression and high [4.25 – 6.75, Mean = 3.58, N = 10] and low [1.75 – 4.00, Mean = 5.06, N = 10] cognitive reappraisal. High expressive suppressors had significantly higher scores than low suppressors, $t(18) = 5.22$, $p < .001$, as did high reappraisers have significantly higher cognitive reappraisal scores than low cognitive reappraisers, $t(18) = 7.36$, $p < .001$.

Finally, three 3 x 2 mixed design ANOVA's for each of the between subject factors separately (low and high Cognitive Control, low and high Cognitive Reappraisal and low, and high Expressive Suppression) with within-subject factor of Emotion Condition (sympathy, anger, and neutral) revealed a significant main effect of Emotion Condition, ($F(2, 26) = 8.52$, $p = .001$). There were no other significant main effects or interactions, ($F(2,26) \leq 1.49$, $p \geq .243$).

Within-subject comparison showed that the overall defection rates significantly increased from sympathy to neutral ($t(19) = -2.79$, $p = .012$) and from sympathy to anger conditions ($t(19) = -4.13$, $p = .001$) while from neutral to anger there was a slight trend towards a significant increase ($t(19) = -2.07$, $p = .052$, Bonferroni-corrected two-tailed alpha = 0.017; Figure 6.2).

Due to the interaction of emotion condition with Cognitive Inhibition not being significant, the current study participants' d' was compared with previous study participants' d'(Experiment 1). The setting of both studies was similar, however participants were different – in the current study participants were health care professionals, while in the previous one they were undergraduate university students. The independent t-test revealed that medical personnel had significantly higher cognitive control compared to the student sample (mean d' medical personnel = 3.80 (.48), students = 3.27 (.65), $t(48) = 3.12$, $p = .003$).

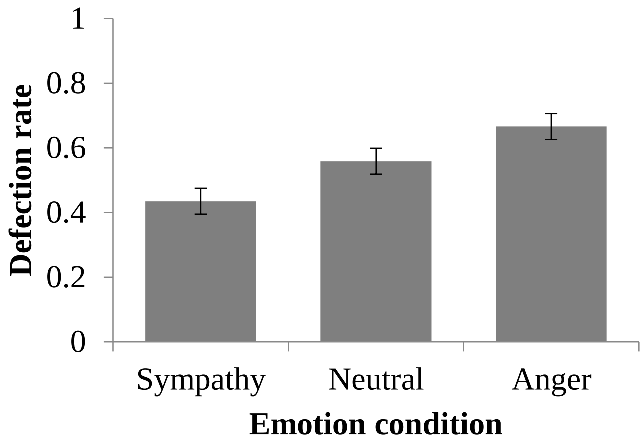

Figure 6.2: Mean defection rates (+/- 1SEM) over three emotion conditions in the iterated Prisoner's Dilemma.

Reaction times

Repeated measures ANOVA with the within-subject factors of two Response (cooperation or defection) and three Emotion Conditions (sympathy, anger, and neutral) showed that the main effect of Emotion Condition and the Emotion Condition x

Response interaction were significant ($F(2, 38) = 6.23$, $p = .005$ and $F(2, 38) = 4.55$, $p = .017$, respectively), but not the main effect of Response ($F(2, 38) = 1.35$, $p = .259$).

The paired t-test between the defection and cooperation choice in each emotion condition revealed a significant increase in the reaction times in the sympathy condition for defection choice compared to cooperation, and also significantly increased from defection to cooperation in the neutral condition ($t(19) = -2.15$, $p = .045$ and $t(19) = -3.20$, $p = .005$, respectively). Although the reaction time in the anger condition increased from defection to cooperation choice, the increase was not significant ($t(19) = -1.13$, $p = .274$;Table 6.2)

Table 6.2: Mean reaction times (*SD*) *across the three emotion conditions depending on choice*

Choice	Emotion Condition		
	Sympathy	Neutral	Anger
Defection	1.90 (0.17)	1.71 (0.15)	1.57 (0.13)
Cooperation	1.70 (0.16)	1.93 (0.18)	1.71 (0.16)

In a further step, mixed design ANOVA's were created with the within-subject factors as above and between-subject factors separately of Cognitive Inhibition (high, low), Expressive Suppression (high, low), and Cognitive Reappraisal (high, low). None of the three-way interactions between Emotion Condition x Response x Cognitive Inhibition/Expressive Suppression/Cognitive Reappraisal were significant ($F(2, 28) \leq 4.67$, $p \geq .185$).

Defection over time

To check if participants' decisions changed over time, a repeated measures ANOVA was designed with within-subject factors of Emotion Condition (sympathy, anger and neutral) and Run (run 1, run 2 and run 3). The main effects of Emotion Condition and Run were significant, $F(2, 38) = 10.29$, $p < .001$ and $F(2, 37) = 7.75$, $p = .002$, respectively. The interaction Emotion Condition by Run was not significant, $F(4, 76) =0 .79$, $p = .537$.

A paired t-test was used to analyse the main effect of Run further and showed a significant increase in defection rates from run 1 to run 3 ($t(19) = -4.11$, $p = .001$), and a trend between run 1 and run 2 ($t(19) = -2.31$, $p = .032$; Bonferroni-corrected two-tailed alpha = 0.017). However, the difference between run2 and run3 was not significant ($t(19) = -1.51$, $p = .148$).

Payoff Matrix x Defection analysis did not show that participants' responses would depend on the presented payoff matrix (see Appendix E on page 221).

6.5.2 Imaging results

The main effect of emotion

The main effect of emotion was analysed by constructing contrasts comparing (1) the sympathy emotion condition with the neutral, (2) the anger emotion condition with the neutral, and finally (3) the sympathy emotion condition with the anger emotion condition.

To have a balance between Type I and Type II error, an initial combined extent k = 10 and strength p < .005 threshold was used as suggested by Lieberman and Cunningham (2009) and then the AlphaSim correction was applied (individual voxel p-value set at .005, 5000 simulations, cluster connection radius r = 6 mm and Smoothing kernel of 6mm). These contrasts showed activation primarily in the frontal lobe and the parietal areas where sympathy and/or anger showed stronger activation compared to the neutral emotion and in the sub-lobar (thalamus and insula) areas when neutral condition was exhibiting more activation compared to the other two emotion conditions (Table 6.3).

The contrast measuring brain activity that was stronger in the anger compared to neutral emotion condition (anger > neutral) showed activation in the right inferior frontal gyrus (BA 9; AlphaSim, $P_{uncorrected} = .000083$), and the reversed contrast neutral > anger revealed left thalamus activation (AlphaSim $P_{FWE} < .05$).

The brain activity in the contrast for stronger activity in the sympathy compared to neutral emotion condition (sympathy > neutral) revealed responses in the left temporal lobe and the right insula, however only the activation in the right posterior cingulate (BA 31) was significant (AlphaSim $P_{FWE} < .05$). The opposite contrast (neutral > sympathy) indicated significant activation in the bilateral insula (BA 13), the right middle frontal gyrus (BA 6) and the left precentral gyrus (BA 4; AlphaSim $P_{FWE} < .05$).

Finally, the contrast looking at higher activation in the anger than in the sympathy emotion condition (anger > sympathy) showed activation in the right parietal lobe (BA 40) and the inferior frontal gyrus (BA 46), however the activation was evident only at p = .005 and KE = 10. The reversed contrast (sympathy > anger) displayed activation in the areas located in the left hemisphere, but only the activation in the left Fusiform gyrus (BA 37) was significant (AlphaSim $P_{FWE} < .05$).

In summary, contrasts of the main effect of emotion have revealed that in the anger emotion condition activation increased in the right inferior frontal gyrus (BA 9) and in sympathy condition activation was observed in the left middle temporal (BA 21) and fusiform gyrus (BA 37) and the right posterior cingulate (BA 31) and Thalamus.

Table 6.3: Brain activity outlined by the main effect of emotion (*at p < .005 , KE = 10*)

Brain Region	Brodmann Area	Hemisphere	# of voxels	peak T	MNI coordinates x	y	z
Anger > neutral							
Frontal Lobe							
Inferior Frontal gyrus	BA 9	R	19	3.02	57	5	31
Neutral > anger							
Sub-lobar							
Thalamus		L	92	5.23	-18	-34	10
Sympathy > neutral							
Temporal Lobe							
Middle Temporal Gyrus	BA 21	L	25	3.32	-51	-4	-17
Fusiform Gyrus	BA 37	L	28	3.76	-39	-46	-20
Limbic Lobe							
Posterior Cingulate	BA 31	R	261	7.19	3	-67	13
Sub-lobar							
Thalamus		R	16	4.83	18	-25	7
Neutral > sympathy							
Sub-lobar							
Insula	BA 13	R	43	3.97	36	-10	16
Insula	BA 13	L	54	4.75	-42	-19	1
Frontal Lobe							
Middle Frontal Gyrus	BA 6	R	61	4.04	33	-7	58
Superior Frontal Lobe	BA 10	R	19	4.20	21	56	28
Precentral Gyrus	BA 4	L	81	5.96	-54	-4	16
Parietal Lobe							
Inferior Parietal Lobe	BA 40	L	20	4.45	-48	-31	22
Postcentral Gyrus	BA 2	R	16	4.51	54	-25	46
Occipital Lobe							
Cuneus	BA 17	L	30	3.87	-18	-82	10
Limbic Lobe							
Anterior Cingulate	BA 24	L	20	3.07	-3	23	25
Anger > sympathy							
Frontal Lobe							
Inferior Frontal Gyrus	BA 46	R	20	4.12	45	35	16
Parietal Lobe							
Inferior Parietal Lobule	BA 40	R	23	3.56	51	-31	49
Sympathy > anger							
Temporal Lobe							
Fusiform Gyrus	BA 37	L	62	5.75	-39	-43	-23
Superior Temporal Gyrus	BA 38	L	19	5.40	-39	17	-23
Occipital Lobe							
Lingual Gyrus	BA 18	L	14	3.85	-21	-76	-8

The main effect of choice

Neutral trials only

To investigate what brain activation patterns are involved while participants choose to defect or to cooperate, the cooperation and the defection trials were contrasted with each other. However, as these areas are not only affected by the decision-making processes but also emotion, the same contrasts were performed in the neutral emotion trials only (Table 6.4). The contrast looking at where defection showed greater activation compared to cooperation (defection > cooperation) did not show any significant result, but the cooperation > defection contrast showed stronger activity in the right inferior parietal lobe (BA 40), and the right superior temporal pole (BA 28); however, only in the left claustrum was the activation significant (AlphaSim P_{FWE} < .05;Table 6.4).

Table 6.4: Brain activity outlined by the main effect of choice in the neutral emotion condition (*at p < 0.001*, *KE = 10*)

Brain Region	Brodmann Area	Hemisphere	# of voxels	peak T	MNI coordinates x {mm}	y {mm}	z {mm}
cooperation > defection							
Parietal Lobule							
Inferior Parietal Lobule	BA 40	R	16	4.19	51	-34	40
sub-lobar							
Claustrum		L	37	4.23	-30	2	13
Limbic Lobe							
Superior Temporal Pole	BA 28	R	15	3.67	27	5	-23

Neutral and emotional (sympathy and anger) trials

To investigate what brain activation patterns are involved while participants choose to defect or to cooperate, the cooperation and the defection trials were contrasted with each other. The main effect of choice revealed an activation in the left caudate in the defection > cooperation contrast. The reversed contrast showed significant activation in the left insula (BA 13) and the right parietal lobe (BA 40; AlphaSim P_{FWE} < .05; Table 6.5).

Table 6.5: Brain activity outlined by the main effect of choice (*at p < 0.001, KE = 10*)

Brain Region	Brodmann Area	Hemisphere	# of voxels	peak T	MNI coordinates x {mm}	y {mm}	z {mm}
cooperation > defection							
Sub-lobar							
Insula	BA 13	L	56	5.10	-42	-4	-5
Frontal Lobe							
Inferior Frontal Gyrus	BA 46	L	14	3.39	-45	39	16
Middle Frontal Gyrus	BA 9	R	14	3.95	36	29	34
Precentral Gyrus	BA 4	R	33	4.40	39	-19	46
Parietal Lobe							
Inferior Parietal Lobule	BA 40	R	76	3.35	53	-31	34
defection > cooperation							
Sub-lobar							
Caudate		L	19	-3.67	-3	14	10

This analysis showed that while comparing defection and cooperation only in the neutral condition the left claustrum was activated, yet the same analysis when the emotional trials were included showed that left insula (BA 13) and the right inferior frontal gyrus (BA 40) were exhibiting stronger activation when participants were deciding to defect but not cooperate.

