The effect of extrinsic and intrinsic factors on cooperation in social conflict situations: the case of the Prisoner's Dilemma Game

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ABSTRACT

Cooperation in our ever changing and growing societies is vital. However, conflict cannot be avoided when it comes to change and growth. I used the repeated Prisoner's Dilemma Game to investigate the impact of extrinsic and intrinsic factors on cooperation in conflict. Four behavioural studies were conducted with 282 participants, playing the game within different social and environmental contexts. Findings from these studies suggest that cooperation in PDG depends on the extrinsic variables of social and environmental contexts, the intrinsic variables of individual differences, and the history of recent interactions. In the fifth study, I ran a meta-analysis using Linear Mixed Effect analysis to examine the effect of each of the above factors across the studies accounting for both mixed and random effects. Finding from the meta-analysis highlights strong dependency of cooperation on participants previous choices, the social and the environmental contexts and gender. Importantly, the environmental context and age and the partner's behaviour and attachment style showed to interactively affect cooperation in the repeated Prisoner's Dilemma Game. Across all studies, cooperation shown to be a function of most recent interactions, social and environmental factors, and individuals dispositions. Therefore, when studying cooperation in conflict, studying one or two variables in isolation without considering the full dynamic of the situation is an incomplete investigation.

This thesis is dedicated to

My sweet, beautiful daughter Rosa

&

All the people who I met in my journey and taught me something meaningful

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This thesis incorporates the three following papers, which corresponding to three of the five empirical studies:

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LIST OF ABBREVIATIONS

AAS	Adult Attachment Style
AWM	Attachment Working Model
DG	Dictator Game
FTF	Face to Face
ICP	Cooperative Potential
IT	Interdependent Theory
p-cooperative	Pretended Cooperative
p-defecting	Pretended Defecting
PDG	Prisoner’s Dilemma Game
RT	Response Time
SVO	Social Value Orientation
TCI	Psychobiological Model of Temperament and Character
TFT	Tit for Tat
TG	Trust Game
UG	Ultimatum Game

1. INTRODUCTION

Overview

The purpose of the present thesis is to investigate the effect of extrinsic and intrinsic factors, and the interaction between the two types of variables on cooperation in conflicting situations of the repeated Prisoner's Dilemma Game (PDG). This investigation has been carried out by conducting four independent behavioural studies and a meta-analysis of the four studies through playing a computerised PDG in different social and environmental contexts and using questionnaires to collect participants' attachment styles and cooperativeness trait data. This work has been performed to deliver a holistic view regarding not only the impact of each of the above factors on cooperation, but also to provide an insight into how these factors interact with each other and how these interactions impact cooperation in dilemmas. In addition to the empirical studies conducted, theoretical frameworks and models are integrated to provide a comprehensive analysis of the findings within the current evidence from the literature and to enhance our understanding of cooperation in social dilemmas.

The introduction chapter starts with an overview of what is cooperation, describing the evolution of cooperation and reviewing the potential explanations for cooperating. The thesis conceptual framework is outlined by introducing the Interdependence Theory and the Game Theory. This is followed by a description of some of the games used to measure cooperation, with a focus on the Prisoner's Dilemma Game and what cooperation in Prisoner's Dilemma Game is. Factors affecting cooperation are briefly presented with a focus on the environmental uncertainty and the individual differences in their attachment style.

1.1 Cooperation

Cooperation is defined as a cooperative joint action performed with a cooperative attitude based on a cooperative joint intention (Tuomela, 1993). The joint action is different from the coaction, in which the individuals have the same goal without a joint intention, for example, people standing up in a festive event following social norms (Tuomela, 1993). Competitive or exchange joint actions, such as playing chess or buying or selling goods, are examples of non-cooperative joint actions. Whilst cooperative joint action is based on joint attitude, non-cooperative joint action can be performed based on different grounds. In cooperative joint actions, in which participants behave on the basis of cooperative attitude, there is a shared 'we intention' that creates a 'social atmosphere' and a sense of 'we feeling'. Hence, fully cooperative joint actions are based on a rewarding outcome of the joint action that depends on the motivation of each participants (Tuomela, 1993).

Cooperation has been of interest to many philosophers, biologists, economists, social psychologists and, recently, social neuroscientists and neuroeconomists. The Darwinian (1859) theory of natural selection claims that only effective strategies that maximise the payoff continue to be passed to the next generations, whilst the least effective strategies drop and become extinct. This view emphasises an individualistic approach for existence of cooperation (Axelrod & Hamilton, 1981). From a classical economic perspective, when an individual evaluates the cost and benefits of cooperation, they are less likely to cooperate in the situation where the likelihood of reciprocation is undermined. For instance, according to rational choice theory, *Homo*

Economicus will not cooperate in exchange situations where there is a risk for an individual to cooperate at a personal cost, whilst the other person may defect (Dawes & Messick, 2000). In most real-life scenarios, there are some uncertainties over the intentions and future actions that may be taken by a partner. These situations pose social dilemmas in which individuals have to choose between the choice to secure their own short-term interests or risking/investing their immediate resources in order to gain any potential long-term collective benefits that will emerge from the cooperative actions (Dawes, 1980). Whilst understanding cooperation within social dilemma is fascinating, it is especially intriguing to understand why we cooperate with a total stranger. Amongst the theories and models that have studied and discussed human motivations for cooperation during social dilemmas are the social contract theory, reciprocity norm, reciprocal altruism and social cognitive theories which present the most judicious arguments in defence of human cooperation with non-relatives and strangers. In the next section, these theories are briefly discussed to support our understanding of human motivations for cooperation during social conflicts.

1.1.1 We follow the societies' visible and invisible rules

One theory that has been viewed and debated by philosophers, such as Hobbs (1588–1679), Rousseau (1712–78), Locke (1632–1704) and Hume (1711–1776), is the social contract theory (Rusling, 2007). Whilst each of these philosophers has taken a different approach to social contract theory, they all imply that there is an actual or a hypothetical agreement between the members of the societies, or with them and their government, that obliges them to follow certain moral decisions and rules. For example, whilst Hobbs (strongly) and Lock (partially) support the social contract, as governed by the state, to motivate humans to obey the rules, Hume suggests that there is no need for an enforced social contract, but rather that humans follow their common sense and this is sufficient to sustain a cooperative society. On the other hand, Rousseau's view is that, by giving right to the state to govern our security, we gain so much in return by cooperating as a part of the society (Rusling, 2007). A century later, Adam Smith offered a similar but different view, the 'invisible hand' that harmonises our societies through greed; everyone is contributing to the benefit of the society by the act of self-love (Sigmund, 2010). In his view, selfish humans maximises the public good more than they intend to by striving to maximise their own revenue (Sigmund, 2010). Although the social contract theory and the invisible hand can justify prosocial behaviours in some situations, behaviours such as altruism or the act of kindness with no expectation of return in some situations cannot be explained by social contract theory nor by the invisible hand.

1.1.2 The future matters

Another factor that motivates cooperation, is the potential for future interactions. As proposed by Axelrod and Hamilton (1981), when there is a likelihood of meeting again, more reciprocation happens. Therefore, cooperation is a 'function of the history of interaction so far'. Axelrod proposed that reciprocity or the Tit for Tat (TFT) strategy to be the best strategy that supports initiation, stability and robustness of cooperation in the long-term, (Axelrod & Dion, 1988). It is worth noting that, since TFT was first studied, various models have proposed assorted factors that affect reciprocities in cooperation. Reciprocation can be based on a direct or indirect reciprocal altruism, as proposed by Axelrod and Hamilton, in reciprocal altruism theory (1981). An example of direct reciprocal altruism is when the person helps themselves whilst helping others, such as in food sharing. On the other hand, creating good reputation through cooperation in humans (Balliet, Tybur, & Van Lange, 2016) and warning calls in birds (in this case the alarmed bird exposing itself to the predator in order to warn its peers) could be examples of indirect reciprocal altruism (Trivers 1971).

1.1.3 Cooperation is rewarding

From an evolutionary point of view, cooperation has been essential for our ancestors to have a better chance of survival when encountering predators or danger. In our modern human lives, however, this sort of reward might be evolved through other forms of social stimuli behaviour, such as gathering information during a social interaction situation (Walter et al. 2005). Therefore, it is arguable that we are wired to cooperate, and cooperation has a rewarding effect in our brain. Whist this is a fairly new area of research, the data from recent studies supports that motivations to cooperate or not cooperate are generated by the reward system in our brain (Declerck, Boone, & Emonds, 2013a). In their literature review, Declerck, Boone, and Emonds, (2013) used the evidence from the recent studies and presented a model to show how the reward system in the brain generates the motivation to cooperate, or not, through modulation of cognitive control and the emotional process system.

Evolution of the social map was suggested by Cosmides and Tooby (1992). The authors argue that the human species has evolved to be able to cognitively map their social world in order to understand and retain their social interactions and social relationships, peoples and their motives and emotions. This social map has an adaptive function that has been essential for human survival.

Evolution of the emotional system is in line with the social map hypothesis. Evolutionary models propose an emotional system that allows cooperative individuals to signal cooperative potential; additionally, in order to continue cooperation, they must be also better able to read the cooperative signals from the other cooperative individuals (Brosig, 2002; Frank, 1987, 2011). For example, a smile is a common signal of cooperation reassurance and trust among humans (Hutchinson et al., 2008). The advance emotional system not only motivates cooperative individuals to cooperate, but also prevents them from defecting through experiencing strong emotions, such as sympathy, shame, guilt and compassion. Similarly, these individuals are better equipped in reading the signals from similar cooperative partners (Frank, 1987).

1.1.4 Other theories and hypothesis

The reciprocity hypotheses provide an explanation for why we cooperate when there is a potential for future interactions, whist the social heuristic hypotheses provide a better explanation for why we cooperate when the likelihood of future interaction is close to zero (Rand et al., 2014). Based on the social heuristic hypothesis, cooperation can be a default response for some people. Social heuristic hypothesis suggests that our decisions are intuitive, and our past experiences can influence our decision to cooperate. For example, in our daily experience, if cooperation in the past paid off, we would intuitively favour cooperation and vice versa (Rand et al., 2014). Last but not least, the empathy–altruism hypothesis (Schroeder, Graziano, Batson, Lishner, & Stocks, 2014) suggest empathy to evoke cooperation in conflict, e.g., through feeling empathy for the others.

There are other theories and models that attempt to explain cooperative behaviour, however, for the purpose of this thesis, I conclude this section here by summarising the important theories that inspired my studies. In summary, cooperation is most beneficial if there is a likelihood of reciprocation through future interactions, whilst defection is the strategy that pays off better almost in immediate interactions (Axelrod & Dion, 1988). Moreover, past experiences make cooperation an intuitive effect on our cooperative decision-making, even when the possibility of future interaction is close to zero (Bereby-Meyer & Roth, 2006). In addition, we humans have developed a set of social and emotional mechanisms that not only enable us to detect co-operators from defectors but also motivate us to cooperate through experiencing certain emotions (Rand et al., 2014) that could vary between the individuals. Last but not least, cooperation and reciprocation are perceived rewarding by our brain, and this perceived rewarding effect may vary between the individuals (Declerck, Boone, & Emonds, 2013b).

The next section briefly presents the Interdependence Theory, as it provides a logical framework to better understand cooperation during social dilemmas. This is followed by an overview of the Game Theory (GT) and the Prisoner's Dilemma Game (PDG).

1.2 Game Theory

To study social dilemmas, Game Theory was first introduced by John Von Neumann and Oskar Morgenstern (as cited by Hargreaves-Heap & Varoufakis, 2004) and it has been used as an umbrella theory by not only economists but also social psychologists, biologists, politicians. The games are defined as set of social situations that are governed by specified rules and each player's action will affect their own and the other player's outcome (Hargreaves, 2004). The Ultimatum Game (UG), the Trust Game (TG), and the Dictator Game (DG) are the most used paradigms to assess prosocial behaviour in the context of equality and perceived social norms. These games include a proposer and a receiver and have an inbuilt asymmetric power relation between the two. The 'proposer' gets an amount of money and decides how to divide the money between themselves and the 'receiver'; the 'receiver' can accept or reject the offer. If the 'receiver' accepts, both players are granted the amount specified by the 'proposer'; if the 'receiver' rejects, neither players receive any money. Moreover, all three games are sequential, in that the second player knows the first player's decision and the power between the two players is asymmetric. In summary, UG, TG and DG are assumed to assess sensitivity to the 'fairness' feature of prosocial behaviour (the way goods are divided); while the PDG assumes to assess propensity to cooperate, as a feature of prosocial behaviour.

1.3 The Interdependence Theory

The Interdependence Theory (IT) provides a systematic theoretical model on social interactions and interpersonal situations whilst accounts for various aspects of the social situation and its properties (Kelley et al., 2009). Based on IT, understanding human interactions would be most possible through differentiating the interpersonal motives and attitudes from the situational properties, whilst considering how interpersonal motives and attitudes transform the situation and how, together, they shape the behaviour (Kelley et al., 2009). For example, the situations can affect participants' behaviour independent of their goals and motives. Moreover, the situation can present different interpersonal problems, e.g., conflict (Kelley et al., 2009). Therefore, another aspect to consider is the transformation process which represents what individuals make of a given situation. Rusbult and Van Lange (2003) referred to the outcome of the interactions between the given situation and the transformation process as the 'effective situations'. Studying human behaviours requires consideration of the psychological mechanism that happens during the transformation process, including cognition, emotions and habits (Rusbult & Van Lange, 2003). It was Herbert Simon (1957) who first acknowledged the psychological aspect of decision makers, as he coined the term 'psychological properties of the agent' (Barros, 2010). He criticised the global rationality theory as being limited in practice when it comes to studying decision-making. In his theory of bounded rationality, Simon used the term 'external constraints' as objective descriptions of the external environment, and the term 'internal constraints' to describe the agent characteristics, such as knowledge of his or her cognitive abilities (Barros, 2010). Since the theory of bounded rationality was proposed, researchers have begun to pay attention to the role of cognition and emotions in decision-making. Other aspects to consider when studying social dilemmas are communication and information, interpersonal disposition and social norms.

1.4 The interdependence situation of the Prisoner's Dilemma Game

In the classic PDG, the players have equal status and they both decide simultaneously. The players win or lose money based on their individual decisions' and their partner's decisions, to 'cooperate' or 'defect': If both players decide to cooperate, both win money, and if both decide to betray, they both lose money (e.g., see Figure 1-1 based on study one, Taheri et al., 2018). Conflict rises when one player decides to cooperate while the other decides to betray, leading to an advantage for the betrayer and a cost for the cooperator. In other words, deciding to cooperate in the PDG means that one must trust the opponent to cooperate as well, otherwise there is a risk to incur a large loss. Hence, the prisoner's dilemma game is one of the best-known dilemmas amongst scholars. It specially used to measure cooperative decisions in the context of trust and conflict (Dawes & Messick, 2000; Taheri, Rotshtein, & Beierholm, 2018).

Player 2

Player 1

	Cooperate	**Defect**
Cooperate	**Player 1 wins 30p** **Player 2 wins 30p**	Player 1 loses 30p **Player 2 wins 50p**
Defect	**Player 1 wins 50p** Player 2 loses 30p	Player 1 loses 10p Player 2 loses 10p

Figure 1-1 Payoff table

Each player had two options, cooperate, or betray, and there are 4 outcomes based on both players' decisions. The payoff scheme is designed to encourage betrayal, as betraying assuming the other cooperates is associated with the highest gains, as in the original PDG (Taheri et al., 2018).

The common finding is that partners favour cooperation (Tomasello, 2014). However, based on the cooperative joint intention definition (see Section 1.2), if PDG is an interactive coaction that results in a collectively preferred joint outcome (Tuomela, 1993), then cooperation is either based on cooperative attitude to accept collective beneficial goals or because the players have agreed to cooperate. Although, cooperation as a joint action with joint intention sounds plausible in PDG, this view seems limited. For example, it does not account for the other's intentions, e.g., cooperation with the intention to impact the other person's intention and behaviour. It is therefore arguable that the joint action in cooperation in PDG always comes with a joint intention at personal level. Another example is the changes in the intention that can be caused by environmental changes, i.e., why certain environment promotes cooperation and others do not.

Overall, and specifically in repeated interactions, PDG is an interdependence situation in which interactions between individuals depends on the social and environmental contexts in which the game is played, and their interaction with the individuals' goals, motivations and interpersonal predispositions (Balliet et al., 2016). It is therefore important to be aware of the dynamics that the repeated interaction creates and to study various factors that impact cooperation. Moreover, as discussed earlier, the 'shadow of the future' is an important factor that affects cooperation in dilemmas, as it is referred to by Kelley et al., (2009) the 'Temporal Structure' of the game (Rusbult & Van Lange, 2003).

The next sections provide an overview of the literature and evidence available on the factors that affect cooperation in PDG; following this is the outline of this research which is presented based on IT.

1.5 Factors that impact cooperation in Social Dilemma Games

Literature on the factors that impact cooperation is extensive. One way to study these factors is to divide them into extrinsic and intrinsic variables (McNamara, Barta, & Houston, 2004). Among the extrinsic factors, the environmental uncertainty (Bendor, Roderick M. Kramer, & Stout, 2017; McNamara et al., 2004) and the social context are shown to affect cooperation in dilemmas (e.g., Biel & Gärling, 1995; Bolton & Ockenfels, 2017; Butler, Burbank, & Chisholm, 2011). Studies on the effect of intrinsic factors or individual differences in decision-making in PDG has mainly focussed on the effect of personality type (Lönnqvist, Verkasalo, & Walkowitz, 2011; Ruch, Bruntsch, & Wagner, 2017) and the Social Value Orientation on cooperation (e.g., Balliet, Parks, & Joireman, 2009). Inspired by IT, the aim of this thesis is to study the social and environmental contexts as external factors (the given situations) and the effect of individuals' differences (interpersonal dispositions) as internal factors, whilst also investigating the interactions between them (transformation process) on cooperation in the conflict situation of the PDG. The following sections provide evidence from research on the effect of environmental uncertainty and attachment type on cooperation. Evidence on the effect of partner type and the type of interactions, participants' previous choices, and the effect of age and cooperativeness trait on cooperation is presented in each relevant chapter.

1.5.1 Environmental uncertainty and cooperation

Environmental uncertainty is defined as 'the variance of outcomes of the events influencing the fitness of the organism' (Andras, Lazarus, Roberts, & Lynden, 2006). This is well conceptualised by Kelley et al. (2009) as the 'discrepancies between the intended and the actual outcome caused by unintended error'. Literature about the effects of environmental uncertainty can be divided into two types of uncertainties: recourse uncertainty and social uncertainty. Resource uncertainty is based on incomplete information about the resources available to the participants (Bendor, Kramer, & Swistak, 1996; Biel & Gärling, 1995). This could be perceived uncertainty (based on participants' perception of the variance in the distribution of resources) and the effective uncertainty (based on the variance of the available resources to the participants) (Andras et al., 2006). Social uncertainty is incomplete information about others acts (Bereby-Meyer & Roth, 2006).

In this research, the environmental uncertainty was based on the resources' uncertainty or the effective resources available to the participants, and the social uncertainty through playing with different social partners. Literature about the impact social uncertainty has on cooperation is presented in the relevant chapter (Chapter 6).

Studies on resources uncertainty during PDG suggests various solutions, such as generous TFT (Bendor et al., 1991; Klapwijk & Van Lange, 2009), chaos or variation in behaviour in order to promote cooperation, (Andras et al., 2006). Evidence of the effect of environmental uncertainty on cooperation, for example exposure to natural disasters, shows an increase in subsequent cooperation. Chantaral et al. (2015), tested altruistic behaviours after a flooding disaster. Using a Dictator Game, the authors showed that those directly affected by the flooding were more generous compared to those who were not. Hence the external environment, or unexpected results, shown to influence human cooperation at least on short time scales. These short-term-effects may be mediated through changes in emotional states (mood) following the external events.

In the following section, the literature on the effect and cooperation during social dilemmas is briefly presented. The effect of environmental uncertainty is expanded further in each empirical chapter in relation to the variables studied in the respective studies.

1.5.2 Cooperation and emotions

Emotions are defined as responses to external or internal events (Wubben, 2009) which directly or indirectly affect behaviour (Baumeister, Vohs, DeWall, & Zhang, 2007). As pointed out by Baumeister et al., 'emotions exist in part to influence behaviour' and if they caused maladaptive behaviour they would have not survived the natural selection. Baumeister et al. (2007) suggested a view of emotion as a feedback system that influences behaviour and decision-making indirectly through influencing the cognitive processes. It is noteworthy to mention, whilst emotions are high-intensity states, moods are low-intensity affective states that have no salient cause and little cognitive content (Lerner, Li, Valdesolo, & Kassam, 2015). This may be why mood has been studied more often than emotions, as it seems to be easier to induced moods in a laboratory setting.

Taking a close look into the evidence from the literature on the affect and social cooperation is not clear (Hertel, Neuhof, Theuer, & Kerr, 2000; Proto, Sgroi, & Nazneen, 2017). For example, Hertel et al. (2000) studied participants' decision-making in the chicken dilemma game and found that positive or negative mood only affected cooperative behaviour indirectly through increasing heuristic processing of decision-making, and this depends on the situation. They found, when participants were induced with positive mood, they followed the specified social norm that was more cooperative, and this was significantly different relative to the negative affect. On the other hand, participants with induced feelings of sadness, showed more rational behaviour by defecting others and only cooperating when the sum of cooperation of the others was lower than minimum required for the common good. They suggested that positive emotion may simply increase tolerance towards risky decisions and that risk tolerance will be decreased by negative emotions.

Contrary to Hertel's study, Tan and Forgas (2010) found that induced positive affect increased selfishness in the DG. They manipulated participants' affects by using positive and negative feedback on the participants' cognitive test results, watching happy and sad videos or by manipulating the circumstances by providing prior information on the players' fairness. They found that positive mood decreases fairness in the context of the dictator game.

In another study (Ketelaar & Tung Au, 2003), it was shown that induced feelings of guilt increased cooperation in the repeated PDG. Based on their study, they suggested that affect, i.e., negative affect of guilt can be used as 'affect as a source of information' model to aid individuals in their subsequent behaviour. The study suggests that the negative affect was only used as a source of information when individuals were uncooperative or selfish and was followed by a change of their behaviour to be more cooperative or more generous in the second round of the game. Frank (1987) proposes that emotions work as a commitment device. For example, feeling guilty would prevent people from cheating (Frank, 2011). Hence, it can be concluded that affects have different impacts on human cooperative or selfish behaviour, and this depends on other variables, such interpersonal differences, and the social context of the situation.

In addition to the effect of environmental contexts on cooperation during conflict, most theories assume cooperative behaviour to be performed by a certain type of individuals, (Brosig 2000). To study the effect of interpersonal disposition on cooperation during different PDG situations, I considered the effect of attachment style and age and cooperativeness trait (as interpersonal variables) interacting with the external variables of the social and environmental contexts, and the impact of participants' cooperative decision-making in a repeated PDG.

The following sections provide an overview on the evolution of attachment, followed by a presentation of the evidence from the literature on the effect of attachment style on cooperation. Literature on the effect of age and individual differences in cooperativeness trait and their impact on cooperation in PDG is presented in the relevant chapters.

1.5.3 Attachment and relationships

Bowlby's (1969) famous theory of attachment bridges evolutionary theory with modern psychology. Bowlby proposed that infants are competent and born with an innate biological system called the attachment system. The primary function of the attachment system is to support the infant's exploration of their surroundings and the mastering of required skills, whilst maintaining the proximity with their primary caregivers as a secure base. By applying some of the cognitive psychology concepts such as 'working model' he suggested that infants develop a secure or insecure working model of attachment based on their early memories which represents their experiences and expectations during early social interactions with their significant others (Bowlby, 1980).

According to Bowlby, the Attachment Working Model (AWM) that is developed during the early years will influence an adult’s interactions later in life through working models of self (representing self-efficacy and self-value) and working models of others (representing the attachment figures’ responses). These working models are viewed as a core mental schema that affect a person’s feelings, behaviour and responses in social relationships and social interactions, or when encountering a new situation (Mikulincer & Shaver, 2003). Moreover, these internal models influence how individuals perceive and regulate or react to their emotions in difference social settings throughout their life (same reference).

The classic model of attachment proposes two main categories: secure and insecure attachment types. The insecure attachment style subdivides into three types: anxious, avoidant and ambiguous. In the case of secure attachment style, individuals are able to interact with others in a positive and trustful manner, whilst the insecure attached individuals are either highly anxious, afraid of rejection or seek closeness at all time (anxious type), or they over emphasise their independence and have difficulty trusting others (avoidant type), or the third type that swing in between the anxious and avoidant type (ambiguous type) (Waters & Waters, 2006)

There is empirical evidence that shows individual differences, such as adult attachment style (AAS), modulate social interactions (Vrtička & Vuilleumier, 2012), emotional regulations (Chavis & Kisley 2012; DeWall et al., 2012), decision-making (Vicary & Fraley, 2007), reward (Poore et al., 2012) and cooperation (De Dreu, 2012). This includes neuroimaging studies and neurochemistry studies of attachment style and how it affects decision-making during social interaction.

1.5.4 Attachment and cooperation

There are only a handful of studies that investigated the effect of attachment on prosocial interactions, particularly cooperation and altruistic behaviour. In one recent behavioural study, Almakias and Weiss (2012) investigated participants' cooperative behaviour in the context of the Ultimatum Game (UG), whilst also assessing their attachment style. They found that individuals with an anxious attachment style accepted smaller offers, whilst the same individuals also made higher offers. On the other hand, individuals with attachment avoidant style made smaller offers, whilst also rejecting smaller offers, although this was not significant. It was suggested that anxious attached participants accepted lower offers and offered higher amount due to their desire to be loved and appreciated, whilst avoidant individuals made smaller offers and also rejected smaller offers in order to protect themselves from being used or perceived rejection. According to attachment theory, anxious attached individuals intensify their perceived emotion triggered by negative social signals, and this hypersensitivity to rejection signal leads them to distinctive emotional regulation. Therefore, they develop learned helplessness that results in their low self-worth and low self-esteem. As a result, an anxiously attached individual may intensify their support-seeking due to their perceived failure in handling threats. Similarly, avoidant attached individual would show more self-reliance and be in fear of rejection and have difficulties trusting others.

Within the context of social cooperation, at least one study has explored the effect of oxytocin on adult attachment and its moderation on cooperation (De Dreu, 2012); examining how oxytocin increases the level of trust in an insecure attached male participant, and suggesting that oxytocin can reduce the betrayal aversion in higher attachment avoidant individuals through facilitating trust. The results showed that these avoidant attached participants were affected by an increased oxytocin level and therefore cooperated more in the PDG. However, this effect was not found in anxious attached participants. The authors proposed that oxytocin could have decreased a highly avoidant individual's feeling of distress and fear and therefore increased their cooperative behaviour, however this was rejected, as the same effect would be expected for the anxious attached individual. Instead it seems the regulation of oxytocin produced by hypothalamus is different between individuals with high and low level of attachment avoidance, highlighting how the manipulation of neuropeptide interacts with attachment style and modulating emotions, i.e., the fear of rejection and facilitating trust and increased cooperation as a result.

While the study of participants' attachment style has shed light on to the research of cooperative decision-making, the effect of attachment is not independent of the environmental context. Therefore, both attachment and environmental factors should be considered when designing an experiment to study prosocial behaviours such as cooperation. As seen above, environmental factors, such as driven emotions from the environment, and interpersonal differences, such as attachment type, impact individuals' prosocial behaviour. The question is to what extent the positive and negative mood triggers attachment system and how people with different attachment types, i.e., anxious or avoidant type, respond to these triggers differently and how this affects their cooperative behaviour as a result.

1.5.5 Attachment and emotions

As discussed, attachment internal models not only influence how individuals socially interact, but also the way in which they perceive environmental clues, such as threat signals, and how they regulate their emotions (Mikulincer & Shaver, 2003). Based on Lazarus' theory of emotion adaptation (Smith & Lazarus, 1990), anything that implies harm or benefit to the person can produce emotions. Various studies have shown the impact of attachment on emotional memory (Edelstein, 2006), information processing (Tsachi Ein-Dor, Mikulincer, & Shaver, 2011) and affect regulation (Mikulincer, Shaver, & Pereg, 2003). In a recent study, it was shown that people with an insecure attachment style (highly anxious or avoidant type) are highly sensitive to threats or negative and positive signals (Vrtička & Vuilleumier, 2012). They used pictures in four emotional contexts: social positive, (i.e., two people playing together) or social negative (i.e., fighting), non-social positive (i.e., a scene of tropical island) or negative (i.e., picture of a dead bird). They asked participants to rate the emotional pictures from 0 to 100 on the three dimensions, feelings (i.e., positive or negative), arousal (high or low), and control aspect (absence or presence). They found avoidant attached participants to rate positive social images less pleasant. Vrtička et al. (2012) suggested that avoidant attached individual use deactivation of attachment system to selectively decrease the pleasantness of positive social scenarios. On the other hand, anxious attached individuals rated the emotional images in general, and the negative social images in particular, higher. They concluded that anxious attached people generally are hypersensitive to negative signals in the social context and that they intensify this feeling and have less control over their feeling of arousal in line with hyper activation of the attachment system. These results confirm the theoretical framework suggested by Mikulincer et al. (2003), that attachment style modulates emotional regulation with both anxious and avoidant type being hyper sensitive to the social signals, whilst one results in hyper activation and the other deactivation of attachment system, respectively. Therefore, considering individual differences in their attachment style, in addition to the effect of mood, should be considered when examining cooperation in conflict.

In my research, it was expected that the environmental uncertainty (e.g., random losses or wins) would trigger emotions in participants and impact their cooperative decision-making through interacting with other factors, such as social context and individual differences.

1.6 Aim of this thesis

Within the last couple of decades, the effect of optimum strategies, social and environmental contexts and the influence of individual differences on cooperative behaviour in the PDG have been studied by evolutionary biologists, social psychologists, neuroscientists and economists (Bixenstine & Gaebelein, 1971). However, to my knowledge, there is little or no study of how environmental and social factors (extrinsic factors), such as uncertainty, type of interactions and partner's behaviour, interact with individual differences (intrinsic factors), such as attachment style, age, and cooperativeness trait, to impact on cooperative decision-making in the

PDG. The focus of this research is to explore the effect of these extrinsic and intrinsic factors, and their interaction on cooperation during the social dilemma of the PDG. The aim is to bridge a gap between the literatures in the domain of social interaction and cooperative decision-making. To investigate the effect of social and environmental manipulation and individual differences on cooperation, four similar computerised repeated PDG in different social and environmental contexts were used to test the hypotheses in each study. In a final study, Linear Mixed Effect analysis was used in order to run a meta-analysis and to study how these variables have a fixed and random effect within and across the studies. Findings from the meta-analysis are discussed in relation to the available literature and an integrated model presented, which can be used when studying cooperation in dilemmas.

1.7 Overview of the chapters

Chapter 2, the Methods chapter, and presents the experimental paradigm, describes the main task and the experimental procedure that is similar in all the four studies. Variations of the experimental task, procedure, and participants for each study is presented in the methods section of the relevant chapter.

Chapter 3 presents the first study that was set to assess the effect of environmental uncertainty and attachment style on cooperation in the two players iterated PDG (during a non-face-face-to-face interaction). Findings from this study were published in a paper in *PLoSONE* journal (Taheri et al., 2018).

Chapter 4 is a replication of the first study whilst also examining the effect of the type of interactions, face-to-face interaction vs non-face-to-face interaction and how this impacts cooperation. Findings from this study is compared with Study one.

Chapter 5 assesses the effect of age and environmental uncertainty on cooperation during a repeated two players PDG. Findings from this study has been submitted to the *Journal of Aging and Psychology* and it is currently under review (Taheri, Beierholm, & Rotshtein, under review, 2020).

In Chapter 6, a computer program was used to control for social partners, e.g., pretend-cooperative vs. pretend-defecting partners and the individual differences in cooperativeness trait was collected using self-report questionnaires. It examined how partner's behaviour and environmental uncertainty affects participants' cooperation in the repeated four players PDG and how individuals with different cooperativeness traits behaved in response to different types of partners and in different environmental contexts. Findings from this study are ready for submission to the *Journal of Experimental Psychology.*

In Chapter 7, Linear Mixed Effect analysis is used to analyse all the data across the four studies to examine how the variables – environmental uncertainty (negative, neutral and positive), social context: interaction type, (face-to-face vs non-face-to-face), partner type, (cooperative vs defecting), and the type of study, (four players vs two players) and the individual differences (in attachment style, cooperativeness trait, age, and gender) – as well as the previous choices affect cooperation in the PDG. This study looked at both fixed effect and the random effect within subjects and across the studies.

Chapter 8 summarises the findings from the five studies. This thesis is concluded by providing the highlights from the findings, limitations of the studies, and suggestions for future direction in studying factors that affect cooperation in dilemmas.

2. METHODS

2.1 Introduction

Through a series of experiments using the PDG, various aspects of social decision -making were tested. The effect of environmental context (the given situation) was varied, through introducing environmental uncertainty to manipulate the effective resources available to the participants. This was done by creating negative and positive environmental contexts, in which participants would lose or gain additional resources (money), as compared to the neutral environmental context, where there are no additional losses or gains to their decision outcome.

In addition to the environmental uncertainty, the social context was also varied by contrasting the regular version of the game, (playing with a human) with a version where participants played against a computer program that implemented a Tit-for-Tat, and a pretend-cooperative and pretend-defecting strategy to control for the social aspect of the interaction.

Individual differences in attachment style, age and cooperativeness were also collected through self-report questionnaires.

2.2 Ethics

The study procedure was approved by the University of Birmingham Science, Technology, Engineering and Mathematics (STEM) Ethical committee. Participants were fully informed about the task, both in writing and verbally, before giving their written consents.

2.3 The experimental paradigm

2.3.1 Task

Participants played a modified version of the repeated prisoner's dilemma game (PDG). To further encourage social cooperation, we explicitly referred to the two choice options for the subject as 'cooperate' and 'betray'. This is in contrast to the way the task is often presented (Boone, De Brabander, & Van Witteloostuijn, 1999) where the two options are merely referred to as 'A' and 'B' without any specific connotations. In our study, we wanted to explicitly engage attachment related systems of participant, hence these terms were beneficial. Whilst participants seen the words 'collaborate' or 'betray' on the screen during the game, throughout this essay I use the words cooperate and collaborate interchangeably and defect when referring to betrayal.

The PDG was coded using MATLAB to record the participants responses and their reaction time. Participants were told that the aim of the game is to win as much money as possible. Participants were also informed that the money in this experiment would be real money and so was any random loss or gain of money during the game. The amount of money that could be won on each trial depended on both players' decisions. In each trial, participants had to choose whether to 'cooperate' or to 'betray' (by pressing one or two on the keyboard). If both participants cooperated, they won 30 pence (30p) each; if both betrayed, they lost 10p each. If one betrayed, whilst the other cooperated, the one who betrayed won 50p and the one who cooperated lost 30p (see Figure 1-1). The payoffs were designed to encourage betrayals, as this was associated with the highest payoff, assuming the other participant cooperated.

Participants were informed that they would take the money what they win in one of the blocks chosen by themselves randomly by throwing a dice in addition to what was agreed as a compensation for their participation in the experiments. In case if the amount of the chosen block was negative, meaning that they lost money they will go with the money that was agreed for their participation.

Participants played with either a human partner (the other participant) or a computer partner in separate blocks. At the beginning of a block, they were informed whether they were playing with a human or a computer.

		Player 2	
		Cooperate	**Defect**
Player 1	**Cooperate**	**Player 1 wins 30p** **Player 2 wins 30p**	Player 1 loses 30p **Player 2 wins 50p**
	Defect	**Player 1 wins 50p** Player 2 loses 30p	Player 1 loses 10p Player 2 loses 10p

Figure 2-1 Payoff table

Each player had two options, cooperate, or betray, and there are 4 outcomes based on both players' decisions. The payoff scheme is designed to encourage betrayal, as betraying assuming the other cooperates is associated with the highest gains, as in the original PDG (Taheri et al., 2018).

Number of trials and blocks

Participant played with each partner for several trials, e.g., between 13 to 17 and in all of the environmental context across several blocks, e.g., between 6 to 8 blocks. The order of the blocks was counterbalanced across participants. The variations in the number of trials and blocks are explained in more detail in each chapter.

2.3.2 Environmental uncertainty in the context of the repeated PDG

For the purposes of this research, the environmental uncertainty was manipulated based on the uncertainty of the resources or the effective resources available to the participants. The environmental context was manipulated across the blocks. I used three contexts: negative, neutral, and positive contexts. In the negative blocks, random monetary losses. (20p) were introduced on 30% of the trials. In the positive blocks, random monetary wins (20p) were introduced on 30% of the trials. In addition to the resource uncertainty created through randomly losing or gaining money, it was expected that these additional losses or gains of resources would trigger participants' positive and negative emotions. Participants were informed that within some blocks they would randomly loss or gain money in some trials and that the extra money lost or gained on those trials are independent of their decisions. However, they would only become aware that they are playing in the negative or positive blocks after the first trial as there was no advance notification on which blocks they are playing. To check for the validity of the environmental manipulation, I used post experiment questionnaires and asked participants to report how they felt after losing the random money and receiving the additional money (please see appendices for a sample of post experiment questionnaires). I also asked them to report how their decision was affected based on these manipulations. Their responses were then compared with their reaction time to see how the environmental manipulation affected their decisions implicitly and explicitly. Based on the implicit reaction time data validation, it was expected that environmental manipulation would affect their decision time during the negative and positive environmental contexts, as compared to the neutral environmental context.

2.3.3 Social context manipulation

The computer partner was programmed to use a Tit-for-Tat (TFT) strategy, collaborating in the first trial, then subsequently performing the same choice as the participant's previous decision. However, to mask this strategy, in 20% of the trials the computer made a random decision. The use of the TFT strategy was done to emulate, as closely as possible, the conditions of playing with another human, by emphasising reciprocation. In addition, TFT is a well-known strategy that emphasises initial cooperation, but which immediately responds to any defection by immediate mutual defection. The strategy has been used to explain aspects of human decision-making and has the advantage of being simple yet effective (Axelrod & Dion, 1988; Ketelaar & Tung Au, 2003; Kjell & Thompson, 2013).

In Study 4 (Chapter 6), in addition to a real human and a computer (TFT), participants also played with a programmed computer pretend-cooperative and a programmed computer pretend-defecting partner to control for the effect of a partner's behaviour on the participant's decision. I used deception to make participant believe that they are playing with a real human. More detail is provided in the respective chapter.

Participants, either verbally or in written form, reported their beliefs about each partner that they played, whether human or the computer, both after the task and during the debrief. The post experiment data was used to validate the manipulation of the social context, through comparing participants' self-report data with their reaction time for the implicit and explicit effect of the manipulation. It was expected that participants' decision time would vary based on the type of partner they played with, e.g., computer vs human, or pretended cooperative vs human.

2.3.4 Experimental procedure

In all the experiments participants were tested on condition that they did not know each other beforehand. At the beginning of the session, the instructions for the game were given to the participants in the same room. They were introduced to the aim and structure of the game and the payoff table was clearly explained to them. The environmental and the partner manipulations were also explained, and subjects were advised that this would be fixed across blocks of trials. They were then taken to separate rooms (this is different in the face-to-face study, please see Chapter 3) where they would play the game. This precluded any communication between participants during the game. In separate rooms, participants practiced the task and the experimenter verified that they understood it. The experimenter left the room before the actual game started, to ensure they could not bias decisions.