The interaction emotion x choice

The behavioural results showed a clear pattern for the defection rate to increase in the anger condition compared to the neutral condition, and for the sympathy condition defection rate to decrease compared to the neutral condition. The main interest of this experiment was the difference in neural activity between the sympathy and anger conditions compared to the neutral condition depending on whether individuals make decisions to cooperate or to defect.

Table 6.6: Brain activity outlined by the contrasts comparing choice and emotion interactions (*s – sympathy, a – anger, n-neutral*)

Brain Region	Brodmann Area	Hemisphare	# of voxels	peak T	MNI coordinates		
					x {mm}	y {mm}	z {mm}
a(d-c) > n(d-c) || a(c-d) < n(c-d)							
Sub-lobar							
Lentiform Nucleus, Putamen*		L	55	4.23	-18	5	-8
Lentiform Nucleus, Putamen*		R	35	3.36	24	11	-5
Limbic Lobe							
Posterior Cingulate*	BA 23	R	53	3.92	3	-37	22
s(d-c) > n(d-c) || s(c-d) < n(c-d)							
Limbic Lobe							
Uncus, Superior Temporal Pole*	BA 28	R	76	4.53	27	5	-23
Uncus, Amygdala**		L	27	5.04	-21	-1	-23
a(d-c) > s(d-c) || a(c-d) < s(c-d)							
Sub-lobar							
Lenntiform Nucleus, Putamen*		L	27	2.94	-18	5	-8
s(d-c) > a(d-c) || s(c-d) < a(c-d)							
Frontal Lobe							
Medial Frontal Gyrus**	BA 10	L	15	-4.05	-9	56	-8

*AlphaSim $P_{FWE} < 0.05$

** AlphaSim $P_{uncorrected} < 0.02$

***Anger* (*defection vs. cooperation*) *vs neutral* (*defection vs. cooperation*)**

Following the participants' behavioural pattern where defection increased from the neutral to anger conditions, a contrast comparing BOLD signal change in the anger and neutral emotion conditions between defection and cooperation responses was constructed. The contrast looking at higher activity at the defection response compared to cooperation in the anger emotion condition versus the neutral condition [anger (defection - cooperation) > neutral (defection - cooperation)] was equivalent to the contrast looking at activity higher in cooperation trials (vs defection) where the neutral emotion condition showed a stronger response pattern than the anger condition [neutral (cooperation - defection) > anger (cooperation - defection)]. This contrast showed bilateral activation in the putamen (Figure 6.3 A), and the right posterior cingulate BA 23 ($P_{FWE} < 0.05$, AlphaSim corrected). The reversed contrast [neutral (defection - cooperation) > anger (defection - cooperation)] equivalent to contrast [anger (cooperation - defection) > neutral (cooperation - defection)] did not show any activation.

If the activation in the triggered areas is a reflection of the participant's choice to defect because of their negative emotion, then the correlation between percent signal change and the defection rate in the anger condition should be significant. Indeed, Pearson's correlation showed a negative correlation in the left putamen between the percent signal change and the defection rate in the anger condition in the trials where participants chose to defect ($r = -.49$, $p = .029$; Figure 6.3 B). Correlations for other brain areas were not significant ($r \leq .25$, $p \geq .288$).

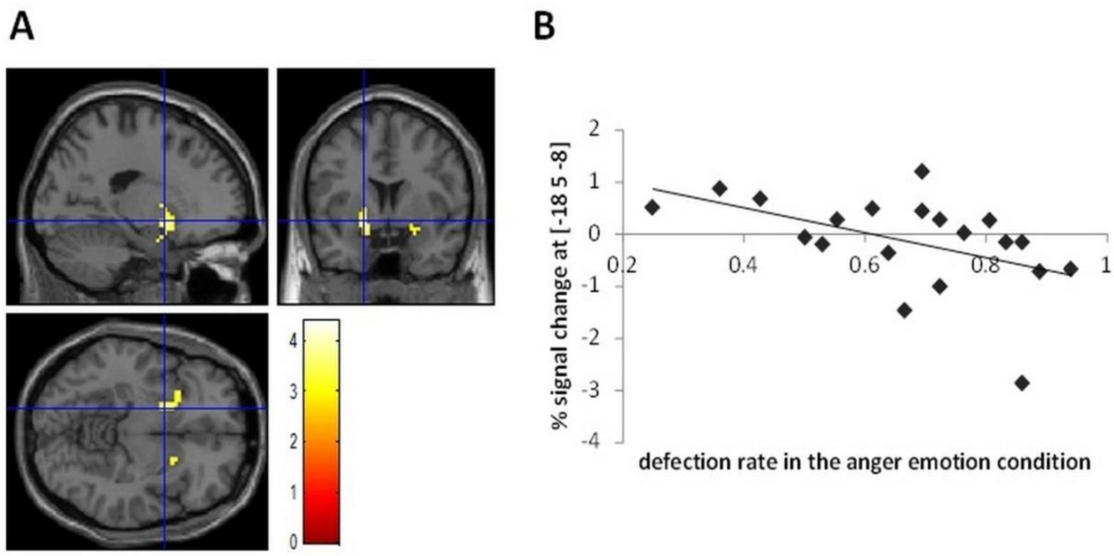

Figure 6.3: Contrast [anger (defection - cooperation) > neutral (defection - cooperation)] (*A*) *left putamen activation overlaid on the MNI single subject brain;* (*B*) *correlation between the percent signal change in the left putamen and the defection rate in the anger condition* (*r = -.49, p = .029, N = 20*)

The reversed contrasts [anger (defection – cooperation) < neutral (defection - cooperation)] equivalent to [anger (cooperation - defection) > neutral (cooperation - defection)] did not show activations at a combined threshold $p < 0.005$ and k = 20.

***Sympathy* (*defection vs. cooperation*) *vs. neutral* (*defection vs. cooperation*)**

Following the interaction contrast between the anger and neutral conditions and the defection with cooperation, a similar analysis was performed between the sympathy and the neutral conditions. The contrast looking into stronger activation in defection trials compared to cooperation in the sympathy emotion condition versus neutral emotion condition [sympathy (defection – cooperation) > neutral (defection - cooperation)] showed activation in the right superior temporal pole (BA 28) (AlphaSim $P_{FWE} < 0.05$) and a trend activation in the left amygdala (AlphaSim $P_{uncorrected} < 0.02$; Figure 6.5 A). This contrast was equivalent to the contrast where cooperation trials showed stronger activation compared to defection trials in the neutral emotion condition than in sympathy [sympathy (cooperation - defection) < neutral (cooperation - defection)].

A correlation analysis was performed to see if there was a relationship between defection in the sympathy or neutral emotion conditions and the activated areas. The left amygdala percent signal change negatively correlated with defection in the sympathy condition (r = -.57, p = .009; Figure 6.5 B). The correlations in the right superior temporal pole and the left putamen with defection in the sympathy and neutral conditions were not significant (r < .33, p ≥ .15).

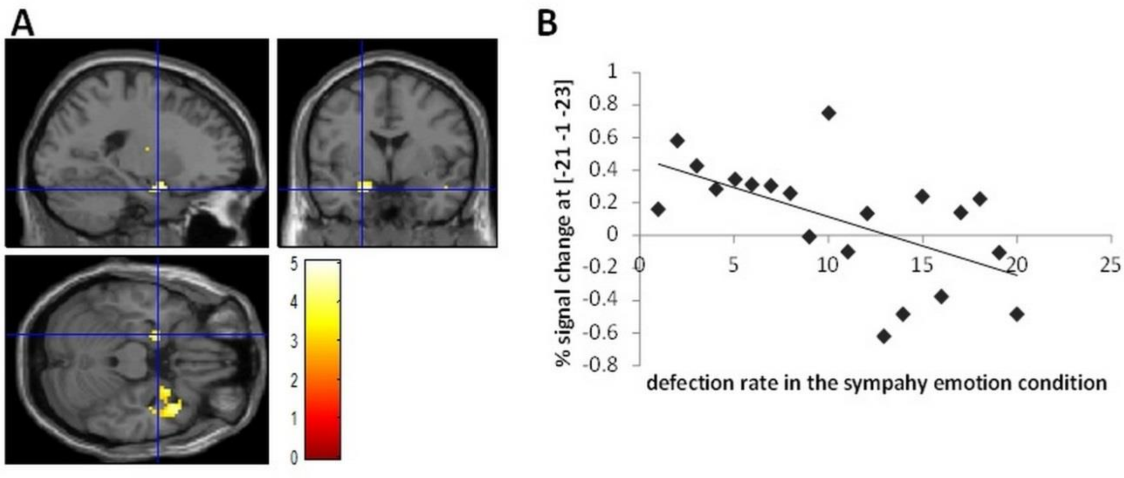

Figure 6.4: Contrast [sympathy (defection – cooperation) > neutral (defection - cooperation)] (*A*) *left amygdala activation overlaid on the MNI single subject brain;* (*B*)

correlation between the percent signal change at the left amygdala and the defection rate in the sympathy condition ($r = -.46, p = .039, N = 20$)

The reversed contrasts [sympathy (defection – cooperation) < neutral (defection - cooperation)] equivalent to [sympathy (cooperation - defection) > neutral (cooperation - defection)] did not show any significant activation at a combined threshold $p < 0.005$ and k = 20.

Sympathy (defection vs. cooperation) vs. anger (defection vs. cooperation)

Finally, in the last contrasts the interaction between the defection and cooperation between the sympathy and the anger emotion conditions revealed activation in the left putamen in the contrast [anger (defection – cooperation) > sympathy (defection – cooperation)] (or equivalent [sympathy (cooperation – defection) > anger (cooperation – defection)]; AlphaSim $P_{\text{FWE}} < 0.05$). The reversed contrast [sympathy (defection - cooperation) > anger (defection - cooperation) equivalent to anger (cooperation - defection) > sympathy (cooperation - defection)] showed activation in the left medial frontal gyrus (BA 10) (AlphaSim $P_{\text{uncorrected}} < 0.04$).

6.6 Discussion

In this study participants' performance on the Prisoner's Dilemma was recorded while they were in an fMRI scanner. The study yielded two main results. First, participants' defection rate significantly decreased from neutral to sympathy as well as from anger to the sympathy emotion condition. There was a trend for an increase in defection rate from the neutral to the anger condition. Secondly, the imaging data yielded increased percent signal change in the left amygdala activity for the contrasts signifying higher activity for defection compared to cooperation choices in the sympathy condition, compared to the neutral condition. The similar contrast comparing defection in the anger condition versus the neutral condition showed decreased activity in the left putamen. The decrease was lower during cooperation compared to defection trials, while in the neutral condition the percent signal change during cooperation and defection was similar.

Behavioural results

The self-report emotion questionnaire showed that emotion induction was successful and the targeted emotions in this experiment were associated with three factor loadings from the principal component analysis. These three factors, representing more than 10% of the variance each, together explained more than a half of the variance of the questionnaire and the results are consistent with Experiments 2 and 3. The first factor loading revealed that sympathy is a complex emotion and includes a variety of emotional experiences. In particular, the feelings of sadness (feeling low, upset, sad, sorrowful) and empathic concern (compassionate, worried, soft hearted, alarmed) or the impact of the other individuals' emotional state has on the participant himself/herself (moved, guilty, grieved, troubled, distressed). The second factor loadings are the most associated with the anger emotion. Emotional reaction to the negative comments from the other "participant" triggered feelings that are commonly described as related to anger (hostile, mad, furious, etc.) and fear (perturbed, nervous). The final factor displayed emotions associated with the neutral emotion condition (content, tranquil), and, as expected, also those going towards positive emotions (happy, glad, satisfied, etc.).

Participants' responses in the Prisoners Dilemma game revealed a pattern of emotional influence on their decisions. The defection rate significantly decreased from the neutral to the sympathy conditions, and the increase from the neutral to the anger emotion condition was a trend. In addition, the interaction between the defection rate in the three emotion conditions and cognitive inhibition or emotion regulation (expressive suppression and cognitive reappraisal) were not significant. One possible explanation for this interaction not being significant is that participants in this study were medical personnel who are possibly better at controlling their actions compared to students or individuals from the general public. In fact, comparing the d' score of participants in this study with students who took part in the previous experiment, the medical personnel have a significantly higher d'.

Furthermore, as this profession is care related, the stronger influence of the sympathy condition on decision-making might be due to their professional skills. Compassion and empathy are desirable skills in nurses and health-care workers as they need to interpret and understand the feelings of the patients as well as demonstrate compassion for their condition (Morse, 1991). In a study by Zhang and colleagues (2001), 50 experienced nurses had to report difficult situations describing what they were feeling and wanting to do, and what they actually did, as well as reporting the outcome of the situation. The researchers coded the responses and calculated frequencies of the competencies from the situations with a positive outcome. Among the ten competencies leading to a successfully solved situation were compassion, an inclination to share feelings and concern for the others' well-being, and self-control; the ability to restrain negative actions, remain calm and in control of their behaviour in a stressful situation (Zhang, Luk, Arthur, & Wong, 2001). Due to these professional characteristics, the participants' might have shown a stronger response towards the sympathy condition compared to anger, as they are expected to be more compassionate as well as controlling their negative emotions.