Each block started by informing each subject of the type of partner they would encounter ("In this block you will play against a computer opponent or human partner"). This stayed on the screen until the participant was ready to start. Participants were then presented with the response screen stating: "Waiting for your response. Press 1 to cooperate or 2 to betray". The word 'betray' was specially chosen as it is more commonly used in the everyday language as compared to the word 'defect'. Throughout this thesis the word defect is used when referring to betrayal and the words cooperate and collaborate are both used interchangeably. After both players decided, a feedback screen appeared notifying both participants of their decisions and the money won/lost for each (see Figure 2-1).

During the negative context block in 30% of the trials, a screen with an unhappy red face appeared after the feedback screen, displaying the following message: “Oops you have accidently lost 0.20”. Similarly, during 30% of the trials under the positive context, after the feedback screen a smiling green face was displayed with the message: “Congratulations, you have won an extra 0.20”. Participants were told that they ‘accidently’ lost money to make it clear that it is not related to their decision, and somewhat give it a little more negative association, raise more negative emotions. This was also similar with the use of the word congratulations and won extra money for the positive context. I wanted to use words that are emotionally more weighted as compared to using ‘randomly’ lost or gained money which would actually have an equal wight for both of them. This context screen was displayed until the subject made a button response, (e.g., Figure 2-2).

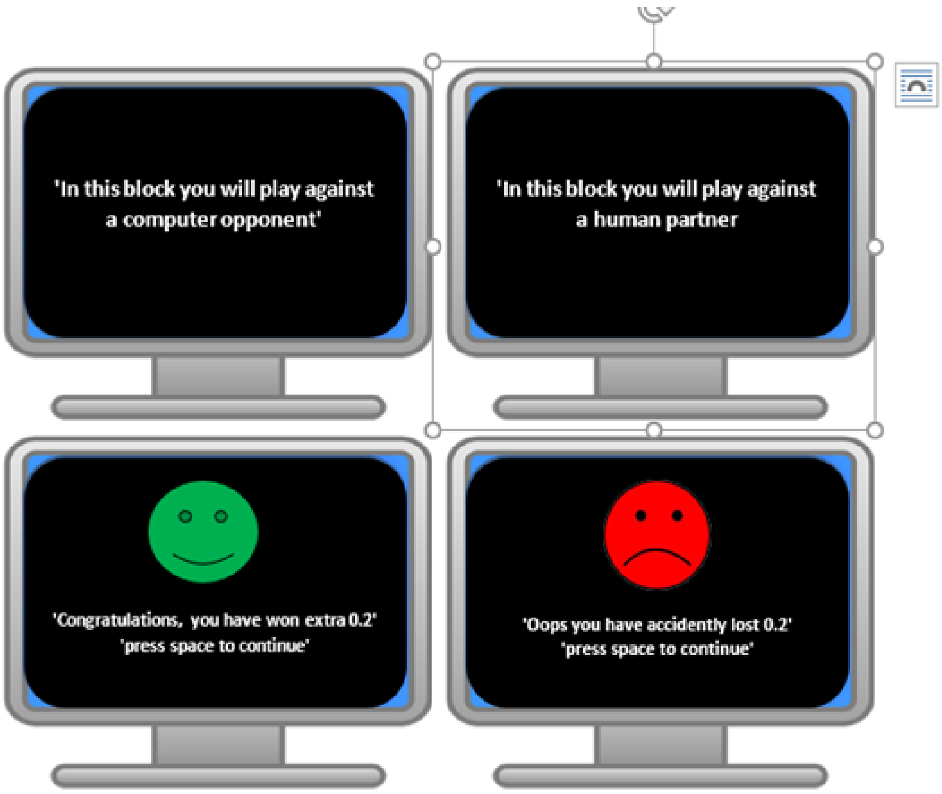

Figure 2-2 Game context: partner and environment conditions

The figure presents the screen participants saw during the game. Information about the conditions: Top, instruction informing the participants who would be their game partner (human or computer). Bottom, instruction informing the participant that they have randomly won/lost 20p. (Taheri et al., 2020, under review)

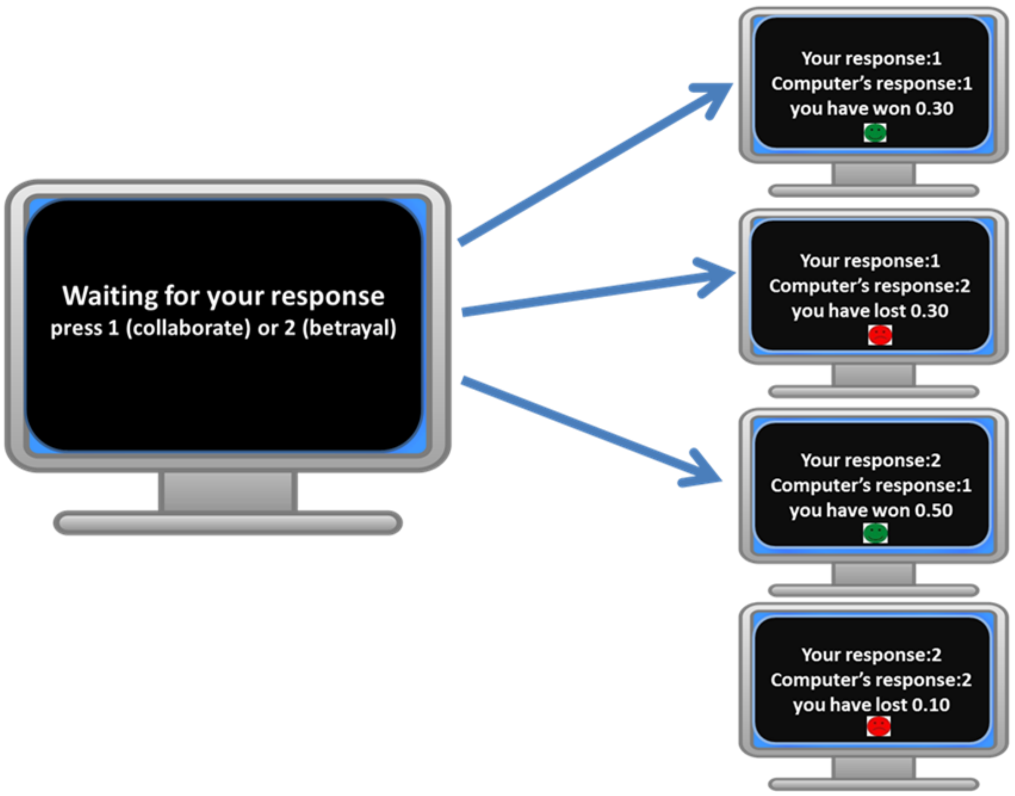

Figure 2-3 Choice and feedback screen

Participants were presented with two options and the choice screen remained until both participants made a response (pressing keys 1 or 2). Right side: Depending on the responses of both participants, one of four potential feedback screens were presented (2 seconds). In the positive & negative environmental context there was a 30 percent chance of a screen informing subjects of a further random gain/loss, before the beginning of the next trial (Taheri et al., 2018).

2.4 Data analysis

2.4.1 Cooperation ratio

Cooperation ratio measured by dividing the number of trials where the decision to cooperate was relative to the total number of trials in the block.

2.4.2 Response time

The response time (RT, decision time) was measured from the onset of the response screen.

2.4.3 Individual differences

Individual differences in attachment style, age, and cooperativeness trait were measured through self-report and questionnaires. This was done on the completion of the game in the individual rooms. All participants were asked to fill out questionnaires with the exception of study 4 (Chapter 6) that filled an online survey. This is explained in the respective chapter. information regarding cooperativeness measure also presented in the relevant chapter, (Chapter 6).

Attachment style

Attachment was assessed in the context of 'intimate relationship' using the Revised Adult Attachment Scale (RAAS) (Collins, 1996); and of 'close relationship' using the Experiences in Close Relationships Inventory (ECR) (Fraley, Waller, Brennan, Brennan, & Clark, 2000). RAAS and ECR measure anxious and avoidant attachment styles in the context of adult relations. The RAAS was completed before the ECR. An example of a question assessing anxious style in the RAAS (6 Items) is: "I often worry that romantic partners won't want to stay with me", and in the ECR (18 Items): "My desire to be very close sometimes scares people away". A question that assesses avoidant style in the RAAS (12 Items) was: "I find it difficult to allow myself to depend on others," and in the ECR (18 Items): "I find it difficult to allow myself to depend on others". In the RAAS participants responded using a scale of 1 (strongly disagree) to 7 (strongly agree); in the ECR they responded using a scale of 1 to 5 (disagree - to - agree, respectively). I used two questionnaires to assess attachment styles in adulthood to increase the reliability of the self-reported measures.

2.4.4 Analysis

Repeated measure of Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA) (in Study one, two, three and four) and Linear Mixed Effect model (in Study four and five) were used to analyse the data. The analysis is described in full details in each empirical chapter. The data was analyzed in SPSS 24 and MATLAB.

3. THE EFFECT OF ATTACHMENT AND ENVIRONMENTAL MANIPULATIONS ON COOPERATIVE BEHAVIOR IN THE PRISONER'S DILEMMA GAME

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A version of this manuscript has been published in *PLoSONE*

3.1 Abstract

Cooperation and competition are vital for human survival and for social progress. In this study we examine the impact of external (environmental) and internal (individual differences) factors on the tendency to cooperate or compete in social conflicts. To this end, 53 young adults played blocks of the repeated Prisoner's Dilemma Game with each other or with a computer. The environmental context was manipulated across blocks, by introducing uncertainty, randomly losing, or gaining money. Individual differences were assessed by participants' attachment style. We found that participants cooperated more when randomly losing money compared to when randomly winning or in the neutral condition. Moreover, in a negative uncertain environment, individuals with higher anxious and avoidant attachment styles cooperated less. The above effects were only observed when playing against a human and not a computer. Overall, the findings highlight the dependency of cooperative behavior on the context as driven by external and internal factors.

Keywords:

Attachment Theory; Cooperation; Prisoner's Dilemma Game; Attachment Style: Psychology and Economics.

3.2 Introduction

Cooperation and competition are vital for our survival in a complex social environment (Adolphs, 1999). The tension between cooperative and competitive behavior is specifically emphasized in a conflict situation. An example is social dilemmas where the interests of the collective are in conflict with the individual's self-interest (Dawes, 1980b). In traditional economic theories decisions are assumed to reflect a 'rational choice', aimed to maximize individual gain (Zey, 2001). However, many theories and empirical findings have challenged this simplistic view (Declerck et al., 2013a; Kahneman & Tversky, 1979). Specifically, in the context of social dilemma, cooperation is suggested to be driven by social factors (Biel & Thøgersen, 2007; Butler et al., 2011; Miwa & Terai, 2012b), emotional context (Hertel et al., 2000a; Ketelaar & Tung Au, 2003; Kjell & Thompson, 2013; Tan & Forgas, 2010) and personality traits (Boone, De Brabander, & Van Witteloostuijn, 1999; Kagel & McGee, 2014a; Kuhlman & Marshello, 1975). In this study, we specifically focus on the impact of the environmental uncertainty, and how individuals with different relational attachment style react to it in a repeated Prisoner's Dilemma Game (PDG).

Social contract theory originally proposed by Hobbes (1651) suggests that cooperative behavior is one of the building blocks of societies. It postulates that despite an incentive to defect in some scenarios (e.g., PDG), it is socially agreed that for long term mutual benefit it is best to cooperate. Cooperation between humans is argued to be an evolutionary behavior that is crucial to our species survival (Nowak, 2006). Indeed, in the context of PDG (both in the single and repeated versions) cooperation is observed, although there is a large variability between studies in the extent of cooperative behavior (Sally, 1995). Unsurprisingly, cooperative behavior in

PDG is greater when playing against human partner as compared to when playing against computer partner (Miwa & Terai, 2012), highlighting the social aspect of the game.

Cooperation has also been hypothesized to depend on factors external to participants. Economic hardship, food sparsity and limited foraging options has been anecdotally claimed to cause humans to be either more or less cooperative. For example, it is suggested that exposure to natural disasters leads to increased subsequent cooperation. Chantaral and colleagues (2015) tested altruistic behaviors after a flooding disaster. Using a DG, the authors showed that those directly affected by the flooding were more generous compared to those who were not. There is also evidence that traumatic experiences in a community can lead to more cooperation (Bauer, Blattman, Chytilová, et al., 2016). Similarly, it has been shown that a positive national event, like winning an international football match, can lead to increased investments in national companies (increase in the FTSE 100 index when England wins (Ashton, Gerrard, & Hudson, 2003). Hence the external environment, or unexpected loss, may influence human cooperation at least on short time scales. This short-term-effects maybe mediated through changes in emotional states following the external events.

Over longer time scales, personality traits are likely to also affect cooperation. The ability to trust others in daily interaction can be affected by an individual's attachment style. The attachment theory advocates that individuals interact with each other based on their internal relational "working model" developed in early childhood (Bartholomew & Horowitz, 1991). Attachment is categorized into secure and insecure types and is described along two dimensional axes: anxiety and avoidance (Bowlby, 1969). Individuals with secure attachment score low on both the anxiety and avoidance axes. Secure attachment is associated with positive, constructive and trustful social interactions. On the other hand, individuals who have insecure attachment, tend not to trust others. Those with high score on the anxiety axis are afraid of rejection and seek closeness at all times. Individuals with high scores on the avoidance axis emphasize their independence and avoid forming relations.

Two studies investigated the impact of attachment on behavior in social dilemmas. Almakias and Weiss (2012) examined how avoidant and anxious attachment styles affect decisions in the UG and DG. In contrast to the PDG, the relation between players in the UG and DG is asymmetric and assumed to measure sensitivity to fairness. In the UG one participant proposes a split of money, with a second participant holding a veto power, while in the DG the receiver has no say over the split. In the Almakias and Weiss study, participants played 40 trials of a one-shot game with different fictitious partners, half as proposers (DG) and half as receivers (UG). They reported that participants with anxious attachment style accepted smaller offers in the UG while also making higher offers in the DG. The authors concluded that this paradoxical behavior where anxious individuals always end up with less money than their partners (either as proposer or receiver) suggest they have lower sensitivity to fairness. It is argued that the desire of a high relational anxious individual to be loved and appreciated leads them to reduce their own share and increases the others'. On the other hand, participants with avoidant attachment style show the opposite pattern – they made smaller offers whilst they also rejected smaller offers (although this was not significant) suggesting that avoidant individuals have higher sensitivity to fairness, where they focus on protecting themselves from exploitation.

In contrast, in social conflict with symmetric relations and where trust rather than fairness is the focus, such as the PDG, individuals with anxious or avoidant attachment styles are reported to be less cooperative (McClure, Bartz, & Lydon, 2013). This was shown using 2 trials of a one-shot prisoner dilemma game (with two fictitious partners).

Attachment style not only affects the way people interact with others, but also affect the way individuals respond emotionally to various situations (Fraley, Niedenthal, Marks, Brumbaugh, & Vicary, 2006). Individuals with high anxious attachment styles show hyper emotional (positive and negative) response, while those with avoidant styles are associated with deactivation of positive emotions (Mikulincer et al., 2003). In support of this, empirical studies have shown that people with anxious relational attachment rated both positive and negative stimuli as more intense, independent of the social content; those with avoidant style rated positive social (but not non-social) images as less pleasant (Vrtička, Sander, & Vuilleumier, 2012). It is suggested that emotions activate the attachment internal working model (Ein-Dor, Mikulincer, & Shaver, 2011).

Two opposing views have been proposed on the impact of attachment style on cooperation when in an uncertain/threatening environment. The affect reactivity and regulation model (Pietromonaco, Barrett, & Powers, 2006) posits that in an uncertain negative environment, individuals with high avoidance will distance themselves from others, and hence are likely to cooperate less; while individuals who have anxious relational style will seek more support, and hence potentially cooperate more. Alternatively, it has been argued that in uncertain situation, in which the behavior of the partner is unpredictable, individuals with insecure attachment (anxious and avoidant styles) expect the worst, showing overall less trust leading to less constructive cooperative behavior, even in repeated interactions (McClure et al., 2013).

The aim of the current study was to revisit cooperative behavior in the context of the social dilemma, examining the impact of attachment style as an internal factor and of the environment (rich (positive), neutral or scarce (negative)) as an external factor. We used the PDG as a manipulation of social dilemma because the relationship between the two partners is symmetric. Hence, we expected the PDG to specifically tap into trusting others' behavior which is assumed to be impacted by the attachment style. To magnify the element of social trust in the game and its emotional and social connotation, we describe the two choices in the PDG as betray and cooperate. We used a repeated version of the PDG to allow reciprocal trust to be triggered across multiple encounters. The PDG task included a manipulation of the environmental context through unexpected monetary losses or wins. Thus, the PDG was played 1) in a positive context, where participants randomly received additional money, 2) a negative context, where money was randomly taken, and 3) in a neutral context where no money was won or lost randomly. This external variable emulated a period of safety/economic growth or threat/recession and would be expected to interact with the attachment style for cooperative decisions. Finally, to rule out that any effect observed is not specific to social interactions we manipulated the partner; participants played against a real human (social) or a computer (non-social) partner. Subjects were aware who their partner was when they played. It is important to note that in contrast to many studies using social dilemma games here participants interacted online with real humans whom they only briefly met at the beginning of the experiment.

While the role of attachment has previously been examined for PDG in single games (McClure et al., 2013) this is the first study to examine cooperation in repeated PDG where participants can build up trust over time, and the first study to examine how the cooperative effect of attachment style is further influenced by uncertain or threatening environments.

Based on literature on threats and uncertainty we expected participants to cooperate less when in a positive supportive context (randomly winning a sum of money) and more when in a negative threatening context (randomly losing a sum of money) and this effect is expected to be larger when playing against a human. How the internal factor (attachment styles) affects cooperation is less clear; previous studies reported that both anxious and avoidant relational styles trended toward less cooperation. We anticipated that external environmental factors (specifically threat and uncertain negative outcomes) would magnify the effects of the internal factors (the attachment style) on cooperative behavior; high avoidant attached participants showing a decrease in social cooperation in response to negative context. The impact of environment on the cooperative behavior of individual with anxious attachment style during interactions is less clear. Furthermore, we expected all of these effects to be specific to interactions with human participants, with generally lower cooperation with computer partners.

3.3 Methods and materials

3.3.1 Participants and design

Initially sixty-two university students were recruited for this study from which there were 10 female, 7 male and the gender for the remaining participants were not collected. The criterion for inclusion was any adults aged 18 and above. Participants were tested in pairs, based on opportunistic matching. Two participants who signed on to the same time slot played together, on the condition that they did not know each other in advance. A follow up lifespan study (not reported here) revealed that the impact of attachment style on cooperative behavior changes with age. Therefore, in the current study we excluded 9 participants whose age was above 30yr. This resulted in 53 participants age between 18 to 29 years old.

The study design was a mixed design with partner (computer, human) and environmental context (positive, neutral, negative) as within-subject factors and attachment styles (anxious, avoidant) as between subject covariates. For the analysis, measured cooperation ratio, the number of trials where the decision was to cooperate relative to the total number of trials in the block, and response time.

Compensation

Participants were informed that they would play for real money, which ensured engagement in the game. Participants received £5 for their participation. In addition to this compensation all participants were told that they would also receive the money they won during one randomly selected block (out of 6 blocks, e.g., from £0 up to £7 depending on their performance in the respective block). Hence, participants received a total compensation of a minimum of £5 up to £12, depending on their performance in the game.

3.3.2 Task and procedure

Participants played a modified version of the repeated Prisoner's Dilemma Game in pairs, (please see Methods section, Chapter 2).

The environmental context was manipulated across blocks, in three contexts: negative, neutral, and positive contexts.

In this study, participants played with either a real human partner (the other participant) or a computer partner in separate blocks.

The game lasted for a total of 93 trials divided into 6 experimental blocks of 13-17 trials in each block. Subjects played with each partner (human or computer) in all three environmental contexts, for a total of 93 trials divided into six experimental blocks of 13 to 17 trials. The number of trials per block varied between blocks to prevent the use of strategic decision making on the last trials, known as end effect (Colman Krockow & Pulford, 2018). The order of the six blocks was counterbalanced across participants, please see Figure 3-1.

6 Blocks (13-17 trials)	Group A	Group B
Block 1	Computer Partner Neutral	Human partner Positive
Block 2	Human partner Negative	Computer Partner Negative
Block 3	Computer Partner Positive	Human Partner Neutral
Block 4	Human Partner Neutral	Computer Partner Positive
Block 5	Computer Partner Negative	Human partner Negative
Block 6	Human partner Positive	Computer Partner Neutral

Figure 3-1 The order of the six blocks was counterbalanced across participants.

3.3.3 Attachment self-report

On the completion of the game, in the individual rooms, participants were asked to fill out 5 personality and trait questionnaires (UPPS+, BISBAS, RAAS, ECR and the Big five). For the purpose of the current study we focused only on the questionnaires that assessed attachment style. Please see Methods, (Chapter 2) for more information about Attachment questionnaires.

In the analysis, we separated responses to questions that measure anxious and avoidant styles. Given the relatively high overlap of the two questionnaires, the data was combined using principal component analysis (PCA). For each sub-scale, we used the first component, i.e., the one that explained the largest amount of the shared variability in these measures (see results below). Thus, each participant had one score reflecting the level of relational anxiety and one score for relational avoidant attachment style. The attachment measures for relational anxiety combined of the RAAS and the ECR found high reliability (24 items: Cronbach's alphas α=0.85). The Cronbach's alpha for relational avoidance of the combined attachment scores also found high reliability (29 items: α=0.68).

3.4 Results

3.4.1 Attachment styles

The distribution of attachment style scores matched responses reported in the healthy population (Fraley et al., 2006) (RAAS-anxiety: *M* = 2.72, *Mdn* =2.83, *SD* = 0.87 ; RAAS avoidance: *M* = 2.81, *Mdn* = 2.75, *SD* = 0.66; ERC-anxiety *M* = 3.41 and *Mdn* = 3.29, *SD* = 1.25; ERC avoidance *M* = 2.98 and *Mdn* = 3.11, *SD* = 0.99).

The scores from the two questionnaires showed high and significant correlation for the RAAS and ECR relational anxiety sub scales, $r = .79$, $p < .001$, as well as for the RAAS and ECR avoidance scores, $r = .56$, $p < .001$. The scores from the relational anxiety and avoidance subscales on the other hand were near orthogonal, with no correlation between them on either questionnaire (RAAS: $r = -.025$, $p = .86$; ERC $r = .25$, $p = .06$). This demonstrates that the two subscales assess different components of adulthood attachment styles.

To achieve a more reliable measure for the relational styles, we used PCA to extract the shared component underlying the two questionnaires of each of the subscales. For relational anxiety the shared component explained 84% of the data and was loaded on both the RAAS and the ECR scales. For the relational avoidance style, the shared component explained 86% of the variability and was loaded on both the RAAS and the ERC scales. The combined score on each sub-scale was mean scaled before it was used as a covariate in the analysis. Figure 3-2 & 3-3 presents the distribution of individual scores on each relational attachment styles (after they were means scaled). The distribution of the combined relational avoidance score (on the right) was slightly positively skewed, while for the combined relational anxiety score (the graph on the left), the distribution is approximately normal.

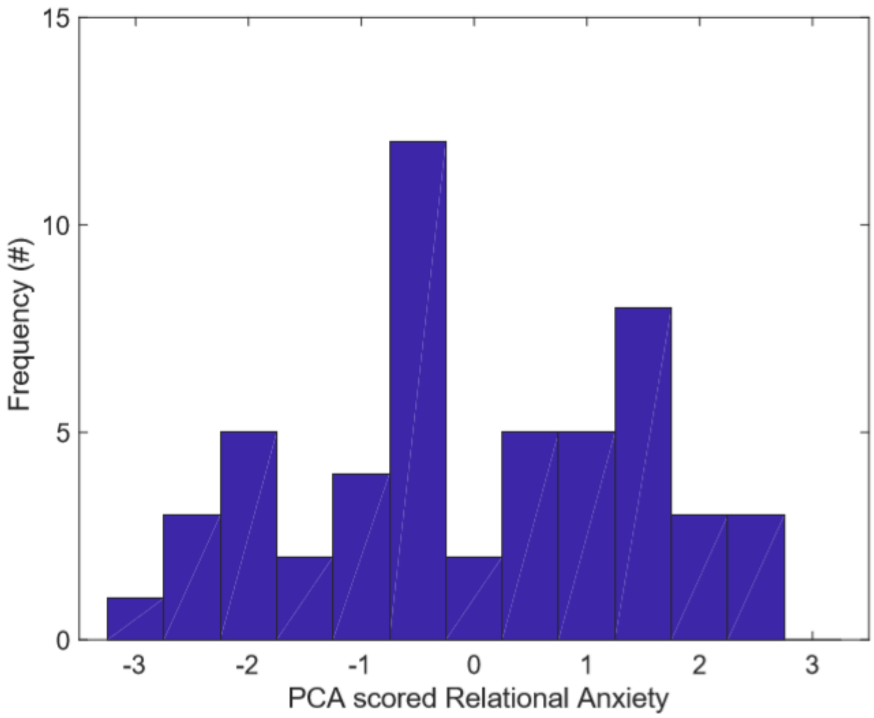

Figure 3-2 Distribution of relational anxious attachment styles in the shared PCAs scores. Low score means less insecure attachment.

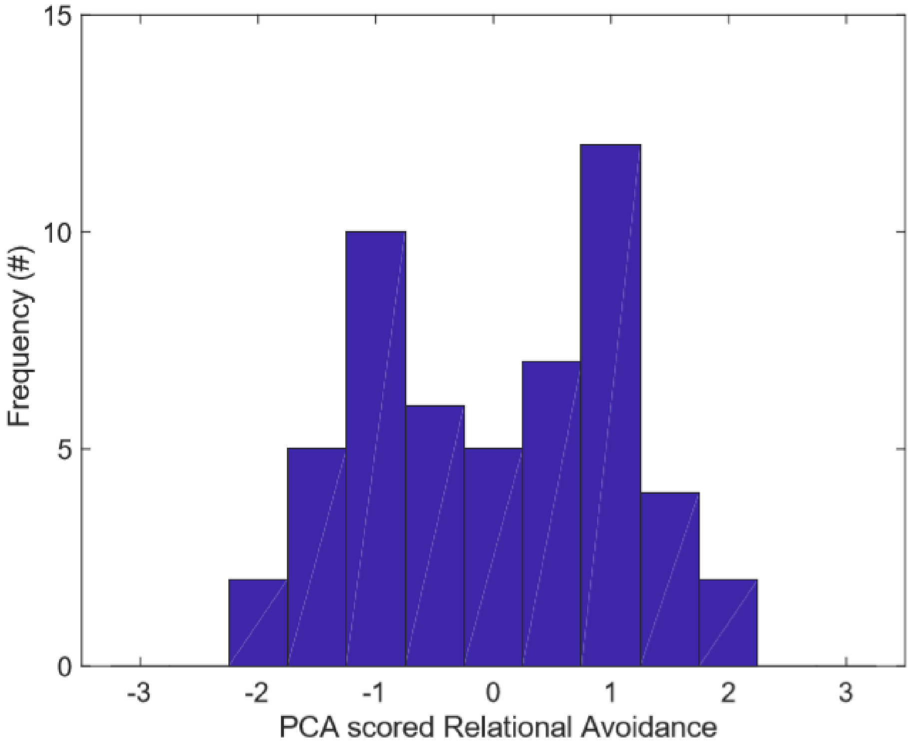

Figure 3-3 Distribution of relational avoidance attachment styles in the shared PCAs scores. Low score means less insecure attachment.

3.4.2 Validation of the environmental manipulation

Participants played the game in three environmental contexts: negative, neutral and positive. To validate the impact of environmental manipulation we used two methods: 1) explicit questions: we asked a sub-sample of 26 participants to report their emotional responses for receiving random wins or losses. This was done after completing the experiment. Of this sub-sample 54% reported that they were not emotionally affected by the manipulation; and 35% reported positive feeling (e.g., joy, encouragement) after receiving a random win; while 23% reported negative feeling (e.g., annoyed, frustration) after receiving a negative loss; some participants were affected by both negative and positive environmental manipulation. Thus, the self-reported data suggested that while subjects were clearly aware of the manipulation only about half of the participants admitted or were consciously aware of being affected by the environmental manipulation.

The second method for validating the environmental manipulation was an implicit measure of response time (RT). Here it was assumed that a consistent change in RT in response to the environmental manipulation will reflect a change in participants' internal states.

The decision time data was used in a 2 (partner: computer, human) * 3 (context: negative, neutral, positive) ANCOVA test with attachment as covariate. The type of partner marginally affected response times to decide, F (1, 46) = 3.47, p = .08, $p\eta^2$ = .06. More importantly there was a main effect of environmental context, F (2, 92) = 5.76, p <.01, $p\eta^2$ = .11, Participants were fastest to make a decision during the neutral context blocks, M = 1041.65ms, SD = 72ms, and slowest during the positive, M = 1238.31ms, SD = 79ms, while decisions during the negative environmental blocks were in between, M = 1157.43ms, SD =73 ms. The effect of the environmental context depended on the type of partner, F (2, 92) = 3.56, p = 0.03, $p\eta^2$ = .07. The interaction showed that the environmental context affected decision times only when playing with a human, where relative to the neutral context decision times were slower in the negative, t (48) = -3.2, p <.05, d = .30 and the positive, t (48) = -3.8, p = .002, d = 0.54, contexts, and there was no significant relationship between the negative and positive environment. When playing with a computer, the environmental manipulation had no effect, t (48) = -.30, p =.76, d = .66. This suggests that the environmental context primarily affected decisions in the social context (Figure 3-4).

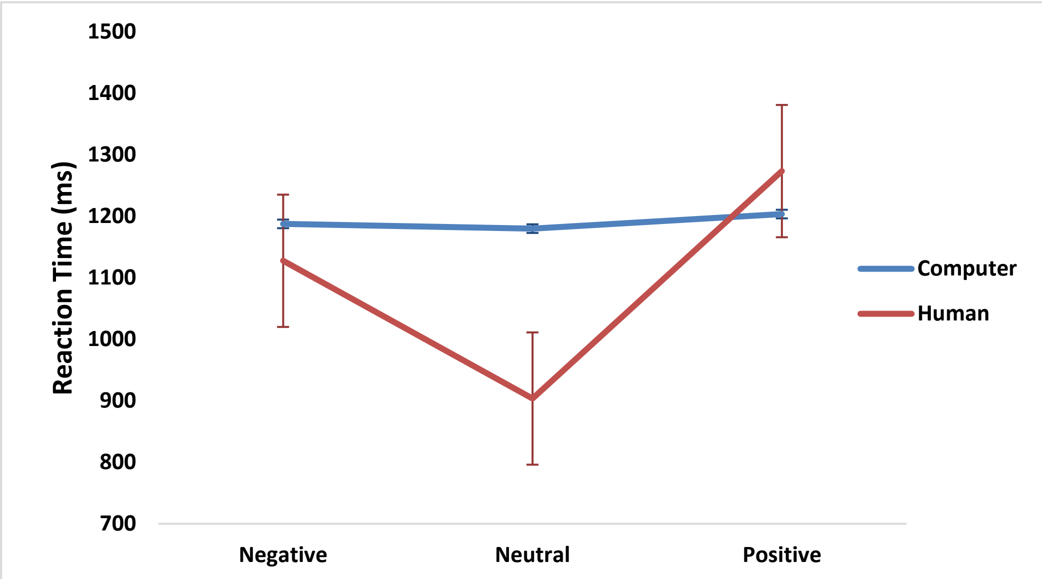

Figure 3-4 Response time when playing against a human and a computer partner in the environments. Subjects were faster in the neutral condition as compared to the negative and positive environments when playing against a human partner. The error bars are standard errors.

3.4.3 Effect of environmental context and relational styles on cooperation

Based on our hypotheses we focused on the proportion of times participants cooperated in each condition. We used an ANCOVA with partner and environment as repeated factors and attachment type as a covariate. The data showed a clear effect of partner, F (1, 50) = 28.56, p <.001, $p\eta^2$ = .36, participants were more likely to cooperate with a human than with a computer partner (Figure 3-5). There was no significant main effect of the environmental context, F (2, 100) = 2.19, p = .11, $p\eta^2$ = .04, but more interestingly a significant interaction between the environmental context and the type of partner, F (2, 100) = 4.93, p = .009, $p\eta^2$ =.09. Further analysis showed that the interaction emerged because the environment only affected participants when playing with a human partner, F (2, 100) = 4.65, p <.001, $p\eta^2$ =.08, but not when playing with a computer partner: there was more cooperation in the negative environment as compared to neutral, t (52) = 2.91, p = .005, d = 0.81 and marginally more cooperation compared to positive environment, t (52) = 1.77, p = .08, d = 0.49. This effect was not significant when playing against a computer (Figure 3-6).

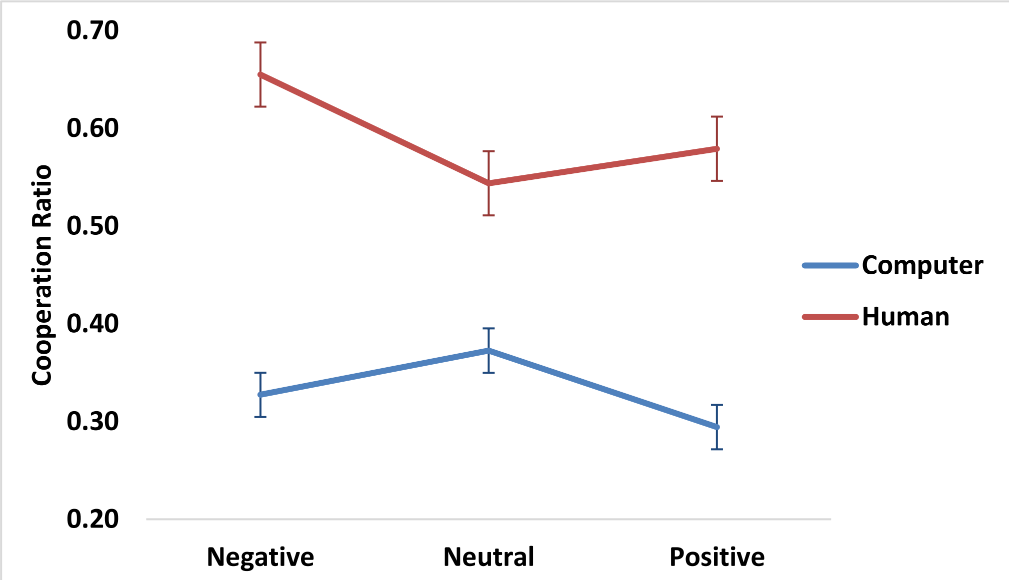

Figure 3-5 Proportion of cooperation with human and computer partner in the three environments. Subjects cooperated more with human than computer partner and were overall less likely to cooperate in the positive environment (see main text). The error bars are standard errors.

Avoidant or anxious relational style did not reliably affect the overall proportion of cooperation, F (1, 50) = 3.25, p = .077, $p\eta^2$ = .061; F (1, 50) = 0.11, p = .74, $p\eta^2$ = .00, respectively. There was also no interaction between the type of partner and the relational style. However, avoidant relational style affected the response to the environmental context, F (2, 100) = 3.19, p =.04, $p\eta^2$ = .06. There was also a three-way interaction of partner and environment with anxiety, F (2, 100) = 4.37, p =.015, $p\eta^2$ = .080 and a trend of three-way interactions of partner and environment with avoidance, F (2, 100) = 2.37, p = .10, $p\eta^2$ = .04 relational styles. Post-hoc power analysis suggests that for the interaction effects observed in the data the power of the current study was higher than .70 for the relational anxiety and higher than .58 for the relational avoidance.

Our *a priori* hypothesis concerned the effects of attachment style on the pattern of cooperation when playing with human in a negative environment. Therefore, the follow up analyses focus on this question. We computed for each partner condition a differential environmental context score. This was done by subtracting the cooperation scores in negative and positive conditions from neutral condition. We then correlated these differential cooperation scores with the anxious and avoidant relational styles. To correct for the multiple comparisons, we used Bonferroni correction (corrected p value: .05/4 = .0125). For the anxiety relational style, the results showed that when playing with a human partner, high anxious individual tended to cooperate less when in a negative emotional state than when in a neutral emotional state, r (n=53) = 0.41, t (52) = 3.24, p = .0125, (Figure 3-6). Similarly, for the avoidance relational, when playing with a human partner high avoidance individual were less likely to cooperate when in the negative state than in the neutral state, r (53) = .48, t (52) = 3.94, p =.012 (Figure 3-7). No significant result was found for the positive minus neutral contrast. When playing with a computer, cooperation ratio during the positive or negative versus the neutral states was not affected by anxiety or the avoidance relational styles.

a

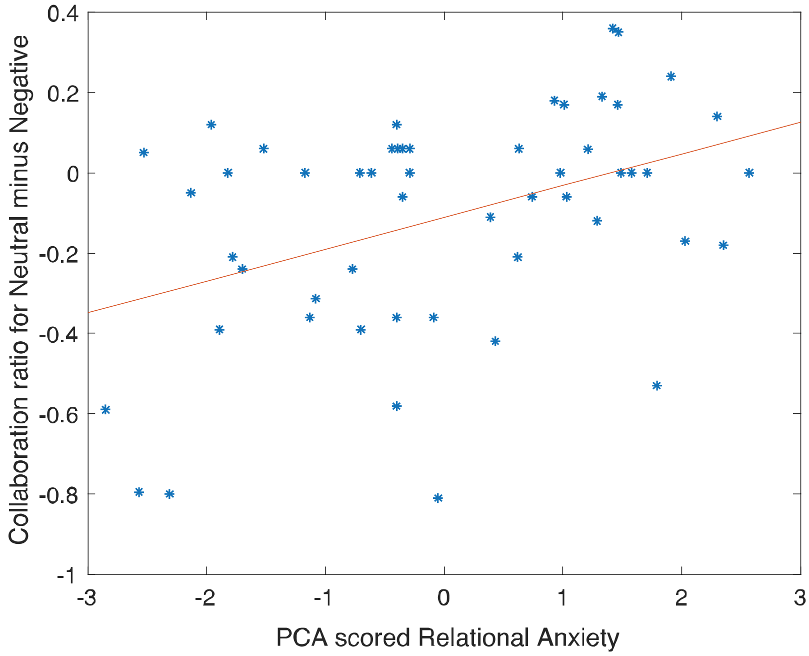

Figure 3-6 Correlations between the differential cooperation scores with anxiety and avoidance PCAs

Differences in the cooperation ratio across negative and neutral environmental contexts correlated with shared PCA components for attachment relational score. High anxious individuals (on the left panel) tended to cooperate less when in a negative environmental context than when in a neutral environmental context.

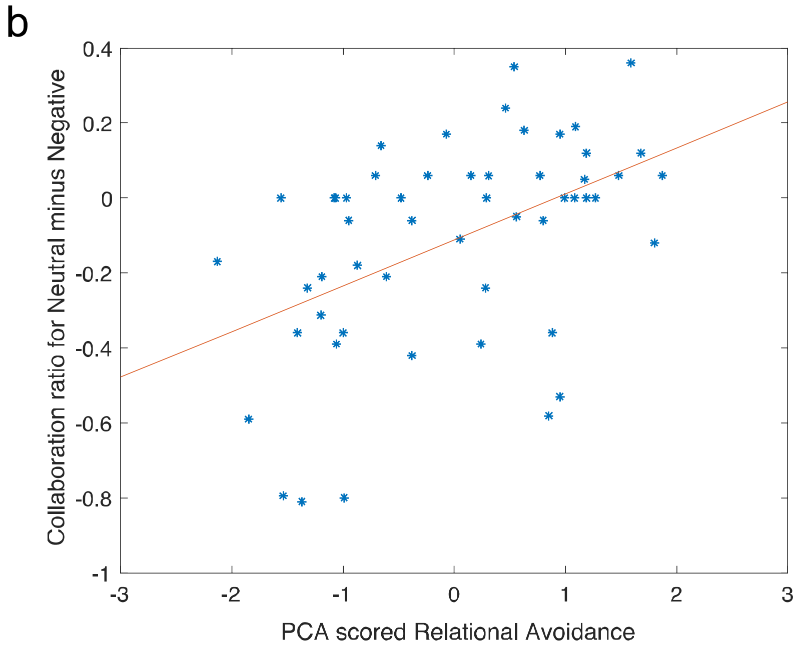

Figure 3-7 Correlations between the differential cooperation scores with anxiety and avoidance PCAs

Differences in the cooperation ratio across negative and neutral environmental contexts correlated with shared PCA components for attachment relational score. High avoidance individuals (on the right panel) were less likely to cooperate when in the negative context than in the neutral context.

In the current experiment, participants played with other participants in half the trials. This means that like in real life, the behavior of any given participant depended to a degree on their partner's and the relationship they formed in the game. In other words, the participants cannot be considered as fully independent samples, as their responses were dependent on the pairing. The lack of independence violates ANOVAs assumptions and may have led to inflation of the degrees of freedom. To ensure the pattern of results was not affected by this procedure, we ran two additional analyses: 1) A non-parametric analysis where independence between measures is not assumed; 2) An analysis where the averaged pair performance was the random variable.

The non-parametric analysis used Friedman's two- way analysis of variance by ranks: with the 2 types of partners by 3 environment conditions. The model was significant (p <.001) showing that the distributions of the data across the conditions were not the same. A follow up analysis showed that the average cooperation ratio when playing with a human was reliably higher than when playing with a computer (p <.001). Participant also cooperated more when playing with a human in the negative context than in the neutral context (p =.015). There was no reliable difference between negative and positive (p = .117) or neutral and positive (p = .451). Environment also affected the way participants played with the computer, showing less cooperation in the positive relative to the negative environment (p =.012), but no difference between the positive and negative (p = .202) and the negative and neutral environmental conditions (p = .423).

Finally, we used Spearman rho correlations to confirm the relations between cooperation ratio in the various conditions (neutral – negative; neutral – positive) and individuals' reported attachment style. While at the group level, participants increased their cooperation when faced with adverse environment, this effect was diminished for high relational anxiety (R_s = .36, p = .009) and for high relational avoidance (R_s = .50, p <.001) participants. Individual difference in attachment style did not affect the pattern of cooperation with computer or in the positive (vs. neutral) environment (p = .184).

In a second analysis we treated the pairs as the random factor, rather than the participants. The response of 22 pairs and their attachment scores were averaged (we excluded participants whose partner was excluded from the analysis due to age).

ANCOVA with the factors partner and environment as repeated factors and attachment type as a covariate revealed a similar pattern. Participants were more likely to cooperate with a human than with a computer partner *F* (1, 19) = 12.52, *p* = .002, $p\eta^2$=.40, and the interaction of partner and environment affected the cooperation ratio, *F* (2, 38) = 3.66, *p* = .03, $p\eta^2$ = .16. Follow up analysis showed that environment affected cooperation with human, *F* (2, 38) = 3.33, *p* = .04, $p\eta^2$ =.15, but not with computer partner.

The average attachment style of the pair also modulated cooperation dependent on the environment when playing with human but not with computer partner (*p* >.2). Specifically, when playing with a human, responses to the environment were affected by the averaged relational anxiety of the pair, *F* (2, 38) = 3.67, *p* = .03, $p\eta^2$ = .16; and the averaged relational avoidance, *F* (2, 38) = 4.10, *p* = .02, $p\eta^2$ = .18. Follow up analysis showed that the increased correlation during negative (vs. neutral), observed at the group level was diminished for pairs with high average of relational anxiety (*r* = .54, *p* = .01) and avoidance (*r* = .615, *p* = .002).

Taken together the data suggest clear effects of partner type and environment which were modulated by individuals' relational attachment scores. These results were also observed using non-parametric statistical analysis, or when using reduced study power by considering the pairs rather than the individuals as the random factor.

3.5 Discussion

In this study, we considered the effect of environmental context and attachment style on human cooperative decision-making in social and non-social contexts. We hypothesized that people make different decisions in a social conflict situation based on their attachment style and influenced by the environment. To test our hypothesis, we employed a modified version of the repeated prisoner's dilemma game (PDG) and attachment questionnaires. Importantly, participants were tested two at a time to increase the validity of the social interaction and played multiple games with each other under different environmental contexts. We then compared individual differences in their cooperative behavior when playing with real human (the other participants) and computer partner under negative, neutral, and positive environmental contexts. Unsurprisingly we found that cooperation was higher when playing against a real human than a computer, but only, when playing with a real human did cooperation increase in the negative environment. High levels of relational anxious and avoidant styles were associated with tuning down the latter effect, reducing cooperative behavior in the negative context. We discuss these findings in the following sections.

3.5.1 Effect of partner; playing with human or computer

Overall participants were more cooperative when playing with human partner as compared to computer partner. This finding is in line with previous research (Biel & Thøgersen, 2007; Butler et al., 2011; Miwa & Terai, 2012b), and merely reflects the social aspect of the game. We observed that cooperation with human partner was higher, even though we used a repeated version of PDG (with a mean of 90 trials) that is shown to decrease cooperation (Hargreaves-Heap & Varoufakis, 2004).

It is worth noting that participants were matched to each other based on opportunistic sampling. Two participants signed up to each experimental time slots, and if they did not know each other they would proceed to play against each other. Participants were conscious that their decisions could affect the responses of the other, which potentially affected their tendency to cooperate. In our experiment, information gathered from post-experiment interviews of participants suggests that some were under the impression that humans in general are more cooperative and that they could influence their human partner's decisions but not the computer's. Hence, they believed that the computer was programmed to respond randomly (whilst the computer was programed to play a tit-for strategy in 80% of the trials, however participants were blind to this). Unsurprisingly, beliefs regarding the ability of one's response to affect the response of the other player is important for cooperation.

A caveat of the above procedure is that differences in cooperation ratio between playing with a human or computer partner can be due to multiple reasons, which we cannot dissociate. For example, cooperation may be affected by 1) participants' belief about the identity of their partner and the social acceptability of defecting; 2) their belief about the ability to modulate the behavior of their partner; and 3) while the computer played tit-for-tat with noise, real humans may not be as reciprocal. Thus the strategy of a computer partner may have been qualitatively different than that of a human, despite the overall high performance of the tit-for-tat strategy (Axelrod & Dion, 1988).

3.5.2 Effect of environmental contexts on cooperative responses

In this study, we manipulated the environmental context as an external factor, by introducing blocks with random monetary rewards or losses. Overall, in blocks when participants randomly lost money (negative context) they cooperated more as compared with the blocks where they randomly won money (positive context) or the neutral blocks. This effect was more reliable when playing against a human partner as compared to computer partner. In other words, participants betrayed more (potentially showing selfish behavior) in a rewarding or predictable environment compared with a threatening uncertain environment.

Human prosocial behavior often increases under negative circumstances. A good example of such altruistic and cooperative behavior can be seen in societies after natural disasters or wars (Bauer, Blattman, Chytilová, et al., 2016). Likewise, during periods of austerity less fortunate economic groups may be placed under extra negative emotional stress, which anecdotally may lead to more cooperative behavior (Chantarat et al., 2015).

From a cognitive perspective, the finding partially also supports the affect information processing idea (Bless & Fiedler, 2006; Hertel et al., 2000a). This theory suggests that negative emotions (as elicited by threats and uncertainty) promote prosocial behavior, as individuals analytically analyze the details of the task and direct their attention to the external environment. Hence, participants are more likely to realize the long-term benefit of cooperation and consider the partner and social norms when making decisions. However, the affect processing information also suggest that positive emotions lead to an optimistic view of outcomes, reliance on heuristics and attention to internal state. This often promotes less cooperative behavior as an individual may seek easy gain.

In the current study a positive supportive environment (winning random money) did not affect cooperative decisions. This is surprising, as the emotional validation measures (the analysis of the subjective reports and RT) showed larger impact of the positive (randomly winning money) than the negative (randomly losing money) environment. The literature on this aspect is less clear and it could be that in the context of trust games positive emotions do not affect pro-social decisions (Kjell & Thompson, 2013). Thus, further research is needed to clarify the impact of positive supportive environments on decision making during social dilemmas.

3.5.3 Cooperation and rational attachment based on different environmental context

We found that relational style modulated the impact of random monetary loss (inducing negative mood) on cooperative behavior. While on average participants tended to cooperate more with their human partner during monetary loss blocks, those with higher relational anxiety or avoidance scores were less likely to cooperate in the negative context as compared to the neutral environmental context when in the social context and playing with a human partner. In other words, relationally anxious and avoidant participants were found to react to this negative environmental context by behaving less cooperatively with their human partner. These finding accords with a report that individuals with insecure attachment tend to trust less initially, and following repeated interactions (Vicary & Fraley, 2007).

The observation that individuals with high avoidance relational style make less pro-social behavior accords with previous observations (Almakias & Weiss, 2012; Vicary & Fraley, 2007). McClure and colleagues (2013) show that individual with high relational avoidance tended to cooperate less in the PDG. They reported that individuals with high relational avoidance tended to show more selfish behavior in the UG (less generous offer) and were less likely to accept offers in the DG. In both these previous studies the effects were weak and unreliable. One important difference between these previous observations and the current study is the introduction of the environmental manipulation. Indeed, we observed the impact of relational avoidance on decision only in the negative environment. As emotions linked with the environment are assumed to trigger the attachment style's working model (Almakias & Weiss, 2012) it is likely that manipulation increased the impact of attachment on behavior. It is possible that relational avoidant participants' decision to cooperate less is driven by fear of betrayal which increases in a negative environmental context. This could also be an indication of their difficulties in regulating their negative emotions and its impact on their interpersonal strategies as a result (Pietromonaco et al., 2006).

Like high relational avoidance, we observed that high relational anxious participants also cooperate less. This finding accords with the observation of McClure and colleagues (2013), showing less cooperation in PDG. As above, McClure at al. reported the effects of relational anxiety on decision were weak and unreliable. Though here, through the introduction of the environmental manipulation the effects were larger and more robust. The current finding may appear to contradict those reported by Mikulincer et al. (2003). The latter report that relational anxious behaved in an opposite way to the relational avoidant participants, making more generous offers (UG) and accepting lower offers (DG). It is possible that differences in the relationship structure between the two players in these games can explain the apparent discrepancy of the findings. As mentioned in the introduction, the ultimatum and the dictator games are based on asymmetric power relations, where resources are held by one of the participants and responses are made based on known (DG), or partly predictable (UG) behavior of the other. While in the prisoner's dilemma game, there is symmetry in power, the behavior of the other is less predictable, and trust between equals determines the distribution of the rewards. Thus, it could be that relational anxious individuals, being less trustful especially in a negative context are less likely to cooperate when the behavior of the other is less predictable. Another important contextual difference is the possibility to lose money in the PDG, while in the UG and DG one cannot lose money, but just not gain a reward. Thus, the impact of loss aversion on interpersonal trust is likely to be larger in the PDG. In PDG, if an anxious attached participant decides to cooperate whilst the other participant betray, the cooperative player loses more money (30p in our game), and if they both betray, they both lose smaller amount (10p in our game). The potential of loss is higher for a cooperating decision. However, in the ultimatum game if an anxious participant offers bigger amount and gets rejected (that is less likely) by the other player, they both get nothing, and if they reject smaller offer, they also get nothing. The ultimatum game thus does not allow for monetary loss (just lack of rewards), which might be more frightening or upsetting. As above, the inclusion of the mood manipulation is likely to have affected the result. The high sensitivity to the negative signals (random loss of money) by anxious attached individuals triggered their attachment system and therefore resulted in untrusting behavior due to fear of betrayal (Almakias & Weiss, 2012).

Taken together, we suggest that people with relational anxiety or avoidance perceived random losses in the negative environmental context as threat signals, significantly affecting their behavior; this was particularly seen in the social context, meaning when they were playing with their human partner and not with the computer partner. We propose that negative environmental context triggers the attachment system in both anxious and avoidant individuals and results in defensive behaviors, such as betrayal of their human partner.

Less cooperative behavior in negative environmental context in both anxious and avoidant relational style could be also due to an individual's internal working models. as suggested by Bowlby (1969). Based on his theory an internal working model affects how we perceive and react to the environmental cues. This can be also explained by Bartholomew's four dimensions model of attachment, according to which people who have a negative model of self and negative model of others are in the high anxiety axis (Bartholomew & Shaver, 1998). According to Mikulincer, Shaver and Pereg (2003) people with high attachment anxiety have difficulties in regulating their negative mood and impulses.

3.6 Limitations of our study and suggestions for future research

One limitation of our study, shared with most versions of the PDG, was the un-natural conditions of the experiment. Whilst in our study we tried to simulate the conditions that people have to make a decision in a conflicting situation with the minimum knowledge of their unknown partners, this was however done over computers and within experimental cubicles. While social interactions involving trust in a computer-based environment are now quite common, it would nevertheless be interesting to study human decision-making in a more natural and social environment. We do note though that, in contrast to many other studies, participants in this study met their partner at the briefing session, highlighting the social context of the study while potentially allowing for less precise control over experimental conditions.

The environmental manipulation, done by providing a random monetary gain or loss, may not necessarily have affected our participants. Though only slightly more than 50% reported being explicitly affected by the manipulation, average RT showed an effect of the manipulation. It could also be that the environmental manipulation and the experimental outcome confounded each other, as both were associated with monetary wins and losses. For example, the impact of random loss on mood may have been magnified following a loss during the trial or lessened following a gain in the trial.

As participants played iterative games (~18 games x 3 blocks) with each other, we often observed that results tended to converge on either Nash equilibria. In other words, in many blocks participants' responses were of mutual cooperation or mutual defection, hence there was relatively little variability and exploration in these blocks. This obviously hinders the ability, and reduces the power, of the study to test the impact of external and internal factors on cooperative behavior, due to ceiling or floor effects.

Lastly, it is hard to isolate the behavior of one participant in an iterated prisoner's dilemma game as the behavior of one player affects the other player's behavior, and vice versa. This leads to a unique pattern between the two players. Hence the interactions between two players are never random but exhibit some kind of heterogeneity and potentially depend on the formed relation and impression made initially and through the game. For example, it is likely that an individual will change their cooperation tendency as a function of their partner in a game, irrespective of their relational attachment style. Therefore, across participants the games were not fully equated, adding unaccounted variability to the measurement. However, the only way to avoid this is issue is to artificially control the partner player (e.g., as hidden computer player), which will lessen the ecological validity.

3.7 Conclusions

The current study showed that both environmental context and its interaction with attachment style affect our cooperative behavior in a social conflicting situation such as PDG. Specifically, the data suggests that whilst a negative environmental context facilitates human cooperation in general, it has a negative impact on both avoidant and anxious attached individuals and results in their decreased cooperative behavior. These results highlight the interaction between environment and attachment as important factors for individual decision-making.

4. THE EFFECT OF ENVIRONMENTAL MANIPULATIONS AND RELATIONAL ATTACHMENT STYLE ON COOPERATIVE BEHAVIOR IN A FACE-TO-FACE PRISONER'S DILEMMA GAME

4.1 Abstract

Most previous studies on cooperation have focussed on anonymous social interactions and only some have investigated the effect of verbal or written communications (Balliet, 2010). In the present study, participants' cooperation during a nonverbal face-to-face interaction was examined. I used the same paradigm as in Study 1 (Chapter 2, Taheri et al., 2018), with the aim of replicating the results, but now participants (fifty male and female) played the game in the same room, enabling non-verbal face-to-face interactions. Replicating the finding from Study 1, participants cooperated more with a human than with a computer partner. However, the environment had a different effect depending on the partner. When playing with a human, participants cooperated more in the positive environmental context rather than in the neutral or negative context. Findings from the effect of environmental context on cooperation with a human partner are the opposite of the findings from Study 1, in which participants cooperated more during the negative environmental context. However, and the same as in Study 1, when playing with a computer partner, participants cooperated more in the neutral context rather than in positive or negative environments. The three-way interaction of attachment style, partner type and environment replicated the results from Study 1, with insecure attachment showing less cooperation with a human during a negative environment. But this was significant only in the pair-based analysis (when considering the average responses of the two partners). Overall, findings from this study partially replicate the results from Study 1, whilst the finding also shows that the type of interaction, face-to-face vs non-face-to-face, affects cooperation differently according to the environmental context and the individual differences.

Keywords: Attachment Theory; Cooperation; Prisoner's Dilemma Game; Attachment Style; Face-to-Face Interaction; Psychology and Economics.

4.2 Introduction

To understand human cooperation in social dilemmas, social psychologists would say we need to understand the whole psychological situation (Lewin, 1936). This is presented by behaviour as a function of the situation. In addition to acknowledging the 'power of the situation', the Interdependence Theory (IT) (Kelley et al., 2009a; Rusbult & Van Lange, 2003a) also emphasises the importance of considering the interpersonal motives and attitude that affects their responses to the specific properties of the situation. For example, the ways that partners affect each other's outcome through the ways that they share information or order their responses (Kelley et al., 2009a). In this study, the impact of the environmental uncertainty, and how individuals with different relational attachment style react to them in a non-verbal face-to-face interaction during a repeated Prisoner's Dilemma Game (PDG), was investigated. The aim of this study is to replicate findings from Study 1, (Taheri et al., 2018) which was conducted in a non-face-to-face condition. However, in this study, the role of the above variables is investigated during a face-to-face interaction.

It is suggested that social dynamics created through face-to-face interactions are guided by two mechanisms: the uncontrolled social utility hypothesis and the communication hypotheses (Kagel and Roth, 1995). The uncontrolled social utility hypothesis suggests that we bring our social learning and motivations, or expectations, into our face-to-face interactions – the so-called mannerism, e.g., interpersonal perceptions, and prejudices. The communication hypothesis proposes that during a face-to-face social interaction, partners communicate with each other through non-verbal interactions. For example, a set of functional patterns at the neuromuscular level that has a semantic meaning, such as yes or no, agreement or disagreement, that are shown to be consistent across cultures; this is known as ‘eyebrow flash’. It is suggested that partners can communicate through facial expressions that facilitate their cooperative decision-making (Brosig, 2002; Grammer, Schiefenhövel, Schleidt, Lorenz, & Eibl-Eibesfeldt, 2010;). A large part of the literature however has focussed on the effect of verbal and written communication (Balliet, 2010). Whilst written or verbal communications are shown to increase cooperation in dilemmas, silent identification is also shown to increase solidarity in the Prisoner’s Dilemma Game (PDG) (Bohnet & Frey, 2002). Bohnet and Frey (2002) called this, the ‘Sound of Silence’ and showed that it has a power of its own. Therefore, the focus of this study is to replicate the first study (Chapter 3), but to investigate the effect of environmental uncertainty and attachment style during a face-to-face interaction on cooperative behaviour in the repeated PDG.

Findings from Study 1 (Chapter 3) showed that participants to cooperate more with the human partner as compared to a computer partner. Overall, when playing with a human partner, all participants cooperated more in the negative environmental context as compared to the neutral and the negative environmental context. This finding was discussed through theories and through evidence such as altruism during negative environmental uncertainty (Bauer, Blattman, Henrich, Miguel, & Mitts, 2016; Samphantharak & Chantarat, 2015), and the cognitive aspect of affect as information through directing the attention to the external environment processing (Bless & Fiedler, 2006; Hertel & Fiedler, 1994). Therefore, it is interesting to see how these environmental uncertainties would affect cooperation when participants interact with each other in a face-to-face setting.

In the first study, it was also found that relational attachment affected participants' cooperation in the negative environmental context during a non-face-to-face PDG (Taheri et al., 2018). The findings showed that whilst overall cooperation increased during a negative environmental context, participants with high relational anxiety and high relational avoidance, cooperated less during the negative environmental context. This finding was discussed based on attachment representation (Almakias & Weiss, 2012), and its moderation of the relationship between emotional contexts and information processing (Leyh, Heinisch, Kungl, & Spangler, 2016), and how this could interfere with the negative and positive environmental context and affect individuals' decision-making. In the current study, the aim is to see how the face-to-face interaction would change the social dynamic, and how individuals with different attachment styles react to the environmental uncertainty in a nonverbal face-to-face PDG.

The importance of attachment style or the 'internal working model' in encoding and decoding nonverbal communication (cues/signals) is well presented by Schachner, Shaver, and Mikulincer, (2005). Amongst these nonverbal cues are facial expressions that have been shown to be perceived, encoded, and decoded by individuals and partners according to their attachment style. In a study conducted by Fraley, et al., (2006), it was shown that anxiously attached individuals show more sensitivity and vigilance to social and emotional facial expression, e.g., they are more likely to perceive the offset and onset of the facial expression. In a brain imaging study based on event-related potential, anxiously attached individuals were found to be more sensitive, and avoidant attached individuals less sensitive to facial expression, as compared to secure individuals (Zhang, Li, & Zhou, 2008). Whilst these studies provide support on how attachment style affects an individual's perception and their reaction to facial expression, different attachment types are also shown to prefer different communication methods. For example, avoidant attached individuals may not feel comfortable during face-to-face interactions (Wardecker, Chopik, Boyer, & Edelstein, 2016). Brain imaging studies using functional magnetic resonance imaging (fMRI) methods and the PDG also showed that individual differences in attachment style correlate at the neural level during a mentalising task (also called theory of mind) (Schneider-Hassloff, Straube, Nuscheler, Wemken, & Kircher, 2015). These findings show the importance of the attachment style as a social cognition trait that impacts social interactions, and that this can vary based on different social contexts, e.g., face-to-face vs. non-face-to-face.

Based on the findings from Study1, in this study I was interested to investigate the effect of environmental uncertainty, and attachment style in a face-to-face interaction on cooperation during a repeated PDG. I used a face-to-face setting as the face-to-face interaction, as it is more ecologically valid as compared to a video or picture; it can increase social pressure whilst decreasing social distance (Bohnet & Frey, 2002), also referred to as social effect. Based on the finding from Study 1 and evidence and theories discussed, the following hypotheses were formulated:

Hypotheses:

- The first study showed that participants cooperate more with a human partner as compared to the computer partner in the non-face-to-face interaction, this finding is expected to be the same during the face-to-face interaction.

- Environmental uncertainty was shown to increase cooperation within the negative environmental context during a non-face-to-face interaction. It is expected to replicate these results or magnify this finding during a face-to-face interaction. Whilst the positive environmental context did not show any effect on cooperation during a non-face-to-face interaction, in this study it is not clear how positive environmental context would affect participants cooperation during a face-to-face interaction.
- In Study 1, it was found that anxious and avoidant individuals cooperate less in the negative environmental context. In this study, it is expected to replicate this finding and that this effect will be magnified during a face-to-face interaction. Whilst the positive environmental context did not show any interaction with attachment style during a non-face-to-face interaction, in this study it is not clear how an anxious and avoidant attached individual would react to the positive environmental context during a face-to-face interaction and how this would affect their cooperation.

4.3 Methods and materials

4.3.1 Study paradigm and participants

The same paradigm as in Study 1 (Chapter 3) was used. However, participants played the game whilst sitting in the same room and facing each other (see Figure 4-1). Fifty university students (age range 18 to 24 years old, six male) were recruited for the study. Whilst participants could see each other's faces, they could not see the other's keyboards. They were also briefed that no verbal communication was allowed during the game. Participants also completed the same self-report attachment questionnaires as in Study 1.

Figure 4-1 Participants sitting arrangement during the face-to-face interaction. Participants were seated on both sides of the table where they played the game. They could see each other's faces but not the other's keyboard. The experimenter was in the room next to the experiment room and could observe the players from the window.

4.4 Results

4.4.1 Attachment styles

The attachment measures for relational anxiety combined score of the RAAS and the ECR found high reliability (24 items: Cronbach's alphas α = .88). The Cronbach's alpha for relational avoidance of the combined attachment scores also found high reliability (29 items: $\alpha = .83$).

The distribution of attachment style scores matched responses reported in the healthy population (Fraley et al., 2006) (RAAS-anxiety: *M* = 2.81, *Mdn* = 2.83, *SD* = 0.81.; RAAS avoidance: *M* = 2.65, *Mdn* = 2.58, *SD* = 0.66; ERC anxiety *M* = 3.35 and *Mdn* = 3.24, *SD* = 0.91; ERC avoidance *M* = 2.85 and *Mdn* = 2.75, *SD* = 1.10). The average score for the attachment, anxiety and avoidance are similar to the distribution of the attachment scores in Study 1, Chapter 3.

The scores from the two questionnaires showed high and significant correlation for the RAAS and ECR relational anxiety sub scales, $r = .79$, $p < .001$, as well as for the RAAS and ECR avoidance scores, $r = .77$, $p < .001$. The scores from the relational anxiety and avoidance subscales were also correlated in RAAS: ($r = .33$, $p = .02$), with no correlation between the anxiety and avoidance subscales in ERC: ($r = .24$, $p = .08$). This is different from the questionnaire results in Study 1, where the scores from the two subscales were orthogonal, showing the two-subscales measured different constructs. Hence, the RAAS in this study measures the overall insecure attachment style, whilst the ERC measures the two constructs: anxiety and avoidance.

In the same way as in Study 1, PCA was used to extract the shared component underlying the two questionnaires in each of the subscales. For relational anxiety, the shared component explained 89.3% of the data and was loaded on both the RAAS and the ECR scales. For the relational avoidance style, the shared component explained 90.09% of the variability and was loaded on both the RAAS and the ERC scales. The

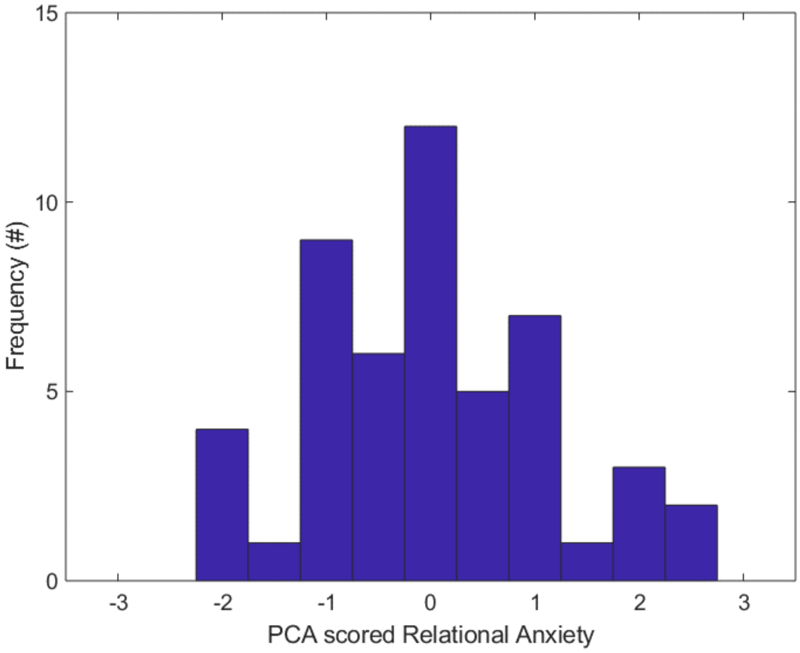

Figure 4-2 Distribution of relational anxiety attachment styles in the shared PCA scores. Low score means less insecure attachment.

combined score on each sub-scale was mean scaled before it was used as a covariate in the analysis. Figure 4-2 and Figure 4-3 present the distribution of individual scores on each relational attachment styles (after they were means scaled). The distribution of the combined relational avoidance score was slightly negatively skewed, for the combined relational anxiety score the distribution is normal. This is slightly different from the Study 1, as in the previous study the avoidance score was positively skewed. In the current study, the two relational PCA scores were significantly correlated with each other, (R_s = .40, p = .004).

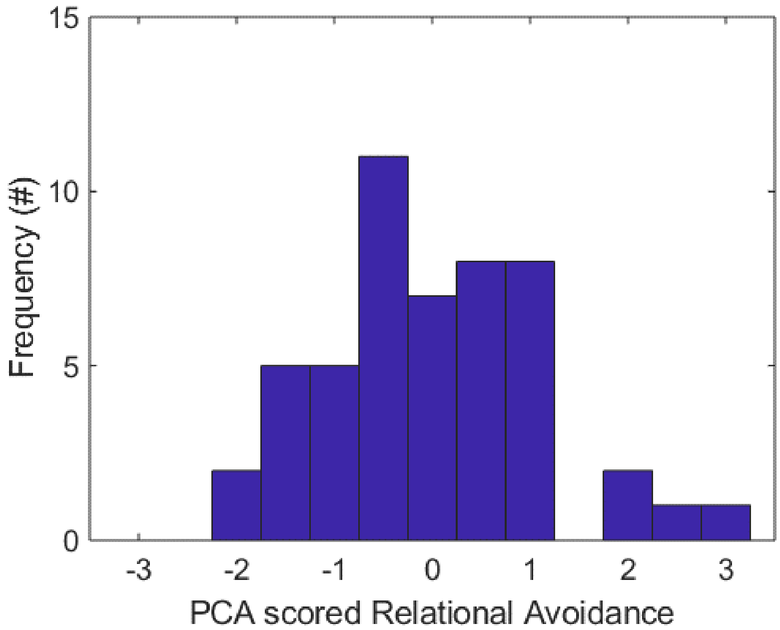

Figure 4-3 Distribution of relational avoidance attachment styles in the shared PCA scores. Low score means less insecure attachment.

4.4.2 Validation of the environmental manipulation

From the post experiment debriefing data, 62% of the participants reported being emotionally affected by the negative environmental uncertainty, whilst 45% of the participants reported that the positive uncertainty has affected their decisions (due the recoding mistakes in participants response to the questions about the feeling of being affected by the positive environmental uncertainty, I only report the feeling of being affected in the negative environmental uncertainty and the decisions being affected by the positive environmental uncertainty). This finding is a slightly different to the post experiment data found in Study 1 in which 54% reported that they were not emotionally affected by the manipulation; and 20% reported that their decision was affected by randomly losing or gaining money. Thus, the self-report data suggest that while subjects were clearly aware of the manipulation, about half of the participants admitted or were consciously aware of being affected by the environmental manipulation. These results are different from the first study (Chapter 3), where about less than half of the participants confirmed that they were consciously affected by the environmental manipulation. Hence it seems participants were slightly more affected by the environmental uncertainty in the face-to-face study.

The second method for validating the environmental manipulation was an implicit measure of response time (RT). Here it was assumed that a consistent change in RT in response to the environmental manipulation will reflect a change in participants' internal states. The decision time data was used in a 2 (partner: computer, human) * 3 (context: negative, neutral, positive) ANCOVA test with anxiety and avoidance attachment PCA scores as covariate. The type of partner significantly affected response times to decide, F (1, 47) = 20.54, p <.001, $p\eta^2$ = .30. More importantly there was a main effect of environmental context, F (2,94) = 6.63, p <.01, $p\eta^2$ = .12, Participants were fastest to make a decision during the neutral context blocks, M = 946.44ms, SE = 50ms, and slowest during the positive, M = 1105.96ms, SE = 64ms, while decisions during the negative environmental blocks were in between, M = 1034.85ms, SE = 40ms. The effect of the environmental context did not interact with the type of partner, F (2,94) = 0.16, p = .852, $p\eta^2$ = .00. However, based on the results of chapter 3, the effect of environment was examined separately for each partner. The environmental context affected decision times only when playing with a human, where relative to the neutral context, decision times were slower in the negative, t (49) = -2.19, p = .033, d = .54, and in the positive, t (49) = -2.93, p <.05, d = .37 contexts. When playing with a computer, the environmental manipulation had no effect. This suggests that the environmental context primarily affected decisions in the social context (Figure 4-4).

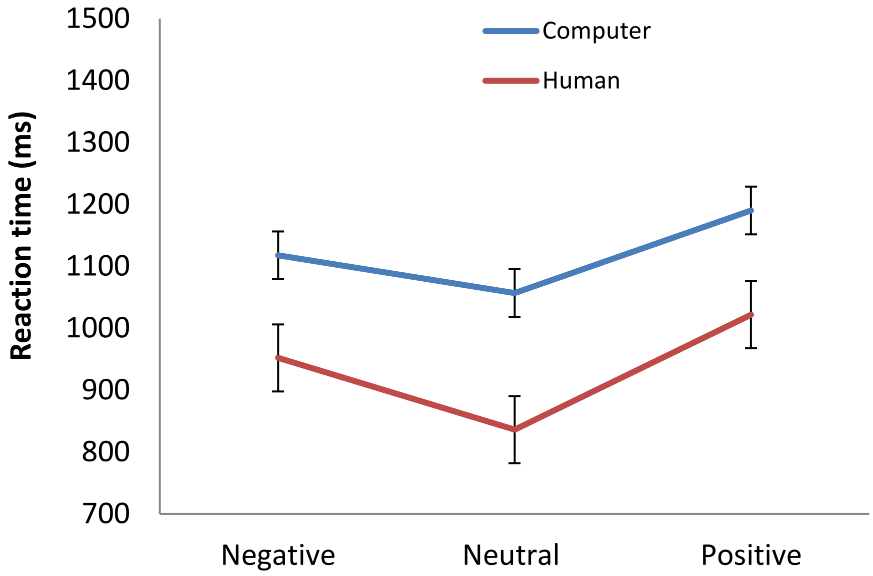

Figure 4-4 Response time when playing against a human and a computer partner across the environments. Participants were fastest to decide during the neutral context and slowest during the positive, and the negative environmental blocks and this was significant when the played with a human partner. . The error bars are standard errors.

4.4.3 Effect of environmental context and relational styles on cooperation

The same analysis as in the first PDG study was used, with a focus on the proportion of times participants cooperated in each condition. ANCOVA with partner and environment as repeated factors, and attachment anxiety and avoidant PCA scores as a covariate, was used. The data showed a clear effect of partner, F (1, 47) = 17.7, p <.001, pη^2 = .27, participants were more likely to cooperate with a human than with a computer partner (Figure 4-5). There was also a significant main effect of the environmental context, F (2, 94) = 6.9, p = .001, pη^2 = .13, and a significant interaction between the environmental context and the type of partner, F (2, 94) = 4.64, p = .01, pη^2 = .09.

Further analysis splits the games played with human and computer. When playing with a human partner, environment affected cooperation ratio, F (2, 94) = 3.36, p <.05, $p\eta^2 = .085$. Participants cooperated more in the positive environment as compared to neutral, t (49) = 2.44, p <.05, d = .00 and negative environment, t (49) = 2.38, p = .001, d = .03. There was no significant difference between participants' cooperation when playing in the negative as compared to the neutral environment. This is different from the first study, in which participants cooperated more in the negative environment, as compared to the neutral and positive environmental contexts.

When playing with a computer partner, environment also had an effect, F (2, 94) = 7.91, p <.001, $p\eta^2 = .14$. Participants cooperated more in the neutral condition as compared to the negative, t (49) = 3.65, p = .001, d = 2.5 and positive environment, t (49) = 2.26, p = .02, d = 2.35, participants also showed a tendency to cooperate more in the positive than in the negative environment, t (49) = 1.95, p = .05, d = 0.22 (Figure 4-6). This finding is similar to the finding from the Study 1.

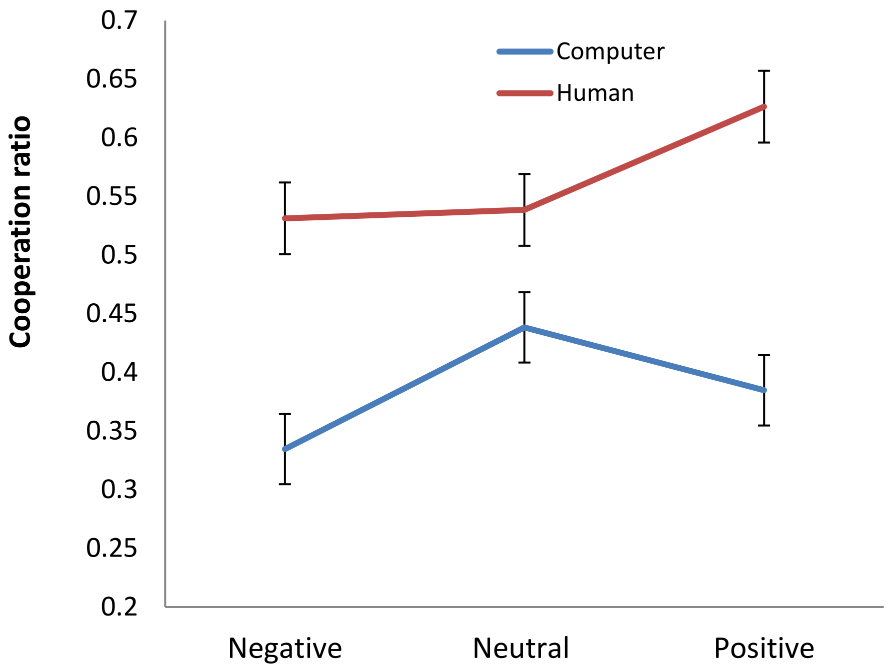

Figure 4-5 Proportion of cooperation with human and computer partner across the three environmental contexts.

Subjects cooperated more with a human than a computer partner and were overall more likely to cooperate in the positive environment whilst they were more likely to cooperate with a computer in the neutral context (see main text). The error bars are standard errors.

In summary, a positive (relative to negative and neutral) environment encouraged participants to cooperate significantly more when playing against their human partner, whilst a certain neutral environment was more encouraging to cooperate than an uncertain environment, when they played against their computer partner.

Avoidant or anxious relational PCA scores did not affect the overall proportion of cooperation, F (1, 47) = .01, p = .91, $p\eta^2$ = .00; F (1, 47) = 3.22, p = .79, $p\eta^2$ = .064, respectively. There was also no interaction between the type of partner and the relational style. Similarly, no interaction was found between the environmental context with anxiety or avoidance relational scores, nor any three-way interactions of partner and environment with avoidance, or anxiety relational styles was found. This is unlike our previous study (Chapter 3) where a three way interaction between the environment, partner and attachment style were found as was a significant trend with the avoidant style.