Imaging results

Imaging results in the interaction between emotion condition with the participant's choice in the Prisoner's Dilemma indicated areas previously reported to be involved in human social interactions - the left putamen, and the left amygdala (Bechara & Damasio, 2005; Castelli, Happé, Frith, & Frith, 2000; Gallagher & Frith, 2003; Hsu et al., 2008; Partiot, Grafman, Sadato, Wachs, & Hallett, 1995; Rilling et al., 2004).

The left putamen

In the left putamen, the anger conditions percent signal change was negatively correlated with the defection rate in the anger condition. Naturally, if participants perceived their opponent to be aggressive and hostile (as it is shown from the self-report emotion questionnaire), they expected defection from the other, and, thus, chose their actions accordingly. However, mutual cooperation over time is more beneficial than defection and participants tend to shift their behaviour towards cooperation (Kollock, 1998; Komorita & Parks, 1999). In the current study, suppressing left putamen activation enabled participants to consider an alternative to defection as is evident from the correlation with percent signal change in the left putamen and the defection rate in the anger condition. As a result, in the anger condition, the left putamen suppression shows overcoming emotional impulse and choosing cooperation as a more optimal choice.

Past studies show putamen activation not only in monetary and non-monetary reward processing (Elliott, Newman, Longe, & Deakin, 2003; Haruno, 2005; Siep et al., 2009) but also deactivation predicting participants' losses, regardless if it is monetary loss or just an increased error rate (Bjork, 2004; Verney et al., 2003). In the Monetary Incentive Delay task the putamen showed deactivation after the trials that resulted in monetary losses (Bjork, 2004) as well as after high error rates while making guesses on which side of the screen a target stimulus will appear (Verney et al., 2003). Therefore if participants feel that they might lose, the activity in this brain region decreases. In the current study to overcome emotion impulse, participants show suppressed activity in the left putamen allowing them to consider an alternative option going against the experienced emotion, that is cognition overrides the feeling. As cooperation is a more "rewarding" option in society (Kollock, 1998; Komorita & Parks, 1999), being a rational individual one would realise that reciprocated cooperation is beneficial to both parties and expect the other "individual" to realise this too. However, as participants did not receive the feedback from the interaction, they could not confirm or reject their assumptions about the other "individual's" choices so the possibly of losing remained until the end of the interactions. As a result, the participants in the anger condition felt they might lose, but managed to overcome this feeling and engage in shifting towards cooperation.

The left amygdala

The contrast [sympathy (defection - cooperation) > neutral (defection – cooperation)] displayed activation in the left amygdala. It can be expected (as evident from the self-report questionnaires) that in the sympathy condition participants would experience an increased negative affect due to feeling sad and compassionate for the "other" and as a result choosing a selfish decision – defection – would increase it as this choice is costly for the "other".

The amygdala activation has been claimed to be involved in moral decision-making (Greene, Nystrom, Engell, Darley, & Cohen, 2004). The amygdala is part of the human reinforcement expectancies system (expectancies about reward or punishment) which is involved in learning the signs of distress of others and in this way guiding individuals from antisocial behaviour (Blair, 2007). In the Ray et al., 2005 study participants viewed pictures (negative and neutral) and were asked to either increase the negative affect, decrease it or do nothing. When participants were asked to increase their negative affect, amygdala activation increased and it correlated with their rumination scores. In the current study, it is possible that the amygdala guided participants from the antisocial behaviour (defection), and the more they thought and felt guilty about the defection choice, the stronger the amygdala response was. This is confirmed by the negative correlation – the less that the participants defected, the stronger the percent signal change was in the defection trials.

In the neutral condition the activation pattern was reversed; the amygdala activation was stronger in the cooperation trials and decreased in defection. In the context of the Prisoner's Dilemma, the biggest possible loss occurs when the participant chooses to cooperate and their opponent simultaneously chooses to defect. On the other hand, choosing defection would result either in the biggest possible win or in a small loss. This finding is consistent with the previous research where the left amygdala has been found to be involved in generating, processing and maintaining fear related responses and detecting untrustworthy individuals in social situations (see Adolphs, (1999) and Phan, Wager, Taylor, and Liberzon (2002)) as well as detecting rewards in decision-making tasks (Winston, Strange, O'Doherty, & Dolan, 2002). According to the Somatic Marker Hypothesis, lesions in the bilateral amygdala prevent individuals from feeling pain when they are experiencing losses in decision-making games. That is, they do not experience pain or regret having lost all their money, and do not change the decisions which drove them to that situation (Bechara & Damasio, 2005). In this case, cooperation is a more risky choice as there are moderate winnings/highest losses, so participants might have decided that cooperation would increase the possibility of monetary loss, and, as a result, the amygdala was activated by the prediction of regret.

Although areas activated in the current study show that participants were engaging in social interactions and their responses were affected by the emotion condition, the reaction times also contribute to the investigation of emotional effects on decision-making. The percent signal change was the lowest in the anger defection trials, and, in addition, the reaction times for the defection trials were the shortest, while on cooperation trials participants took more time to make this decision. In moral dilemma tasks when participants had to make hard choices about appropriate actions (to push one person from the bridge to save five others) it took longer than dilemmas where the choices were easier (push the lever to save five individuals; Greene et al., (2004)). Greene and colleagues suggest that in moral reasoning and decision-making increased reaction times means that individuals are considering emotional impulse and engaging in abstract reasoning controlled by cognition. In the current study, anger emotion showed differential activation compared to neutral emotion in the left putamen, and their reaction times were shorter for defection than for cooperation trials, though it was not significant. Indeed, the left putamen has been found to be involved in the cognitive control tasks as well as reward processing. Padmala and Pessoa (2011) asked participants to perform on the stop signal task, and one of the regions active during signal inhibition was the putamen (Padmala & Pessoa, 2010). On the other hand, participants took more time deciding to defect than to cooperate in the sympathy condition. The left amygdala is not only activated by negative emotion, but also involved in cognitive reappraisal of emotion and working memory (Goldin, McRae, Ramel, & Gross, 2008; Koch et al., 2007; Ochsner et al., 2004; Schaefer et al., 2002). This goes along with the interpretation suggested by Greene et al. (2004) that if decisions are made quickly, the individual might have acted under emotional impulses, but longer reaction times are affected by abstract thinking influenced by cognitive control.

This is consistent with the idea that low cognitive control participants tends to rely on intuition and heuristics more (Kahneman & Frederick, 2002; Stanovich & West, 2000; Sunstein, 2005). In addition, according to the dual system framework (Evans, 2008), Type I reasoning results depend on emotions, intuitions and past experiences and it is a quicker decision-making process, while Type II is a slower process and engages analytical thinking that relies on working memory and intelligence (Stanovich et al., 2011). In the context of this study, it supports the left putamen being responsible for overcoming an emotion by engaging in analytical thinking in the anger condition, while the left amygdala is involved in giving in to the sympathy emotion.

The current study shows that the effects of sympathy and anger on decision-making are represented by activation in the prefrontal areas and, in particular, in the left putamen and the left amygdala. In addition, reaction times for decisions when participants go against their emotional impulse increase, suggesting that participants are engaging in rational thinking while considering their choices and realizing that their behaviour might have been affected by emotional impulses. Due to the profession of the participants (health care personnel), the behavioural response might have been shifted strongly towards the sympathy condition. At the neural level the anger condition showed the stronger effect on the left putamen and sympathy in the left amygdala suggesting that both emotions have strong neural appearance and those two emotions compared to neutral emotion were showing a differential effect. However, expected activation in the orbital-frontal cortex and the ventromedial prefrontal cortex was not observed at set threshold in the contrast involving interaction between the emotion conditions and participants’ choices. Although the possibility that the task did not activate these areas can’t be rejected, an alternative explanation is that EPI pulse sequence that was not optimised to record orbitofrontal brain areas leading to dropouts near sinuses. To investigate the role of the vmPFC/OFC future studies with patients having lesions in these areas are necessary. However, due to time constraints and costs the study reported in the next chapter used archived patient data to analyse disjunctive reasoning with emotional and neutral content in a brain damaged-sample.

Chapter 7 Experiment 5: Lesions of vmPFC Selectively Impair Disjunctive Reasoning with Emotional Content

7.1 Overview

The fMRI study in Chapter 6 did not show the expected activation in the OFC and vmPFC and it was decided to explore how lesions in these areas affect individual's reasoning with emotional content. Both disjunctive operators and decision-making rely on deductive reasoning and, although viewed as two separate research fields, can be investigated together. This chapter aims to explore the role of the vmPFC and OFC in solving exclusive disjunctions with neutral and emotional content.

7.2 Introduction

In the previous study it was expected that brain activation would occur in the OFC and vmPFC during emotional decision-making, although the results did not indicate significant activation in these areas. However, knowing that these areas are involved in decision-making under emotion (Anderson et al., 2000; Bechara, 2000; Bechara & Damasio, 2005; Bechara et al., 1999; Damasio, 1994; Goel & Dolan, 2003; Sanfey et al., 2003), a question about the vmPFC and OFC's role in emotional decision-making was left unanswered in the previous experiment. However, due to time constraints not being able to test patients with the current paradigm, archival patients data with disjunctive operators with neutral and emotional content was analysed.

Reasoning and decision-making for a long time were investigated as separate fields, however, at the moment there is a tendency to study them together (Evans, 2012; Johnson-Laird & Shafir, 1993). In the current thesis there are a few reasons why, in addition to the social exchange decision-making, reasoning with emotional content is investigated. First, both paradigms are looking at emotional influences on participant choices. Second, both of them are based on deductive reasoning. Therefore the underlying logic processes are the same (Legrenzi et al., 1993). Third, the Prisoner's Dilemma, as well as disjunction operators have similar cognitive load as the presented choice for the individual in the Prisoner's Dilemma and the exclusive disjunctions is very similar. While in the Prisoner's Dilemma one has to choose either defection *or* cooperation, in the exclusive disjunction the individual has to make a choice depending on the premise (“A *or* B but not both”).

Past studies in neurological patients demonstrated that a balance between emotional and reasoning processes is necessary to achieve normatively correct answers in reasoning tasks. In particular, patients with damaged orbital frontal and ventromedial prefrontal areas were found to have difficulties in emotion processing and showed ineffective decision-making in gambling tasks, although their logical reasoning abilities were not disrupted (Bechara, 2000; Bechara, 2004; Bechara & Damasio, 2005; Clark et al., 2007; Gläscher et al., 2012). Additional evidence for the differential role of frontal cortical areas comes from Goel and Dolan (2003) who investigated brain activity in healthy participants during reasoning with emotionally charged and neutral syllogisms. They observed that compared to neutral syllogisms reasoning on emotionally charged syllogisms activated the ventromedial prefrontal cortex bilaterally (vmPFC; BA 11/25), while the left dorsolateral prefrontal cortex (BA 44, 8) was suppressed. Furthermore, reasoning processes have been shown to involve activation in mainly left but also bilateral fronto-parietal brain networks including BA 6 and BA 44 during reasoning with emotionally neutral content syllogisms (Goel & Dolan, 2003; Goel et al., 2000; Goel, Gold, Kapur, & Houle, 1998; Knauff, Mulack, Kassubek, Salih, & Greenlee, 2002; Prado, Chadha, & Booth, 2011). Taken together, there is clear evidence, that the ventromedial prefrontal cortex is specifically implicated in reasoning with emotional content, as pure reasoning (neutral content) does not activate this area.

It is therefore conceivable that reasoning with emotional content depends on an intact ventromedial prefrontal cortex. Thus, it is predicted that lesions to the vmPFC and orbital frontal areas (BA 10 and BA 11) will result in impaired reasoning with emotional content but not neutral content compared to normal and patient controls with lesions in parietal areas (mainly BA40) whose performance is not expected to differ. Furthermore, the differences were expected to emerge in the incongruent trials as opposed to congruent due to the belief bias effect - reasoning about the real world is influenced by the participant’s experience and knowledge (Evans, Barston, & Pollard, 1983). To test these predictions, 20 patients with vmPFC lesions, 23 patients with parietal lobe lesion and 23 normal controls were tested in a disjunctive reasoning task involving emotional and neutral content.