As in Study 1, the *a priori* hypothesis was concerned with the effects of attachment style on the pattern of cooperation when playing with a human in a negative environment, but during a face-to-face interaction. Therefore, the same computation was done for each partner condition to create differential environmental context scores. This was done by subtracting the cooperation scores in negative and positive conditions from the neutral condition. These differential cooperation scores were then correlated with the anxiety and avoidance relational styles scores. To correct for the multiple comparisons, Bonferroni correction was used (corrected *p* value: .05/4 = .0125). Despite expectations, for both the anxiety relational and the avoidance relational scores, no significant difference between their cooperation was found when playing with a human partner in a negative environmental context – as compared to a neutral environmental context – nor when in the positive context relative to the neutral context.

(Figure 4-7). When playing with a computer, the cooperation ratio during the positive or negative versus the neutral states was not affected by anxiety or the avoidance relational styles.

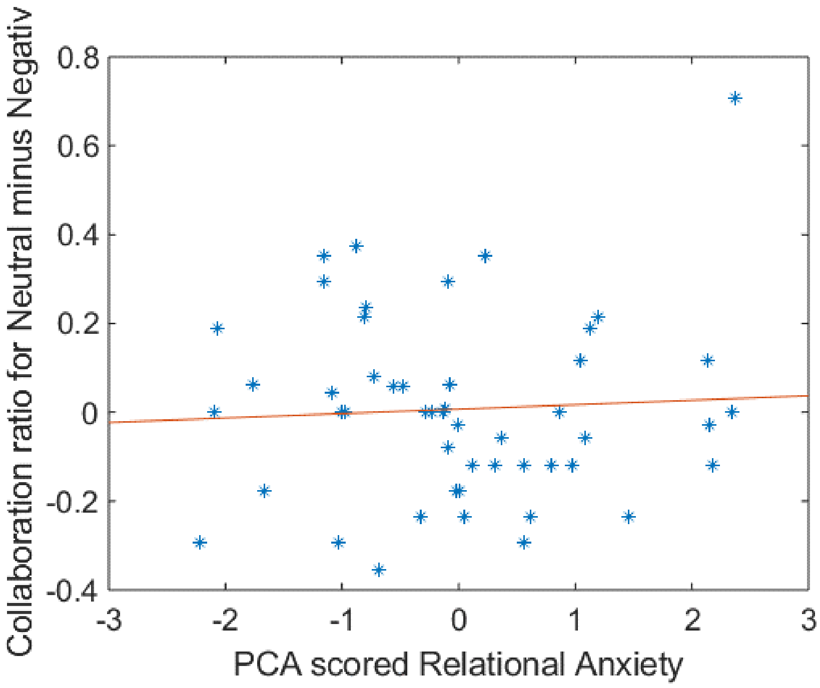

Figure 4-6.a Correlations between differential cooperation scores with anxious and avoidance PCA Scores.

For the anxiety relational scores (up) and avoidance (down) we did not find any significant difference between their cooperation, when playing with a human partner, when in a negative environmental context than when in a neutral environmental context nor when in the positive context relative to the neutral context.

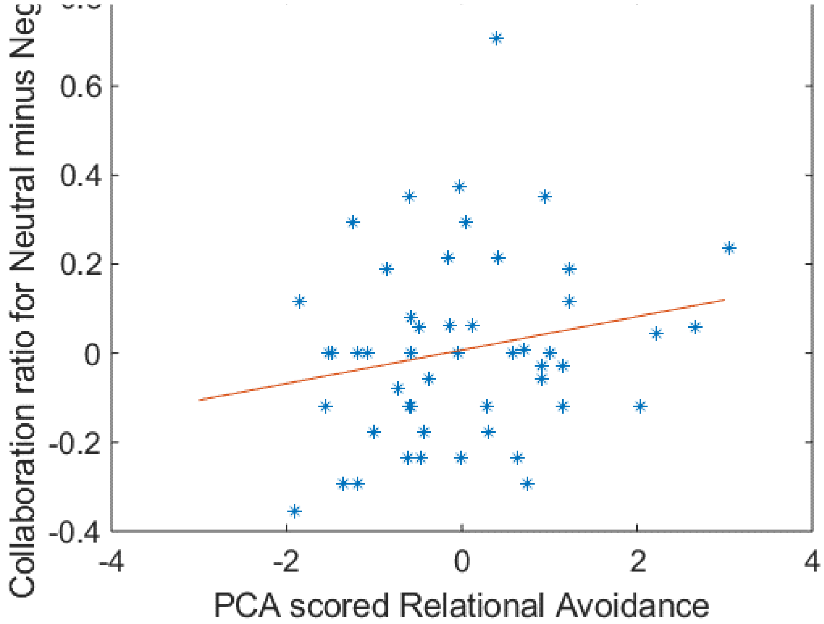

Figure 4-6.b Correlations between differential cooperation scores with avoidance PCA Scores.

In the current experiment, just the same as before, participants played with the other participants on half the trials. This means that like in real life, the behavior of any given participant depended to a degree on their partner's and the relationship they formed in the game. In the same way again, to ensure the pattern of results was not affected by this procedure, two additional analyses were run 1) a non-parametric analysis, where independence between measures is not assumed; 2) an analysis, where the averaged pair performance was the random variable.

The same non-parametric analysis of Friedman's two- way analysis of variance by ranks was used: with the 2 types of partners using 3 environment conditions. Here again the model was significant ($p < .001$), showing that the distribution of the data across the conditions were not the same. A follow up analysis showed that the average cooperation ratio when playing with a human was significantly higher than when playing with a computer ($p < .001$). Participants also cooperated more when playing with a human in the positive context than in the neutral context, but this difference was only marginally significant ($p < .06$). However, there was a significant difference between negative and positive ($p = .024$), but no significant difference was found between the negative and neutral context ($p = .96$). Environment also affected the way participants played with the computer, showing more cooperation in the neutral relative to the negative environment ($p < .015$), as well as more cooperation in the neutral as compared to positive condition, ($p = .02$). But only a marginal difference was shown between the positive and negative ($p = .06$) environmental conditions.

Finally, Spearman rho correlation was used to confirm the relations between cooperation ratio in the various conditions (neutral – negative; neutral – positive) and individuals' reported attachment styles. Similar to the ANCOVA results, individual differences in attachment style did not affect the pattern of cooperation with a computer or a human in any of the environmental conditions.

In the second analysis the pairs were treated as the random factor, rather than the participants. The response of 25 pairs and their attachment scores were averaged. ANCOVA with the partner and environment as repeated factors and attachment PCAs score as a covariate, revealed a similar pattern. Participants were more likely to cooperate with a human than with a computer partner F (1, 22) = 11.31, p = .003, $p\eta^2$ = .40, but the interaction of partner and environment did not affect the cooperation ratio, F (2, 46) = 2.77, p =.07, $p\eta^2$ = .11. Follow up analysis showed that environment affected cooperation with a computer partner. F (2,46) = 6.29, p = .003, $p\eta^2$ = .215, but the effect of environment was not significant when participants played with a human partner F (2,46) = 2.36, p = .106, $p\eta^2$ = 09.

Similar to the ANCOVA results with individual scores, the average attachment style of the pair for avoidance (mean PCAs) did not modulate the cooperation, F (1,22) = .14, p = .71, $p\eta^2$ = .00. However, pairs' anxiety scores (mean PCA) were found to significantly affect their cooperation F (1,22) = 9.13, p = .006, $p\eta^2$ = .30.

Further analysis showed a marginally significant effect of anxiety score when pairs played against their human partner, F (1,22) = 3.71, p = .06, $p\eta^2$ = .14, which showed pairs with an average high anxiety relational scores cooperated marginally significantly less in the negative environment, r = -.37, p = .06. There was also a significant effect of mean PCA for anxiety attachment scores when they played with the computer partner, F (1,22) = 6.79, p = .01, $p\eta^2$ = .24, with anxious pairs cooperating significantly less during the negative and positive environment, r = -.43, p = .03, and r = -.45, p = .02. Pairs' avoidance scores did not affect their cooperation with the human or with the computer partner in any of the environments.

The PCA scores for the two anxiety and avoidance dimensions where highly correlated, (R_s = .40, *p* = .004, please see 4.4.3). Hence, the two PCAs scores averaged and included the mean PCA as a covariate in ANCOVA test for the pair analysis in the next step. The new mean PCA showed a significant main effect on cooperation *F* (2,23) = 6.92, *p* = .004, $p\eta^2$ = .23, with participants being affected when played with their human partner, *F* (2,23) = 4.72, *p* =.01, $p\eta^2$ = .17 and not when they played against a computer. Follow up analysis showed a significantly negative correlation between the mean anxiety and avoidance PCAs in the negative environment, *r* = -.45, *p* = .02, when participants played with their human partner. This finding shows that pairs with higher averaged scores in anxiety and avoidance showed mutually less cooperation in the negative environment than when they played with their human partner. This is different from the results from the individual PCAs, which showed them to be more affected when they played with the computer as compared with the human.

Taken together, the data suggests an effect of partner type and environment on cooperation, but this was not modulated by individuals' relational attachment scores. These results were also similar using non-parametric statistical analysis, when using reduced study power by considering the pairs, rather than the individuals, as the random factor. However, the pairs' anxiety PCA scores did affect their cooperation, when they played with the computer and human partner in different environmental contexts. Moreover, including the mean of anxiety and avoidance PCAs scores showed a main effect of the attachment and its modulation on cooperation during playing with the human partner, mainly showing less cooperation in the negative environmental contexts. These findings partially replicate the findings from Study 1 and the explanations are discussed further in the following section.

4.5 Discussion

The aim of this study was to replicate the finding from Study 1 (Chapter 3). It was set to examine the effect of environmental uncertainty, and how individuals with different attachment styles react to them within the context of a nonverbal face-to-face interaction as compared to a non-face-to-face setting (Study 1) during a repeated PDG. Similar to the results reported in Study 1 (Chapter 3), more cooperation was found when participants played with their human partner, as compared to their computer partner, however the effect size was smaller. Partially replicating Study 1 results, the environmental context affected participants' decisions differently when playing with humans and computers. When playing against a human, participants cooperated more in the positive environment; this was unlike the results from Study 1, where participants cooperated more in the negative environment. When playing with the computer, participants cooperated most in the neutral context in both studies.

Despite the hypotheses, and unlike the first study, the environmental context did not affect individuals differently based on their relational attachment style in the face-to-face PDG. However, when considering the pairs' combined behaviour, pairs with an overall higher anxiety relational scores cooperated less during a negative environmental context when playing with human but cooperated more in a negative and positive environment when playing with a computer. Avoidance relational scores did not affect the cooperation ratio. Furthermore, on averaging the scores, the two subscales of anxiety and avoidance for the pairs showed pairs with higher average scores in their anxiety and avoidance to cooperate less during the negative environmental context. The next section first discusses the findings from the current study and compares the results with the findings from the PDG in Study 1 (the non-face-to-face condition).

4.5.1 Effect of a partner; playing with a human or a computer, face-to-face vs. non-face-to-face interaction

Overall participants were more cooperative when they played with a human partner, as compared to a computer partner. This finding is similar to the first study, with a slightly smaller effect size. Nevertheless, our finding is in line with previous research (Biel & Thøgersen, 2007; Butler et al., 2011; Miwa & Terai, 2012), highlighting the importance of cooperation within social context vs. with a computer.

4.5.2 Effect of environmental contexts on cooperative responses, face-to-face vs. non-face-to-face interaction

The same as in the first PDG study, the environmental context was manipulated as an external factor, by introducing blocks with random monetary rewards or losses. In the current study, participants cooperated more during the positive blocks, (when they randomly won money), as compared to the negative block, (when they randomly lost money), and the neutral environmental context when participants played against their human partner. This is different from the first study, in which participants showed more cooperation in a negative context as compared with the positive context or the neutral. Moreover, in the current study a more reliable effect of environment was found during the interaction with the computer, with a similar pattern to the first study and the least cooperation in the negative environmental context, as compared to the neutral and positive conditions but with a bigger effect size. In other words, during the non-face-to-face interactions, participants betrayed more (potentially showing selfish behaviour) in a rewarding (positive) or predictable (neutral) environment, as compared to a threatening uncertain (negative) environment. However, when they played the game in the similar environmental context but in a face-to-face interaction, the cooperation pattern changed in the opposite direction., with most cooperation in the rewarding environment with a human partner, and least cooperation in the negative environment with a computer partner.

Literature on the impact of the environment on cooperation is complex and unclear. In both studies it was observed that participants collaborate more in an uncertain than in a certain environment. In Study 1 (Chapter 3), increased cooperation was observed during negative uncertainties, while in the current study during a positive uncertain environment. It is unclear what gave raise to these differences. Previously, it was discussed how the negative affect triggered by environmental context can change the direction of our emotional information processing, by bringing the focus of our attention to the external environment as a resource for affect information processing, whilst the positive emotions has the opposite effect (Bless & Fiedler, 2006; Hertel et al., 2000a). As an example of the negative affect, it is the natural disaster that brings communities and strangers together to help each other (Chantarat et al., 2015). However, during a face-to-face situation, one speculation is, that when we see each other face-to-face, the positive environmental context does not have the similar affect as in a non-face-to-face situation, e.g., instead of focusing our attention on our internal affects as source of information, we have an external stimulus that is the other person in front of us! Hence, the positive environment could be attributed to the other person’s behaviour and encourage more cooperation. But this could be also true for the negative triggers. Therefore, more research needs to be done on the effect of face-to-face interaction and environmental uncertainty on cooperation.

4.5.3 Cooperation and relational attachment based on different environmental context, face-to-face vs. non-face-to-face interaction

In the current study, it was expected to replicate the finding from Study 1, with less cooperation by anxious and avoidant individuals when playing with a human partner during the negative environmental context. It was also expected that this effect would be magnified, due to the sensitivity of anxious and avoidant attached individuals to facial expressions and their potential ability to read the nonverbal defecting signals by their partner (Schachner et al., 2005). Unlike the Study 1, in this study, individuals' relational attachment did not affect participants' cooperation during different environmental contexts. But, when the pairs' relational scores were averaged, it was found that pairs with higher averaged anxiety scores cooperated less across the board, but specifically during the negative environment, and they also cooperated less in both the negative and the positive context when they played with a computer partner. In addition to this, and because the anxiety and avoidance PCAs scores were positively correlated, after averaging the two scores, it was found that pairs with higher overall PCA scores (meaning both high in anxiety and high in avoidance scores; referred to as insecure pairs) cooperated less during the negative conditions when they played with their human partner.

The finding from this study is partially similar to the findings from the first study. In the current version of the PDG where participants interacted face-to-face, they cooperated more with their human partner (same as in Study 1). Participants cooperated more in the positive environment; whilst in the non-face-to-face, PDG participants cooperated more in the negative environment. In the non-face-to-face study we found that both anxious and avoidant attached individuals cooperated less in the negative environment, and in the face-to-face version, mutual cooperation decreased by pairs with higher averaged relational insecurity scores during the negative environments.

As discussed before, a negative environment can trigger trust issues in anxious and avoidant attached individuals, hence causing less cooperative behaviour (Mikulincer & Shaver, 2007). Whilst our findings from both the non-face-to-face and face-to-face studies support this argument, in the face-to-face interaction, it seems the whole uncertain environment affects pairs with high averaged anxiety and avoidance scores more.

Previous studies have shown that, compared to the insecurely attached individuals, secure individuals have a positive view of human nature (Mikulincer & Shaver, 2007) in general, and have positive expectations regarding their partner's intention and behaviour (Collins & Read, 1990; Hazan & Shaver, 1987). Moreover, secure individuals are also shown to be better able to cope with distressing situations (Mikulincer & Shaver, 2007). This could potentially help them in dealing with interpersonal conflict raised by distorted perceptions due to overactivated or deactivated attachment systems by external triggers. Hence, as compared to a securely attached person, an insecure individual lacks the ability to use constructive strategies for affect regulation and optimistic belief, which may interfere with their decision-making and cooperative behaviour, especially in a threatening environment. But it is also possible that it is not only the negative environment that triggers their attachment system, but also an uncertain environment as a whole, which makes the emotion regulation difficult, and this may attribute into their perception of their partner's behaviour or even trustworthiness. For example, Mikulincer and Shaver (2007), showed that prosocial values and inter-group tolerance can be increased by boosting attachment security through priming experiments.

The finding was interesting in that anxious participants were also affected negatively when they played with the computer partner. This could mean that participants were more anxious with the computer partner, because the computer strategy was unknown to them. For example, in the debriefing questionnaires, most of participants mentioned the lack of control over the computer's strategy and the randomness of the computer strategy, as compared to being able to potentially affect their human partner's decision. This could be an additional trigger to the attachment system of anxious participants, encouraging them to defect more when they played with their computer partner in an uncertain environment.

The finding from pairs averaged attachments scores and their cooperation ratio was also intriguing in that it was found that pairs with higher averaged anxiety and avoidance scores to cooperate less in the negative environment with their human partner. It is noteworthy that this does not mean that both individuals were insecure in their attachment as the score was averaged across the pairs. One speculation is that the negative environment triggered one of the pairs with higher insecure attachment scores and affected their behaviour, hence their mutual interactions through less cooperation. This can be explained through reciprocation (Bolton & Ockenfels, 2000) that has been shown to shape the repeated interaction in the PDG which could also give rise to reciprocation (in this case less cooperation) as the social norm of the situation (Biel & Thøgersen, 2007)

Finally, what could be the reason for not finding any effect of attachment on cooperation during the face-to-face interaction? Could it be that in the face-to-face environment, the level of trust changes and possibly increases, or at least the environment does not trigger the trust in the same level as it does in the anonymous interaction. Based on social effect theory, face-to-face interaction can decrease social distance (Bohnet & Frey, 2002), and although an avoidant attached individual may not feel comfortable, an anxious individual may feel more comfortable with this, and both may trust more.

4.6 Conclusion

To conclude, when studying cooperative behaviour in the repeated PDG, the interaction should be considered within the specific social and environmental situations, whilst accounting for the individual differences. This is evident from the finding of the two studies with the same paradigm, and two different set ups: one in a non-face-to-face interaction and one in a -face-to-face interaction. Findings from the two studies showed how environmental uncertainty affected participants differently in the two different set ups, e.g., more cooperation in the negative environment whilst playing the game in a non-to-face condition, whilst it was the opposite when the game was played in a face-to-face condition. Furthermore, whilst anxious and avoidant individuals cooperated less across the board during the uncertain environment, mutually insecure individuals' betrayal was magnified during the face-to-face condition.

5. COOPERATIVE DECISION-MAKING IN THE REPEATED PRISONER'S DILEMMA GAME ACROSS ADULTHOOD

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5.1 Abstract

In this study we examine the impact of age and environmental context on cooperative decision-making in social conflict. We employed the Iterated Prisoner's Dilemma Game and recruited 132 subjects: 53 young (age 18-29), 31 middle age (age 30-59), and 48 older subjects (age 60-87). Participants played the game across 6 blocks (each block between 13-17 trials), against each other or a computer. The environmental context was manipulated across blocks by introducing uncertainty, randomly losing (negative), or gaining money (positive). When playing with a human, cooperation across adulthood followed an asymmetric inverted 'U' shape pattern, with a sharp increase in cooperation from young to middle age and a slow decline thereafter. The uncertainty of a negative environment affected cooperative decisions made by the younger participants. Age affected the relative speed of cooperative decision making. Young participants were less cooperative in slow responding trials, while elderly participants were more cooperative when they responded faster. Regression analyses showed that beyond age decision times best predicted cooperation ratio. When playing with a human, slow decisions were associated with more cooperation, while the reverse was observed when playing with a computer. These findings show that cooperative behaviour differs across adulthood. While the young and elderly both collaborate less than the middle aged, cooperation decisions in the young and elderly reflected different processes. We conclude that cooperative behaviour is dependent on the context, as driven by the environment, the nature of the partner, and the age of the participant.

Keywords: Experimental Economics, Behavioural Economics, Cooperation, prisoner'sDilemma Game, Aging and Economics.

5.2 Introduction

Cooperation is the fundamental building block of human society (Adolphs, 1999). However, in order to cooperate it is often necessary to forgo the temptation to compete or defect. This is especially true when an uncooperative decision has a potential for larger immediate benefits. Social conflict describes scenarios where decisions need to be made between long-term collective interest and short-term self-interest, referred to as 'prosocial' as opposed to' proself' decisions (Balliet et al., 2009). Factors such as individual differences (e.g., Balliet et al., 2009; Boone et al., 1999; Taheri et al., 2018), social context (e.g., Biel & Gärling, 1995; Bolton & Ockenfels, 2000; Butler et al., 2011; Taheri et al., 2018) and environmental contexts (Andras & Lazarus, 2006; Taheri et al., 2018) have been suggested to affect cooperative behaviour. In this study, we aim to investigate how decision-making in social conflicts differs across adulthood, using the iterated Prisoner's Dilemma Game.

Decisions are assumed to reflect wisdom. The common belief is that with age people become wiser, as incapsulated by the quote attributed to Abraham Lincoln: "*don't think much of a man who is not wiser today than he was yesterday*". Wisdom is often associated with an increase in prosocial decisions, emotional homeostasis (Meeks & Jeste, 2009), and adaptable pragmatic knowledge (Baltes & Staudinger, 2000). In the context of non-social decisions, the personal-task fit framework (Finucane & Lees, 2005) highlights the importance of considering the decision-maker, the task and the context, when evaluating decision competence. Specifically, the decision-maker, age, education, experience, cognitive ability, knowledge, motivation as well as their affective state would contribute to their decision process (Finucane et al., 2005). Similarly, Strough and colleagues (Strough et al., 2011), stressed that the motivation of the decision-maker is a key driver of decisions, which itself depends on the decision maker's pragmatic knowledge, deliberative abilities, and emotional state.

Motivational goals differ across adulthood. The socio-emotional selectivity theory (Carstensen et al., 1999) suggests, that with increased age people prioritize emotional goals and trusting relationships (Ryff & Keyes, 1995) over immediate materials gains. Increases in prosocial decision with age was demonstrated by Van Lang and colleagues (Van Lange et al., 1997). The authors used the Social Value Orientation measure (Messick & McClintock, 1968) and reported that prosocial behaviour increased non-linearly until the age of 65 and remained stable afterward. The authors suggested that prosocial growth in old age reflects changes in the functional aspects of motivations and the nature of social interdependence that comes with age (Van Lange et al., 1997). In a community-based US sample, older adults relative to young, used more prosocial reasoning when deliberating on social conflicts (Grossmann et al., 2010);although the impact of age on prosocial reasoning was dependent on culture, (Grossmann et al., 2012).

Increased age has also been associated with an improved ability to regulate emotions (Charles, 2011; Mather & Knight, 2005). With increased age, individuals also shift their focus from negative to positive emotions, an effect known as the positive age bias (Mather & Carstensen, 2005; Swirsky & Spaniol, 2019). For example, examining community-dwelling adults, Grossman and colleagues (2014) show that relative to young, older adults in the US (but not in Japan) reported more positive and less negative emotional life experiences. Concerning monetary gains/losses, relative to older adults, young report more negative emotions when anticipating monetary loss (Nielsen et al., 2009), and experiencing loss (Bruine de Bruin et al., 2018).

Social and emotional components of wisdom are hypothesized to change linearly across adulthood. In contrast, changes in the skill and knowledge component of wisdom, display an inverted ‘U’ across adulthood, peaking at middle age (Ardelt et al., 2018). Education delays the age that skill and knowledge-based wisdom peaks (Ardelt et al., 2018). The inverted ‘U’ shape is assumed to reflect an interaction of age-related changes in crystallized intelligence and fluid intelligence, assumed to display opposite trajectories across adulthood (Bruine de Bruin et al., 2012). Crystallized intelligence reflects the ability to utilize prior acquired knowledge to solve problems. Fluid intelligence reflects the ability to learn and adapt to new situations (Cattell, 1963). Crystalized intelligence, increases across adulthood and/or plateaus around midlife, as individual gain more experience and knowledge of the world (Kaufman, 2001). Fluid intelligence declines with age, a decline that is accelerated after the age of 50 years (Verhaeghen & Salthouse, 1997). Meta-analysis showed that changes to fluid cognition, such as memory and reasoning abilities, can be accounted for by differences in response times (Verhaeghen & Salthouse, 1997). Beyond response times, individual intra-trial variability in response times is also proposed to be a good proxy for cognitive ability associated with fluid intelligence, specifically of executive functions and sustained attention (De Felice & Holland, 2018; Der & Deary, 2017; MacDonald et al., 2006). Overall response times and intra-individual trial variability increase with age and reflect poorer executive functions and a decline in fluid intelligence.

In the context of economic decisions, older participants showed equal, and in some studies, superior ability in financial and debt literacy (Li et al., 2013). Compared with the young, older adults are better at discounting irrecoverable costs from bad investment, called "sunk-cost", and hence minimizing their overall loss (Bruine de Bruin et al., 2014). While age is often associated with improved economic knowledge (potentially reflecting crystallized intelligence), actual financial decisions may not show a similar advantageous pattern with increased age. Older adults develop wiser investment strategies, but as compared to the middle age group make more mistakes in applying their strategies (Korniotis & Kumar, 2011). Agarwal and colleagues (2009) examined three financial decisions, related to credit transactions. They showed a 'U' shaped performance across adulthood, with middle-age participants best at optimizing their credit decisions.

Optimal decision in social-economic conflict relies on all the components of wisdom: prosocial, emotion regulation, and practical knowledge (Lim & Yu, 2015). Decisions would reflect a tendency for prosocial/proself acts, and the ability to regulate emotions in light of changing environments and outcomes. An optimal strategy also depends on the strategy of the opponent. Against an opponent who is inflexible and always either defects or always cooperates, the optimal strategy would be to always defect, as it respectively minimizes losses and maximizes gains. However against more realistic opponents who are themselves adaptive, the player would also need to adapt their behaviour (Hauert & Stenull, 2002). Hence an economic game potentially relies on fluid components of cognition, beyond the knowledge and understanding of the rules of the game.

In a lab context, social-economic conflict is typically studied using economic games such as the Prisoner's Dilemma Game, Ultimatum Game, and Dictator Game.

All these games measure an individual's responses when faced with a conflict between self-interest and collective interest. For example, in the prisoner's dilemma game players win or lose money based on their own and partner decisions. If both players decide to cooperate, both win money, and if both decide to defect, they both lose money (or win smaller amounts). Conflict arises when one player decides to cooperate while the other decides to defect, leading to an advantage for the defector and a cost for the cooperator. Decisions made in the Prisoner's Dilemma Game are predicted by the Social Value Orientation theory (Balliet et al., 2009; Matsumoto et al., 2016). It is further shown that individual response time in social-economic games (including Prisoner's Dilemma Game) reflects their Social Value Orientation. Prosocial individuals made cooperation decisions faster, while proself individuals made betrayal decisions faster (Yamagishi et al., 2017).

There has been intensive usage of economic games in research with young participants, but only a few studies investigated how behaviour in these games changes across adulthood. To date the results are inconclusive (for review see Lim & Yu, 2015). For example, in a Trust economic game, the amount of money entrusted to a stranger did not differ across adulthood, though numerically the amount peaked at middle age and slightly reduced for retired participants (Sutter & Kocher, 2007). A separate study that used a Trust game, showed that the elderly behave as the young in response to 'certain' stereotypical-trusted strangers, but trust more uncertain strangers (Bailey et al., 2016). Matsumoto et al., (2016) used several different economic games (including the Prisoner's Dilemma Game), with a large sample of Japanese adults between the ages of 20 to 59 years old, finding in all games an increase in prosocial decisions across this age range.

Two studies investigated the rule underlying processes that change across adulthood in social economic-based decisions. Harle and Sanfey (2012) showed that relative to the young, older adults were less willing to accept unfair offers sacrificing proself benefits, presumably as these reflect a violation of prosocial norms. More interestingly, within the older sample, prosocial decisions were correlated with measures of executive function, a component of fluid cognition. Zhu and colleagues (2012) assessed consistency in repeated investment decisions in young and older adults, in a winner-take-all investment game. They reported that relative to young, older adults (mean age 64 years) showed higher consistency in their investment decisions. Modeling work suggested that relative to young, older adults show less ability to accumulate knowledge (learn) throughout the experiment and adapt their strategy accordingly. Taken together these studies suggest that components of fluid cognition have hindered effective decisions in older adults leading to an increase in prosocial decisions.

The aim of the current study is to examine prosocial decisions across adulthood and how these are affected by various external factors and change to internal processes. The current study builds on our previous work reported by Taheri et al. (2018) which recruited young participants. Here we added middle age and older participants and assessed them using an identical paradigm. The experiment was designed based on a principle common in the social-economy research field, which prioritizes external validity (Hertwig & Ortmann, 2001). In line with these principles we ensured that participants were not deceived, they played repeatedly with the same partner, had context information about this partner (they briefly met the partner prior to the game), and had a performance-based financial incentive. The conscious knowledge of the partner enabled them to assess cooperative decision making based on the perceived nature of the partner, the iterative game enabled them to assess learning, and specifically social learning, as it requires an adaptation of responses to the partner strategy.

Participants played six blocks of the iterated version of the Prisoner's Dilemma Game, either with each other or with a computer. The computer predominantly used a tit-for-tat strategy. A tit-for-tat strategy was selected for the computer partner as an approximation to human behaviour (Axelrod, 1984). The computer partner was added to enable us to measure whether individual decisions vary between social and non-social context. A relevant criticism of any computer-based game-theory study is that participants do not feel that they are truly playing against another human, but merely a computer (Miwa & Terai, 2012). Including a specific computer condition, allowed us to rule out such reasoning. In the context of adulthood, it also enabled us to test the ability of participants across adulthood to adequately adapt the strategy to the player they face. Each participant was informed of the identity of their partner (human/computer) prior to each block of trials.

Participants played in three environmental conditions, which were manipulated across blocks: uncertain-negative, in which participants may randomly lose money; uncertain-positive, in which participants may randomly win money; and certain-neutral, in which no loss, or win occurred. Importantly, participants were informed of these environments in advance, to enable them to form expectations for losses/gains/none. However, participants would only notice the environmental context of the blocks after playing the first trial. They were also informed that losing or winning money was not related to their decisions. We used the iterated (repeated) Prisoner's Dilemma Game played with known partners during certain and uncertain negative/positive environments. We assumed it has higher ecological validity, as often people financially interact repeatedly with the same partners, in semi-known environment conditions that are often independent of the interaction outcomes (e.g., stability and trends in the stock market).

Using this paradigm with young adults (Taheri et al., 2018), we found that participants cooperated more with a human than computer partner; and more in the uncertain negative than the neutral or the uncertain positive environment. The environmental effect was larger when playing with a human than with the computer.

The present study aimed to extend our previous study by widening the age range of the participants (including age 30 – 87). We recruited participants with a university education, to ensure that education does not confound the pattern of results. We also aimed for participants to play with other participants from the same age group, to avoid contaminating the results with age-related stereotypical thinking on cooperation behaviour (Schniter et al., 2013), and avoid confounding the results with effects of in/out-group (Yamagishi et al., 2008).

To validate the experimental manipulations (partner and environment), we used subjective reports and decision times. The main measure of prosocial behaviour was the cooperation ratio. To assess 'natural tendencies' to make pro-social decisions as per (Yamagishi et al., 2008), we computed a separate cooperation ratio for fast and slow trials. Decision times and individual intra-trial variability in decision times during the neutral environment were used as proxy measures for executive function ability. The difference in decision times, when playing in a positive versus a negative environment, was used as a proxy for positivity bias in aging, as it is assumed that with increased age participants shift attention from negative to positive events (as per Mather & Knight, 2005). Finally, to provide a measure for optimum financial decisions, we computed the money each participant won, independent of the random losses and gains induced by the experimental manipulation,

Based on the previous literature, we hypothesized the following regarding the impact of age on cooperation ratio: (1) We expected that young would make less cooperative decisions than middle-age and elderly participants, but we had no directional prediction regarding the difference in cooperative decisions between middle-aged and elderly. (2) We predicted that all participants would cooperate more with a human than a computer partner. We assumed that an increase in cooperation with a human (relative to a computer) opponent related to social and emotional processing and hence would increase with age. (3) We expected that uncertainty of the environment (especially negative) would affect cooperation ratio and that this effect would primarily be manifested when playing with another human, but not with a computer. We assumed that with age, participants are better equipped to cope with uncertainties and hence the impact of the environment would decrease. (4) We assumed that the natural tendency for prosocial decisions increased with age. Hence with increased age fast trials would be associated with more cooperative decisions than slow trials. (5) Measures of executive function and positivity bias would positively relate to cooperation ratio, independent of age, especially when playing with a human. Finally, (6) we hypothesized that the cooperation ratio would positively correlate with the net amount of money won.

5.3 Methods

5.3.1 Power calculation

G*Power 3.1 (Faul et al., 2007) was used to compute the necessary sample size for a power of 0.80, with $\alpha = .05$, using the reported effect size from the literature.

We used Matsumoto and colleagues' study (Matsumoto et al., 2016) to compute the necessary sample size for obtaining a correlation between age and cooperation ratio. Matsumoto and colleagues (2016) reported a positive correlation with increased age, with an effect size of $r = .28$ for repeated one-shot game (Matsumoto et al., 2016). 103 participants are needed to replicate this effect.

We used Yamagishi and colleagues (Yamagishi et al., 2017) to compute the necessary sample size for the effect of decision times as a marker of natural prosocial tendency and cooperation decisions. The authors report a positive correlation ($r = .24$ & $r = .4$) of cooperative decision times and prosocial orientation, and a negative correlation ($r = -.40$) for uncooperative decision times and prosocial orientation. We used $r = .3$ for the power calculation and estimated that 85 participants will be sufficient.

5.3.2. Participants and Design

One hundred and thirty-two male and female participants, consisting of 48 older (age range: 60 to 86, $M_{age} = 72$, 25 females), 31 middle age (age range: 30 to 59, $M_{age} = 36.6$, 13 females) and 53 young adults. Part of the demographic data from the young participants were lost due to a computer and office change (young age range: 18 to 29, $M_{age} = 22.5$ mostly female, [exact age and gender of 14 young adults at their first and second undergraduate studies was lost). Part of the data from the young participants was reported in a previous paper (Taheri et al., 2018). All the young people were studying at the university, and most (27/31) of the middle-aged and older (44/48) participants had a University degree, all were professional by occupation.

The division to age group was primarily driven by the mode of recruitment. Young were recruited using the Research Participation Scheme primarily targeting year 1 and 2 undergraduate and year 1 master students. The older participants were recruited from the University of Birmingham Lifespan Cognition database. 38 of them have completed the MoCA (the Montreal Cognitive Assessment; Nasreddine et al., 2005) and their results showed that they had normal cognitive ability (e.g., higher than 26). The middle-aged participants were mostly University employees or mature postgraduate students. The study was approved by the University of Birmingham Science, Technology, Engineering, and Mathematics (STEM) Ethical committee. All participants were given full information about the study and signed an informed consent.

The study design was a mixed design with partner (computer, human) and environmental context (positive, neutral, negative) as within-subject factors and age (young, middle, and old) as between subject covariates.

Compensation

Participants were informed that they would play for real money, which ensured engagement in the game. Whilst young and middle-aged participants received £5 for their participation, older participants received an additional £2 (in total £7) to compensate for their travel expenses. In addition to this compensation all participants were told that they would also receive the money they won during one randomly selected block (out of 6 blocks, e.g., from £0 up to £7 depending on their performance in the respective block). Hence, participants received a total compensation of a minimum of £5 up to £14, depending on their performance in the game.

5.3.3. Task

We used the iterated (repeated) Prisoner's Dilemma Game task from Taheri et al., (2018).

The environmental context was manipulated across the blocks with three, negative, neutral and positive environment, (please see Chapter 2)

In total, participants played 93 trials, divided into the six experimental blocks, each block consisting of 13 to 17 trials. The number of trials per block varied between the blocks, to prevent the use of strategic decisions on the last trials.

5.3.4. Experimental Procedure

Participants were tested in pairs and each pair was opportunistically assigned based on time-scheduling, with the condition that the participants did not know each other beforehand. Most pairs were from participants of the same age group, except for eight pairs in which young played with young middle-age participants, please see Chapter 2 for more information.

At the end of the game participants were presented with the outcome of the 6 blocks and received the money (positive only) from one of the blocks, chosen by rolling a dice, as well as the show-up fee (in total ranging between £5 - £14). They then completed a post-experiment questionnaire, being asked the following questions: 1) "Were human and computer partners different?" "Did the computer have a strategy?” 2) “How did you feel about winning (or losing) money?” 3) “Did winning or losing money affect the way you played?” The post-experiment questionnaire was available for 31 out of the 53 younger participants, and all of the middle age and older participants, during debriefing. Participants were able to give a verbal reply or fill in a Likert scale (1 = no effect to 7 = strong effect). They were also encouraged to make any comments they wished to, regarding the experience and thoughts about the experiment. Participants also completed personality questionnaires, although the data is not reported here. This was done separately for each participant in their individual cubicle.

5.4. Data analyses

The data was analyzed in SPSS 24 and MATLAB.

The age factor. In most analyses, age was modeled as a categorical variable, to avoid constraining the analysis to linear relationships. However, in follow-up analyses we used age as a continuous variable to provide a more detailed descriptive pattern.

Subjective reports. The responses in the post-experiment questionnaires were binaries (no reported emotional response, and reported emotional response, separately for the negative and positive environments. An emotional response was coded, whether it was reported in the free wording answers or any response larger than 1 on the Likert scale. Frequency of yes/no responses were analyzed with Chi-square.

The response time (RT, decision time) was measured from the onset of the response screen. Per standard methods, all RT data were log-transformed within MATLAB. Averaged logRT was computed per condition and per block. The data was analyzed using mixed ANOVA, with partner and environment as repeated factors, and age as between factors.

We used the coefficient of variation to compute the **intra-individual variability**, known as CoV-IIV. This procedure ensures that CoV-IIV is not confounded by differences in response latency (Wojtowicz et al., 2012). For each partner condition and each participant, we computed CoV-IIV: the standard deviation of the decision times divided by the average decision times (i.e., RT.SDT/RT.mean). The impact of the experimental conditions on the CoV-IIV was computed using a mixed ANOVA, with partner and environment as repeated factors, and age as a between factors. Detailed results are reported in the Supplementary material.

Cooperation ratio was computed as the proportion of cooperative decisions relative to the total number of trials per condition. To compute separate cooperation ratios for **fast and slow trials**, we used the RT data to median split the trials in each block. The data was analyzed using mixed ANOVA with ‘partner’ (human, computer), ‘environment’ (negative, positive, neutral) and ‘decision time’ (fast, slow) as repeated factors and ‘age’ as a between factor (young, middle, older adults). Significant main effects of multilevel factors and interactions were followed by reduced ANOVAs and t-tests. For descriptive purposes we scattered age in years as a continuous variable against the cooperation ratio for the human and computer partner, separately. The 'two-lines test' (Simonsohn, 2018) non-parametric test was used to fit a function to the data. The advantage of this procedure is that it does not assume a symmetrical shape and allows varied slopes on either side of the peak. We used the Robin Hood algorithm in the 'two-lines test', to identify the age when cooperation peaked.

In the current experiment, participants played with another participant in half the trials. This means that, as in real life, the behavior of any given participant depended, to a degree, on their partner's behavior and the relationship they formed during the game. In other words, participants cannot be considered as fully independent, as their responses were dependent on the pairing. Statistically, the lack of independence violates ANOVAs assumptions and may have led to inflation of the degrees of freedom. To ensure the pattern of results was not affected by this procedure, we ran additional analysis where the averaged pair performance was the random variable. The results are reported in the Supplementary material.

To be able to compare the results with the **single-shot prisoner's dilemma game**, we extracted the first decision of the first block a participant made, when knowingly playing with a human or a computer. Recall, that for the first decision, the environment context was unknown. Participants were informed that they will play in blocks where there will be additional random money won or lost independent of their decision or their partner's decision. However, they would only notice the additional losses or gains after they played their first trial a there was no notification about which blocks (negative or positive) they would play at the start of the respective block. The two blocks order varied, in who participants played with first. In order A: participants played first with a human and then with the computer and vice versa in order B (see above). We used Chi-square to analyze the frequency of cooperate/betray decisions, as a function of partner and age, separately (& combined) for each version. The results are reported in Supplementary materials.

We computed for each block the **net money won**, the money collected based on the decision made by the players, independent of the random monetary gains and losses from the environment manipulation. We used a mixed ANOVA with the factors: 'partner', 'environment' and 'age'.

Predicting cooperation ratio with a human and a computer. Two separate regression analyses were used, separating human and computer games. The regression tried to predict cooperation ratio, with each partner using age, proxy for executive function, and positivity bias. **Executive function ability** was estimated by the time it took to make a decision during neutral blocks (removing the impact the random loss/win had on decision times). The assumption was that faster decisions were associated with less deliberation and better executive functions. A second measure for executive function was the CoV-IIV during neutral blocks. Here it was assumed that larger variability reflects weak sustained attention or lapses in attention. We also estimated a **positivity bias index,** by computing per participants, the difference between decision times in the positive versus the negative environments and dividing it by the sum of these responses. The assumption was that positive values indicated that participants were more affected by the positive environment (wins) than the negative, and conversely for a negative value.

5.5 Results

5.5.1 Validation of Experimental Manipulation

The post-experiment briefing indicated that participants were blind to the computer strategy. Two participants from the middle age and older groups questioned whether the human was a real human player or a computer that was programmed to behave like a human. One of the older participants said that because the players were sitting in different rooms it felt as if they did not interact with a real human. However, as the pattern of results was no different than that of the other players', we did not exclude them from the analysis.

Table 5-1 reports the statistical details and shows the percentage of participants in each age group that reported positive or negative feelings, driven by the random monetary losses or gains. Across all the groups, more than half of the participants declared that they were not emotionally affected by the uncertainty of the environment, neither when gaining or losing money. Across all the three groups the frequency of reporting emotional responses, was significantly smaller than that of reported neutral responses. There were no differences between the age groups in their reported emotional experiences (see Table 5-1 for details).

Table 5-1 Subjective report of emotional response to the environment manipulation

Age group	Affected Negatively by random loss (%)	Affected Positively by random win (%)	Negative vs. Neutral
Young	7/31 (23%)	11/31 (35%)	$\chi^2 = .33$, $p = .564$
Middle	10/31 (34%)	8/31 (26%)	$\chi^2 = .33$, $p = .564$
Old	12/48 (25%)	12/48 (25%)	
Age effect	$\chi^2(2) = 1.31$, $p = .519$	$\chi^2(2) = .84$, $p = .657$	
No effect of emotion across the ages	$\chi^2(1) = 26.04$, $p < .001$	$\chi^2(1) = 20.94$, $p < .001$	

Note: Percentage of participants in each group reported to be emotionally affected during each emotional condition, e.g., 23% from the subsample of younger participants reported negative feelings (e.g., anger, frustration, sadness) when randomly losing money, and 35% reported positive feelings (e.g., happiness) when randomly receiving money, whilst 54% reported no negative or positive feelings when either randomly losing or receiving money in the negative and positive environmental context.

To measure the implicit effect of the environmental manipulation we used the mean of the log reaction time (logRT), and intra-trial individual variability of this measure, with the assumption that environmental manipulation would affect participants' emotional processing, required to exert emotion regulation. This would have potential cost on executive function, which will be manifested by decision-making time (Donders, 1969). We used the average logRT for all the trials within each block. The results are presented in Table 5-2. We note that response times may appear short for this overall complex decision. However, participants had 2 seconds to view the outcome of the previous trial, during which they potentially started to think about the decision for the following trial. Furthermore, during the uncertain environment, participants had unlimited time to process this information prior to self-initiating the next trial.

Table 5-2 ***Descriptive - decision times measures***

Age	**Partner**	**Environment**	**Log RT**	**CoV-IIV**	**RT milliseconds**
			Mean (SEM)	Mean (SEM)	Mean (SEM)
Young	Human	Negative	6.74 (.06)	.62 (.05)	113 (134)
		Neutral	6.52 (.06)	.41 (.03)	898 (89)
		Positive	6.84 (.06)	.8 (.08)	1325 (130)
	Total		*6.70 (.05)*	*.61 (.03)*	*1119 (99)*
	Computer	Negative	6.91 (.05)	.61 (.04)	1274 (104)
		Neutral	6.67 (.07)	.60 (.04)	1145 (105)
		Positive	6.89 (.05)	.49 (.02)	1194 (103)
	Total		*6.82 (.05)*	*.56 (.02)*	*1205 (89)*
Middle	Human	Negative	7 (.08)	.64 (.06)	1577 (175)
		Neutral	6.74 (.08)	.49 (.04)	1158 (117)
		Positive	7.04 (.08)	.74 (.10)	1624 (170)
	Total		*6.93 (.07)*	*.62 (.04)*	*1453 (129)*
	Computer	Negative	7.11 (.07)	.56 (.05)	1524 (136
		Neutral	6.96 (.09)	.56 (.06)	1422 (138)
		Positive	7.08 (.07)	.49 (.03)	1486 (135)
	Total		*7.05 (.067)*	*.54 (.02)*	*1477 (116)*
Elderly	Human	Negative	7.38 (.07)	.43 (.05)	1933 (141)
		Neutral	7.16 (.07)	.41 (.03)	1620 (94)

	Positive	7.52 (.07)	.51 (.08)	2203 (136)
Total		*7.35 (.06)*	*.45 (.03)*	*1919 (104)*
Computer	Negative	7.50 (.05)	.45 (.04)	2165 (109)
	Neutral	7.45 (.07)	.49 (.04)	2159 (111)
	Positive	7.50 (.05)	.41 (.02)	2139 (108)
Total		*7.48 (.05)*	*.45 (.02)*	*2155 (93)*

Effects on logRT were tested using mixed ANOVA, with 'partner types' (computer, human),* 3 'environmental contexts' (negative, neutral, positive) as repeated factors, and a between-subject variable of 'age' (young, middle, older adults). There was a main effect of age, F (2, 129) = 37.9, p <.001, $p\eta^2$ = .37. As expected, young participants were faster than middle age, and elderly participants were the slowest. But age did not interact with any of the conditions (p >.38).

Participants made faster decisions when playing with a human than a computer, *F* (1, 129) = 39.45, *p* <.001, pη^2 = .23. Participants slowed down in the uncertain (positive or negative) environments *F* (2, 258) = 50.39, *p* <.001, pη^2= .28. There was a significant interaction between the type of partner and the environment, *F* (2, 258) = 5.41, *p* = .005, pη^2 = .04. The effect of environment was larger when playing with humans *F* (2, 262) = 39.71, *p* <.001, pη^2 = .23 (Negative vs. Neutral: *t* (132) = 7.93, *p* <.001, *d* =.69; Positive vs. Neutral: *t* (132) = 8.99, *p* <.001, *d* = .72; Negative vs. Positive: *t* (132) = -2.24, *p* = .027, *d* = .19) than with the computer *F* (2, 262) = 9.34, *p* <.001, pη^2 = .062 (Negative vs. Neutral: *t* (132) = 3.72, *p* = .002, *d* = .28; Positive vs. Neutral: *t* (132) = 3.57, *p* <.001, *d* = .31; Negative vs. Positive: *t* (132) = 0.55, *p* = .581, *d* = .05. These results confirmed that the environmental and the partner manipulations affected participants' decision-making processes. The environmental manipulation had a larger effect when participants played in a social context with a human partner.

Variability in decision times was affected by age *F* (2, 129) = 12.50, *p* <.001, pη^2 = .16. Though in contrast to simple RT studies, elderly (M_{human}: 0.52, SEM: 0.03; M_{comp}: 0.51, SEM: 0.02) showed less variability in decision times compared with middle age (M_{human}: 0.77, SEM: 0.07; $M_{computer}$: 0.61, SEM: 0.02), all *t* (77) > 3.42, *p* <.001, *d* > .49; and also compared with young (M_{human}: 0.76, SEM: 0.04; M_{comp}: 0.66, SEM: 0.03), all *t* (99) > 3.21, *p* <.001, *d* >.54. There was no significant difference between young and middle-aged (*p* >.23). Age did not interact with any of the experimental factors.

The repeated factor manipulations affected variability in decision time in a similar way to the averaged decision time measure. Larger intra-trial variability was observed when playing with a computer than with a human, and during uncertain than certain environments. Furthermore, decision time variability due to the environmental factor was larger when playing with a human. Significant effects were observed and are reported in detail in the Supplementary material.

5.5.2 Cooperation ratio

To assess the impact of the experimental factors on cooperation ratio, we performed a mixed ANOVA analysis with ‘partner’ (human, computer), ‘environment’ (negative, neutral, positive), and ‘decision speed’ (fast, slow) as repeated factors, and ‘age group’ (young, middle, older adults) as a between-subject factor (Figure 5-1A). The statistical results are presented in Table 5-3. A similar pattern of results was observed, when using the average cooperation ratio across pairs as a dependent variable - see Supplementary material for details.

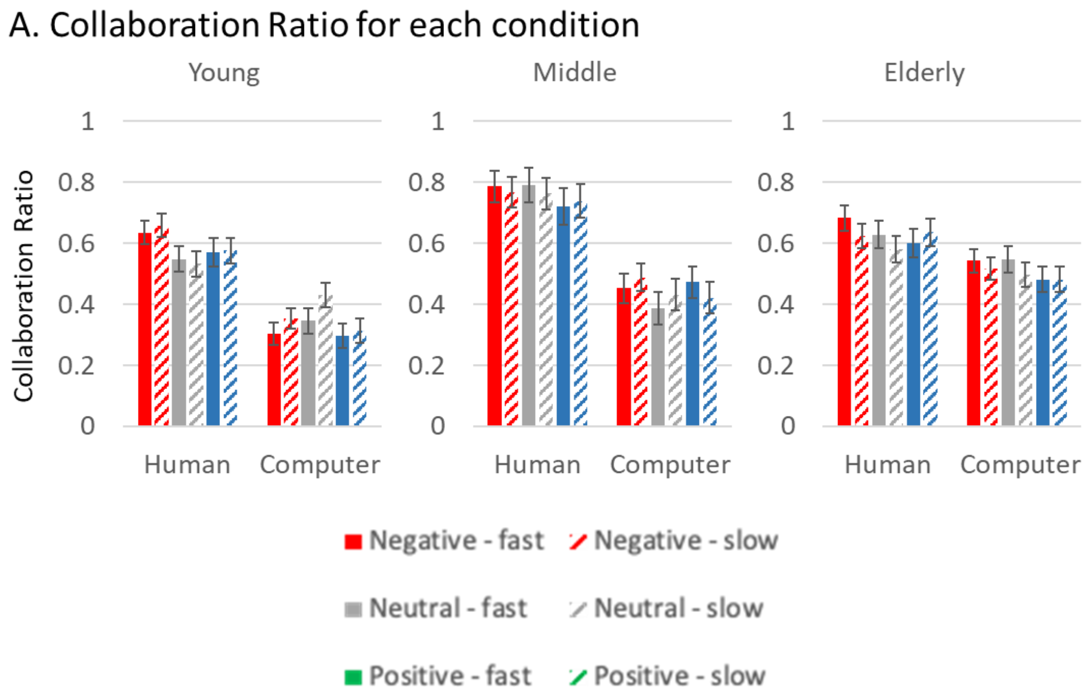

Figure 5-1 A. Cooperation ratio presented for each condition. Separate graphs for young, middle, and older adults. B. Bar charts of interaction effects on cooperation ratio, the 'y' axis presents the difference between the levels of one factor.

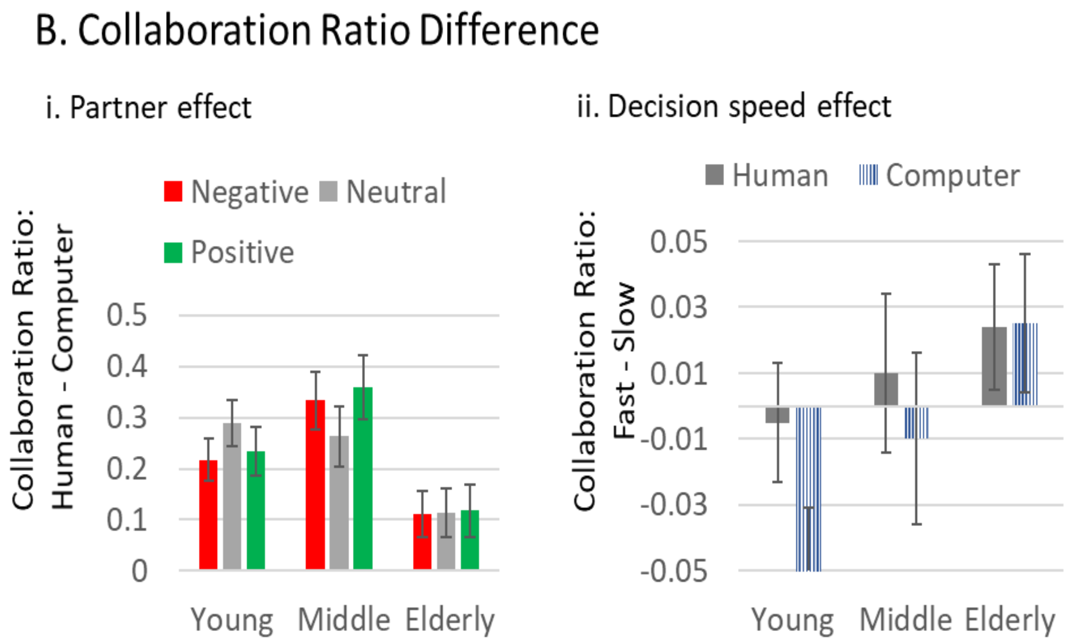

Figure 5-2 B.i Interaction effect with partner type (computer, human). Y-axis shows the cooperation ratio difference when playing with a human versus a computer. This was computed for each individual in each condition. B.ii Bar charts presenting the interaction effect of decision times. The Y-axis is the cooperation ratio difference between slow and fast trials computed per individual, for the human and computer conditions, collapsed across the environment. Errors bars are the standard error of the means.

Did participants' age affect cooperation?

Across all conditions there was a main effect of age, showing a linear increase of cooperation with age (Table 5-3)

Table 5-3 Statistical results for cooperation ratio

Comparisons		Test(df)	Stats	P	p/η^2	D	mean diff	pooled std
ME: Age		F(2,129)	8.06	0	0.11			
	Y vs. M	t(82)	-3.52	0.001	0.13	0.79	-0.14	0.17
	Y vs. E	t(99)	-2.99	0.003	0.08	0.59	-0.10	0.17
	M vs. E	t(77)	1.06	0.292	0.00	0.24	0.03	0.15
ME: Partner		F(1,129)	73.9	0	0.36	0.98	0.21	0.29
2 INT: Partner*Age		F(2,129)	5.02	0	0.07			
Human	Age	F(2,129)	5.39	0.006		0.07		
	Y vs. M	t(82)	-3.00	0.004	0.65	0.09	-0.17	0.26
	Y vs. E	t(99)	-0.71	0.476	0.13	0.00	-0.03	0.26
	M vs. E	t(77)	2.94	0.006	0.67	0.10	0.13	0.20
Comp	Age	F(1,129)	8.52	0		0.11		
	Y vs. M	t(82)	-2.10	0.038	0.47	0.05	-0.10	0.22
	Y vs. E	t(99)	-4.27	0	0.85	0.15	-0.17	0.20
	M vs. E	t(77)	-1.56	0.122	0.36	0.03	-0.06	0.18
Human – Computer								
	Y vs. M	t(82)	-0.90	0.37	0.20	0.00	-0.13	0.65
	Y vs. E	t(99)	2.52	0.013	0.58	0.06	0.28	0.48
	M vs. E	t(77)	3.57	0.001	0.82	0.14	0.41	0.50
ME: Environment		F(2,258)	3.83	0.023	0.02			
	Neg vs. Neu	t(131)	1.68	0.094	0.14	0.02	0.02	0.17
	Neg vs. Pos	t(131)	2.93	0.004	0.25	0.06	0.04	0.16
	Neut vs. Pos	t(131)	1.17	0.243	0.10	0.01	0.01	0.16
3 INT: Partner*Env*Age		F(2,258)	2.54	0.04	0.03			
Human	Env	F(2,258)	3.60	0.029	0.02			
	Neg vs. Neu	t(131)	2.96	0.004	0.25	0.06	0.06	0.23
	Neg vs. Pos	t(131)	2.29	0.023	0.20	0.03	0.05	0.26
	Neut vs. Pos	t(131)	-0.31	0.754	0.02	0.00	-0.00	0.24
	Age * Env	F(4,258)	1.061	0.376	0.01			
Comp	Env	F(2,258)	1.29	.276	.01			
	Age*Env	F(4,129)	1.66	.158	.02			
Human – Computer								
Young	Env	F(2,104)	4.99	0.008		0.08		
	Neg vs. Neu	t(52)	2.93	0.005	0.40	0.14	0.16	0.41
	Neg vs. Pos	t(52)	0.98	0.327	0.13	0.01	0.05	0.36
	Neut vs. Pos	t(52)	-2.14	0.037	0.29	0.08	-0.11	0.39
Middle	Env	F(2,60)	1.10	0.337		0.03		
Elderly	Env	F(2,94)	0.71	0.494		0.01		
ME: Decision speed (DS)		F(1,129)	0.01	0.909	0			

INT: DS * Age		**F(2,129)**	**3.38**	**0.037**	**0.05**			
Fast Tr	**Age**	**F(2,129)**	**5.37**	**0.006**				
	Y vs. M	**t(82)**	**-2.67**	**0.009**	**0.39**	**0.08**	**-0.12**	**0.31**
	Y vs. E	**t(99)**	**-2.69**	**0.008**	**0.32**	**0.06**	**-0.10**	**0.32**
	M vs. E	**t(77)**	**0.43**	**0.667**	**0.05**	**0.00**	**0.01**	**0.35**
Slow Tr	**Age**	**F(2,129)**	**9.79**	**0**				
	Y vs. M	**t(82)**	**-4.06**	**0**	**0.91**	**0.16**	**-0.15**	**0.17**
	Y vs. E	**t(99)**	**-2.91**	**0.004**	**0.58**	**0.07**	**-0.10**	**0.17**
	M vs. E	**t(77)**	**1.62**	**0.108**	**0.37**	**0.03**	**0.05**	**0.14**
Fast – Slow								
	Y	**t(52)**	**-2.30**	**.025**	**.01**	**.31**	**-0.02**	**0.08**
	M	**t(30)**	**.00**	**.995**	**00**	**.06**	**-0.00**	**0.14**
	E	**t(47)**	**1.44**	**.155**	**.03**	**.20**	**0.02**	**0.11**
	Y vs. M	**t(82)**	**-1.36**	**0.176**	**0.30**	**0.02**	**-0.02**	**0.09**
	Y vs. E	**t(99)**	**-2.55**	**0.012**	**0.50**	**0.06**	**-0.05**	**0.10**
	M vs. E	**t(77)**	**-0.97**	**0.335**	**0.22**	**0.01**	**-0.02**	**0.11**

Were participants affected by the partner?

Participants cooperated more with a human (*M* =.65, SEM = .021) than with a computer (*M* =.43, SEM = .019). Furthermore, across all three age groups, compared to ‘random’ decision ratio (0.5), participants cooperated more with humans across all conditions (chance = .05 and less with computers across most conditions, apart from slow trials in neutral blocks where the effect only trended significance (Figure 5-1A).

Did age modulate the cooperation pattern with the partner?

There was a significant interaction, showing that the effect of the partner was modulated by the age group (Figure 5-1 B.i). To unpack this two-way interaction, we first analysed separately, games played with a human and with a computer. Participant age affected the cooperation ratio when playing with a human. This effect had an inverted ‘U’ shape pattern: young (*M* = .58) < middle (*M* = .76) > older adults (*M*= .62). Young participants cooperated less than the middle-aged but showed no difference from older adults. Middle-aged participants cooperated more than older adults. Participants’ age also affected cooperation when playing with a computer. Overall age had a linear effect on cooperation decisions during the computer condition: young (*M* = .34) < middle (*M* = .44) < older adults (*M* = .51). Young participants cooperated less than middle-aged, and less than older adults. Cooperation decisions made by middle and older adults did not significantly differ.

To further explore this effect we used the 'two-lines test' (Simonsohn, 2018), searching for a U-shaped tendency in the human condition; using the Robin Hood algorithm in the 'two-lines test' we identified the breaking point at around 32 years old. The two lines were significant predictors of the data (Figure 5-3), showing the cooperation with humans sharply increased (beta = .02, Z = 3.95, p <.001) in participants from 18 till the age of 32 years, where it plateaued and slowly decreased (beta = -.00, Z = -2.20, p = .03). The effects were similar, irrespective of include or excluding the young participants with missing age.

This interaction also suggested that age may have affected the ability to adapt the strategy to changing partners. Hence next, we computed for each participant the difference between their cooperation ratio when playing against a human and a computer, collapsed across environment and decision speed. A positive difference indicates more cooperation with a human than a computer, while a negative difference indicates the opposite. This analysis showed that older adults showed smaller cooperation difference (human vs. computer; *M* = .21, SEM = .05), compared with the young (*M* = .50, SEM = .09) and middle age groups (*M* = .63, SEM = .11). There was no significant difference between the young and middle age groups.

A similar pattern of results was observed when analyzing the first trial, when participants played with a human or a computer. Participants were more likely to collaborate with a human than with a computer on the first trial, while the young were less likely to cooperate on their first trial, than middle age and elderly participants. see Supplementary Table S1 for details

Did the environment affect the cooperation ratio?

There was a main effect of the environment on the cooperation ratio (Figure 5-1B. i, Table 5-3). Independent of partner, decision speed and age, participants cooperated more in uncertain negative (*M* = .55, SEM = .017) than positive (*M* = .51, SEM = .019) environments. There was also a trend towards increased cooperation in negative relative to the neutral environment (*M* = .53, SEM = .017). The cooperation ratio was not different between neutral and positive environments.

Did age and partner modulate the impact of the environment on cooperation?

There was a significant three-way interaction between the environment, age, and partner. To unpack this three-way interaction, we first analyzed separately games played with a human and with a computer. Independent of age, ***when playing with a human***, the environment affected the cooperation. This effect emerged because participants cooperated more when playing in uncertain negative, than in positive uncertain or neutral certain environments. There were no significant differences between neutral and positive environments. Age also did not modulate the impact of the environment on cooperation with a human. **When playing with a computer**, the environment did not affect the decision and its impact was also not modulated by age.

As per the partner by age interaction (above), the three-way interaction suggested that age and the environment may have affected the ability to adapt to changing partners. Therefore, we computed the difference in cooperation ratio of human minus computer for each environmental context, collapsed across decision speed. The cooperation difference (human vs. computer) of young participants was affected by the environment. In comparison to the neutral environment, young participants showed a large cooperation difference in both the negative and positive environment. The cooperation difference for middle age and elderly participants was not affected by the environment.

Was there a difference between fast and slow trials? There was no overall difference in the cooperation ratio between relative fast and slow responses **(Figure 5-2 B.ii).**

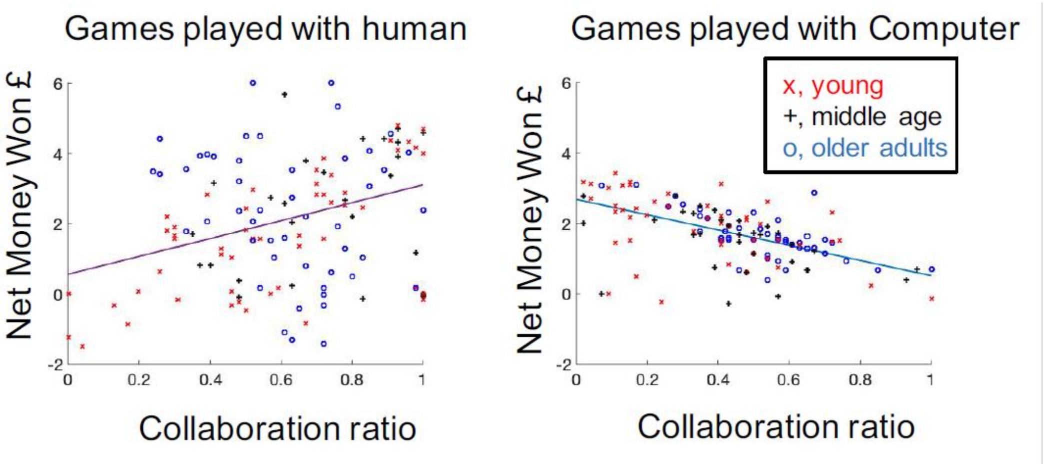

Figure 5-3 Interaction - Net money & cooperation ratio by partner

Scatter plots of the cooperation ratio plotted against the net money won. The right scatter represents games played with a human, while the left scatter represents games played with a computer. The points are color-shape coded based on the participants' group affiliation.

Did age modulate the types of decisions made in fast/slow trials?

Interestingly **age interacted with decision speed**. To unpack this interaction, we first computed a separate ANOVA for fast and slow trials. Age affected the cooperation decision in both the fast and slow trials. In both the fast and slow trials, young participants made significantly fewer cooperative decisions than middle-aged and elderly, but the effect size was larger for slow trials.

We next computed the difference in cooperation ratio between fast and slow trials. Positive difference suggests more cooperation during fast than slow trials, while a negative difference indicates the opposite. Figure 5-1B.ii showed an opposite pattern between the young and elderly group, with the middle-aged group showing an in-between pattern. Specifically, young participants cooperated less in fast than slow decision trials, older adults showed the opposite pattern, as they cooperated more in the fast than slow decision trials, though the effect was not significant. cooperation ratio of middle age was not affected by the speed of their decisions. The inverse response pattern between young and adult was confirmed when using age as a continuous measure, with increasing age participants cooperated more on fast than slow response trials (Pearson rho = .212, p = .01).

Can cooperation ratio be predicted from measures of executive function and positivity bias?

Analyses were done separately for games played with human and computer. We first computed Pearson correlations between cooperation ratio, age, emotional (i.e., positivity bias index), executive function (logRT, Cov-IIV). We next report a linear regression, computed to predict cooperation ratio when playing with a human and a computer partner, using the predictors: age in years, positivity bias, neutral logRT, and neutral CoV-IIV.

When playing with a human, cooperation ratio positively, but non-significantly, related to the positivity bias index (r = .16, p = .067). Participants who were affected more by the positive gains than the negative loss, cooperated more. Cooperation with a human was non-significantly negatively related to the executive function measures: decision times made during neutral environment (r = -.16, p = .053) and the-intra-individual variability (r = -.15, p = .073). This suggests that participants who dwell longer on the decision and were more varied in their decision times also cooperated less. Age did not correlate with overall cooperation with human (r = .01, p = .865). Age positively correlated with decision times (logRT, r = .54, p <.001), and was not significantly related to the COV-IIV (r = .13, p = .882) and the positivity bias (r < .02, p >.8). Positivity bias did not correlate with logRT (r = .25, p = .132) or COV-IIV (r = .14, p >.090). We note that all the above correlations are very weak and explain less than 3% of the variability in the data. As this was an exploratory analysis we did not corrected for multiple comparisons, hence these results should be treated with caution.

The regression model (which includes all the variables above), significantly predicted cooperation ratio when playing with a human F (4,127) = 2.74, p = .031, R^2 = .07, (Mean Sum of Squares: model = .15, residual = .05). The only significant predictor of the model was the logRT, the executive function estimates. LogRT negatively predicted cooperation ratio (unstandardized Beta = -.09, [-.180, -.005], *t* = -2.09, *p* = .038). The directions of the non-significant predictors were as expected: like log RT, Intra-trial variability was a negative (unstandardized Beta = -.09, [-.251, .054], *t* = -1.27, *p* = .203). The positivity bias was a positive predictor (unstandardized Beta =.77, [-1.861, -.314], *t* = 1.40, *p* = .162), suggesting that participants who were more affected by the positive than the negative uncertainty, cooperated more with a human. Age did not relate to cooperation ratio (unstandardized Beta = .001 95% CI [-.001, .003], *t* = 1.30, *p* =.193). This analysis suggests that beyond age, participants who took longer to make a decision were also more cooperative.

When playing with a computer, cooperation ratio positively correlated with age (r = .30, p <.001) and with decision times (r = .42, p <.001). Cooperation ratio was unrelated to the intra-trial variability (r <.002, p = .981) and to the positivity bias (r < - .047, p = .573). Age positively correlated with decision times (r <.567, p <.001) and a trend towards negatively correlating with intra-individual variability (r = -.158, p =.066). Age was unrelated to the positivity bias (r = -.00, p = .981). Positivity bias positively correlated with decision times (r =.24, p = .002) and intra-individual variability, COV-IIV (r = .27, p = .001), indicating that participants who slowed down more on positive (gains) than negative (losses) blocks were also slower in making decisions, and showed higher variability when playing with a computer during the neutral condition.

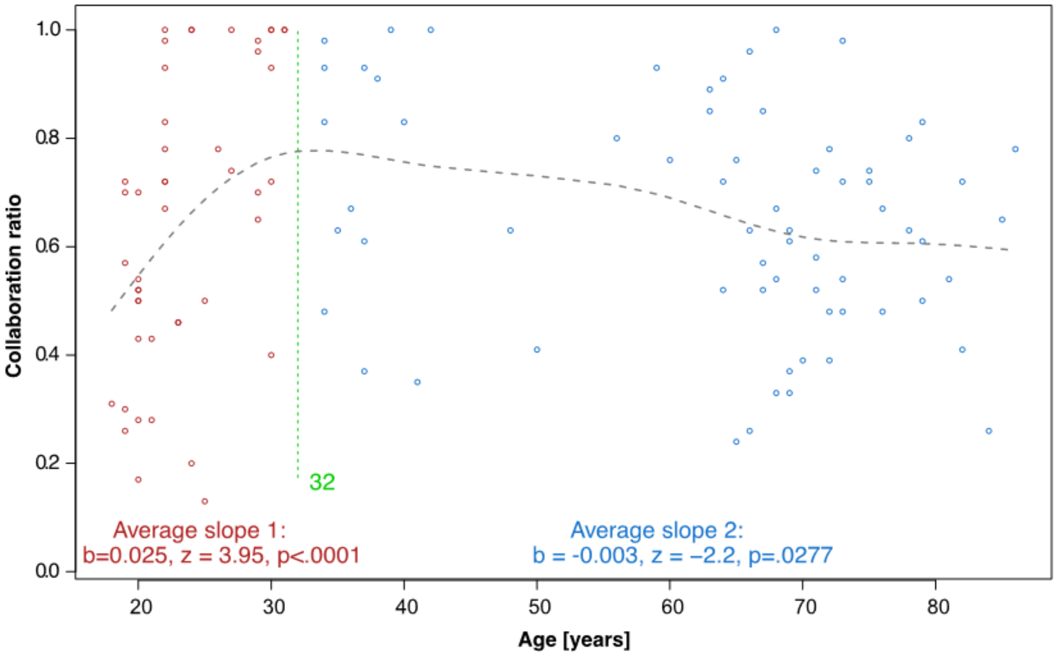

Figure 5-4 Age and Cooperation Ratio when playing with a human

The regression model, which include the above variables significantly predicted cooperation ratio with a computer *F* (4,127) = 6.58, *p* <.001, (Mean Sum of Squares: model = .27, residual = .041). The only significant predictor was log RT during neutral trials. But unlike games played with a human, longer decision times were associated with more cooperation (unstandardized Beta = .105, 95% CI [.030, .179], *t* =2.77, *p* = .006). The direction of the non-significant predictors were as follows: age was a positive predictor (Beta = .00, [.000, .004], *t*= 1.68, *p* = .094); intra-trial variability was also a positive predictor (unstandardized Beta = .006, [-.105, .117], *t* = .10, *p* = .917). Positivity bias negatively predicted cooperation ratio (unstandardized Beta = -.84, [-2.65, .96], *t* = -.92, *p* =.357).

In summary, beyond age, when playing with human participants, poorer executive functions, estimated by decision times, were associated with less cooperation. However, the reverse was observed when playing with a computer. Emotion related processes estimated using the positivity bias, had no impact on decisions to collaborate.

5.5.3 Net Money Won

Did cooperation translate to larger monetary earnings?

Table 5-4 presents the average earning per block per condition. We found a significant effect of the type of partner, F (1,129) = 12.31, p = .001, pη^2 = .087. Participants earned more money when playing with a human than with a computer. There was also a significant effect of environmental context, F (2,258) = 12.50, p <.001, pη^2 = .08. Participants made more net money in the negative environmental context as compared to the neutral, one t (131) = 3.85, p <.001, d = .33 and positive, t (131) = 5.22, p <.001, d = .45. This partially mirrors the results of the cooperation ratio, above.

Age did not affect the net money won (p = .694, pη^2 = .00). But there was a significant interaction between the age and the type of partner, F (2, 129) = 7.32, p = .001, pη^2 = .10. When playing with a human, age only marginally affected the earnings, F (2,129) = 2.89, p = .059, pη^2 = .04. Young people (Mean per block: £1.79) earned less than middle age (M = £2.75), t (82) = -2.40, p = .018, d = .54, and earned a non-significant less amount than older adults (M = £2.34), t (99) = -1.51, p = .31, d = .30. Middle age and older adults did not significantly differ in their earnings t (77) = .947, p = .347, d = .22. When using age as a continues variable, it did not linearly relate to earnings (r = .087, p = .319). The pattern of earning maps to the asymmetrical inverted 'U' shape seen in the cooperation ratio results.

When playing with a computer, age affected the earnings, *F* (2,129) = 5.05, p = .008, $p\eta^2$ = .07. Young (Mean per block = £2.03) earned more than middle age participants (£1.48), *t* (82) = 2.73, *p* = .008, *d* = .61, and more than the older participants (£1.67), *t* (99) = 2.26, *p* = .026, *d* = .44. Middle and older participants did not reliably differ in their earnings, *t* (77) = -1.10, *p* = .273, *d* = .25. When using age as a continuous variable, a linear relation between earning and age was observed (*r* = -.27, *p* = .002). This pattern maps again to what was observed in the cooperation ratio analysis.

Further analysis showed that the effect of a partner (increased amount of money won with human relative to computer) was larger in middle aged, *F* (1, 30) = 21.74, *p* <.001, $p\eta^2$ = 0.42, and older participants, *F* (1, 47) = 5.65, *p* <.05, $p\eta^2$ = .10, compared to younger participants, *F* (1, 52) = 0.88, *p* = .35, $p\eta^2$ = .01.

The overall net money won, independent of age, showed a positive correlation with the cooperation ratio when playing with a human partner, *r* (131) = 0.31, *p* <.001 (R_s = .33, *p* <.001) and a negative correlation when cooperating with a computer partner, *r* (131) = -.62, *p* <.001 (R_s = -.65, *p* <.001). These results suggest that participants made more money when they cooperated with another human partner whilst it was more beneficial to betray the computer partner.

Table 5-5 Net money won

The table describes the average money earned (£) per block

Age	**Partner**	**Environment**	**Net money won** £ mean (SEM)
Young	Human	Negative	2.23 (.29)
		Neutral	1.59 (.27)
		Positive	1.55 (.28)
	Total		*1.79 (.24)*
	Computer	Negative	2.41 (.17)
		Neutral	1.84 (.18)

		Positive	1.83 (.15)
	Total		*2.03 (.11)*
Middle	Human	Negative	3.10 (.38)
		Neutral	2.82 (.37)
		Positive	2.32 (.37)
	Total		*2.75 (.32)*
	Computer	Negative	1.61 (.22)
		Neutral	1.63 (.24)
		Positive	1.67 (.20)
	Total		*1.48 (.14)*
Elderly	Human	Negative	2.65 (.30)
		Neutral	2.23 (.30)
		Positive	2.14 (.30)
	Total		*2.34 (.26)*
	Computer	Negative	1.88 (.18)
		Neutral	1.46 (.19)
		Positive	1.67 (.16)
	Total		*1.67 (.11)*

5.6 Discussion

In this study, we examined the effect of age, environmental context, and partner on human cooperative decision-making in an iterated (repeated) Prisoner's Dilemma Game. We first found that while most participants reported feeling unaffected by the environment manipulation, their decision times and variability in decision times showed that they slowed down and were more variable in their decisions in uncertain environmental conditions (associated with random monetary loss or gains). Across all conditions, the young cooperated less than middle age and elderly participants. As expected, all participants cooperated more when playing with a human than with a computer partner. More importantly, age modulated the way participants reacted to the different partners. When playing with a human, an asymmetrical inverted 'U' shape pattern of cooperation was observed, with a sharp increase in cooperation ratio from young to middle age and a slower decline thereafter. In contrast, when playing with a computer, a positive linear relationship was observed, where cooperated increased with increasing age. The environment also affected the cooperation ratio, with participants most likely to collaborate when facing a human in an uncertain negative environment. The effect of the environment was most pronounced in young participants. We also observed that with age, fast responses, reflecting natural decision potency changed. In fast trials, elderly participants were more likely to collaborate than middle age and young participants. A regression analysis showed that beyond age, measures associated with executive functions, mostly decision speed, predicted cooperation ratio in opposite directions when playing with a human and a computer. When playing with a human, faster participants cooperated more, whilst when playing with a computer, slower participants cooperated more. Finally, money won through decisions during the games, reflected the cooperation ratio pattern when playing with a human but not with a computer. As expected, based on the payoff table of a Prisoner's Dilemma Game, when participants played with a human, those who cooperated more, earned more money. Although surprisingly, when playing with a computer, betrayals led to larger earnings. We next discuss each of these effects in detail.

5.6.1 Effects of Age on Cooperation with Humans

Participants made more cooperative decisions when playing with a human than expected by chance. This was already evident in the first trial. It is in line with most studies measuring cooperation and trust in economic games, showing that participants by default will trust and cooperate, in support of the social contract theory (Binmore, 1994).

The main finding of the current study was that cooperation with humans sharply increased from young till middle adulthood and then slowly decline until late adulthood (Figures 5-2, 3). This was also reflected in the net money the participants earned during the games (Table 5-4). Already at the first trial of the game, young participants were more likely to betray, compared with the more mature participants (Supplementary Table S2). These results are in line with previous studies, showing an increase in trust and cooperation up until middle adulthood (Matsumoto et al., 2016). The inverted 'U' shape pattern also matched previously reported results on changes in financial credit decisions across adulthood (Agarwal et al., 2009). The slow decline in cooperation following middle adulthood may explain the inconsistent results that are reported in the literature, regarding the impact of age on prosocial decisions in economic games (Lim and Yu, 2015).