7.3 Methods

7.3.1 Participants

Participants were drawn from the Phase III of the Vietnam Head Injury Study (VHIS) registry. This registry contains data from Vietnam war veterans who served in Vietnam in the late 1960's and early 1970's (Barbey et al., 2012; Grafman et al., 1988; Koenigs, Barbey, Postle, & Grafman, 2009; Raymont et al., 2010). Patients for this study (N = 92) were matched in terms of age, education and neurological assessment scores with normal controls (N = 23), who also served in Vietnam. The lesion volumes ranged from 1cc to 97.13cc, but were not larger than 75cc in a single hemisphere. Thirty-eight patients had unilateral right-brain damage, 31 unilateral left-hemispheric damage, and 23 patients had bilateral lesions. The location of lesions varied between patients, although the majority showed prefrontal, temporal or parietal damage. A lesion overlay plot is given in Figure 7.1. The language, motor and sensory functions of the patients were sufficiently intact to take part in the experiment (see also Cognitive Assessment for details).

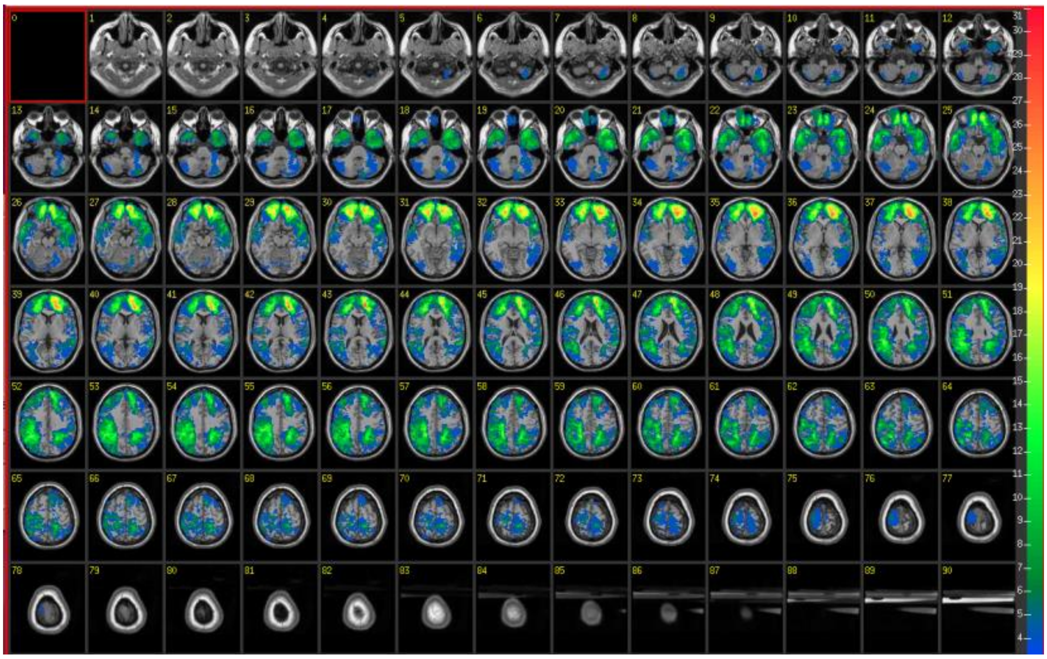

Figure 7.1: Lesion overlay of all 95 patients. The colour bar indicates the number of patients with lesion in that area. Images are shown following radiological convention (Left = Right, Right = Left).

7.3.2 Lesion assessment

Patients CT axial scans without contrasts were acquired at Bethesda Naval Hospital on a GE Medical Systems Light Speed Plus CT scanner in helical mode (150 slices per subject, field of view covering head only). Images were reconstructed with an in-plane voxel size of 0.4 x 0.4 mm, overlapping slice thickness of 2.5 mm, and a 1 mm slice interval. A trained psychiatrist with clinical experience in neuropsychological testing manually traced lesions in all relevant slices of the CT scan images in native space. Following this the investigator (J.G.), blind to the results of the psychological testing, reviewed the lesions.

Spatial normalization to a CT template brain in MNI space was achieved stepwise: first, all non-brain tissue was automatically removed using the BET algorithm in MEDx (Medical Numerics). Following this, the automated image registration (AIR) algorithm (Woods, Mazziotta, Cherry, & others, 1993) using a 12-parameter affine linear transformation was applied to individual brain volumes allowing for translation, rotation, scaling and shearing to normalize the volume to a reference template volume of an MRI of a 27-year-old normal male, which was later transformed to Talairach space using a 12-parameter affine linear transformation. The lesion voxels in the normalization process were not included. Lesion location and volume were determined from CT images using the Analysis of Brain Lesion software (ABLe; Makale et al. (2002), Solomon, Raymont, Braun, Butman, and Grafman (2007)) contained in MEDx v3.44 (Medical Numerics) with enhancements to support the Automated Anatomical Labelling atlas (Tzourio-Mazoyer et al., 2002). The resulting normalised lesion mask was used in the VLSM analysis for each subject.

7.3.3 Cognitive assessment

In order to assess the patients' cognitive, emotional and psychological functioning, the Wechsler Adult Intelligence Scale (WAIS-III, (Wechsler, 2008)), the Wechsler Memory Scale (WMS-III,(Wechsler, 1997) the Beck's Depression Inventory (BDI) and the Structural Clinical Interview for DSM-IV (SCID), were administered. In addition, pre-injury intelligence was assessed with the Armed Forces Qualification Test (AFQT-7A) conducted upon their entry into the military. This test has been standardised within the U.S. military and the scores are found to be positively correlated with WAIS IQ scores (Grafman et al., 1988). The scores of this test are given as percentiles (Table

8.1). There was no significant difference between patients and normal controls in any of these measures (independent t-tests (corrected for homogeneity violations), $t(113) \leq 1.50$, $p \geq .135$). All the patients were right-handed males and aged between 52 and 70 years (Table 7.1).

Table 7.1: Demographic and assessment data for patients and normal controls. Mean percentiles (SD) are provided for Pre-injury IQ (AFQT-7A) and means for the rest of the results

	Patients	Normal Controls
N	92	23
Age	58.17 (2.51)	58.69 (2.96)
Education (years)	14.91 (2.31)	14.23 (1.97)
Verbal IQ (WAIS)	106.16 (13.34)	104.61 (10.17)
Performance IQ (WAIS)	101.13 (14.81)	106.13 (11.41)
Full Scale IQ (WAIS)	104.59 (13.31)	105.61 (8.39)
Working Memory (WMS)	101.17 (12.92)	104.57 (13.06)
Pre-injury IQ (AFQ T-7A)	61.47 (25.24)	62.05 (21.04)
BDI	8.47 (8.60)	10.22 (8.96)
SCID	75.87 (13.73)	73.87 (11.38)

7.3.4 Tasks

Participants were presented with 8 exclusive disjunctions distributed among other operators. Exclusive disjunctions were constructed so that the first premise included an exclusive ‘or’, for example “Either there exist pink elephants or white mice, but not both”. The disjunctions differed in their emotional content being either emotional or neutral resulting in overall 4 emotional trials, and 4 neutral trials. All emotional content was negatively valanced. Examples of emotional and neutral exclusive disjunctions can be found in Table 7.2 (see Appendix D on page 220 for the complete list of items).

The disjunctive items were counterbalanced to include an even number of congruent (believable and valid or unbelievable and invalid) and incongruent items (unbelievable and valid or believable and invalid). As a result, there were two congruent emotional trials, two incongruent emotional trials, two congruent neutral trials and two incongruent neutral trials. The presentation order of the neutral and emotional disjunctions was counterbalanced between-subjects, and the order of disjunctions within neutral or emotional content disjunctions was randomised

Table 7.2: Examples of emotional and neutral exclusive disjunctions by content

	Emotional Disjunction	Neutral Disjunction
Congruent	Either in Korea there are edible dogs or opossums, but not both.	Either there are Christians or atheists in America, but not both.
	In Korea there are no opossums.	There are no Christians in America.
	In Korea there are edible dogs.	There are no atheists in America.
Incongruent	Either there are paedophiles or politicians in Texas, but not both.	Either there exist pink elephants or white mice, but not both.
	There are politicians in Texas.	There are no white mice.
	There are no paedophiles in Texas.	There are pink elephants.

7.3.5 Procedure

At the start of the experiment, the task was explained to the participants along with the concept of argument validity. The stimuli were presented on a computer screen (pixel resolution 512 x 384) with SuperLab v1.5 Software. In each trial participants were shown two premises and a conclusion at the same time, for example:

Premise 1:“Either there exist pink elephants or white mice, but not both.

Premise 2: “There are no white mice.”

Conclusion: “There are pink elephants.”

Task instructions were presented in writing informing the participants that their task was to determine if the third sentence followed logically from the first two. If it did, participants had to press the designated “yes” key, and if not they had to press the designated “no” key. Each trial remained on screen until response which triggered the next trial. Participants were encouraged to be as accurate and as quick as possible, but there were no time constraints. All participants completed all the trials.

After completion of the reasoning task, participants were given a break with no limited time and then the conclusions (3^{rd} sentences) of the arguments were presented once again on screen. The participants gave belief on the scale from 1 to 5, where 1-represented very unbelievable and 5-represented very believable. These ratings were used to control for the belief bias effect.

7.3.6 Congruency reclassification

Although the disjunction items were balanced prior to the experiment to include an even amount of congruent and incongruent items, they were re-classified after the experiment based individually on each participants' belief rating for each of the conclusions. For all trials where participants indicated a belief rating of 3, the initial congruency classification was maintained, but the invalid trials which participants indicated to be unbelievable (ratings of 1 or 2) and valid trials that were rated believable (4 and 5) were classified as congruent. Conversely, ratings of 1 and 2 for valid trials and ratings of 4 and 5 for invalid trials were classified as incongruent. In order to account for variations in the number of congruent valid/ invalid, and incongruent valid /invalid items, the average rating score was weighted (for example exclusive emotional = (emotional congruent valid + emotional congruent invalid + emotional incongruent valid + emotional incongruent invalid)/4).

7.3.7 Analysis

The data were analysed in two steps: in the first step, voxel based lesion symptom mapping (VLSM) using MEDx was performed to create the patient groups. In a second step, the interaction between patient groups and their performance on the disjunction task was explored.

7.4 Results

7.4.1 Constructing lesion groups with VLSM

First, all patients were included in an VLSM analysis (Forbes et al., 2014); Solomon, Raymont, Braun, Butman, & Grafman, 2007). This analysis correlates patients' behavioural scores with their lesion status (grey and white matter density). Five contrasts for the behavioural scores were entered: the mean correct responses for all exclusive disjunctions, the mean correct responses for emotional and neutral exclusive disjunctions separately, and the mean correct responses separately for congruent and incongruent exclusive disjunctions. For each whole brain voxel, the analysis grouped patients into those who showed a lesion in a particular voxel vs. patients who did not. Subsequently, independent t-tests were performed to determine whether patients with a lesion in a particular voxel differed behaviourally from normal controls (Solomon et al., 2007). A false-discovery rate (FDR) correction of 0.05 was applied for multiple comparisons. The minimum cluster size was set to 10 voxels and only those voxels where at least four patients showed overlapping lesions were used for the analysis.

The VLSM analysis with an initial automated anatomical labelling (AAL) indicated significant results for the emotional and neutral content trials. The analysis for the emotional content trials revealed that patients having lesions to the right and left ventral medial frontal areas, mainly BA 11 and BA 10 (Talairach coordinates [-22 38 -18], [-28 26 28] and [44 56 12]) performed poorly in emotional exclusive disjunctions compared to normal controls and other patients ($U = 72.00$, $p < .001$ and $U = 204.00$, $p < .001$, respectively). Analysis for the neutral trials indicated patients with right parietal lesions affecting mainly BA 40 and BA 7 (Talairach coordinates [34 -36 56] and [42, -60 50]) to perform poorer than normal controls and patients with other lesions, however this difference was not significant ($U > 212.00$, $p > .234$). As the main interest of the study was focused on the emotional content, parietal lobe patients were used as a patient control group. Furthermore, to make the parietal lobe patients group more comparable with the patient group having lesions in the ventromedial prefrontal areas, patients with lesions to the left parietal structures (BA 40; N = 6) were included in the parietal lobe group (Figure 7.2 B). Overall, the consequent analysis consisted of 20 vmPFC group patients and the PL group consisted of 23 patients (Figure 7.2)

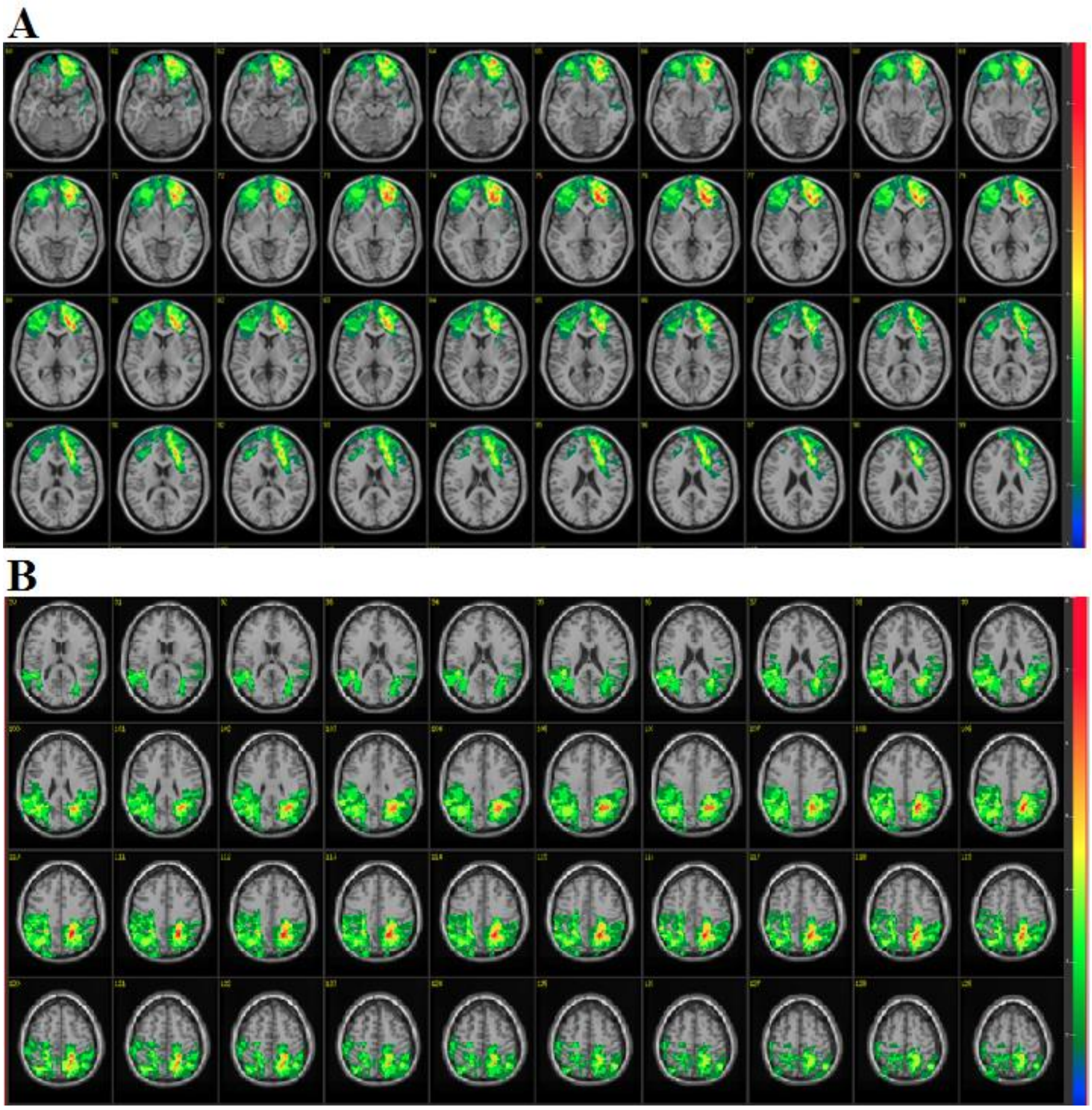

Figure 7.2: Lesion overlay maps for patients displayed on the VOTL Atlas found in ABLe software with overlap threshold of 2. (*A*) *Slices 60 - 99 of ventromedial lesion patients group* (*n = 20*)*;* (*B*) *Slices 90 - 129 of parietal lesion patients group* (*n = 23*)*. Images are presented in radiological convention* (*Left = Right, Right = Left*)*.*

In addition, group comparisons of lesion volumes (cubic centimetres in total, left right hemisphere) between vmPFC and PL patients (independent t-test, 2-tailed, alpha = .05) showed only a trend towards larger lesions in the left hemisphere for the vmPFC group (t(41) = 1.90, p = .065) but no other significant group differences (t(41) ≤ 1.03, p ≥ .309; Table 7.3).

Table 7.3: Lesion information for unilateral and bilateral patients in vmPFC and PL groups

	vmPFC		PL	
	unilateral	bilateral	unilateral	bilateral
Right Hemisphere	19.41 (17.74)	20.68 (25.68)	18.79 (9.27)	16.2 (23.19)
Left Hemisphere	32.03 (16.74)	44.21 (18.26)	35.42 (25.04)	25.78 (20.36)
Total	28.66 (17.35)	64.77 (21.93)	25.47 (17.80)	44.68 (38.28)
N	13	5	17	6

In order to control for possible confounding variables, potential differences between the 3 groups (vmPFC, PL, NC) with respect to education, BDI, SCID, pre-Injury IQ, WAIS Verbal IQ, Performance IQ and Full IQ, and WMS Working Memory Primary Index Scores were tested with a one-way ANOVAs for each test separately. The ANOVA results were approaching significance for Education ($F(2, 62) = 3.12$, $p = .052$) and a trend towards significance for the WMS Working Memory Primary Index Score ($F(2, 63) = 2.67$, $p = .077$), but there were no significant differences in any of the other measures ($F(2, 65) \leq 2.33$, $p \geq .106$; Table 7.4).

The *post-hoc* comparison with independent t-test showed that although the number of years of education for the vmPFC participants was less than PL and NC, it did not significantly differ ($t(39) \leq 2.11$, $p \geq .041$; Bonferroni-corrected for multiple comparison, alpha = .017). Similarly, comparisons between the WMS Working Memory Primary Index Scores did not yield any significant group differences ($t(40) \leq 2.17$, $p \geq .036$; Bonferroni-corrected for multiple comparison, alpha = .017)

Table 7.4: Clinical and demographic information (SD) from vmPFC, PL and NC samples

	vmPFC	PL	NC
Number of Patients	20	23	23
Age (years)	57.60 (1.39)	59.08 (2.94)	58.69 (2.96)
Education (years)	14.07 (1.92)	15.59 (2.55)	14.22 (1.97)
Pre-injury IQ (AFQ T-7A)	49.63 (23.01)	62.00 (26.44)	62.05 (21.04)
WAIS			
Verbal IQ	99.00 (12.49)	105.74 (13.13)	104.61 (10.17)
Performance IQ	98.21 (11.97)	102.74 (16.25)	106.13 (11.41)
Full Scale IQ	98.58 (11.01)	104.78 (13.81)	105.61 (8.39)
WMS Working Memory Primary Index Score	95.53 (13.83)	100.82 (10.99)	104.56 (13.05)
BDI	10.55 (9.26)	6.61 (5.59)	10.22 (8.96)
SCID-GAF	73.50 (20.46)	78.26 (11.53)	73.87 (11.38)
Total Volume Loss (cc)	37.69 (24.09)	29.88 (25.38)	0

WAIS = Wechsler Adult Intelligence Scale; WMS = Wechsler Memory Scale; BDI = Beck Depression Inventory; SCID-GAF = Structural Clinical Interview for DSM-IV – Global Assessment Function; vmPFC = Ventromedial Prefrontal Cortex; PL = Parietal Lobe; NC = Normal Controls

7.4.2 Statistical analysis of exclusive disjunctions by group

As the first step analysis did not allow investigation of the interactions between variables, in the second stage of the analysis, the interaction between emotional and neutral content with patients groups was explored using a non-parametric statistical analysis. Non-parametric tests were used for the behavioural scores due to the small number of trials in the task (as has been done previously by e.g. Brosig (2002), Falk et al. (2005)) and because the data was not normally distributed. The dependent variables were correct responses and response times for correct responses in the exclusive disjunction task. The independent variables were Content (Emotional, Neutral) and Group (ventromedial prefrontal cortex (vmPFC), parietal lobe (PL), normal controls (NC)) as determined by the VLSM analysis. A two-way mixed non-parametric

Friedman ANOVA was carried out. Significant main effects and interactions were followed-up by non-parametric post-hoc tests; between-subject differences were explored with planned Mann-Whitney *U* tests adjusted for multiple comparisons (Bonferroni-corrected, alpha = .017, two-tailed).Wilcoxon Signed-Rank tests were used for evaluating within-subject differences.

Overall accuracy in the exclusive disjunctions was 0.67 (vmPFC: Mean = 0.56, SD = 0.15; NC: Mean = 0.76, SD = 0.16; PL: Mean = 0.68, SD = 0.18), indicating that participants were performing above chance level and were engaged in the reasoning task.

Emotional Content by Group: Mean Accuracy Scores

For Disjunctive items a non-parametric mixed design Friedman's ANOVA with the within factor Content (Neutral, Emotional) and the between factor Group (vmPFC, PL, NC) was performed. The results yielded a significant main effect of Group and Content x Group interaction (Q = 5.62, p = .008 and Q = 5.60, p = .009, respectively), but there was no significant effect of Content (Q = 0.67, p = .416; Figure 7.3).

The analysis of the main effect of Group with Mann-Whitney tests revealed a significantly lower accuracy for vmPFC than NC (vmPFC: Mean = 0.56, SD = 0.15 vs. NC: Mean = 0.76, SD = 0.16; U = 90.00, p = .001;) and a trend difference between vmPFC and PL (PL: Mean = 0.68, SD = 0.18; U = 143.50, p = .033; Bonferroni-corrected for multiple comparisons two-tailed alpha = .017). There was no significant difference between PL and NC accuracy rates (U = 204.50, p = .182).

To investigate the Group x Content interaction further, a post hoc between-subject analysis was performed. The comparisons showed significantly lower accuracy rates for vmPFC vs. PL (vmPFC: Mean = 0.48, SD = 0.22; PL: Mean = 0.75, SD = 0.26; U = 102.00, p = .001) and vmPFC vs. NC (NC: Mean= 0.81, SD = 0.22; U = 72.00, p < .001). There was no significant, difference between PL and NC (U = 236.00, p = .505). For the Neutral Content the group comparisons between the three groups yielded no significant result ($U \leq$ 212.00, $p \geq$ .234). In these trials the mean accuracy in the PL group was 0.61 (SD = 0.24), in the vmPFC group the mean was 0.64 (SD = 0.18) and 0.70 (SD = 0.15) in the NC group.

To test for differences in accuracy rates between Emotional and Neutral content items, a Wilcoxon Signed Rank test was performed for each group. A significant decrease in correct answers from Neutral to Emotional items was found for the vmPFC group (Z = -2.46, p = .014). Conversely, the opposite pattern of a significant increase in accuracy from Neutral to Emotional items in NC was found (Z = -2.28, p = .022). The PL group showed no significant accuracy change related to emotional content (Z = -1.63, p = .103; Figure 7.3).

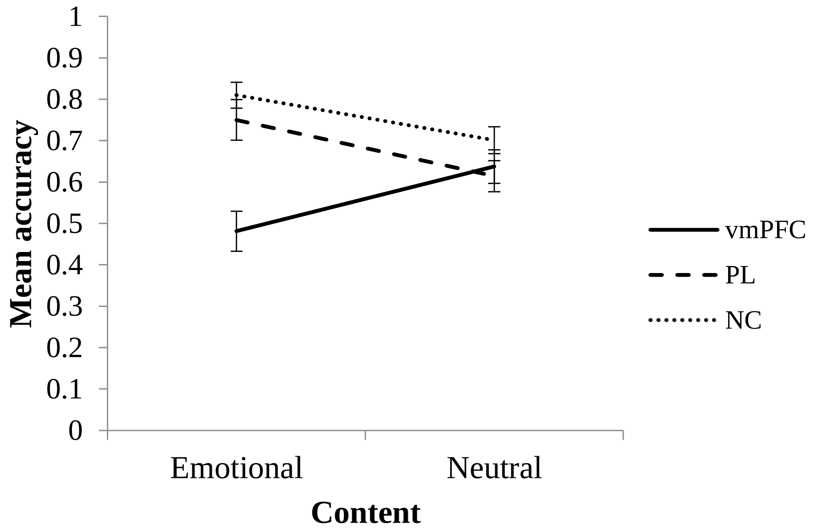

Figure 7.3: Mean accuracy rates (*±1SEM*) *for Exclusive Disjunction items with Emotional versus Neutral Content for neurological patients* (*vmPFC, PL*) *and normal controls* (*NC*).

Emotional Content by Congruency by Group: Mean Accuracy Scores

To investigate if Congruency of the Disjunction items can help to explain the interaction effect between Content and Group, Disjunctions were separated into Congruent and Incongruent and analysed separately.