The propensity to cooperate more with increased age was reflected in the clear cooperation bias in fast, relative to slow decision trials, in older adults, and an almost reverse pattern in the young. This is in agreement with the reported age-related increases in the subjective reports of the Social Orientation Value (Van Lange et al., 1997). Like Yamagishi and colleagues (2017), we showed that individual decision times can be used to measure individual 'natural' cooperation propensity.

Taken together, the results provide some support for the socio-emotional selectivity theory (Carstensen et al., 1999) which hypothesized a shift in goals across adulthood, where the young prioritized immediate material gains, opting for more pro-self decisions, while older adults, focusing on more social gains, are biased toward pro-social decisions. Similarly, the data support the prosocial growth hypotheses (Van Lange et al., 1997), by showing an increase in trust and prosocial decisions with age. This is specifically reflected in reduced cooperation and propensity to cooperate in young participants. The young also tend to show a high tendency for taking risks to optimize immediate material goals (Roalf et al., 2012). While the propensity to cooperate increased with age, the above theories fail to account for the observed slow decline after middle age in the actual number of cooperative decisions.

Why did older adults reduce their cooperation when playing with a human? The regression analysis suggested that factors associated with executive function, a component of fluid intelligence, were negatively associated with the cooperation ratio. As the payout for games with a human partner increased with the level of cooperation, these results support previous findings, showing reduced ability to make financial decisions with age when they rely on fluid cognition (Bruine de Bruin et al., 2012). The estimated measure for emotional processing changes across adulthood - the positivity bias index, was positively associated with the cooperation ratio, but did not significantly contribute to the regression model when all other variables were accounted for. This suggests that the effect of emotional processing on cooperative decisions is weaker in comparison to the impact of cognitive abilities. These observations are in line with previous studies (Harlé & Sanfey, 2012; Zhu et al., 2012), showing that age-related differences in social decisions are primarily driven by factors related to differences in fluid cognition, rather than a difference in emotional processing.

The Prisoner's Dilemma Game has a complex decision tree. There are only two decisions to choose from (cooperate and betray), but each can lead to diametrically opposite outcomes (win, loss), depending on the partner response. As the response keys and their meaning were present on the screen throughout the decision process and were fixed across the entire experiment, it is unlikely that elderly participants simply forgot the mapping between keys and decision types. The repeated aspect of the game allowed participants to take into account their partner strategy as reflected in their decision patterns, which potentially added complexity.

Older adults are suggested to perform poorer on tasks that include conditional contingencies, resorting to automatic heuristic responses (Finucane et al., 2005; Finucane & Lees, 2005). Hence, it is possible that the task complexity led older adults to adopt a heuristic response. Overall, compared with the young and middle aged, older adults showed small intra-trial variability in decision times, though they took longer to make a decision (Table 5-2). Consistent decision times may suggest that old adults have adopted a heuristic response and/or were less affected by the context (e.g., partner's decision strategy, partner's nature, environment). Limited cognitive resources and lack of adaptability may have led to sub-optimal decisions in the older adults’ group (this also matches the observed decision pattern of elderly when playing with computers, see below). This contrasts with young and middle-aged adults, who showed larger variability in decision times, hinting at a non-heuristic approach to decisions.

Another potential reason for older adults' reduced cooperation with human partners, is familiarity with the digital format of social communications. The older generation was not born into the computer and social media era, and may not perceive social interaction via a computer medium as real as a human interaction (Sayago et al., 2011). Thus, older adults may lack knowledge and experience of digital social interactions, making them qualitatively different decision-makers than young and middle-aged adults (Finucane and Lee, 2005). This can be partly supported by the testimonies of four participants (2 older adults and 2 middle-age participants), that they did not believe the human partner that they interacted with was a real human. This may explain why older adults used a similar strategy when playing with a human and a computer (see below). It is also possible that older adults found it difficult to trust a person who is not known to them, whilst interacting with them via a computer. This was mentioned by one of the older participants, that because the interaction was mediated via a computer, it did not feel like a face-to-face interaction. Most social interaction and financial transactions in the developed world are mediated via computers. Hence it is important to consider the impact of familiarity with the communication/interaction formats when assessing financial decisions. Further research should examine directly the impact of different formats of interaction on cooperative decisions across adulthood.

5.6.2 The impact of age and environment on cooperative decisions when playing with a human

Only a few participants subjectively reported that they were emotionally affected by the environmental manipulation. This did not vary with age or as a function of the environment (Table 5-1). Lack of emotional response and age effect on expected gains or losses contradicts previous reports (Nielsen et al., 2009), (Bruine de Bruin et al., 2018). This may be because Nielsen and college used one Likert scale of valance, from negative to positive, whereas we used two different scales. The authors also requested a rating during each trial, while we only asked participants to reflect on their experience at the end of the study. Finally, in the current study, participants had other means of gaining and losing money, which may have masked the emotional response of the uncertain environments.

Despite a lack of effect in the subjective reports, when playing with a human, participants took longer to make decisions in uncertain blocks (Table 5-3), specifically when the environment was negative (30% chance for incurring monetary loss). They were also more variable in their time to make the decision (Supplementary Table S1). Variability was largest when the uncertainty of the environment was positive (30% chance of gaining money). Age did not modulate the impact of the environment on decision times. This shows that the environment had a differential effect on the decision process.

Participants cooperated most when playing in a negative uncertain environment. In comparison to games played with computers, the young showed the largest increase in cooperative decisions during negative blocks, while the impact on middle aged and elderly participants was not significant. The observation that increased age reduces the impact of the environment on cooperative decisions, is in line with theoretical models that predict better emotional regulation (Charles, 2011) and better ability to cope with uncertainty with increased age (Meeks & Jeste, 2009). Similarly, Harlé & Sanfey (2012) showed that relative to young, older adults recruited less emotional brain regions when making social decisions.

5.6.3 Effect of Age when playing with computer

Overall participants were less cooperative when playing with a computer partner compared to when playing with a human (Figure 5-1). With a computer partner, participants were more likely to select a proself betrayal behavior when compared with random selections. The bias to betray a computer was evident already in the first trial (Supplementary Table S2). Reduced cooperation with a computer partner has been reported before (Miwa & Terai, 2012). It supports the idea that motivation to cooperate relies on an assumption of reciprocation (Bolton & Ockenfels, 2000), which participants perceived to be absent when playing with a computer. The environment did not affect cooperation ratio with a computer, again showing that all participants approached the computer as a non-social agent, appreciating that unlike themselves they were not affected by the certainties of the environment. It is interesting to note, that perception and beliefs had a larger effect on decisions than the actual strategy used by the computer, which reciprocated in 80% of the decisions, due to its tit-for-tat strategy.

-The data clearly showed that participants played with a computer using a different strategy than with a human. This accords with the subjective reports, in which participants reported that they believed they were playing with a computer that made a random decision. Some testified that they did not trust the adaptability of the computer in reciprocation. This contrasted with the perception of the interactions with human partners, where they believed that they could influence their partner's behavior. This was reflected in the decision times data. Independent of age, decision times and variability in decision times varied between games played with a computer or human partner. In comparison to playing with a human, participants were slower to make a decision when playing with a computer but showed less variability. This suggests that in general they deliberated more when playing with a computer, but when playing with a human they showed larger variability between trials in the processes that led to a decision. It is possible that when playing with a human, unexpected partner's decision led to more deliberation, compared to an expected response. As most participants declared that they believed the computer made random decisions, their strategy was less likely to be guided by their expectations of the computer.

In contrast to games with a human, age was linearly related to cooperation ratio when playing with a computer (Figure 5-2), increased age was associated with more cooperation decisions. Though interestingly, the effects of age were nonsignificant when considering only the first trial (Supplementary Table S2). This suggests that participants did not differ in their initial approach to the computer partner, and differences in strategy only emerged throughout the repeated encounters. The change in strategy between playing against a human and a computer was more evident in middle age than young, while the older adults hardly changed their overall game strategy. We note, that even if older adults did not believe, forgot, or were insensitive to the computer/human partner manipulation, nevertheless these two partners potentially used different strategies, which older adults did not adapt to.

The regression analysis showed that, beyond age, cooperation ratio was positively predicted by the time it took to make a decision, but not by variability in decision times or the positivity bias index. The positive relation between decision time and cooperation decisions, when playing with a computer, was the opposite to what was observed when playing with a human, where the two variables were negatively related. Thus, when playing with a computer, poorer executive functions, or less deliberation times, were associated with more cooperation decisions.

Participants earned more money when playing with a human than with a computer. This mirrors as expected the cooperation results. A somewhat surprising result of the net money earned showed that when playing with a computer, cooperation negatively predicted the net money earnings, the more a participant cooperated the less they earned. This contrasted the positive relations between earning and cooperation when playing with a human. It is unclear, why betrayal was associated with more earning when playing with a computer. But it could be a combination of participants' tendency to betray a computer, combined with computer 80% tit-for-tat strategy.

Taken together, most importantly, young, and middle-aged participants adapted their behavior when playing with the computer, but elderly participants did not. Similarly, Harlé and Sanfey (2012) showed that social decisions made by older adults, relative to young, are less sensitive to change in context (e.g., partner's type [human, computer], Partner's behavior). This accords with observations of a decline in cognitive flexibility with age (Coubard et al., 2011). Young participants also showed the highest betrayal rates when playing with a computer, potentially reflecting increased risk-taking behavior in young in order to maximize profit (Lim & Yu, 2015).

5.6.4 Aging and decision making in the context of social-economic conflict

The current study showed an asymmetric inverted ‘U’ shape across adulthood of prosocial decisions and money earnings in social-economic conflicts when playing with a social partner. There was a sharper increase from young to middle age in cooperation and a smaller decline thereafter. Young showed a propensity to betray and take risks, while older adults show a propensity to collaborate. We further showed that this was mediated by executive function abilities. When playing a computer, young and middle age, but not older adults, adapted their behavior to maximize their profits. The results suggest that both cooperative decisions and money earned are driven through an interaction of fluid intelligence (executive function abilities and the ability to adapt to changing contexts, environments, and partners), crystallized knowledge (digital interaction format) and shift in the propensity to act from proself to prosocial. In older age, when playing with a human, prosocial propensity mitigated the impact of fluid cognition on optimal decisions. In contrast, when playing with a computer, the use of the prosocial cooperation heuristic hindered performances. These results support a previous model of wisdom dynamics and decision making across adulthood, highlighting the importance of experience, fluid cognition (Bruine de Bruin et al., 2012), and affective processing (Ardelt et al., 2018; Finucane et al., 2005).

5.6.5 Methodological considerations and limitations

An advantage of our study was that interaction with human partners took place in real-time. Participants were given a brief chance to meet their human partner, (whilst limiting any interaction between them), before they were guided to their cubicle, which increased the ecological validity of the social conflicts. Ecological validity typically comes at a cost of less control over the dyad's behavior and pattern of responses given by each. In this context, we note that the pairing was done in a semi-random opportunistic procedure. Participants played as pairs, only with one other person in repeated encounters. Furthermore, participants played with participants of the same age group to minimize the in-group/out-group effect. But this within-age pairing meant that different age participants played with qualitatively different partners (both human and tit-for-tat computers). This is likely to have affected their overall behavior. Because the partners were constant throughout the game (one human partner, tit-4-tat computer), we cannot assess the dependency of individual decisions on their specific partner. In other words, participants from different ages may employ different strategies if partnered differently.

Participants played six blocks of 13-17 trials. Dyad participants often adopted one strategy within each block, either of cooperation or betrayal. Thus, the responses of the participants to each other were not independent, as any interaction between two humans depends on many factors (e.g., their age, mood, history), especially in the context of repeated interactions. We believe that repeated interactions are ecologically more valid, as interactions in real life of social-economic conflicts are often made with familiar partners. Nevertheless, to address these statistical and theoretical dependencies, we ran two additional analyses. In one we examined the first trial played, and in a second, we treated the pairs as the random variable. In both analyses, the effects of age and partner types on cooperation decisions were similar.

We used measures based on decision times to validate the experimental manipulation, as well as to estimate core abilities (e.g., executive functions, positivity bias). However, participants were not instructed to respond as fast as possible. There were no restrictions on the time to respond, but there was some 'social pressure' to respond in a reasonable time, as participants had to wait for each other's responses to be able to continue. Therefore, the measures related to decision times are likely to have a low signal-to-noise ratio.

Response time and response time variability as proxy measures of executive functions are typically based on tasks where there is a clear correct response and accuracy rates are high. The prisoner's dilemma game is more complex, with no clear correct answer. While in our data, age positively related to decision times as expected, intra-trial variability related inversely to age, is the opposite to what is expected. Thus, the interpretation of these measures should be done in the context of the experiment.

We assumed that across the adulthood lifespan, the same amount of money is associated with similar reward values. This is unlikely to be the case, as younger, and maybe some older participants, are likely to be in a more disadvantaged financial situation, e.g., a £10 profit for a student or a pensioner may be more desirable than it is for a full-time working middle age professional. Nevertheless, middle age participants made the highest earnings, suggesting motivation to earn was not driving the difference.

All participants were residents in the urban areas of Birmingham, UK, and all had University or equivalent level of education. Participants also played with a partner of a similar age group. This enabled us to minimize the confounding effects of culture, education, in/outgroup, when examining decisions in social conflicts across adulthood. But at the same time, it limits the ability to generalize the findings to other populations.

Another limitation was the relatively small number of participants within the middle age range. Specifically, we had fewer participants between the ages of 45 to 65. The lack of data points may have affected the estimation of the peak cooperation age.

For the computer we employed a tit-for-tat strategy, with 20 percent random choices to mask this. While tit-for-tat is generally considered an effective strategy (Axelrod, 1984), it is not meant to replicate human behavior, hence we cannot completely rule out that differences in behavior towards the computer opponent (relative to a human opponent), do not merely reflect the differences in the partner's strategy employed by a real human and a computer. This is an issue to potentially examine in future studies.

5.7 Conclusion

Prosocial decisions in social conflicts differ across adulthood. Young participants were more likely to betray, making risky proself decisions to maximize personal gains and were also more affected by the environment. Increased age was associated with an increased propensity to cooperate and reduce the impact of the environment. When playing with humans, beyond age, cooperation ratio negatively correlated with measures of executive functions. This suggests that when playing with a human, an increase of prosocial tendencies in older adults mitigated the negative impact of reduced executive functions on making the optimal decision in the prisoner dilemma game. This is reflected by the asymmetric inverted 'U' shape of decisions, that potentially reflects adulthood dynamics of wisdom as employed in social contexts. In a non-social context, when playing with a computer, prosocial (cooperative) tendencies of older adults hinder optimal decisions. In contrast to older adults, young and middle-aged participants adapted their strategy to the partner, reducing their cooperation and maximizing the earnings. Cooperation ratio with a computer linearly related to age was also predicted by slow decision times (potentially indicating poorer executive functions), though it was negatively related to the money earned in the games.

6 THE EFFECT OF PARTNER’S BEHAVIOUR, ENVIRONMENTAL MANIPULATIONS, PAST CHOICES, AND INDIVIDUAL DIFFERENCES IN COOPERATIVENESS TRAIT ON COOPERATION IN THE REPEATED PRISONER’S DILEMMA GAME

6.1 Abstract

In this study, the effect of environmental manipulation, partner's behaviour, past decisions, and individual differences in the repeated Prisoner's Dilemma Game was examined. The data was collected from 100 students, (age 18 to 26yo) playing eight blocks (16 trials in each bock) with four different partners in the two different environmental contexts. Environmental context was manipulated by introducing random monetary losses within the blocks (negative) as opposed to a neutral environment. Partner's behavior was controlled by introducing a pretended cooperative partner (80% cooperation), and a pretended defecting partner (80% defection), in addition to a real human and a computer. Individual differences in their prosocial trait of cooperativeness were measured using questionnaires. Analysis of variance shows that the environment affected participants' decisions, with more cooperation in the neutral than the negative environment only when they played with a human or a computer partner. Participants cooperated more with their pretend-cooperative partner as compared to their human partner, and they defected more with their pretend-defecting partner as compared to a computer. Findings from a Linear Mixed Effect model show similar effects of the environmental context, and partner's behaviour, but participants also showed more cooperation in the negative environmental context with their pretend-cooperative partner. Participants with higher scores in cooperativeness showed more cooperation with the pretend-cooperative partner and more defect with their pretend-defecting partner. Importantly, participants' decisions were strongly affected by their own and their partner's previous decisions, with more cooperation followed by mutual defecting.

Keywords: Cooperation; Decision making; Prisoner's Dilemma Game; Cooperation and Reciprocation; Individual Differences.

6.2 Introduction

Factors such as environmental context (Andras, Lazarus, Roberts, & Lynden, 2006; Taheri et al., 2018), social context (e.g., Biel & Gärling, 1995; Bolton & Ockenfels, 2017; Butler, Burbank, & Chisholm, 2011), and the individual differences (e.g., Balliet et al., 2009; Boone, De Brabander, & van Witteloostuijn, 1999), are suggested to affect cooperative behaviour in social dilemmas. In this study, the focus is to examine cooperation in the repeated Prisoner's Dilemma Game (PDG) as manifested by the environmental context and partner's behaviour, and also to investigate how individuals with different prosocial traits react to them. In addition to these, the effect of the participant's own and their partner's previous choices on cooperation, is also investigated by using a Linear Mixed Effect Model.

Cooperation in social dilemma is shown to be affected by the environmental context in which the decisions are made (Samphantharak & Chantarat, 2015; Molander, 1985; Bauer, Blattman, Henrich, Miguel, & Mitts, 2016; Molander, 1985). In Study 1 (Chapter 3), it was found that uncertain environmental context affects cooperative behaviour (Taheri, Rotshtein, & Beierholm, 2018). It was found that in the blocks where participants randomly lost money (negatively uncertain environment), they cooperated more, as compared to the blocks where they randomly won money (positively uncertain environment), than in the neutral blocks where money was not randomly given or taken from them. Previously it was discussed that the negative environmental uncertainty could have potentially triggered the negative emotional stress and led to more cooperation (Hertel et al., 2000).

Moreover, in social situations especially in social conflicts one's decisions are not independent of the partner's decisions (Bolton, Brandts, & Katok, 2000). Particularly in the repeated PDG, where participants play the game more than once and often in several trials, continuous interactions create a social dynamic that affects participants' decisions respectively. This interdependency of decisions is well presented in the equity, reciprocity, and competition model through showing that it is not just the pecuniary payoff that motivates the decision makers but also its interaction with the relative payoff to others that affect decisions (Bolton & Ockenfels, 2017). Similarly, fairness equilibrium proposed by Mathew Rabin, (1993) suggests that "people are kind to people who are kind to them and hurt people who hurt them". He emphasized that we do not cooperate based on unconditional altruism, and we are not "unconditional co-operators" who find pleasure in cooperation per se, but rather "conditional co-operators" who choose to cooperate as long as our partner is not clearly identified as defecting.

Previous studies show that the interdependency of decisions in the repeated Prisoner's Dilemma develops into three main strategies: a mutual cooperative strategy, a mutual competitive strategy or a third group, who moved away from competition, but not to quite well established mutual cooperation either (as cited by Bixenstine & Gaebelein, 1971). To test participants' decisions as a function of their partner's ('other") strategy in a repeated PDG Bixenstine and Gaebelein (1971) used an apparatus that allowed the counterpart to know participants' decisions. To explore which strategies elicit more cooperation or competition they composed 5 strategies to respond to participants' decisions in a systematic way. For example, in the quick to cooperate or quick to compete strategy the counterpart followed participant's cooperative or competitive decision respectively with a high probability of 100%. On the other hand, in the quick to cooperate but slow to compete strategy the counterpart's decision was made based on a probability of 100% to cooperate but only 60% to compete. Interestingly, they found some participants did choose competitively whilst "other" chose cooperatively, and some participants did choose cooperatively whilst "other" chose competitively. Findings from the Bixenstine and Gaebelein (1971) study provides evidence showing that individuals react to "other's'' behavior not purely based on the "other's'' strategy; i.e., reciprocation did not occur all the time. It is likely that individuals react to the emerging social dynamic based on other variables such as individual differences in their motivational orientations (Kuhlman & Marshello, 1975). Matthew Rabin also highlighted that in the PDG people may be kind to or hurt others not solely based on the other's actions but based on their own motives and expectations about the other's motives. Amongst the prosocial traits and motives, Social Value Orientation and cooperativeness traits are suggested to directly influence social decisions especially in an interdependence and conflicting situation. Both the Social Value Orientation and the cooperativeness trait evaluate individual differences with regard to their preferences to self and others.

Social Value Orientation (SVO) is defined as a dispositional construct that is shown to capture individual differences in their goals and motives in allocation of resources to themselves and to others (Murphy, Ackermann, & Handgraaf, 2011). SVO is measured based on participants preferred outcomes in relation to the other's outcome in social dilemmas (Messick & McClintock Charles, 1968). In the context of the repeated Prisoner's Dilemma Game (PDG), individuals' motivational orientations (SVO) have been shown to have a direct impact on reciprocity or exploiting the cooperation (Kuhlman & Marshello, 1975). In a study Kuhlman and Marshello (1975) categorized subjects into three motivational orientations: cooperative, competitive, and individualistic. This was done based on subjects' responses in relations to the gains or losses of the other person in a variation of PDG labelled as decomposed game. As an example, cooperation was the orientation with the motivation to maximize the gains of both players. They used three computer programs (100% Tit for Tat, 100% cooperation, 100% defection), to study participants' responses based on their motivational orientation in reaction to these strategies. Interestingly, they only found subjects with the cooperative orientation to reciprocate with all three strategies whilst the competitively oriented subjects defected against all the three strategies.

Cooperativeness trait is a character trait that is measured through self-report questionnaires. It is a subscale of the Psychobiological Model of Temperament and Character (TCI) that comprises three character dimensions: Self-Directedness behaviour, Cooperativeness and Self-Transcendence, that not only measure the goals and values, but also the emotional reactions and habits (Cloninger, M Svrakic, & R Przybeck, 1994). For the purpose of this study, we only focused on Cooperativeness, accounting for individual differences in social acceptance, empathy, helpfulness, and compassion. Despite the lack of empirical studies on the measure of Cooperativeness and its impact on decision making in the context of economic games, studies have shown the Cooperativeness measure to be the unique predictor of the emergence of leadership (O'Connor & Jackson, 2010), that is known to be a quality of leaders in conflict resolution (Gächter, Nosenzo, Renner, & Sefton, 2012). Moreover, TCI has been shown to correlate with the Big-Five Personality trait measure (Fruyt, Wiele, & Heeringen, 1988), that has been studied to predict cooperation in the Prisoner's Dilemma Game (Kagel & McGee, 2014a; Lönnqvist et al., 2011). Specifically the

Cooperativeness measure of TCI is shown to correlate with the Agreeableness subscale of the Big Five Personality measure (Fruyt et al., 1988) that has also been shown to predict the probability of cooperation in the Prisoner's Dilemma Game (Kagel & McGee, 2014b). Therefore, in this study participants were asked to complete a self-report questionnaire assessing their cooperativeness after they completed the task, (see the methods section).

As mentioned earlier, an important dimension of the Prisoner's Dilemma is its temporal structure (Kelly 1984). The repeated interactions allow for the development of a social dynamic that evolves and mutates between individuals and needs to be understood not only in terms of immediate outcomes,, potential future outcomes (Rusbult & Van Lange, 2003), but also previous behaviour (Axelrod & Hamilton, 1981). Cosmides and Tooby, (1992) proposed that humans have acquired domain-specific cognitive modules to engage in social exchange through reciprocal altruism. They suggested that humans have evolved a social map that keeps track of their relationships and their interactions, in order to be able to adapt to their social life. The availability of a cognitive social map seems essential, particularly in repeated interactions when the probability of future interaction is evident as in the repeated PDG. Hence, in the current study the previous choices of participants and its effect on their cooperative decisions were included in the analysis.

Since the findings from study 1 (Chapter 3) showed no significant effect of positive environment (Taheri et al., 2018), in this study it was decided not to include the positive environmental context. Therefore, the negative environmental context was manipulated through random loss of money and the neutral environment with no loss of money. In the previous study, participants played either with a human partner or a computer partner in relevant blocks, and they had prior information about who they played against. It was therefore argued that whilst the computer's responses were controlled (Tit for Tat strategy), there was no control over the human partner's responses, and therefore the partner's behaviour was not factored in the analysis. Thus, there is a confound in the use of the regular Prisoner's Dilemma Game; that when analyzing the causes of a decision, it is impossible to completely disentangle the contribution of each participant from that of their partner's history of choices. As an example: if a partner always defects, we cannot disentangle the propensity to defect from the response to the partner's previous behavior. It is therefore important to be able to study cooperative decision in the context of previous choices. With a computer partner there is obviously that variability, allowing it to make statements about changes in behavior given previous choices. In order to overcome this confound factor, studies have used deception by introducing a computer programmed partner (e.g., see Kuhlman & Marshello, 1975) or a human counterpart that plays a certain strategy (e.g., see Bixenstine & Gaebelein, 1971). This is normally unknown to the participants, to make them believe that they are playing with a real human. By controlling the behavior of the partner (a computer masquerading as a human), each subject's decision can be analyzed separately. Therefore, to create a controlled but socially uncertain environment, the partner's behaviour was manipulated by introducing a pretend-cooperative (p-cooperative 80%), a pretend-defecting (p-defecting 80%), and a computer (Tit for Tat), in addition to a real human partner. Both the manipulation of the environmental context and the social context was validated through post experimental questionnaires and implicit measure of response time (please see the Data Analysis, 6.4). An incentivized game was used to make the decisions more real

(Lönnqvist, Verkasalo, & Walkowitz, 2011). Importantly, participants played the game online, meaning they played with their partner at the same time, to create a social environment as real as possible. To measure the individual differences in their prosocial trait of cooperativeness and how it modulates their cooperative decisions in an environmentally and socially uncertain situation, the Cooperative subscale of the Cloninger's Psychobiological Model of Temperament and Character (Cloninger et al., 1994) was used (see Methods 6.3.3).

Cooperation ratio was used as a main measurement of cooperation and the time course as a measure of response stability to explore the data more (please see the Data Analysis section). Moreover, the last two choices of participants and their partners' previous two choices were also included in the Linear Mixed Effect model, to account for the effect of the recent history of interaction on cooperative decision making.

Hypotheses

- Based on the finding from Study 1, it is hypothesised that participants would cooperate more in the negatively uncertain environment as compared to the neutral environment (Taheri et al., 2018).
- Similar to Study 1, a computer partner was used as a control measure and it is expected to see more cooperation with a human partner (real and pretended) as compared to the computer (Taheri et al., 2018).
- It is hypothesised that participants would react differently based on their partner's behaviour, i.e., more cooperation with p-cooperative and more defect with p-defecting partner. The effect of a partner's

behaviour (p-cooperative or p-defecting) is expected to be magnified by the environment, e.g., more cooperation with p-cooperative partner during the negative environment.

- It is predicted that individual's own cooperation will increase the probability of their subsequently cooperating.
- It is expected that an individual's cooperativeness trait affects a participant's mutual cooperation, e.g., participants who score higher in their cooperativeness measure cooperate more with the p-cooperative partner but not with the defecting partner.

6.3 Methods

6.3.1 Participants and Design

One hundred university students, age range between 18 to 26 years old (male =12), participated in the study which lasted about one hour. Participants were tested in groups of four, based on opportunistic matching, by participants signing up for the same advertised time slot. Participants received course credits for their participation and any additional money won during the game (see below).

The Use of Deception - each of the participants were told that they would be playing with the other three participants and a computer (identified as computer) in a randomised order. In reality, they only played against one human, the computer and two instances of a computer program masquerading as participants. The false computer algorithm was programmed to respond with a bias towards cooperative or defecting decisions.

To test the effect of the deceit, i.e., participant's beliefs about their partners (human or computer), they were asked to complete a post-experiment questionnaire (see Data Analysis). Finally, participants were debriefed and explained the rationale for the deceit manipulation. They were also requested to keep the deceit confidential until the end of the data collection.

The study was a repeated designed with four types of partners (a computer, a human, a pretended cooperative (p-cooperative) partner and a pretended defecting (p-defecting) partner and in two environmental contexts (one negative and one neutral environment).

6.3.2 Task

Participants were invited to play a modified version of the repeated Prisoner's Dilemma game in groups of fours. The game was designed to be played in pairs of two at a time (see Methods, Chapter 2).

The environmental context was manipulated across blocks (see the Method Chapter). Based on our previous study (Taheri et al., 2018), two contexts were used: negative (uncertain) and neutral (certain), as a control condition. It was decided to exclude the positive environmental context as it did not show any effect in the first study (Chapter 3).

The computer used a Tit for Tat (TFT) strategy as in previous studies. In addition to this, in the current study, a p-cooperative program was designed to cooperate 80% of the time with 20% random decision, and a p-defecting program was designed to defect 80% of the time and respond randomly on the remaining 20% trials. Importantly, in the latter two cases, participants were informed that they are playing with a. human.

The game lasted for a total of 128 trials divided into eight experimental blocks of 16 trials in each block. There were two fixed game orders. In the first four blocks, participants played all four partners in pseudo-random order, half in a neutral and half in a negative environment, the matching of partner and environment was pseudo-random. In the following four blocks the order of partner's blocks was repeated but now played in the context of the opposite environment. The two orders were counterbalanced across participants. The orders were: Order 1: Computer Tit For Tat Neutral, Human Partner Negative, Pretended cooperative Negative, Pretended Defecting Neutral, Computer Tit For Tat Negative, Human Partner Neutral, Pretended cooperative Neutral, Pretended Defecting Negative, Order 2: Human Partner Negative, Computer Tit For Tat Neutral, Pretended cooperative Neutral, Pretended Defecting Negative, Human Partner Neutral, Computer Tit For Tat Negative, Pretended cooperative Negative, Pretended Defecting Neutral. The rationale for this structure was to ease comparison across the two orders, by keeping the history and experience of each participant in the game constant within each order. To account for the order induced variability, order was included as a between factor in all analyses.

The instructions of the game were given to all four participants in the same room. They were introduced to the aim and structure of the game and the payoff table was clearly explained to them. The environmental and the partner manipulations (e.g., whether they were playing against human or computer) were also explained. They were advised that the type of partner and environment would be fixed across each block. They were then taken to four separate rooms, where they played the game. This precluded any communication between participants during the game. In separate rooms, participants practiced the task and the experimenter verified that they understood it. To strengthen the potential for monetary gain or loss, £3 were placed on the table in front of each participant. It was explained to the participants that they could top this up or lose it, depending on the game result. The experimenter then left the room before the actual game started, to ensure that their presence would not bias the participants' decisions.

After participants completed all 8 blocks, they were given a post-experiment questionnaire. A Likert scale (1-7) was used to tap into their beliefs about the partner ('between 1 to 7 how much you believed), and how much the environment manipulations affected their negative feelings (e.g., ‘between 1 to 7 how much you felt sad). After completing the debriefing scales, one of the blocks was randomly selected and based on the results of that block, they were given the additional money won (maximum pay was £9), or left with zero money if they lost more than £3. Finally, participants were asked to complete the cooperativeness measure as an online survey.

6.3.3 Cooperativeness measure

On the completion of the game, participants were asked to answer a survey that comprised the Relationship Structures (ECR-RS) Questionnaire (Fraley, Heffernan, Vicary, & Brumbaugh, 2011) and the two subscales of Reward Dependency and Cooperativeness from the Temperament and Character Inventory, TCI (Cloninger et al., 1994). For the purpose of the current study, I focus only on the questionnaires that assessed Cooperativeness trait.

Cooperativeness was measured using the subscale from the TCI. Some examples from the measures are: “I enjoy getting revenge on people who hurt me”, “I like to help find a solution to problems so that everyone comes out ahead”. Participants were asked to read the statement and decide which choice best describes them by selecting TRUE or FALSE for each statement.

In the analysis, the items were added together from the 4 subscales, including: Social Acceptance vs Social Intolerance, Empathy vs Social Disinterest, Helpfulness vs Unhelpfulness, Compassion vs Revengefulness, and Pure-hearted Conscience vs Self-serving Advantage to achieve a total score of Cooperativeness. The Cronbach’s alpha for Cooperativeness from 90 participants (10 participant did not complete the Cooperativeness scale) was found reliable (42 items; $\alpha = 0.53$).

6.4 Data Analyses

One main aim of the current study was to control the opponent's behaviour and to take the opponent out of the equation. Therefore, to be able to analyse each subject's decision separately, a controlled but socially uncertain environment was created using a computer masquerading as a human and introducing a p-cooperative (80%), a p-defecting (80%), as well as a computer (Tit for Tat), in addition to a real human partner.

To analyse the data and to provide converging evidence, two statistical approaches were used. One based on summary statistics and ANOVA, and a second by using a Linear Mixed Effect model considering the individual trials.

6.4.1 Repeated measures ANOVA

Two dependent variables were used to assess cooperative behaviour and two variables to assess stability. Cooperative behaviour was assessed using the ***cooperation ratio.*** The proportion of cooperation decisions in each block (number of cooperation / total number of trials per block).

To assess ***stability***, two measures were used: the standard deviation of the smoothed response, and the time for strategy convergence.

For the first measure, first a time course was created to represent participant changes in responses across the 8 blocks. All participant responses were concatenated into one vector, ignoring the blocks. The response time series was then modelled using simple exponential decrease functions, which affectively smoothed the binary data. Each response is a weighted combination of the current and 3 preceding responses

($smoothT_0 = respT_0*.455+respT_{0-1}*.276 + respT_{0-2}*.167+respT_{0-3}*.102$). The consequences of this smoothing meant, for example, that a score of 1 will represent that a person had been consistently collaborating for 4 trials, while a score of zero meant that a person had been consistently betraying for 4 trials. The smoothed response vector was split into the individual blocks again. The stability of responses was measured by computing the standard deviation within each block of the smoothed response.

The second measure of stability examined ***how quickly participants converged to a single strategy*** (cooperate or defect). This was done by looking at the first time they started to show a stable decision for the preceding 5 trials. In cases where participants never cooperated (defected) in five consecutive trials a value of 17 was given to them (as the maximum number of trials per block was 16). Stability was computed in a similar way for defecting responses.

In all the above analyses a mixed ANOVA was used with the following factors: four (partner types) * two (environments), as repeated factors and the order of the blocks as a between factors.

6.4.2 Linear Mixed Effects Model

An alternate way to examine the data is by fitting a Linear Mixed Effects model (LME), that includes both random effects (subject specific) and constant effects, and that analyses individual responses. This was done using Matlab's 'fitlme' function (Mathworks, Cambridge, MA). An LME was used to test the variables that predicted a decision in any given trial. The model included 1-2) the previous two responses of the participant, and 3-4) the partner and 5-7) the partner types: computer, p-cooperative, p-defect, 8) negative environment, 9) block number, 10) trial number, 11) cooperativeness measure, as well as the interactions between 12-13), subject and partner choices in the last two trials, 14-15), the negative environment with either the p-cooperative or p-defecting partner, and 16-18), the cooperativeness questionnaire measure with either p-cooperative op partner, p-defecting partner or negative environment (see Table 6-1 in Results).

Subject responses were encoded as binary, ‘Cooperate’ as zero and ‘Defect’ as one, hence positive beta estimates imply an increased tendency to defect. A logit link function was used in the generalised linear model, based on a Binomial distribution of responses. In total, 12 regressors were included in the model and the model includes the following variables and interactions:

*'Choice~ (Choicem1*Otherm1+Choicem2*Otherm2) + (EnveNega)*(Cooperativeness)+ (TypeCol+ TypeDef)*(EnveNega +Cooperativeness) + TypeCom + BlockNumber+trial+(1|subject)'*

The data consisted of a total number of 11264 observations, explained through a Linear Mixed Effect Model (Table 6-1) with 19 fixed and 88 random-effects coefficients and one covariance parameter.

6.5 Results

6.5.1 Cooperativeness Measure

From 100 participants, 90 participants' questionnaires data were collected for the Cooperativeness measure, with *M* = 34.04 and the *SD*. = 5.2, Figure 6-

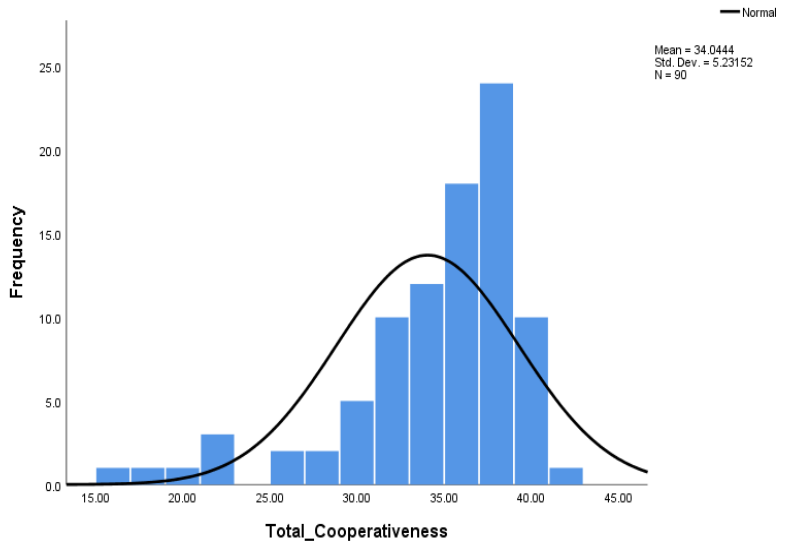

Figure 6-1 Distribution of cooperativeness scores

Higher score indicates more cooperativeness. The line indicates a fitted normal distribution showing the distribution of the data is negatively skewed.

6.5.2 Validation of Environmental Manipulation

To validate the environmental context manipulations, an explicit subjective report was collected after completing the experiment, and an implicit measure of response time was used.

The explicit subjective report for partner manipulation asked participants to rate on a scale of 1 to 7 how much they believed that they were playing against human partners for blocks with reported human partners, and similarly how much they believed that they were playing against computer partners for blocks with reported computer partners. Participants on average rated their belief that they played with a human 5.95 (*Mdn* = 6.00, *SD* = 1.11), and 88% of participants rated their belief higher than the 4 (neutral). They also believed that they were playing with a computer, with an average rating of 6.02 (*Mdn* = 7 and *SD* = 1.4), with 85 % rating their belief higher than 4. Note that as the block instruction did not differentiate between the different human/pretended partners, neither did the validation question. None of the participants mentioned any suspicion that sometimes the human partner was not real. This suggests that the partner manipulation worked, and that subjects did not perceive real human partners differently from simulated human partner (p-defecting, p-cooperative).

Participants played the game in two environmental contexts: negative and neutral. I asked participants to reflect on their emotional responses for receiving random losses in the negative environment (1 being not affected and 7 being highly affected). On average, participants rated the emotional impact of random loss to be 3.32; 42% reported that they were not emotionally affected by the manipulation; and 48% reported negative feelings (e.g., annoyance, frustration) after receiving a negative loss. Thus, the self-reported data suggested that while subjects were clearly aware of the manipulation, only less than half of the participants were explicitly emotionally affected by the environmental manipulation.

The second method for validating the environmental and partner manipulation was an implicit measure of response time (RT) (Figure 6-2).

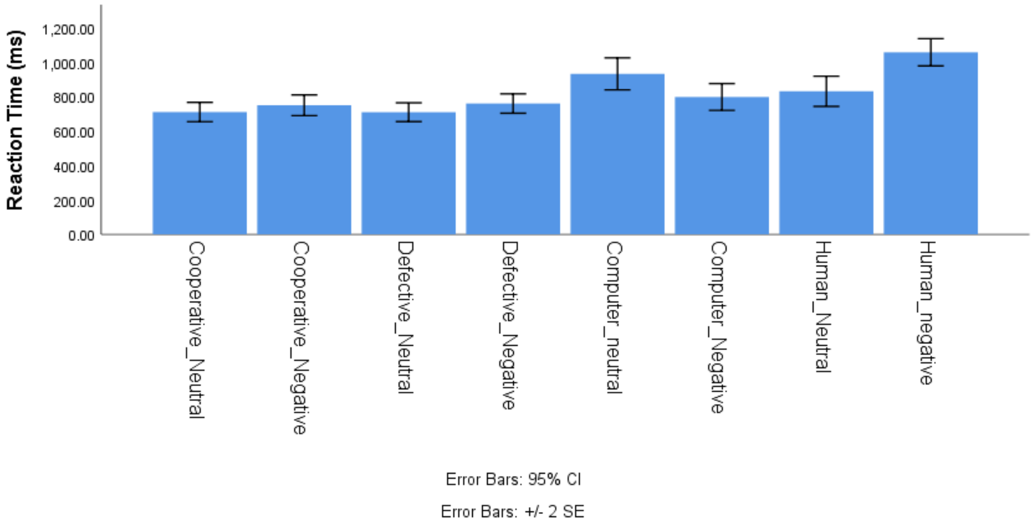

Figure 6-2 Response time when playing with different partners in the negative and neutral environmental context.

The RT shows that the environment only affected participants' response time when they played with a computer and a human partner, but not with the cooperative or defecting partner.

It was assumed that a consistent change in RT in response to the environmental and or partner manipulations will reflect a change in participants' emotional states and decision process. Response time to make a decision was used in a four (partner types: computer, human, pretended cooperative, pretended defecting) * two (environmental contexts: neutral, negative) ANOVA test with the order as a between factors. A strong main effect of partner type was found, F (3, 294) = 41.27, p <.001, $p\eta^2$ = .30. Participants were slowest when playing against a real human, (M = 944ms, SD = 350ms), then a computer, (M = 865ms, SD = 351), followed by a defecting partner, (M = 734ms, SD = 240ms), and fastest when playing against a cooperative partner, (M = 730ms, SD = 251ms). This suggests that participants were presumably faster with the p-cooperative and p-defecting partners as they tended to not vary their responses, making the subject responses easier.

There was also a main effect of environment, F (1, 96) = 10.02, p = .002, $p\eta^2$ = .09. Moreover, an interaction between the partner and the environmental manipulation was found, F (3, 294) = 12.99, p <.001, $p\eta^2$ = .11. The interaction showed that the environmental context did not affect decision times when playing with a p-defecting partner; nor when playing with a cooperative. However, when playing with a computer partner the environment had a significant effect on the decision time, F (1, 98) = 7.98, p <.05, $p\eta^2$ = .075, participants were slower in the neutral environment (*M*=932*ms*, *SD* = 466ms) as compared to the negative environment, (*M* = 798*ms*, *SD* = 388ms). The effect of environment was reversed when playing with a real human partner F (1, 98) = 25.76, p <.0001, $p\eta^2$ = .208, with participants being the slowest when playing against a human partner in the negative environment (*M* = 1056ms, *SD* = 395ms) compared with the neutral environment (*M* = 830*ms*, *SD* = 438ms). This suggests that the environmental context primarily affected decisions when the partner's responses were less predictable (i.e., real human and computer playing Tit-for-Tat strategy).

6.5.3 The effect of partner's decision on cooperation ratio based on the repeated measure of ANOVA

Based on the hypotheses, I first focused on the proportion of times participants cooperated in each condition. I used an ANOVA with the environment and partner type as repeated factors and the games order as between factors. The data shows a clear effect of partner, F (3,294) = 108.41, p <.001, $p\eta^2$ = 0.52, participants were more likely to cooperate with a p-cooperative partner than with a human, t (99) = 5.16, p <.001, then with the computer (relative to human), t (99) = -6.86, p <.001, and least with the p-defecting (relative to computer) partner, *t* (99) = -4.32, *p* <.001, *d* = .43, (Figure 6).

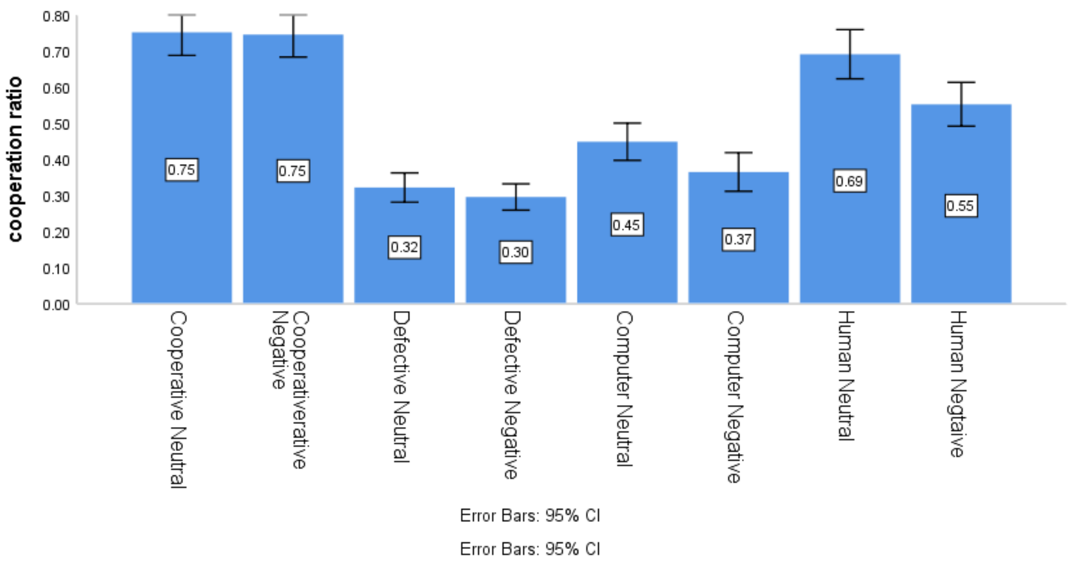

Figure 6-3 Proportion of cooperation with different partner types in a neutral and a negative environment.

6.5.4 The effect of environmental context on cooperation ratio with different partners based on the repeated measure of ANOVA

There was a significant main effect of environment, *F* (1,98) = 25.46, *p* <.001, $p\eta^2$ = 0.21, and importantly a significant interaction between the environment and the partner type *F* (3,294) = 5.09, *p* = .001, $p\eta^2$ = 0.49. Participants showed more cooperation with both a human and a computer in the neutral environment *t* (99) = 3.86, *p* <.001, and *t* (99) = 4.34, *p* <.001, as compared to the negative environment. Environment did not affect cooperation when participants played with a p-cooperative and p-defecting partner. There was no effect of order of blocks, nor any significant interaction between any other factors.

6.5.5 The effect of partner type on decision pattern and the speed in reaching a stable pattern

I: The decision pattern as measured by the stability in responses

Analysis of response stability was computed using the standard deviation of the smoothed response function (*Sdsr*) for each participant and each condition. A mixed ANOVA (four partner type * two environmental contexts) and the order of the game was used as a between variables. A main effect of a partner was found on the *Sdsr*, F (3,294) = 26.52, p <.001, pη^2 = 0.21. Participants showed the largest response variability when playing with a p-defecting partner (*MeanSdsr* = 0.29) than with a computer (*MeanSdsr* = 0.22), t (99) = -6.04, p <.001, and with a human (*MeanSdsr* = 0.22), relative to p-defecting partner t (99) = -6.08, p <.01. Responses varied similarly when playing with a computer or a human, but both were more variable compared to playing with a p-cooperative partner (*MeanSdsr* = 0.18); vs. a computer partner, t (99) = 3.24, p <.05; vs. a human partner (*MeanSdsr* = 0.22), t (99) = 2.83, p <.05.

Table 6-1 Means, standard deviations and minimum and maximum scores for the standard deviation of the smoothed response function (Sdsr)

	Minimum	Maximum	Mean	*SD*
Human	.00	.38	.22	.08
Computer	.00	.38	.22	.07
Cooperative	.00	.46	.18	.11
Defecting	.07	.42	.29	.08

II: The speed to reach a stable decision pattern

A specific decision stability using the parameter: the first time a participant opted for identical decisions (cooperate or defect) on 5 consecutive trials was estimated.

In the following mixed ANOVA, in addition to the partner, environment and the order, the decision type as a within subject factor (cooperate, defect) was also included.

There was a main effect of a partner, F (3,294) = 2.61, p <.001, pη^2 = .03. Overall, stability was evident sooner when playing with a p-cooperative partner (*M* = 10.36 *SD* = .23), than with a p-defecting partner (*M* = 11.22, *SD* = .26), human (*M* = 11.32, *SD* = .27) and slowest when played with the computer (*M* = 11.83, *SD* = .295). The main effect of decision type was not significant, but as expected decision type interacted with partner type, F (3,294) = 12.64, p <.001, pη^2 = .11. Participants tended to stabilize faster on cooperative (*M* = 6.18, *SD* = .61) than defecting (*M* = 14.55, *SD* = .45) decisions when playing with a p-cooperative partner; and a reverse pattern was observed when playing a p-defecting partner (Cooperate, *M* = 14.25, *SD* = .44, vs. defect, *M* = 8.2, *SD* = .47). Participants were also faster to stabilise on cooperation responses (*M* = 9.22, *SD* = .63) with a human than on defecting decisions (*M* = 13.43, *SD* = .45), and again showed a reversed pattern when playing with a computer (cooperate, *M* = 10.48, *SD* = .55, vs. defect, *M* = 13.19, *SD* = .55).

6.5.6 Effect of environmental context on decision pattern and the speed to reach a stable pattern with different partner types

I: The decision pattern as measured by the stability in responses

Analysis of response stability shows no significant main effect of the environment on the stability of the responses, nor any interaction between the environmental context and the type of partner.

II: The speed to reach a stable decision pattern

Findings from the speed of reaching a stable decision show a main effect of the environment, F (1,98) = 9.02, p = .003, $p\eta^2$ = .08, whilst the environment also interacted with the type of partner, F (3,294) = 101.11, p <.001, $p\eta^2$ = .51 and the response type, F (1,98) = 33.70, p <.001, $p\eta^2$ = .26 respectively. Moreover, there was a three-way interaction between, the environment, partner type, and decision type, F (3,294) = 9.00, p <.001, $p\eta^2$ = .08. Whilst the environment did not affect the time to stabilise on cooperation or defection with a p-cooperative partner, participants were faster to stabilise in cooperating with a human in a neutral rather than in a negative environment, t (99) = 6.52, p <.001, d = 0.13. Surprisingly, participants were also faster in stabilizing on cooperation with a p-defecting partner in a neutral than in a negative environment, t (99) = 1.99, p = .04, d = 0.04, note the effect did not survive Bonferroni correction. In addition, the number of participants who persisted in cooperating with a defecting partner for at least 5 trials was relatively small: 14/100 in the negative condition and 25/100 in the neutral condition. There was no impact of the environment on the speed to stabilise on defection with a defecting partner. The reverse pattern was observed when playing against a computer. Participants were faster to stabilise on a defect response in the neutral than in the negative environment, t (99) = -4.76, p <.001, d = 0.05. In summary, participants showed more stable responses in the neutral than in the negative environment only when they played with human and computer partners.

6.5.7 Linear Mixed Effects modelling of cooperative choices

As an alternative analysis, data were also fitted in to a Linear Mixed Effects model (see methods). Results from fitting the model (Figure 6-4 Table 5-1), showed that subjects were significantly less likely to cooperate if they themselves or their partner had defected on any of the previous two trials, for all, and vice versa (a positive beta estimate implies an increased tendency to betray). On top of this, the interaction between one's own choice and their partner's choice shows that if they both defected in the previous trials, they were more likely to cooperate, for one and two trials back.

There was no significant effect of trial or block number on cooperation, whilst across the blocks subjects were more likely to defect when knowingly playing a computer partner than a human, and more likely to defect with their p-defecting partner, as compared to the human partner and there was no significant difference in cooperation between a human and a p-cooperative partner.

Subjects were less likely to cooperate in the negative environment, and on top of this, the environment showed an interaction with p-cooperative partner, meaning that participants were more likely to cooperate (less likely to defect) with their p-cooperative partner in the negative environment.

The outcome from the cooperativeness questionnaire showed subjects with a high score to cooperate more. On top of this, cooperativeness interacted with the type of partner, with individuals with a higher score in the cooperativeness measure showing more cooperation with the p-cooperative partner and being more likely to defect with the defecting partner. The environment did not interact with the cooperativeness measure.

In summary, the LME model showed strong effects of choices in previous trials, but also the effects of partner, environmental manipulation and the cooperativeness measure, and the interaction between the environment and partner type, as well as the cooperativeness and partner type on cooperative decisions.

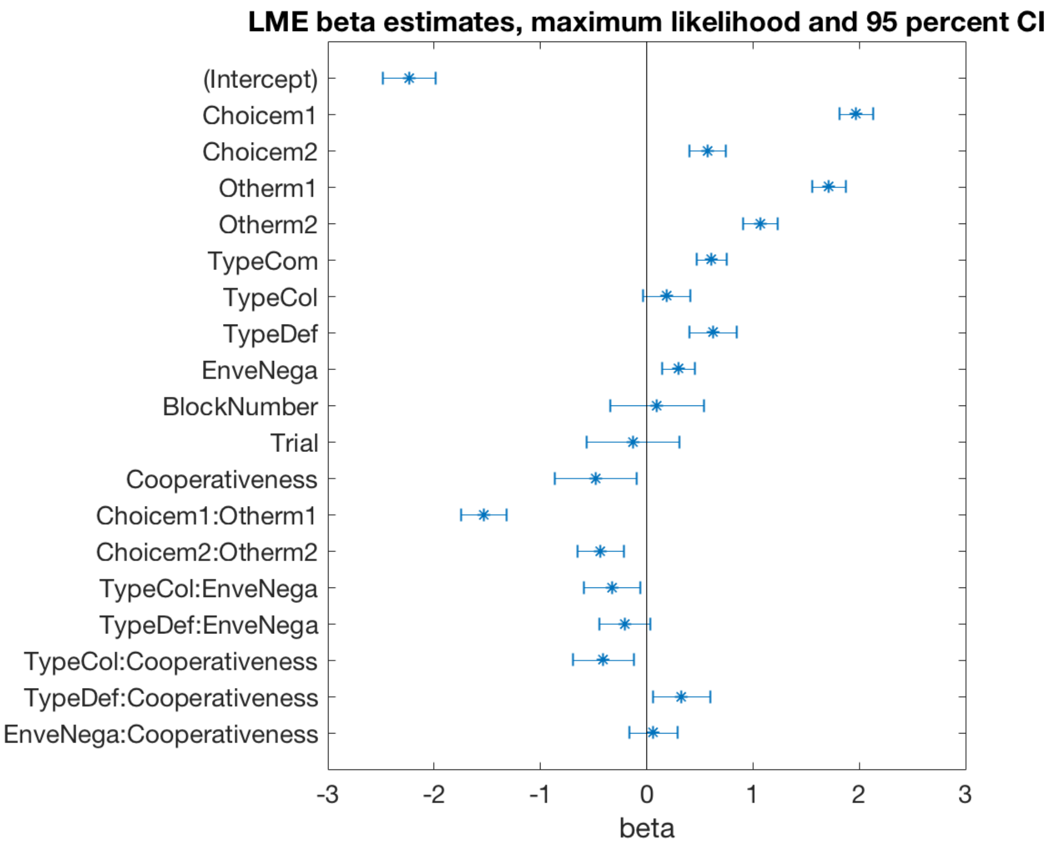

Figure 6-4 Estimated beta values for LME model, mean and estimated 95 percent confidence intervals

Table 6-2 Estimated parameters from LME model.

Table shows standard error, t-statistics, degrees of freedom, p-value, and lower and upper 95 percent confidence estimates.

Name	Estimate	SE	tStat	DF	pValue	Lower	Upper
'(Intercept)'	2.23	0.12	-17.79	11245	0	-2.48	-1.99
'Choicem1'	1.97	0.08	23.93	11245	0	1.81	2.13
'Choicem2'	0.57	0.08	6.68	11245	<.001	0.40	0.74
'Otherm1'	1.71	0.08	21.02	11245	0	1.55	1.87
'Otherm2'	1.07	0.08	13.12	11245	0	0.91	1.23
'TypeCom'	0.70	0.07	8.44	11245	0	0.47	0.75
'TypeCol'	0.19	0.11	1.63	11245	.10	-0.04	0.41
'TypeDef'	0.63	0.11	5.48	11245	<.0001	0.40	0.85
'EnveNega'	0.30	0.08	3.77	11245	<.0001	0.14	0.46
'BlockNumber'	0.10	0.22	0.44	11245	.66	-0.34	0.54
'trial'	-0.13	0.22	-0.57	11245	.57	-0.56	0.31
'Cooperativeness'	-0.48	0.19	-2.45	11245	.01	-0.86	-0.10
'Choicem1:Otherm1'	-1.53	0.11	-14.22	11245	0	-1.74	-1.32
'Choicem2:Otherm2'	-0.43	0.11	-3.90	11245	<.0001	-0.65	-0.22
'TypeCol:EnveNega'	-0.32	0.13	-2.43	11245	.01	-0.59	-0.06
'TypeDef:EnveNega'	-0.21	0.12	-1.71	11245	.09	-0.44	0.03
'TypeCol:Cooperativeness'	-0.41	0.14	-2.80	11245	.005	-0.69	-0.12
'TypeDef:Cooperativeness'	0.33	0.14	2.38	11245	.017	0.06	0.60
'EnveNega:Cooperativeness'	0.06	0.11	0.56	11245	.58	-0.16	0.29

6.6 Discussion

In this study the effect of environmental uncertainty, partner's behaviour, and individual differences in cooperativeness trait, as well as the effect of participants' previous responses on cooperation in the repeated PDG was investigated. It was hypothesised that environmental uncertainty and the partner's behaviour would affect participants' cooperative decisions and that this would interact with individual differences in their cooperativeness trait. It was also predicted that participants would cooperate more in subsequent trials, following the individuals' previous cooperation. To test the hypothesis, a modified version of the repeated Prisoner's Dilemma Game (PDG) was used and participants' data from the Cooperativeness subscale of the Cloninger's Psychobiological Model of Temperament and Character questionnaires (Cloninger et al., 1994) was collected. An intensified game was used, and participants were tested four at a time to increase the validity of social interaction. Importantly, the partner's behaviour was controlled by introducing a pretend cooperative partner (p-cooperative) and a pretend defecting partner (p-defecting), in addition to a real human and a computer partner. Individual differences in their cooperative decisions were then compared when played with different partner types in negative and neutral environmental contexts.

The analysis of variance, with four partner types and two environmental contexts shows that overall, cooperation was higher when participants played in the neutral environment as compared to the negative environment, when participants lost random money. Participants cooperated more when they played with a p-cooperative partner, with a human rather than with a computer and showed least cooperation with a p-defecting partner.

The response pattern was more stable when participants played against a p-cooperative partner and least stable when played against a p-defecting partner whilst responses were equally varied when participants played with their human or the computer partner. Furthermore, participants were faster in developing a cooperative pattern with a p-cooperative and a human partner as compared to the p-defecting partner, and slowest to develop a stable pattern of decisions when played against a computer. Additionally, participants were faster to reach a cooperative pattern in a neutral environment when playing with a human partner.

In addition to the environmental contexts and the partner type, the two previous choices of participants and their partners, as well as their cooperativeness scores, were included in a Linear Mixed Effect model (LME). When controlled for the effect of the previous choices and the cooperativeness trait, findings show similar results, with a negative environment leading to decreased cooperation. However, LME findings show that participants cooperated more with p-cooperative partner in the negative environment. Similarly, whilst the findings from LME show that participants cooperated more with both a p-cooperative and a human partner (as compared to the computer), the findings also show that participants with high scores in cooperativeness cooperated more with p-cooperative partner whilst they defected more with the defecting partner. Importantly, LME findings show a strong effect for participants' own and their partner's previous choices on their cooperative behaviour. Participants showed more cooperation followed by previous mutual defection. However, the effect of previous choices diminished as they moved further in time. These findings are discussed in the following sections.

6.6.1 Effect of partner's behavior on cooperative decisions based on the repeated measure of ANOVA

An important aspect of this study was to control for the impact of a partner's behaviour on cooperation. To do so, participants played with a p-cooperative partner (80% of the time) and a p-defecting partner (80% of the trials), in addition to the blocks where they played with a human and a computer partner (80% Tit for Tat). Participants were unaware of the role of deception (of their pretended partners) and were informed of this during the final debrief, whilst the computer's strategy was also masked (please see Methods). Overall, participants were more cooperative when they played with a p-cooperative partner, than with their human and computer partner respectively, and they were least cooperative with their p-defecting partner. In other words, participants cooperated most with their p-cooperative partner and a human as compared to the computer (non-social) partner, whilst they defected more with their p-defecting (social) partner.

More cooperation with human (and p-cooperative partners) supports previous studies, showing participants expectations of their partner's behaviour to have a strong effect on their behaviour (Miwa & Terai, 2012a; Taheri et al., 2018). Similar to Miwa and Terai, (2012) in our study, participants defected more when the partner was instructed as a computer and this was observed regardless of the actual behaviour of the computer (that was a 80% Tit for Tat strategy). It is suggested that participants saw computers as being incapable of producing adaptive behaviour like humans, e.g., in response to either cooperation or defection (Taheri et al., 2018). For example, participants did not expect to fall into mutual distrust with a computer partner.

The Findings also support previous research conducted by Baker and Rachlin, (2001), who tested the probability of reciprocation when participants played with a computer and a social partner and reflects the reciprocation aspect of cooperation with social partner in the PDG (Bolton & Ockenfels, 2017). This is evident from our finding showing participants reciprocally defecting most with their defecting social (perceived to be a human) partner.

Importantly, findings from p-cooperative and p-defecting partners provide support for two main properties of reciprocation, clarity and consistency, as participants cooperated most with their p-cooperative partner, and defected most with their p-defecting partner (Komorita, Hilty, & Parks, 1991). One main aspect of the pretended partners' strategies in our experiments, were their clarity and consistency of cooperate or defect, 80% of the time. This follows the main feature of the Tit for Tat strategy that has been shown to be the simplest strategy but also the most effective strategy by Axelrod (1980), as it is consistent and predictable. On the other hand, whilst the computer had 80% reciprocation (Tit for Tat) strategy, the clarity of the computer's strategy could be diluted by the participants' perception of the computer's behaviour, as being inconsistent or unpredictable. This was also reported by participants in their post experiment debriefing.

Consistent cooperation or defect (for 80% of the time) by p-cooperative and p-defecting partners, regardless of participants' initial behaviour, could have also activated an internalised social norm in our participants. For example, an initially defecting participant repeatedly sees their partner cooperate with them and decides to change their strategies from defecting to cooperating because they feel guilty not to do so. It is also likely that by observing their partner's repeated cooperative or defecting behaviours, participants inferred the social rules of the given situation (Biel

& Thøgersen, 2007) to be cooperation or defect respectively, the so called 'perceived' or 'observed' norm, (Chen, Arzu Wasti, & Triandis, 2007). For example, in the case of a cooperative participant who repeatedly faces the p-defecting behaviour and decides that defection is the social rule of the situation and it is to be followed. These activations of the internalised social norms and inferring the social rules based on the partner's behaviour could both give rise to reciprocation as the social norm of the situation (Biel & Thøgersen, 2007).

In summary, it can be concluded that participants adjusted their behaviour based on the perceived social identity of their partner, expected probability of reciprocation by their partner and potentially the perceived social norm of the situation. These findings highlight that expectation of the partner's commitment to reciprocation, based on the perceived social identity of the partner and the partner's consistent and clear behaviour, affects cooperation in the PDG.

Response stability and the speed of reaching a stable strategy with different partner types based on analysis of repeated measure of ANOVA

Using standard deviation of smoothed responses, and the time for strategy convergence, the data was analysed looking for the effect of the partner's decision in developing stable strategies and the speed to reach stable strategies (please see Methods-Data Analysis). Findings show that participants overall developed a more stable decision pattern with their p-cooperative partner whilst their response pattern was most varied with their p-defecting partner. This finding is intriguing as it shows that when participants played against their p-defecting partner, they showed more response variabilities, whilst mutual cooperation was more consistent and less varied across the trials when they played with a p-cooperative partner. It can be speculated that participants were trying to influence the behaviour of their p-defecting partner by occasional cooperation. Furthermore, participants were faster to establish a stable pattern of decisions with both their p-cooperative and p-defecting partners, providing support for the effectiveness of clear and consistent strategies (here, 80% of the time cooperate or defect), and on the speed to reach a stable pattern of decisions (here reciprocation).

In summary, our findings suggest reciprocation to be a social behavior that can be probed by the social norms of the situation, as exemplified by the behavior of the p-cooperative and p-defecting partners in our study.

A caveat of the above procedure is that differences in cooperation ratio between playing with a human and a computer partner can be due to multiple reasons, which cannot be dissociated. For example, cooperation may be affected by: 1) participants' belief about the identity of their partner and the social acceptability of defecting, 2) their belief about the ability to modulate the behaviour of their partner, and, 3) while the computer played Tit-for-Tat with noise, real humans may not be as reciprocal. Thus, the strategy of a computer partner may have been qualitatively different than that of a human, despite the overall high performance of the Tit-for-Tat strategy.

6.6.2 Effect of environmental uncertainty on cooperative responses with different partners based on the repeated measure of ANOVA

To investigate participants' cooperativeness in an uncertain environment, negative blocks were introduced in which participants lost random money, (please see Method, Chapter 2) and compared to the neutral blocks where no random money was taken from participants. Overall, findings show that negatively environmental uncertainty only affects a participant's cooperation when they played against a human and a computer partner, with less cooperation in the negative environment as compared to the neutral environment with both partners. This finding does not match the previous study, (Study 1, Chapter 3) in which a higher proportion of cooperation was found in the negative environment as compared to the neutral environment (see Taheri, et al., 2018). There are a couple of speculations about this contrasting finding, one being that in our previous study we had three environmental contexts, including a positive environment in which participants were given random monetary rewards. Therefore, it is possible that the environmental uncertainty or the context has created a different dynamic and hence led to different behaviour. For example, in terms of resources, overall across the three type of blocks (negative, neutral, positive), participants may felt that they have received extra money and hence they took more risks or behaved more cooperatively in the negative environment. Secondly, It can be also speculated that the negative emotions that were triggered in the participants in our previous study, were in the context of positive and neutral, whilst in the current study the negative environment was only compared to a neutral environment.

Interestingly, cooperation with p-cooperative or p-defecting was not affected by the environmental context. This could imply that in the circumstances where reciprocation or social norms are developed, the context in which the interaction takes place has less effect.

Response stability and the speed to reach a stable strategy with different partner types in different environments based on the repeated measure of ANOVA

Findings show that environmental uncertainty did not affect the response stability nor the speed to reach a stable response pattern when they played with a cooperative partner. Similar to the effect of environment on participants responses to p-cooperative and p-defecting, the stability of the responses and the speed of reaching to stable pattern not being affected by the environmental context could mean participants reached a stable decision with their p-cooperative partner, and it did not matter in which context they played. In other word, this confirms strengths of the dynamic (e.g., reciprocation) that has developed between the partners irrespective of the environmental context they played when the dominant strategy is cooperation. Similarly, when participants played with a p-defecting partner, the environment did not affect the speed of reaching a stable strategy.

Unlike playing with p-cooperative and p-defecting partners, when played with a human and a computer partner, the environment did affect participants speed to reach a stable partner, showing faster stability in the neutral environment as compared to the negatively uncertain environment. In a repeated PDG experiment, Bereby-Meyer and Roth, (2006) showed that variance in rewarding the action, would slow the learning process to the point that cooperation is hardly learnt. If cooperation or defect can be learnt in the repeated interactions (Cimini & Sánchez, 2014), it is possible when participants played with their human/computer partner during the negative blocks. The random additional losses acted as a punishment that impacted on participants learning to reach a stable strategy.

In summary, participants were faster to reach a stable strategy in the neutral environment with their human and computer partner, whilst with the p-cooperative and p-defecting partner the environment did not have any effect on reaching a stable strategy. This finding specifically highlights the effect of negative environmental uncertainty on cooperation when the partners' behaviour is also less certain (predictable), e.g., human or perceived as less certain - computer vs with p-cooperative and p-defecting that is predictable.

6.6.3 Effect of partner type on cooperation ratio based on Linear Mixed Effect Model

Cooperation ratio data, including participants' own and their partner's two previous responses were fitted in a Linear Mixed Effect Model (LME) (please see the Methods-Data Analysis, 6.4.2), to account for the effect of participants' previous responses on their current decisions, in addition to the environmental uncertainty and partner type. In addition to this, individual differences in their cooperativeness traits were also included into the model. LME was used to test for both the random effects (subject specific) and fixed effect, or constant effects of the variables, within each block and across all the trials. When including the past two responses into the model, findings show that participants were more cooperative with their human and their p-cooperative partners whilst they defected most with their p- defecting partner. This confirms the finding from the repeated measure of ANOVA and similarly supports the reciprocity hypothesis (Cimini & Sánchez, 2014) as it was discussed in the previous section.

6.6.4 Effect of environment type on cooperation ratio based on Linear Mixed Effects Model

Results from LME shows that environment had a similar effect, with less cooperation in the negative environment by participants.

6.6.5 Effect of past interactions on cooperation ratio based on the Linear Mixed Effect Model

When including the previous two choices into the model, findings show that participants cooperated more if they themselves or their partner cooperated in any of the previous two trials. Conversely, if participants themselves or their partner defected in the previous trials, they were less likely to cooperate in the current trial. In short, they were reciprocating, e.g., defection increased the chance of defection. This finding supports reciprocation whilst it highlights the importance of learning and experience and supports the development of the social map as proposed by Trivers, (1971) and Cosmides and Tooby, (1992) who first proposed that a human has acquired domain-specific cognitive modules to engage in social exchange through reciprocal altruism. Finding from the effect of previous decisions on participants' current decision, shows that our participants have retained their own as well as their partner's previous behaviour and responded based on them. Finding from participants' previous choices also shows, that if they themselves defected in the trial before and their partner also defected in the previous trial, they were more likely to cooperate in the current trial. This shows possible cooperation as an act to recover, i.e., to avoid getting stuck in mutual defection.

In summary, the findings highlight the importance of the cognitive adaptation modules that human has developed to retain the social map of their social situations in order to guide them through their decisions in social dilemmas. Moreover, the interaction between one’s own previous decision and a partner’s precious decision can provide a source of information for future decisions, such as cooperation following a mutual defection.

6.6.6 Effect of individual differences in their cooperativeness trait on their cooperation based on Linear Mixed Effect model

To control for the effect of individual differences in their cooperativeness traits, their data from cooperativeness scores were put into the model. Findings show that participants who scored higher in their cooperativeness measure showed more cooperation. Moreover, higher scores in cooperativeness also affected participants’ cooperation with different partner types. In other words, participants who scored higher in cooperativeness showed more cooperation with a p-cooperative partner whilst they also showed more defect with a p-defecting partner. Our finding supports previous literature (Kuhlman & Marshello, 1975), showing participants with higher scores in cooperativeness trait reciprocate with the relative strategies. Similarly, Kelley and Stahelski (1970) showed that when initial cooperators in a Prisoner’s Dilemma are paired with initial competitors, the cooperators conform to the low level of cooperation demonstrated by their competitive partners, a process known as behavioral assimilation.

Moreover, when including participants cooperativeness scores, findings show more cooperation with the cooperative partner in the negative environment. Previous studies suggested that people cooperate in a negative environmental context, such as a natural disaster (Chantarat et al., 2015; Taheri et al., 2018). Whilst this can be explained by evolutionary reasons, i.e., it is best for our species survival to help each other during the difficult times, it also perfectly makes sense to cooperate with the co-operator during tough times.

In summary, reciprocation or conditional cooperation seem to be the simplest answer for the effect of a partner's behavior on cooperation. Taking a partner's behaviour out of the equation by controlling their current and previous decisions, provides evidence showing that cooperation by subjects with high scores in cooperativeness is not simply because of the partner's behaviour. Similarly, the effect of the environment was modulated by individual differences in cooperativeness traits and a partner's behaviour. Hence, in addition to the effect of a partner's behavior, and the environmental context, the importance the effect of the participant's own and their partner's previous choices, and their cooperativeness trait is highlighted in the current study.

6.7 Strengths and limitations of our study and suggestions for future research

This experiment was set up with four people briefed initially in the same room to increase participants' beliefs that they would play against the three other different individuals anonymously. Therefore, the setting provides a better social environment, allowing individuals to adjust their behavior based on the behavior of their partner. Furthermore, the study was different from a two players game, for example, it has been shown that increasing the number of players makes cooperation more difficult (R. Axelrod & Dion, 1988). Another advantage of the current study is that it allows an investigation of the history of past behavior and shows how past behavior interacts with participants' decisions. This was done through studying the stability and time course, as well as by looking at the fixed effect and the random effect across the blocks and trials. A limitation of this study is the demographic bias of gender with most participants (90%) being female.

6.8 Conclusions

Previous studies did not permit fully ruling out the role of the partner's behaviour, hence the need to analyse as pairs, which we had no control over. The current study however showed, that when controlling for a partner's behaviour, factors including the participant's recent choices, partner type, and the participant's cooperativeness traits as well as the environmental context, affect cooperation in the repeated PDG. This was evident in the ratio of cooperation, as well as in developing a stable pattern of decisions, and the speed of developing these patterns. Specifically, the finding suggests mutual reciprocation to be more favourable when playing with a human partner and a social partner and reaching a stable cooperative pattern is faster with a p-cooperative partner and p-defecting (more consistent partners). It can be concluded that cooperation is favourable, however it is not unconditional, and defect would be a preferred decision if the partner did not reciprocate the cooperation. Here, we also found that if a subject score high in cooperativeness, they show more cooperation, and this will not be just because of the partner's behaviour. These results highlight the importance of not only the environmental and the social contexts in which the decisions are made, but also the importance of the recent history of interactions and the effect of individual differences in their cooperativeness on cooperation in the repeated PDG.

7 A META-ANALYSIS OF FOUR STUDIES LOOKING AT THE EFFECT OF SOCIAL AND ENVIRONMENTAL CONTEXTS, ATTACHMENT STYLE, AGE, GENDER AND PREVIOUS RESPONSES IN REPEATED PRISONER’S DILEMMA GAME (PDG)

7.1 Abstract

The aim of this study was to apply a meta-analysis on the four studies that were previously conducted, to examine the effects of both the external (environmental and social contexts) and internal (individual differences) factors on the tendency to cooperate or compete in the Prisoner's Dilemma Game. The environmental contexts are defined as negative, neutral and positive and the social contexts included: partner type (a real human, a pretend-cooperative, a pretend-defecting, and a Tit-for-Tat computer) and the interaction type, (face-to-face vs non-face-to-face), study type (two players vs four players). Individual differences included attachment style, age, cooperativeness trait and gender. In addition to these variables and their interactions, participants' previous choices were also included in the analysis. Data from 285 participants were analysed using Linear Mixed Effect analysis. Findings show strong dependency of cooperation on participants' previous choices, trial and block number, the partner type, the environmental context, anxious attachment style, and the gender. On top of these, the interactions between variables showed; that participants cooperated following mutual defect, older adults cooperated more in the negative environment, and avoidant individuals defected more with a p-defecting partner. Overall, findings from this meta-analysis show that cooperation in the Prisoner's Dilemma Game is a function of recent decisions, social and environmental contexts and importantly their interaction with individual differences in attachment style, age, and cooperativeness trait.

Keywords: Cooperation; Decision Making; Prisoner's Dilemma Game; Cooperation and Reciprocation; Environmental Uncertainty, Partner's Behaviours, Individual Differences.

7.2 Introduction

When studying cooperation in the Prisoner's Dilemma Game, a differentiation of the situational properties from the interpersonal motives and attitudes (Kelly 1984) is suggested. It is vital to consider the effect of both the environmental context (Bendor et al., 1991; Klapwijk & Van Lange, 2009), and the social context (Kelley et al., 2009a), (Balliet, 2010; Sparks, Burleigh, & Barclay, 2016), as well as the interdependence of the outcomes (Bolton & Ockenfels, 2017). In addition to these, an important dimension of the Prisoner's Dilemma is its temporal structure (Kelly 1984). In a one-shot PDG, Nash equilibrium suggests defect to be the optimum strategy (Hargreaves-Heap & Varoufakis, 2004). However evidence shows that individual differences in personality traits, social value orientation and gender modulate participants cooperative decisions (Colman, Pulford, & Krockow 2018; Kuzmanovic, Djurovic, & Martic, 2012; Pothos, Perry, Corr, Matthew, & Busemeyer, 2011). Furthermore, repeated interactions allow for the development of a social dynamic that evolves and mutates between the individuals. This needs to be understood not only in terms of immediate and future outcomes (Rusbult & Van Lange, 2003), but also considered in the context of previous behaviour (Axelrod & Hamilton, 1981).

The aim of this study is to run a meta-analysis across the four behavioural studies that were conducted independently (Chapter 3 through to 6), to explore the effect of the environmental and social context, individual differences, and previous choices on cooperation in the Prisoner's Dilemma Game, whilst investigating both the random effects (subject specific) and the fixed effects or the constant of these variables, within each study, and across all the studies. This is done by pooling all the data from the four studies together and applying Linear Mixed Effect modelling (LME) using Matlab's 'fitmle' function (Mathworks, Cambridge, MA). In addition to this, analysis was done, including only the first choice of participants, in a model to investigate the effect of social contexts and individual differences on cooperation in a one-shot PDG, and similarly to examine the fixed effects of these variables within each study and across all the studies.

The Prisoner's Dilemma Game is a two persons dilemma by its nature whether is played once or repeatedly. Dawes (1980), suggetsed three main characteristics for two-persons PDG. Firstly, that the harm from the defection is only focused on one other person. Secondly, that bacause they only play with one other person, participants can control and shape the other person's behavior through their own sterategy, e.g., by conditional cooperation. Thirdly, players are less anonymous to each other, as they know that they only play with one other person. All of these features change when the number of players increases to more than two, so called the N-player PDG. For example, less harm is focused on one person as it defuses between the number of players, plus there is more anonymity and less control over shaping the other's behavior. Therefore, based on Dawes definition, the nature of the 4 players experiment used here is similar to the N-player PDG suggested by Dawes, (1980).

In his review, Dawes, (1980) suggests that the likelihood of defection increases with group size as the harm from defection decreases due to it being defused between more people. Moreover, it makes it easier to defect, as participants become more anonymous to one other, whilst it becomes harder to shape others' behaviour through one's own strategy, (Kollock, 1998). In other word, identifiability increases cooperation since the contributions of individuals are noticed (Biel & Gärling, 1995). Moreover, Biel and Gärling, (1995) suggested two more reasons for increase of cooperation in smaller groups, one the increase of responsibility with the decrease of group size, whilst one individual's contribution becomes less essential with an increase in group size.