Congruent trials. A 2 x 3 Friedman's non-parametric mixed design ANOVA with the within-subject factor Content (Emotional and Neutral) and the between-subject factor Group (NC, vmPFC, PL) for Congruent items indicated a significant main effect of Group (Q = 4.20, p = .029), but the main effect of Content and the Group x Content interaction were not significant ($Q \leq 0.98$, $p \geq .331$).

The main effect of Group revealed that NC were significantly more accurate on the Congruent Disjunctions than vmPFC patients (NC: Mean = 0.92, SD = 0.25; vmPFC: Mean= 0.72; SD = 0.27; U = 111.00, p = .002), but the difference between vmPFC vs. PL or PL vs. NC were not significant (PL: Mean = 0.79, SD = 0.28; U = 180.50, p = .206 and U = 196.50, p = .083, respectively).

Incongruent trials. Friedman's ANOVA for the Incongruent trials revealed significant main effects of Group (Q = 4.95, p = .014) and Content (Q = 8.39, p = .006) as well as a significant Content x Group interaction (Q = 6.68, p = .004). *Post-hoc* comparisons for Emotional Content accuracy rates showed a significantly lower accuracy for vmPFC vs. NC (U = 95.00, p = .001) and. PL (U = 115.50, p = .003). In contrast there was no significant difference between PL and NC (U = 246.00, p = .652; Figure 7.4 A). The accuracy rate for the Emotional Incongruent trials in the NC group was 0.73 (SD = 0.36), the PL group 0.67 (SD = 0.39), and in the vmPFC mean accuracy was 0.33 (SD = 0.30). For Neutral Content there were no significant group differences (NC: Mean = 0.45, SD = 0.30; PL: Mean = 0.47 SD = 0.29; vmPFC: Mean = 0.48, SD = 0.28; $U \geq$ 193.00, $p \geq$ .507). The within group comparisons between Emotional Incongruent and Neutral Incongruent trials revealed a significant increase in accuracy rates between Emotional and Neutral items for the NC group (Z = -2.99, p = .003) and for the PL group (Z = -1.99, p = .047). The decrease in accuracy from Neutral to Emotional items for the vmPFC group was at a trend level (Z = -1.76, p = .079).

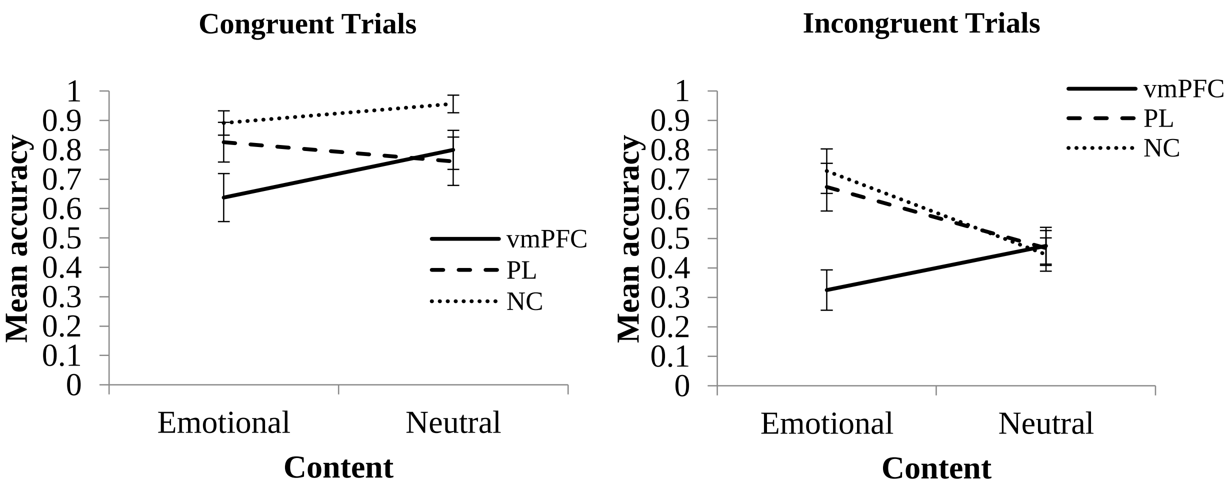

Figure 7.4: Mean accuracy rates (±1SEM) for (A) Exclusive Incongruent Disjunction items and (B) Exclusive Congruent Disjunction items as a function of Content (Emotional, Neutral) and group (vmPFC, PL, NC).

7.4.3 Response times

In order to evaluate if negative emotional content encouraged longer deliberations. Separate 3 (Group) x 2 (emotional content) Friedman ANOVAs were performed on the reaction times for Congruent and Incongruent disjunctions.

While no significant results were found for Congruent Disjunctions ($Q \leq 1.85$, $p \geq .184$), the analysis of Incongruent Disjunctions yielded a significant Group x Content interaction ($Q = 5.68$, $p = .012$). The main effects of Group and Content were not significant ($Q \leq 0.03$, $p \geq .963$).

A between-subject analysis showed that vmPFC, NC and PL groups did not significantly differ in reaction times neither in neutral nor in emotional content disjunctions. However within-subject analysis indicated that vmPFC participants were significantly quicker in Emotional trials compared to Neutral trials ($Z = -2.13$, $p = .033$). In contrast, NC response times were quicker for Neutral trials than for Emotional, yet this difference was only approaching significance ($Z = -1.92$, $p = .055$). No differences were found for the PL group ($Z = -1.538$, $p = .124$; Table 7.5).

Table 7.5: Mean response time (SD) for Neutral and Emotional trials from vmPFC, PL and NC samples

	Content	
	Emotional	Neutral
vmPFC	16765 (8265)	20442 (9270)
PL	19562 (8266)	18410 (9270)
NC	21643 (12617)	16767 (10408)

7.4.4 Belief strength

The possibility that the vmPFC groups impaired performance on the Emotional trials might be due to stronger (or weaker) participants belief in the provided conclusion was explored further. At first the mean belief rating for all disjunctions was calculated separately for each participant and then compared between groups. The vmPFC group's belief mean was 2.31 (SD = 0.52), PL mean was 2.29 (SD = 0.24) and the Normal Controls 2.19 (SD = 0.32). The between group analysis showed that there was no significant difference in belief strength between the groups ($\chi^2(2) = 1.48$, $p = .477$).

Subsequently, the belief ratings for valid and invalid conclusions were also compared without identifying a significant difference between the groups (valid conclusion: χ^2 (2) = 1.97, p = .374; invalid conclusion: χ^2 (2) = 0.30, p = .861). The mean ratings for valid items in the vmPFC group was 2.05 (SD = 0.66), for the PL group it was 2.03 (SD = 0.29) and for the NC group the mean rating was 1.85 (SD = 0.40). For invalid items the mean ratings for vmPFC, PL and NC were as follows – 2.62 (SD = 0.65), 2.55 (SD = 0.40) and 2.5 (SD = 0.47), respectively.

Taken together, there was no significant difference in belief strength between the groups that could have affected performance of the groups.

7.5 Discussion

The results of the current study show that, consistent with past studies with categorical syllogisms, patients with lesions to the ventromedial prefrontal cortex made more incorrect answers on emotional compared to neutral content. Furthermore, this study extends this result to exclusive disjunctive operators. Interestingly, both parietal lobe patients and normal controls showed the opposite pattern of increased accuracy in emotional compared to neutral trials. More specifically this effect was most evident for incongruent disjunctions.

These results can neither be explained by differences in age and education, nor by emotional or cognitive differences, as the vmPFC and PL patients did not significantly differ on any of these measures from each other or from healthy controls. Although vmPFC patients had slightly fewer years of education and lower scores on the WMS Working Memory Primary Index Score, the *post-hoc* analysis did not reveal these differences to be significant. This clearly indicates that patients had similar cognitive abilities and all three groups were similarly capable of solving the task. Furthermore, although the main effect of group was significant in the content by group analysis, it was driven by the emotional exclusive disjunctions, and the difference in accuracy in the neutral items was not significant. In addition, as the number of congruent and incongruent items in the task was weighted equally and the believability ratings were similar across the three groups, the possible explanation is that the findings are due to vmPFC lesions and this patient groups' performance on disjunctions with emotional content.

The decreased performance of the vmPFC group (having lesions in the vmPFC and OFC areas) in solving emotional disjunction items is consistent with the past literature emphasizing a critical role of the vmPFC in reasoning under emotional influence. Goel and Dolan (2003) found that emotional ("hot") reasoning was associated with increased activation in the bilateral ventromedial prefrontal cortex in healthy participants. In addition, bilateral orbito-frontal cortex (OFC) lesions were related to greater impulsivity and stronger expressions of negative emotion (Berlin, Rolls, & Kischka, 2004). The orbitofrontal areas are also involved in the cognitive control of emotion: the OFC seems to provide context-appropriate values in relation to specific situations or stimuli which are instrumental in selecting appropriate actions (K. Ochsner & Gross, 2005). The ventromedial prefrontal and orbito-frontal areas are also known to be involved in affective processing in decision-making (Bechara, 2000; Bechara, 2004; Bechara & Damasio, 2005; Clark et al., 2007; Gläscher et al., 2012), moral reasoning and moral decision-making (Greene, Sommerville, Nystrom, Darley, & Cohen, 2001; Moll et al., 2002). These regions are, however, not activated during logical reasoning tasks (Prado et al., 2011) which suggests that lesions in these areas would not affect reasoning ability significantly. It is therefore likely that these regions are required to filter the emotional content of logical arguments before these are passed on to the reasoning system. This provides an evidence based explanation of why vmPFC patients are impaired in solving syllogisms with emotional, but not neutral content.

In contrast, the performance of vmPFC patients in the neutral content trials was similar to the other two groups. This could be explained by the neural systems required for logical (neutral) reasoning being preserved in vmPFC patients. vmPFC patients have an intact left BA 44/45 and these areas are involved in disjunction reasoning with neutral content (Reverberi et al., 2007) and categorical syllogisms with neutral content (Goel, Buchel, Frith, & Dolan, 2000; Goel, Gold, Kapur, & Houle, 1998; Knauff, Mulack, Kassubek, Salih, & Greenlee, 2002). Also Goel and Dolan (2003) showed that the neural correlates associated with while reasoning in a neutral content ("cold reasoning") were the left dorsolateral prefrontal cortex. Taking everything into consideration, due to an intact BA 44/45, vmPFC patients performed on the neutral content disjunctions as well as PL and NC participants and their reasoning abilities in these trials were not impaired. This suggests that vmPFC patients were able to detect the conflict between belief and logical validity of the neutral disjunction, and to overcome the belief bias effect. Furthermore, the behavioural differences between the groups was driven by the incongruent but not congruent trials, even though the increase of accuracy rates from emotional to neutral trials was only a trend in the vmPFC group.

In addition, the performance of the normal controls and the parietal lobe group shows a reversed behavioural result compared to vmPFC; these participants had significantly more normatively correct answers in the emotional than neutral content incongruent trials. Although it is commonly assumed that emotion hinders reasoning, there are some studies suggesting that it can be enhanced by negative emotional content (Blanchette, Richards, Melnyk, & Lavda, 2007; De Jong et al., 1997; Gangemi, Mancini, & Johnson-Laird, 2013; Goel & Vartanian, 2011). Blanchette, Richards, Melnyk and Lavda (2007) showed that participants were more accurate in emotional incongruent syllogisms about the (at the time of the study) recent terrorist attacks in London. In addition, Goel and Vartanian (2011) and Goel et al., (2007) gave patients neutral and negative emotional categorical syllogisms to solve. Both studies showed that participants were overall more accurate on emotional incongruent trials compared to neutral incongruent trials.

In the Goel and Vartanian (2011) study the results were explained in terms of the affect infusion model (AIM; Forgas,(1995)), which suggests that negative emotions trigger more systematic processing of the information. The explanation is that emotional content creates an additional conflict which results in participants spending more time on thinking about the conclusion of the disjunctive operator. Additional time and effort while reasoning leads to evaluating the premise logically, that is, engaging in Type II process, and overcoming the belief bias effect. All this process leads to normatively correct answers. The AIM suggests that when individuals encounter a situation that does not evoke a strong affective response, they choose the easiest and fastest way to make their-decision (Forgas, 1995). On the other hand, if an individual experiences a highly affective response, it requires learning more about the new situation and is followed by relating the newly acquired information to pre-existing knowledge. Thus, if an individual approaches an incongruent trial that does not have an affective impact, the information will be processed quicker compared to the trials with high affective content. As a result, due to the need for considering new information in the incongruent trials it is more likely that the belief bias effect will be overcome in a time costly manner (Forgas, 1995).

Indeed the reaction time data in this study is consistent with this explanation. In this study normal controls spent more time on the incongruent emotional trials compared to incongruent neutral and this difference was approaching significance, whereas for vmPFC patients this response time pattern was reversed, as they were significantly quicker to respond to emotional than to neutral trials. Given that vmPFC lesions in the study patients included damage to the frontal-orbital areas, it is conceivable that their emotional processing was impaired which may have resulted in a lack of emotion contribution to the existing conflict between belief and reasoning item validity. Normal controls, on the other hand, had their emotional processes undisrupted resulting in a stronger conflict between emotional content, argument validity and participants' belief that induced more analytical processing of the disjunctions. Finally, although the response times of the PL patients did not differ significantly between emotional and neutral trials, they were still numerically quicker on neutral than on emotional disjunctions, providing additional support for the previous discussion.

The results of this study provide additional information as well as confirm reaction time results from the previous experiments in this thesis. To start with, this study provides evidence supporting the idea that not only the left amygdala and putamen, but also vmPFC and OFC could be involved in decision-making under emotion. Patients with lesions to these areas were performing worse on disjunctions with emotional content compared to parietal lobe patients and healthy controls. As both decision-making and reasoning processes depend on deductive logic it is highly likely that brain areas involved in one task would show activation in the other task also. Furthermore, performance of both tasks rely on the interaction between Type I and Type II processes. In general, reaction times data show that by spending more time on the emotional trials (either disjunctive operators, or while making their decision on the Prisoner's Dilemma) participants overcome emotional impulses to act in a certain way. In current study they give normatively correct answers in exclusive disjunctions and in the Prisoner's Dilemma in the sympathy condition participants' defect and in the anger condition cooperate. This was evident in Experiment 1 (Chapter 3) with low cognitive inhibition participants, in Experiment 2 (Chapter 4) with low expressive suppression participant and was an overall tendency in the fMRI study (Chapter 6) when participants spend more time deciding to cooperate in the anger condition, and defect in the sympathy condition.

Taking all results together, the current study shows that lesions to the vmPFC impair reasoning on exclusive disjunctions with emotional content while on the neutral content trials the performance of vmPFC patients does not differ from normal controls and parietal lobe patients. This result was driven by the incongruent trials. In addition, contrary to past findings (Blanchette & Richards, 2004), performance was significantly improved by the emotion content in normal controls and though not significant, but showing the same patter in the parietal lobe patients. The response time comparison for vmPFC, normal controls and parietal lobe patients shows that vmPFC patients spent more time on the neutral compared to emotional content incongruent trials while normal controls and parietal lobe patients' data showed a reversed pattern. This confirms the ideas proposed by the affect infusion model. In sum, the results show that the reasoning process depends on the intact prefrontal cortex, and not only rational thinking but also negative emotional content can help to bring participants to the right conclusion on the exclusive disjunction task.

Chapter 8 General Discussion

8.1 Research aims and summary of the findings

The first aim of this thesis was to clarify the impact of positive and negative emotions in socio-economic decision-making and to evaluate how individual differences in cognitive control and emotion regulation modulate the effect of these emotions. Secondly, in addition to behavioural effects, the functional anatomy of socio-economic decision-making with respect to individual differences and the role of ventromedial prefrontal cortex (vmPFC) in the deductive reasoning task with emotional content were explored. The findings will be discussed in relation to the research questions from the General Introduction emphasizing what has been answered and what remains unanswered.

The effect of sympathy and anger on decision making in a social exchange context

Based on previous studies, it was expected that the defection rates in the sympathy condition would decrease compared to a neutral emotion condition and increase when feeling anger (Batson & Ahmad, 2001; Batson & Moran, 1999; Ben-Shakhar, Bornstein, Hopfensitz, & Van Winden, 2004; Bosman & Van Winden, 2002; Duersch & Servátka, 2007; Van Lange, 2008). Overall, the behavioural results of Experiments 1 to 4 were consistent with this expectation. However, there are a few important variations to this pattern regarding the level of change in defection rates.

One aspect is the context of social-decision making, that is, the presented possibility to gain or to lose. Experiment 1 with the same group of participants yielded significant differences between anger and neutral emotion in the Prisoner's Dilemma (loss frame), and in the Trust Game (gain frame) between sympathy and neutral emotion. This result is consistent with the past literature showing a tendency towards risk averse behaviour (cooperation in the context of the Trust Game) in a gain frame scenario, while a loss frame induces more risky choices (defection in the Prisoner's Dilemma) (De Dreu & McCusker, 1997; Frank & Claus, 2006; Tversky & Kahneman, 1981). In the context of this study emotion enhanced this effect.

Furthermore, switching between emotions in an event-related design was expected to serve as a distractor eliminating emotion as an effect on behaviour (Boden & Baumeister, 1997; Spielmann, MacDonald, & Wilson, 2009; Wenzlaff, Wegner, & Roper, 1988). However, the findings of Experiment 2 suggest that different emotion durations as determined by the block- versus event-related emotion induction does not affect the behavioural pattern across emotion conditions. However, there are a few possible limitations that need to be considered: first, the overall emotion duration was limited to eight trials in a sequence and with longer exposure a different behavioural pattern might have been obtained. Secondly, when taking into account framing effects, it is possible that different emotions in different decision-making scenarios might yield variable decision-making patterns.

Finally, past research has shown that direct as well as displaced emotions affect individuals' choices (Batson & Ahmad, 2001; DeWall et al., 2010; Reijntjes et al., 2013; Van Lange, 2008). However, only a few studies have compared the effect of these two types of emotions directly in socio-economic games, and the results are inconsistent (Bartlett & DeSteno, 2006; DeSteno et al., 2010). Experiment 3 showed the defection rates in the Prisoner's Dilemma to be modulated in the direct, but not displaced emotion group. These results are unlikely due to group differences as the displaced and direct group measures of cognitive inhibition or expressive suppression were not significantly different. Also, displaced and direct emotions were of similar strength as indicated by the factor analysis. However, it is possible that the economic context encouraged participants to act more strategically or that displaced emotions need longer duration than those in this study to have an effect on individuals' choices.

The behavioural findings of this thesis and previous studies show that experienced emotions affect choices in socio-economic games in specific circumstances, but other contributing factors such as individual differences in cognitive control and emotion regulation ability cannot be ruled out.

Cognitive control and emotion regulation ability in social exchange decision making

Based on evidence from the dual-process theories in general cognitive control and emotion regulation strategies can influence the extent emotions will impact individuals' choices. The experiments in this thesis investigated the potential influence of cognitive control (inhibition and flexibility) and emotion regulation ability (expressive suppression vs. cognitive reappraisal) on decision making.

As expected, in Experiments 1 - 3 the level of cognitive inhibition modulated participants' defection rates in the three emotion conditions in the Prisoner's Dilemma, with defection rates in low cognitive inhibitors mirroring the emotion conditions. In contrast, the defection rates of high cognitive inhibitors were not significantly modulated by sympathy or anger. This pattern suggest that high cognitive control participants engage in Type II processes and do not rely on intuition as opposed to low cognitive control participants (Stanovich & West, 2000; Sunstein, 2005). With respect to emotion regulation ability, the defection rates of participants' with high scores in expressive suppression, but not cognitive reappraisal, were modulated by the sympathy and anger conditions. This result can be partially explained by the fact the participants in the sample had higher scores for cognitive reappraisal than expressive suppression. Therefore, the question about the role of emotion regulation requires future investigation using different samples of participants, or by using experimental paradigms that require participants to actively engage either in cognitive reappraisal or expressive suppression strategies. On the other hand, in contrast to expectations, cognitive flexibility did not modulate task performance in the Prisoner's Dilemma game. This is possible as for flexibility to take an effect, feedback of the interaction outcome is necessary (Sutton & Barto, 1998) and in the current study the outcome was provided only at the end of trial blocks.

Taken together, the findings support the dual-process theory explaining that low cognitive inhibition and expressive suppression participants might rely on Type I processes more and therefore be more affected by the emotion (Stanovich & West, 2000; Sunstein, 2005), while high ability participants rely on abstract thinking (Type II). In addition, the reaction time data from Experiments 1, 2, and 4, suggests that by processing the decision in the emotion condition longer (engaging in Type II processing) as opposed to quick decisions (Type I), participants are able to consider alternative options by overcoming the emotional impulse to act in a certain way (defect in the anger condition and cooperate in the sympathy; Forgas, 1995; Greene et al., 2004).

So far the behavioural experiments showed that emotions can influence decision-making. This influence depends not only on the type of emotion (sympathy vs. anger and direct- vs. displaced emotion), decision-making context (gain vs. loss frame), but also individual differences (cognitive inhibition and expressive suppression). These results give insight about what is happening at a behavioural level. The question about the underlying anatomy was also addressed.

Functional anatomy of social exchange decision-making under emotions

The literature on social decision-making under emotion indicates a substantial number of brain areas involved in this process. First, the emotion component is associated with activations of the orbital frontal cortex (OFC), ventromedial prefrontal cortex (vmPFC) and amygdala (Bechara & Damasio, 2005; Sanfey et al., 2003). Reward/loss processing has been found to activate the striatum and in particular the putamen and caudate nucleus (Izuma, Saito, & Sadato, 2008; Zink et al., 2008). Finally, as social-decision making tasks are played with other individuals they also trigger Theory of Mind processes which are associated with medial prefrontal cortex, insula, paracingulate gyrus and superior temporal sulcus activations (Decety et al., 2004; Frith, 2001; Fukui et al., 2006; Gallagher et al., 2002; Rilling et al., 2004). Yet, an experimental paradigm involving the emotional, strategic thinking and economic decision-making processes might expand the understanding we have how social processes are processed in the human brain.

The results of the fMRI experiment showed that during defection trials in the sympathy condition activation in the left amygdala increased while in the cooperation trials there was barely any change. The amygdala is known to be activated by signs of distress in other individuals and when participants choose actions that harm others (Blair, 2007). Moreover, the negative correlation between defection rates and the left amygdala's percent signal change suggest that the more participants defected the lower their percent signal change was. This result might suggest that participants who defected only occasionally felt uneasy about their behaviour. Thus it is possible that increased left amygdala activity in these trials was associated with acknowledging feelings of distress in the opponent while making a choice that would disadvantage that person. On the other hand, activity in the left putamen decreased significantly during cooperation compared to defection trials in the anger condition. Suppressed putamen activation may be associated with overcoming the emotional impulse to defect and choose cooperation instead. In other words, the decrease in putamen activation may reflect a rational player who -acting on the presumption that the opponent is also rational (Kollock, 1998; Komorita & Parks, 1999)- is engaging in cooperation as a more optimal choice. Yet, as the Emotion Regulation Questionnaire was used only at the end of the experiment, supporting evidence for participants showing stronger expression suppression in the anger condition was not obtained. The reversed contrasts looking at cooperation in the sympathy and defection in the anger conditions did not show significant results at the set threshold.

The vmPFC and OFC activity which was expected to be observed when participants made their decision in the sympathy and anger conditions did not emerge in the analysis. This leads to a few possible speculations. Firstly, the scanner sequence was not optimised, and the scans show signal drop-outs in the OFC area. Secondly, knowing this area's involvement in deduction processes under the influence of emotion, and that the Prisoner's Dilemma was performed in the emotionally charged context, it is possible that it was constantly active and the designed contrasts were not able to pick up the activation. Following this, the role of the vmPFC/OFC on deductive reasoning under emotion was explored with the last experiment.

The role of the ventromedial prefrontal cortex in reasoning with emotional context

The final experiment using exclusive disjunctions with emotional and neutral content was analysed in order to determine whether specific reasoning processes can be affected by emotion processing deficits. The results showed that patients with lesions to the vmPFC/OFC made more incorrect answers on emotional compared to neutral content trials. Interestingly, both parietal lobe patients and normal controls showed the opposite pattern: in these groups, accuracy increased in emotional compared to neutral trials. This effect was especially evident in the incongruent disjunction trials where the normatively correct answer was not in line with the participant's belief. Furthermore, the vmPFC/OFC patients were significantly quicker to respond to emotional than to neutral content exclusive disjunction trials, but this pattern was reversed for healthy controls.

The accuracy results combined with reaction time data show that emotional content triggered more systematic processing of the information and helped to overcome the belief bias (AIM; Forgas, 1995), and indicates the interaction between Type I and Type II processes. Overall these results suggest that the prefrontal cortex is important in deductive processes which are used for exclusive disjunctions and may also apply to socio-economic games such as the Prisoner's Dilemma. The limitation of this interpretation is that although there is a current shift to study deductive reasoning and decision-making tasks together, they still are separate processes which may have led to vmPFC lesions having impact on the reasoning task, but might not show any significant activation in the Prisoner's Dilemma.

8.2 Conclusions and future directions

The findings of this thesis show that emotions have a strong impact on social decision-making, but their impact is modulated by a series of other factors – individual differences in dealing with the emotions (cognitive inhibition and expressive suppression), type of the decision-making task, context and whether the target of the emotion is present or not. Anatomically, increased left amygdala activation was observed when participants defected in the sympathy condition, while left putamen suppression was strongest when participants cooperated in the anger condition. The final study emphasized the vmPFC and OFC role in deductive reasoning with emotional content. Yet, not all questions have been fully answered and future research is needed.

Decision-making vs. reasoning. Following the limitations of the current experiments in the investigation of the role of the vmPFC/OFC, further research to determine the extent to which social decision-making and reasoning differs is needed. The current shift towards studying these two processes is already being made (Evans, 2012). A possible future study could look into both deductive reasoning under emotion and social decision-making with tDCS stimulation over the vmPFC region. The results could shed light not only into the role of the vmPFC in social decision-making, but also to disentangle deductive reasoning and decision-making processes in terms of underlying anatomy, emotional impact and individual differences.

Cognitive reappraisal vs. expressive suppression. The unexpected result showing that participants' behaviour was modulated by expressive suppression, but not cognitive reappraisal, might have been influenced by the majority participants having higher cognitive reappraisal skills. The role of these two emotion regulation strategies could be investigated further by instructing participants to apply either cognitive reappraisal or expressive suppression strategies while interacting on the Prisoner's Dilemma.

Sympathy and anger vs. other emotions. Finally, although sympathy and anger can clearly affect decision-making in social exchange games, the investigation of other emotions could expand our understanding about the complex social environment people live in. Thus the impact of other emotions on human social interactions such as pride and shame, or even basic emotions like happiness and sadness need to be investigated. This also applies to the issue related to the potential impact of displaced emotions on behaviour. Taken together, it remains to be clarified whether different types of emotion result in different behavioural choices depending on the decision making context such as gain/loss frames, emotion duration and direction (direct vs. displaced).

This thesis takes a step in combining economic, psychological and neuroimaging approaches to study the effect of emotion on human decision-making. Overall, the results provide some clarifications as to what extent internal and external factors can influence an individual's choices in the social context. These findings have important implications in today's world where people are faced with emotionally charged situations and it is important to recognise the decision-making approaches that do not rely on formal logic. The possible implications can be seen in consumer research and political/social policies influencing humans to buy certain products (Spence & Townsend, 2006) or vote/express their reactions to certain government policies. By refuting the emotional disinformation related to GM foods or negative stereotypes attached to migrants, and engaging individuals in cognitive control or emotion regulation strategies, the social and economic atmosphere and decisions in this context might be more effective. Finally clinical applications in a form of developing therapies are possible as emotions largely influence the life choices and quality of life of individuals with obesity (Davis, Levitan, Muglia, Bewell, & Kennedy, 2004) or depression (Smoski et al., 2008).

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Appendix A: Emotion Manipulation Stimuli

Sympathy essay:

In this essay I was asked to write about something personal to myself, something which affects me deeply. There are many topics which I could happily discuss, lots of things that move me and motivate me, but at the moment there is only one thing in my thoughts. I have cancer...

This is the second time I have had cancer, but that doesn't make it any less scary. If anything it makes me even more afraid. Waking up every morning and thinking that this may be the last day, that I soon may leave this world and will never enjoy simple things like playing in the beach football with friends, laughing at stupid jokes... that makes me scared and hopeless.

Living with cancer is hard. As much as I hate being sick and tired from chemo, the worst is seing how hard my sickness is on my family. My little sister didn't even recognize me after my first time through chemo, when I was bald. Why I am such a burden to my family, why this happened to me? I feel it is unfair; I didn't do anything so wrong to deserve this and also to put such pain on my family.

I want to live the time I have as much as possible as normal. Surviving cancer the second time round is less likely I am told, but I can't lose hope.

I hope this experiment will cheer me up at least a little bit, because recently I feel subdued. And overall I can't be waiting for someone to find a cure, I have to live my life as active as I can, try to catch up with studies, rest and get amusement I can.

Sympathy evaluation:

Essay Evaluation Sheet

Unintelligent — Intelligent
1 2 3 4 5 6 7 8 9
|------|------|------|------|------|------|------|------|

Thought-provoking — Boring
1 2 3 4 5 6 7 8 9
|------|------|------|------|------|------|------|------|

Friendly — Unfriendly
1 2 3 4 5 6 7 8 9
|------|------|------|------|------|------|------|------|

Illogical — Logical
1 2 3 4 5 6 7 8 9
|------|------|------|------|------|------|------|------|

Respectable — Unrespectable
1 2 3 4 5 6 7 8 9
|------|------|------|------|------|------|------|------|

Irrational — Rational
1 2 3 4 5 6 7 8 9
|------|------|------|------|------|------|------|------|

I can understand why this person thinks like this

Anger essay:

I have been asked to write about something which is important for me personally. So, I am going to write about my interest in the Scandinavian countries, in Sweden and Norway.

Scandinavian countries are interesting to me for quite some time. When I was a teenager, I had the friend from Norway, which represented to me this part of Europe, and after that I found myself trying to learn more and more of these countries.

Why I am interested in cold North; it's a question people usualy ask me. My answer would be 'for several reasons'. First, the Scandinavian language is very melodious. It does not matter if the person is from Sweden and Norway, but when he speaks, seems to be singing.

Second, the Scandinavian peninsula has very charming character. Many forests, lakes, mountains and sandy beaches nearby, and what more, most unique phenomenon - Northern Lights.

Finally, tales and legends and most well-known hystorical data - Vikings. Strong and ruthless travelers scared people around the Europe and have discovered various world places before Columbus did.

Considering everything, Sweden and Norway fascinates me because you can see the hystory and nature combine with each other and results in the mixture of reality and mystery.

Anger evaluation:

Essay Evaluation Sheet

Unintelligent — Intelligent
1 2 3 4 5 6 7 8 9
|--------|--------|--------|--------|--------|--------|--------|--------|

Thought-provoking — Boring
1 2 3 4 5 6 7 8 9
|--------|--------|--------|--------|--------|--------|--------|--------|

Friendly — Unfriendly
1 2 3 4 5 6 7 8 9
|--------|--------|--------|--------|--------|--------|--------|--------|

Illogical — Logical
1 2 3 4 5 6 7 8 9
|--------|--------|--------|--------|--------|--------|--------|--------|

Respectable — Unrespectable
1 2 3 4 5 6 7 8 9
|--------|--------|--------|--------|--------|--------|--------|--------|

Irrational — Rational
1 2 3 4 5 6 7 8 9
|--------|--------|--------|--------|--------|--------|--------|--------|

This is the stupidest thing I have ever read!

Neutral essay:

Recently, I became very concerned about global warming, so I am going to write this essay about this problem the world is facing now. Global warming is a process which changes world's climate – Ocean's levels rising and extreme weather conditions.

Global warming is caused by CFC gases which appear from using cars, plains, trains, ships and all transport which use fossil fuel gases. Also global warming is caused by factories, power plants, even aerosol and other chemicals makes CFC gases too which are destroying ozone layer which is very important to our Earth and ourselves. The Ozone layer protects us from too much sun which could cause a lot of problems.

What is the solution? First we must more often use renewable power [illegible] sources. Sun power, wind energy and many others are already known, so we just need to use it more often instead of petrol and gases.

Secondly, try to decrease CO_2 emissions [illegible] to the air. This could be done by using public transpoport instead of going by car every morning to uni or work. Or use bikes all the time and everywhere!

To sum up, [illegible] I believe we will stop global warming only when people will unite their efforts and do everything whats in their power to save the Earth.

Neutral evaluation:

Essay Evaluation Sheet

Unintelligent — Intelligent

1 2 3 4 5 6 7 8 9

|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|

Thought-provoking — Boring

1 2 3 4 5 6 7 8 9

|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|

Friendly — Unfriendly

1 2 3 4 5 6 7 8 9

|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|

Illogical — Logical

1 2 3 4 5 6 7 8 9

|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|

Respectable — Unrespectable

1 2 3 4 5 6 7 8 9

|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|

Irrational — Rational

1 2 3 4 5 6 7 8 9

|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|

Appendix B: Self-report questionnaire Experiment 1

Read each item and then mark the appropriate answer in the space provided. Indicate what emotion you felt towards which participant. Use the following scale to record your answers.

1= towards the first participant
2 = towards the second participant
3 = towards the third participant
0 = did not feel this emotion

____ afraid	____ tranquil	____ active
____ scared	____ angry	____ glad
____ alert	____ furious	____ nervous
____ content	____ attentive	____ jittery
____ determined	____ pleasant	____ irritable
____ enthusiastic	____ hostile	____ pleased
____ enraged	____ excited	____ guilty
____ calm	____ inspired	____ agitated
____ happy	____ interested	____ mad
____ ashamed	____ proud	____ upset
____ strong	____ distressed	____ good mood
____ joyful	____ frustrated	____ satisfied
____ disgusted		

Appendix C : Self-report questionnaire Experiment 2 – 4

Read each item and then indicate what emotion you felt towards the *purple/blue/green* participant during description reading and evaluating task. Use the following scale to record your answers.

1 – not at all

2 – a little bit

3 – average

4 - strong

5– very strong

____low_ spirited	____glad	____distressed	____worried
____sorrowful	____frustrated	____enraged	____jittery
____agitated	____active	____attentive	____guilty
____compassionate	____happy	____soft-hearted	____sympathetic
____calm	____feeling low	____afraid	____interested
____satisfied	____hostile	____determined	____mad
____excited	____strong	____proud	____content
____tranquil	____alert	____good mood	____inspired
____pleasant	____nervous	____joyful	____disgusted
____bothered	____ashamed	____furious	____scared
____irritable	____tender	____perturbed	____enthusiastic
____angry	____heavy-hearted	____alarmed	____upset
____pleased	____grieved	____sad	____troubled
____warm	____moved		

Appendix D: Emotional and Neutral Disjunctions

Emotional Disjunctions:

Either there are pedophiles or politicians in Texas, but not both.

There are politicians in Texas.

There are no pedophiles in Texas.

Either there are slaves or negroes in America, but not both.

There are no slaves in America.

There are no negroes in America.

Either homosexuals are Christians or atheists, but not both

Homosexuals are atheists

Homosexuals may or may not be Christians

Either in Korea there are edible dogs or opossums, but not both.

In Korea there are no opossums.

In Korea there are edible dogs.

Neutral Disjunctions:

Either there are tigers or women in NYC, but not both.

There are no tigers in NYC.

There are women in NYC.

Either there are Christians or atheists in America, but not both.

There are no Christians in America.

There are no atheists in America.

Either there exist pink elephants or white mice, but not both.

There are no white mice.

There are pink elephants.

Either there is life on mars or Jupiter, but not both.

There is no life on mars.

There may or may not be life on Jupiter.

Appendix E: Payoff Matrix and Defection

Chapter 4: Payoff Matrix and Defection

The same as with defection over time, the participants' decisions depending on the seven payoff matrixes was explored. 7 x 3 repeated measures ANOVA (seven within-subject variables of Payoff Matrix, and three variables of Emotion Condition and two Design types) as expected indicated the main effect of Emotion to be significant ($F(2, 20) = 14.16$, $p < .001$. The main effect of Payoff Matrix, as well as other main effects and interactions were not significant, $F \leq 1.69$, $p \geq .138$.

Chapter 5: Payoff Matrix and Defection

A mixed design ANOVA with within-subject factors of Emotion Condition and Payoff Matrix and between-subject factors of displaced or direct Group were combined to explore if there was an effect of Payoff Matrix on participant's behaviour on the Prisoner's Dilemma task. The main effect of Emotion Condition and the interaction Emotion Condition x Group were significant, $F(2, 86) = 13.27$, $p < .001$, and $F(2,86) = 5.61$, $p = .005$, respectively. However neither the main effect of Payoff Matrix, nor interactions of Payoff Matrix x Emotion Condition, Payoff Matrix x Group, Payoff Matrix x Group x Emotion Condition were significant, $F(2, 86) \leq 1.12$, $p \geq .341$.

Chapter 6: Payoff Matrix and Defection

To investigate if the participants' responses depended not only on the Emotion Condition, but also on the Prisoner's Dilemma Payoff Matrix, a 3 x 6 repeated measures ANOVA was used (within-subject factors of Emotion Condition (sympathy, anger and neutral) and Payoff Matrix (6 payoff matrixes). The main effect of Emotion Condition was significant, ($F(2, 38) = 9.02$, $p = .001$). However, the main effect of Payoff Matrix and the interaction Emotion Condition by Payoff Matrix were not significant, ($F(2, 38)$ ≤ 1.92, p $\geq .237$).