Based on the finding from Study 4 and the evidence from literature, during the repeated PDG it is expected to see effects of participants recent choices on their current decisions. It is also expected that the social and environmental context affect participants' cooperation: based on partner type, e.g., more cooperation with a human and a p-cooperative partner, and based on environmental context, e.g., more cooperation in the negative environment. Moreover, it is expected to see effects of individual differences, e.g., less cooperation by anxious and avoidant attached participants, and more cooperation with age, and by an individual with higher scores in cooperativeness measures. In addition to this, it is expected to see interactions between the social and environmental context and individual differences, e.g., less cooperation by anxious and avoidant attached individuals in the negative environment, and more cooperation by individuals with higher cooperativeness scores during the negative environmental context. Based on the literature, it is expected to see more cooperation by female participants (Stockard, van de Kragt, & Dodge, 1988), and to see more cooperation during 2 player studies as compared to the 4 player study (Dawes, 1980). In addition, when considering the first choice only, (one-shot) game, it is expected to see a stronger effect for individual differences, e.g., less cooperation by anxious and avoidant individuals, more cooperation by older adults and more cooperation by individual with higher scores in cooperativeness and more cooperation by female participants.

7.3 Methods

All four studies used a similar paradigm (please see Methods Chapter, Experimental Paradigm, 2.3), with some variations to account for the relative variables investigated in the respective study. The following section provides definitions of the variables investigated in this study, the coding procedure and analysis and the models that are created for the meta-analysis.

7.3.1 Participants

Two hundred and eighty two participants, aged between 18 to 86, (*M* = 30, *SD* = 20), were recruited across the four behavioral studies. From this 67 were male and 179 were female. The gender of thirty-six participants is not available, due to a computer fault and office change which resulted in a loss of information.

7.3.2 The Prisoner's Dilemma Game (PDG)

The game that was used was the same in all four studies, with some variation in the number of trials and the blocks in some of studies (this is described in detail in each chapter).

7.3.3 The environmental context

Environmental uncertainty was manipulated by introducing random monetary losses (negative environmental context) and gains (positive environmental context), relative to no manipulations (neutral environmental context). In three of the four studies, all the three, negative, neutral, and positive environmental contexts were included. Study 4 only consisted of the two environmental contexts of negative and neutral.

7.3.4 The social context

7.3.4.1 Interaction type

The interaction type was defined based on the participants' sitting arrangement during the game. Non-face-to-face interaction is when participants were seated in different rooms and were not able to see each other during the game. Face-to-face (FTF) interaction is when participants played the game seated in the same room and across the table facing each other when playing the game. Only Study 2 (Chapter 4) was set in a face-to-face interaction.

7.3.4.2 Partner type

All participants played with their human and a computer partner, (please see Methods, Chapter 2). In study 4 participants also played against a pretended cooperative (p-cooperative) and a pretend defecting (p-defecting) partner. This is explained in more detail in Chapter 6.

7.3.4.3 Study type

Study type is defined based on the number of players playing the game at the time. All studies were played in groups of two, apart from Study 4 which participants played in groups of four. This is explained more in the relevant Chapter 6.

7.3.5 Previous responses

Participant's own current response (choice), the trial before (choice -1), plus two trials before (choice -2) and their partner's current response, (other) and their partner's previous response in one and two trials before, (other-1 and other -2 repeatedly) was included in the analysis.

7.3.6 Attachment self-report

In all four studies, participants were asked to fill out the attachment questionnaires on completion of the game, whist being in a room on their own (without the presence of the experimenter or other participants). For the purpose of the current study, attachment (anxiety and avoidance) scores from Experiences in Close Relationships Inventory (ECR) from Study 1, 2, and 3, and the global attachment score (global anxiety and global avoidance) Relationship Structures (ECR-RS) Questionnaire from Study 4, were included in this meta-analysis.

7.3.7 Cooperativeness trait

Cooperativeness trait was measured in Study 4, using the two subscales of Reward Dependency and Cooperativeness from the Temperament and Character Inventory, TCI (Cloninger et al., 1994), please see Chapter 6.

7.3.8 Coding procedure

The data was coded as binary, for example, zero if cooperate and one if defect. This was done similarly for the type of interaction. If the interaction was non-face-to-face, it was coded as zero and if face-to-face it was coded as one. The study type, 2 players vs. 4 players was coded as zero and one respectively. Gender was coded as one for female and two for male.

All the data was put together in a table and visually inspected to detect any possible error.

7.4 Analysis

7.4.1 Linear Mixed Effects Model

To test for both the random effects (subject specific) and fixed effects of the variables within each study and across all the studies and data from the four studies was fitted to models using Linear Mixed Effects model (LME), that analyses individual responses. This was done using Matlab's 'fitlme' function (Mathworks, Cambridge, MA). LME was used to test the variables that predicted a decision in any given trial. As the responses were binary (‘Cooperate’ (zero) or ‘Defect’ (one)), a logit link function was used in the generalised linear model, based on a Binomial distribution of responses. All continuous variables (e.g., Age, questionnaire scores) were normalised (mean subtracted and divided by standard deviation), before being entered into the model.

7.4.1.1 A Priori **Model**

An ‘a priori ‘model was created by including the variables of environment (two binary variables Negative, Positive), attachment style (two continues variables: Anxiety & Avoidance relational), age as continuous variables, the mode of interaction, (binary variable: non-face-to-face, face-to-face), and the type of human partner (two binary variables: p-cooperative and p-defecting, these two variables only available for the 4 players study). In addition to the main variables the following two way interaction variables were included: environment by attachment style (four continuous variables), the environment and age (two continues variables), the environment and the type of interaction (two continuous variables), attachment and age (two continuous variables), attachment and interaction mode (one continuous variable and one binary), and attachment and partner type (one continuous variable and one binary), all together. From the 4 player study we know that the previous choices by participants and their partner affects their decision, and one's own choice interacts with a partner's choice. We therefore included the past two choices and their interactions with one's own choice into the model as well. Block number and trial number were also shown to have an effect on participants' decision, therefore there were too added into the model as additive variables. Finally, Gender (one for female and two for male) and the study type '4 players' (one) vs. '2 players' (zero) were also added into the model as additional variables. In total, 38 regressors were included in the model (Figure 7-1). This model is called *a priori* model (model P) and includes the following variables and interactions:

*'Choice~ (Choicem1*Otherm1+Choicem2*Otherm2)+(EnveNega+EnvePosi)*(Anxiety+Avoidance+Age+ StudytypeF2FvsAnonymous)+ EnveNega *(TypeCol+ TypeDef) + (Age+ StudytypeF2FvsAnonymous) *(Anxiety+Avoidance) + Gender + Studytype2Pvs4P + TypeCom + BlockNumber+Trial+(1|Subject)',*

The data consisted of a total number of 21892 observations, explained through a Linear Mixed Effect Model (Table 7-1) with 36 fixed and 207 random-effects coefficients and one covariance parameter. The response variable was modelled by a binomial distribution with a logit link function, with parameters estimated by maximum likelihood.

Explorative Model based on A Priori Model (Model EP)

This model was created using backward stepwise linear regression based on *a priori* model. This was done by eliminating the interactions that showed the highest non-significant *p* values, followed by the elimination of the variables that had the highest non-significant *p* value in the model. This was done one step at the time and the BIC (Bayesian models comparison, where change in model evidence is valued in light of the models' complexity) was checked every time to make sure of the improvement of the model. This elimination continued until removing the additional variable significantly reduced the ability of the model to predict the data, see (Figure 7-2). This model is called explorative model based on *a priori* model (model EP) and includes the following variables and interactions:

*'Choice~ (Choicem1*Otherm1+Choicem2*Otherm2) + (EnveNega) :(Age) + StudytypeF2FvsAnonymous + Gender + Studytype2Pvs4P + TypeCom + BlockNumber+Trial+ (1|Subject)',*

The data consisted of a total number of 21892 observations, explained through a Linear Mixed Effect Model (Table 7-2) with 16 fixed and 207 random-effects coefficients and one covariance parameter. The response variable was modelled by a binomial distribution with a logit link function, with parameters estimated by maximum likelihood.

7.4.1.2 Model with the First Choice (Model F)

To explore variables that affected participants' first choice, a model was created using the main variables as in *a priori* model: attachment scores, age, gender, interaction and study type and the block number. We only included the first choice from each block and the interactions between the attachment scores and the interaction type, study type, and block number. For this analysis trial and block number were omitted from the model, see (Figure 7-3). This model is called the model with the first choice (model F) and it includes the following variables:

'Choice~ (Anxiety+Avoidance) (StudytypeF2FvsAnonymous + Studytype2Pvs4P + TypeCom + BlockNumber)+ Age + Gender+(1|Subject)'*

The data consisted of a total number of 1892 observations, explained through a Linear Mixed Effect Model (Table 7-3) with 17 fixed and 232 random-effects coefficients and one covariance parameter. The response variable was modelled by a binomial distribution with a logit link function, with parameters estimated by maximum likelihood.

Explorative Model based on First Choice (Model EF)

Backward stepwise linear regression was used based on the model F. This was done by eliminating the interactions that showed the highest non-significant *p* values, followed by the elimination of the variables that had the highest non-significant *p* value in the model. This was done one step at a time and the BIC was checked every time to improve the model and this was continued until all the remaining variables in the model and their interactions showed significant effect, see (Figure 7-4). This is an explorative model based on first choice, (EF) and includes the following variables and interactions:

'Choice~ (Anxiety) (Studytype2Pvs4P)+(Anxiety)*(TypeCom)+(Avoidance):(BlockNumber)+ BlockNumber+(1|Subject)',*

The data consisted of a total number of 2192 of observations, explained through a Linear Mixed Effect Model (Table 7-4) with 8 fixed and 282 random-effects coefficients and one covariance parameter. The response variable was modelled by a binomial distribution with a logit link function, with parameters estimated by maximum likelihood.

7.5 Results

7.5.1 Linear Mixed Effects modelling of cooperation choices

LME was used to test the variables that predicted a decision in any given trial, by assuming a general linear model with variables of interest as fixed effects and the subject as a random effect.

7.5.1.1 *A Priori* Model (Model P)

The *a priori* model includes the variables that are expected to have an effect (a priori) and their interactions based on the previous findings (see Methods section). From the model, (Figure 7-1 Table 7 1) it can be seen that subjects were significantly less likely to cooperate if they themselves or their partner defected in the previous two trials, with the strongest effect of their own previous choice. On top of this, the interaction between the subject’s own choice and their partner's choice shows that if they both defected in the previous trials, the subject would be more likely to change behaviours and cooperate in the current trial.

Moreover, the results show that participants were less likely to cooperate in the later trials within the blocks, whilst they were more likely to cooperate in the later blocks.

Across blocks, subjects were more likely to defect with a known computer partner, relative to a human partner. Similarly, when playing with a defecting partner (believed to be human), participants were more likely to defect. Moreover, the type of partner defecting also interacted with an avoidant attachment type, with more defection by avoidant attached individuals when playing with a defecting partner. However, when participants played against a cooperative partner (believed to be human), they were more likely to cooperate. Whilst the negative environmental context made participants defect more overall, the negative environment also showed an interaction with age, meaning older adults were more likely to cooperate in the negative environment.

The model did not show any significant effect of anxiety and avoidance attachment scores on decisions, nor any significant effect of age on cooperation. However, gender showed a significant effect, with female participants more likely to cooperate as compared to male participants. Interestingly, there was also a significant effect for the type of interactions, Face-to-Face vs. non-face-to-face and 4 players vs. 2 players, with less cooperation in face-to-face and the 4 players study.

There were no other interactions between the environment and partner type, nor between the environment and the type of interactions.

In summary *a priori* model shows that the two previous choices have the strongest effect on a participant's decisions and the interaction of participants' previous choices showed more cooperation following defection. Whilst participants cooperated more with human, and their p-cooperative partner, they defected more with the p-defecting partner. In addition to this, avoidant individuals cooperated less with the defecting partner, whilst older adults cooperated more in the negative environment. Finally, the model showed that females cooperated more, and participants defected more in the face-to-face and 4 players setting.

Table 7-1 Estimated parameters from LME a priori model (model P).

Table shows standard error, t-statistics, degrees of freedom, p-value, and lower and upper 95 percent confidence estimates.

Name	Estimate	SE	tStat	DF	pValue	Lower	Upper
'(Intercept)'	-2.38	0.15	15.93	21856	7.79E-57	-2.67	-2.08
'Choicem1'	1.71	0.05	33.83	21856	1.49E-244	1.61	1.81
'Choicem2'	0.66	0.05	13.11	21856	3.62E-39	0.56	0.76
'Otherm1'	1.31	0.05	25.38	21856	4.29E-140	1.21	1.41
'Otherm2'	0.78	0.05	15.47	21856	1.07E-53	0.67	0.87
'TypeCom'	0.44	0.04	11.45	21856	2.99E-30	0.36	0.51
'TypeCol'	-0.32	0.10	-3	21856	0.0027029	0.52	0.10
'TypeDef'	0.72	0.10	7.27	21856	3.78E-13	-0.52	-0.91
'EnveNega'	0.12	0.05	2.22	21856	0.026534	0.01	0.22
'EnvePosi'	0.16	0.11	1.38	21856	0.16791	-0.06	0.38
'BlockNumber'	-0.45	0.15	-3.17	21856	0.0015164	-0.75	0.17
'Trial'	0.54	0.15	3.64	21856	0.00027093	0.24	0.82
'Anxiety'	0.15	0.08	1.87	21856	0.060808	-0.00	0.30
'Avoidance'	-0.13	0.07	-1.73	21856	0.084281	-0.27	0.01
'Age'	0.06	0.07	0.89	21856	0.37371	-.078	0.20
'Gender'	0.23	0.11	2.03	21856	0.042387	0.00	0.45
'Studytype2Pvs4P'	0.52	0.19	2.79	21856	0.0052209	0.15	0.89
'StudytypeF2FvsAnonymous'	0.63	0.23	2.73	21856	0.0062494	0.17	1.08
'Choicem1:Otherm1'	-1.25	0.07	-18.30	21856	3.06E-74	-1.38	-1.11
'Choicem2:Otherm2'	-0.55	0.07	-8.10	21856	5.90E-16	-0.69	-0.42
'TypeCol:EnveNega'	-0.21	0.12	-1.69	21856	0.090471	-0.45	0.03
'TypeDef:EnveNega'	-0.12	0.11	-1.05	21856	0.293	-0.34	0.10
'TypeCol:Anxiety'	-0.032	0.10	-0.31	21856	0.75434	-0.23	0.16

'TypeDef:Anxiety'	-0.16	0.09	-1.80	21856	0.070945	-0.34	0.02
'EnveNega:Anxiety'	-0.07	0.05	-1.45	21856	0.14803	-0.17	0.02
'EnvePosi:Anxiety'	0.05	0.06	0.70	21856	0.48472	-0.08	0.18
'TypeCol:Avoidance'	0.11	0.09	1.12	21856	0.26195	-0.08	0.29
'TypeDef:Avoidance'	0.16	0.08	2.00	21856	0.04488	0.00	0.32
'En-veNega:Avoidance'	0.03	0.04	0.67	21856	0.50222	-0.06	0.12
'EnvePosi:Avoidance'	-0.01	0.05	-0.27	21856	0.78631	-0.13	0.10
'EnveNega:Age'	-0.09	0.03	-2.40	21856	0.016487	-0.16	-0.02
'EnvePosi:Age'	-0.04	0.06	-0.71	21856	0.47769	-0.16	0.08
'EnveNega:StudytypeF2FvsAnonymous'	-0.13	0.11	-1.20	21856	0.22983	-0.36	0.08
'EnvePosi:StudytypeF2FvsAnonymous'	-0.25	0.17	-1.44	21856	0.14831	-0.58	0.09
'Anxiety:StudytypeF2FvsAnonymous'	-0.07	0.18	-0.36	21856	0.7156	-0.29	0.43
'Avoidance:StudytypeF2FvsAnonymous'	-0.12	0.13	-0.90	21856	0.36695	-0.14	0.38

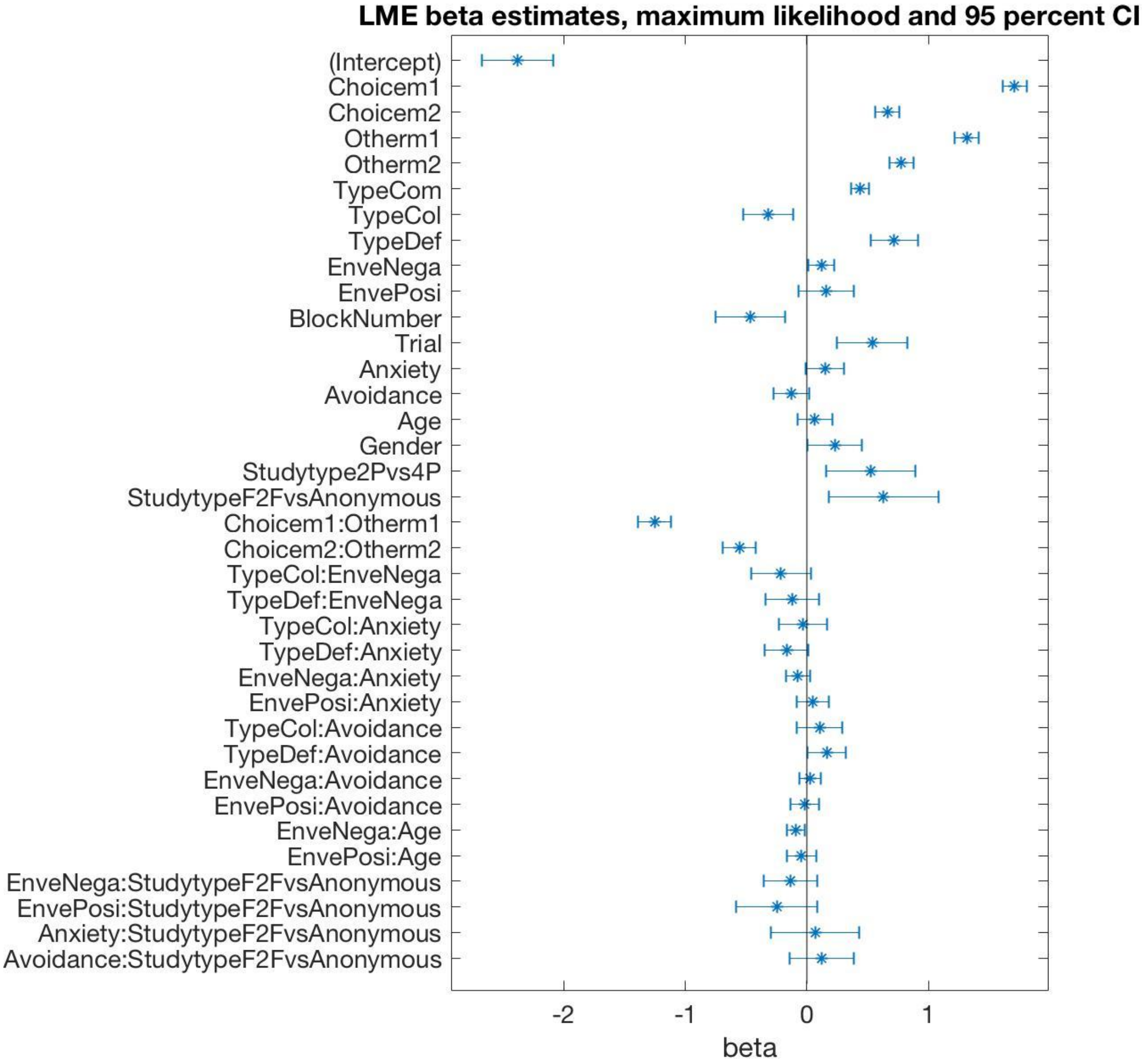

Figure 7-1 Figure Estimated beta values for LME *a priori* model, mean and estimated 95 percent confidence intervals.

Explorative Model based on A Priori Model (Model EP)

To further explore the best model that fit the data, a backward step was used, using *a priori* model as a base (see Methods section).

The results from the explorative analysis (Figure 7-2 Table 7-2) confirm the same finding as *a priori* model. Whilst the interaction between the partner type, defecting and avoidant attachment, did not survive the analysis, based on Bayesian information criterion (BIC), the explorative model fits better with smaller BIC.

From the explorative model, it can be seen that subjects were significantly less likely to cooperate if they themselves or their partner defected in the previous two trials, with the strongest effect of their own previous choice. On top of this, the interaction between one's own choice and their partner choice shows if they both defected in the previous trials, this would make them to more be likely to cooperate, for all trials.

Same as *a priori* model, again, the results show that participants were less likely to cooperate in the later trials within the blocks, whilst they were more likely to cooperate in the later blocks.

Similarly, across blocks, subjects more likely to defect with a known computer partner, relative to a human partner and same again they were more defecting when playing with a defecting partner (believed to be human). When participants played against a cooperative partner (believed to be human), however, they were more likely to cooperate. Whilst the negative environmental did not show any significant effect on participants tendency to cooperate, similarly, the negative environment showed an interaction with age, meaning older adults to be more likely to cooperate in the negative environment.

Table 7-2 Estimated parameters from LME the exploratory model based a priori model (model EP)

Table shows standard error, t-statistics, degrees of freedom, p-value, and lower and upper 95 percent confidence estimates.

Name	Estimate	SE	tStat	DF	pValue	Lower	Upper
'(Intercept)'	-2.23	0.10	-22.17	21876	9.94E-108	-2.43	-2.03
'Choicem1'	1.71	0.050	34.01	21876	4.03E-247	1.62	1.82
'Choicem2'	0.67	0.05	13.26	21876	5.46E-40	0.57	0.77
'Otherm1'	1.32	0.05	25.57	21876	4.14E-142	1.22	1.42
'Otherm2'	0.78	0.05	15.60	21876	1.39E-54	0.68	0.88
'TypeCom'	0.43	0.04	11.31	21876	1.43E-29	0.35	0.50
'TypeCol'	-0.42	0.07	-5.96	21876	2.50E-09	-0.55	-0.28
'TypeDef'	0.72	0.07	10.64	21876	2.22E-26	0.58	0.85
'BlockNumber'	-0.46	0.15	-3.16	21876	0.0015858	-0.75	-0.17
'Trial'	0.54	0.15	3.63	21876	0.00027782	0.25	0.82
'Gender'	0.24	0.11	2.07	21876	0.037974	0.01	0.46
'Studytype2Pvs4P'	0.36	0.11	3.18	21876	0.0014728	0.14	0.58
'StudytypeF2FvsAnonymous'	0.51	0.15	3.29	21876	0.00098568	0.20	0.81
'Choicem1:Otherm1'	-1.26	0.07	-18.38	21876	6.39E-75	-1.39	-1.12
'Choicem2:Otherm2'	-0.56	0.07	-8.14	21876	-16	-0.69	-0.42
'EnveNega:Age'	-0.06	0.03	-2.24	21876	0.025288	-0.12	-0.00

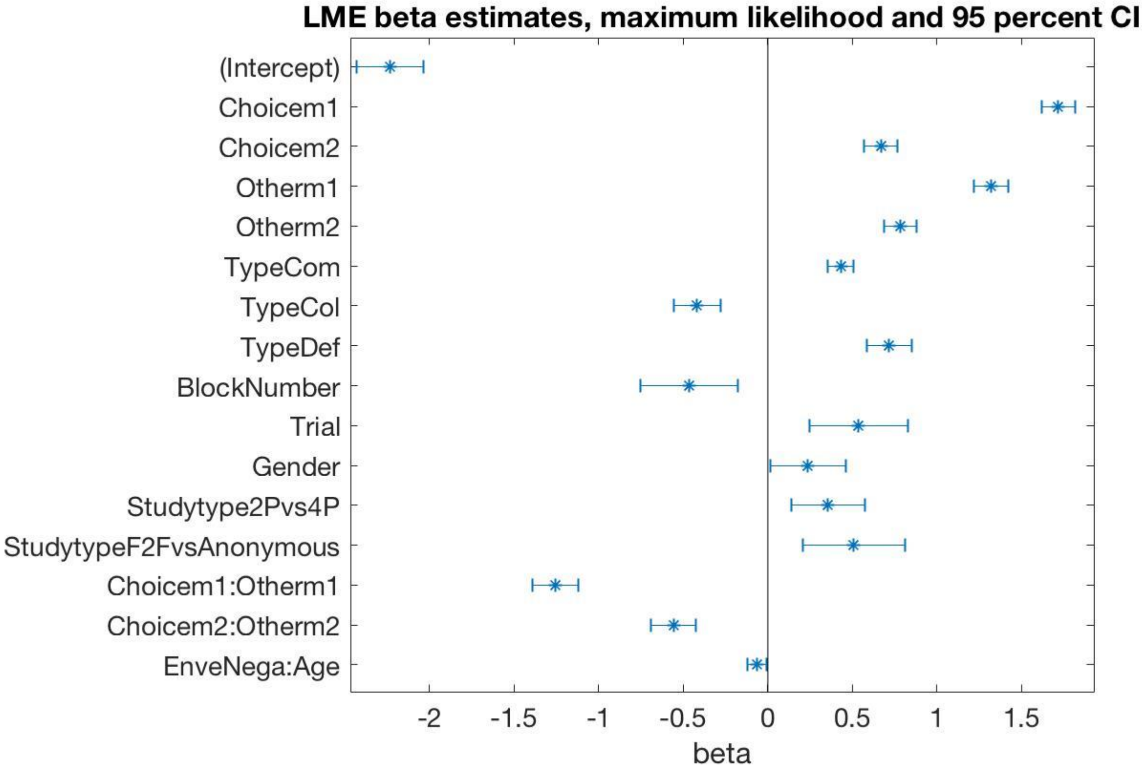

Figure 7-2 Figure Estimated beta values for LME exploratory model based on *a priori* model, mean and estimated 95 percent confidence intervals.

In summary, from the explorative model (model EP), the same as the results from the a priori model, it can be seen that the variable that had the strongest effect on a participant's tendency to cooperate is that of their previous choices and the interaction of their choice with their partner's choice, as well as the type of partner, defecting or cooperative, as that also shows a strong and consistent effect on participants' decisions. Whilst the environmental context in itself did not affect participants' decisions, a negative environment showed an interaction with age. No other effect of attachment type or interactions between attachment and environment were found based on both models. The type of study, FTF vs. anonymous and 2 players vs. 4 players as well as gender, does have an effect on participants' decisions when including the previous responses into the model.

7.5.1.2 Model with first choice (model F)

To see which variables had an effect on participants' first choice, a model was created using the main variables from *a priori* model, excluding the previous 2 choices, the environmental context, partner type, cooperative and defecting and the trial number, but including the block number.

The finding from the model F, see (Figure 7-3 Table 7-3) was interesting, as the effect of various variables disappeared from the model when considering the first choice only, and the following variables and their interactions showed a significant effect on a participant's decision.

Same as *a priori* model, (model P) and model EP, participants were more cooperative with their human partner as compared to their known computer partner.

On top of this and interestingly, participants with higher anxiety score were more likely to cooperate with a computer as compared to a human. Moreover, anxiously attached individuals showed more defection overall. Unlike the previous models, participants were more likely to cooperate in early blocks as compared to later blocks, when considering the first choice only. In addition to this, avoidant attached individuals showed more cooperation in the later blocks. There was no other effect of age, gender, the type of interaction: F2F vs anonymous, type of study: 4players vs 2 players and no interactions between any other variables were found.

In summary, when only considering the first choice, partner type computer showed the most consistent effect on participants' decisions, with more defection with a computer as compared to a human partner. However, this effect was reversed for anxious attached individuals. In addition to this, anxiously attached individuals also showed less cooperation overall. Moreover, whilst participants overall showed less cooperation in the later blocks, avoidant attached individuals showed more cooperation in the later blocks.

Table 7-3 Table Estimated parameters from LME model with first choice (model F)

Table shows standard error, t-statistics, degrees of freedom, p-value, and lower and upper 95 percent confidence estimates.

Name	Estimate	SE	tStat	DF	pValue	Lower	Upper
'(Intercept)'	-1.79	0.30	-5.90	1875	4.45E-09	-2.39	-1.20
'TypeCom'	0.95	0.12	8.15	1875	6.63E-16	0.72	1.18
'BlockNumber'	0.33	0.06	5.75	1875	1.03E-08	0.21	0.44
'Anxiety'	0.50	0.23	2.19	1875	0.028916	0.05	0.95
'Avoidance'	-0.02	0.23	-.08	1875	0.93553	-0.46	0.42
'Age'	0.22	0.15	1.49	1875	0.13694	-0.07	0.51
'Gender'	0.31	0.22	1.36	1875	0.17243	-0.13	0.75
'Studytype2Pvs4P'	0.11	0.39	0.29	1875	0.76995	-0.65	0.88
'StudytypeF2FvsAnonymous'	0.76	0.40	1.90	1875	0.056669	-0.021	1.54
'TypeCom:Anxiety'	-0.36	0.13	-2.65	1875	0.0081632	-0.62	-0.09
'BlockNumber:Anxiety'	0.09	0.07	1.39	1875	0.16469	-0.04	0.22
'TypeCom:Avoidance'	-0.11	0.13	-0.82	1875	0.41229	-0.37	0.15
'BlockNumber:Avoidance'	-0.18	0.06	-2.70	1875	0.0068784	-0.31	-0.05
'Anxiety:Studytype2Pvs4P'	-0.53	0.31	-1.69	1875	0.091326	-1.14	0.08
'Avoidance:Studytype2Pvs4P'	0.06	0.29	0.22	1875	0.8244	-0.51	0.64
'Anxiety:StudytypeF2FvsAnonymous'	-0.06	0.30	-0.20	1875	0.84173	-0.66	0.54
'Avoidance:StudytypeF2FvsAnonymous'	0.07	0.27	0.25	1875	0.80237	-0.46	0.60

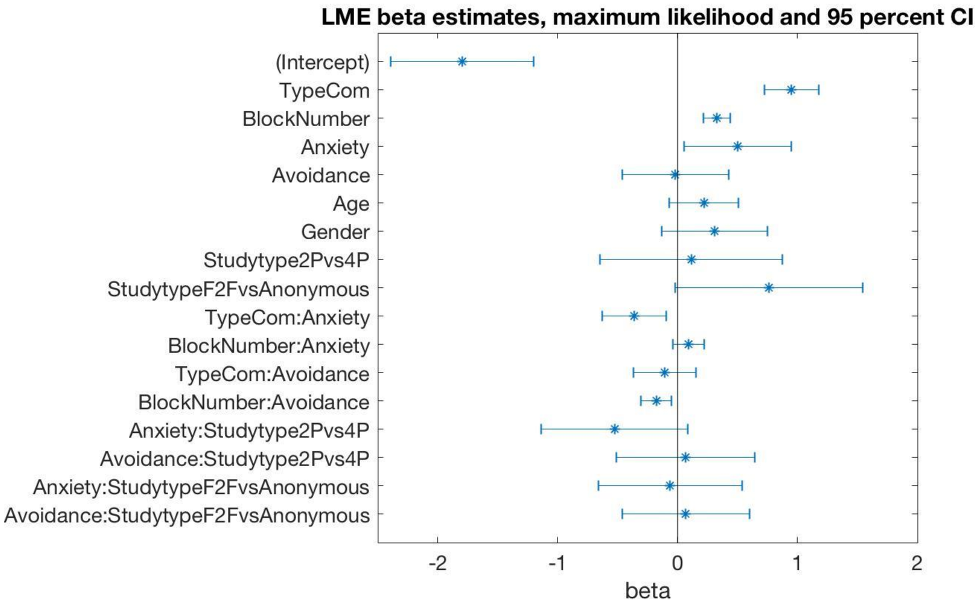

Figure 7-3 Estimated beta values for LME model with first choice, mean and estimated 95 percent confidence intervals

Explorative Model based on First Choice Model (model EF)

To further explore the best model that fits the data when considering the first choice only, a backward step was used, based on the first-choice model (model F) as a base (see Method section).

The results from the explorative analysis (Figure 7-4 and Table 7-4) confirm the same finding, with the first-choice model with additional variables and interaction showing a significant effect. Moreover, based on Bayesian information criterion (BIC), the explorative model (model EF) fits the data better than the Model F.

From the explorative model based on first choice, (model EF), it can be seen that subjects were significantly more likely to cooperate with their human partner as compared to a known computer partner. On top of this and similarly to model F, participants with higher anxiety attachment score showed more cooperation with their computer partner as compared to the human partner. Overall participants showed more defection in the later blocks, whilst avoidant attached individuals showed more cooperation in the later blocks. In addition, anxious attached individuals showed less cooperation. Finally, participants showed more cooperation when they played the game in the 4 players study, whilst on top of this, anxiously attached individuals also showed more cooperation when they played the game in the 4 player condition.

Overall, whilst the results from the explorative model (model EF) confirm findings from the model with first choice (model F), it also shows significant findings for study type 2, players vs 4 players, and its interaction with anxiety attachment scores.

Table 7-4 Table Estimated parameters from LME exploratory morel based on the model with first choice (model EF).

Table shows standard error, t-statistics, degrees of freedom, p-value, and lower and upper 95 percent confidence estimates.

Name	Estimate	SE	tStat	DF	pValue	Lower	Upper
'(Intercept)'	-1.28	0.12	-10.57	2184	1.69E-25	-1.51	-1.04
'TypeCom'	1.05	0.11	9.76	2184	4.70E-22	0.84	1.26
'BlockNumber'	0.34	0.05	6.59	2184	5.61E-11	0.24	0.44
'Anxiety'	0.46	0.11	4.00	2184	6.55E-05	0.23	0.68
'Studytype2Pvs4P'	-0.48	0.20	-2.37	2184	0.017832	-0.87	-0.08
'TypeCom:Anxiety'	-0.30	0.10	-2.94	2184	0.0033537	-0.51	-0.10
'BlockNumber:Avoidance'	-0.10	0.05	-1.97	2184	0.048344	-0.20	-0.00
'Anxiety:Studytype2Pvs4P'	-0.46	0.20	-2.21	2184	0.026907	-0.86	-0.05

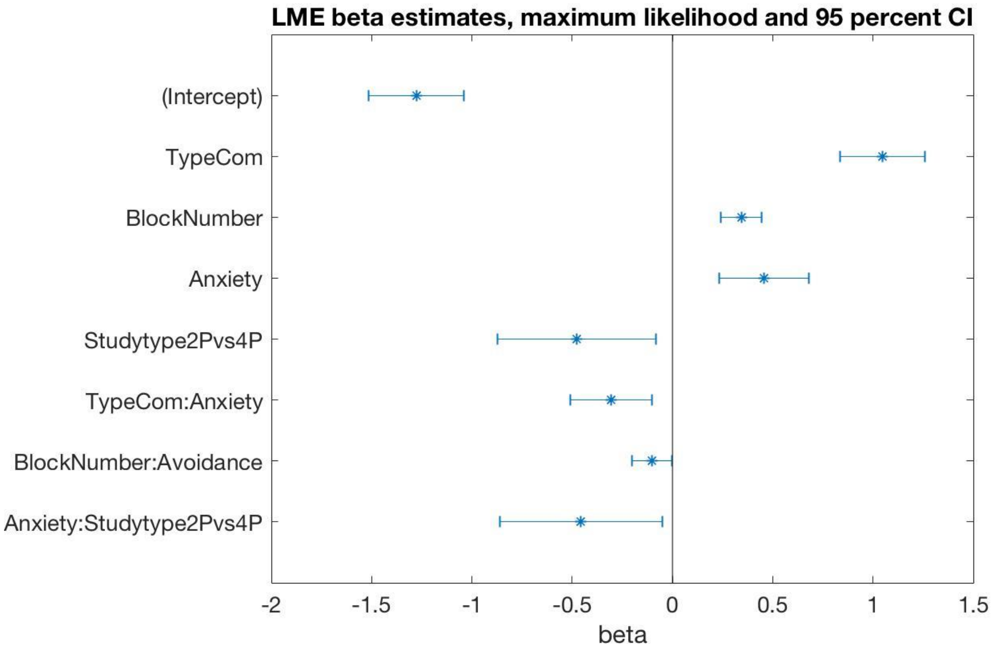

Figure 7-4 Estimated beta values for LME exploratory model based the model with the first choice, mean and estimated 95 percent confidence intervals

In summary, when considering the previous two choices, findings from the *a priori* model (model P), showed that participant's own and their partner's previous choices have the strongest effect on cooperation. Moreover, trial and block numbers, partner type, negative environmental context, gender, the interaction type and the study type are shown to affect cooperation. There were also significant interactions of the partner type with avoidant attached style and the negative environment with age. When looking at the first choice, model F shows that participants' cooperative decisions depend on: the partner- computer or human, block number, anxiety score, and that there were interactions between the anxiety attachment scores and the partner type, human or computer, as well as anxiety attachment scores and the study type, 2 vs 4 players. Findings from the above models will be discussed in the following section.

7.6 Discussion

The aim of the current study was to understand the effect of environmental context (resources uncertainty), and social context (interactions type and partner type), and individual differences in attachment style and age, as well as participants' previous choices on cooperation in the Prisoner's Dilemma Game (PDG). Moreover, the interactions between social and environmental contexts with individual differences was investigated. To achieve this, a meta-analysis was run on four studies that were previously conducted by pooling the data together and applying Linear Mixed Effect modelling using Matlab's 'fitmle' function (Mathworks, Cambridge, MA). *A priori* model (model P) was created based on *a priori* variables and their interactions, and the two previous choices of the participants and their partners, as well as the trial and block numbers. The results from model P shows that cooperation strongly depended on participants' own previous choices and their partner's previous choices, whilst there was also an interaction between participants own previous choices and their partner's previous choices. In addition to this, participants' cooperative decisions depended on their partner type: human or a known computer as well as partner type: defecting or cooperative, and trial and block number, gender, interactions type, and the type of study. Model P also showed an interaction between the avoidant attachment score and the partner type: defecting, and an interaction between the negative environmental context and age. The results from the explorative model (model EP) confirmed findings from model P, with an exception that the findings did not show any significant interaction of partner type defecting and avoidant attachment style.

In addition to model P with the previous two choices, model F was created based on the *a priori* variable but including only the first choice of participants from each block. Findings from model F show that cooperation in the first choice can be predicted by the type of partner: computer, partner type defecting, attachment anxiety scores as well as block number. Moreover, model F also showed that participants' cooperative decision, in the first trial, can be interactively affected by their anxiety and avoidance attachment scores and block number. In the following sections these findings are discussed based on the results from model P and model F.

7.6.1 Participants own, and their partner's previous responses based on *a priori* model

In this meta-analysis the data from all four studies were pooled together and fitted into a Liner Mixed Effect model. When factoring in the previous two choices of participants and their partner's two previous choices, findings show that overall and across the four studies, participants' cooperative or defecting decisions strongly depended on their own previous two decisions as well as their partner's decisions in one and two trials before the current trial. For example, if they themselves cooperated in a trial before (current choice -1), they were more likely to cooperate again in the current trial. Similarly, if their partner cooperated in a trial before, they were more likely to cooperate in the current trial. However, the effect of their own previous choices on their current decision was stronger than that of their partner's previous choices on their decision. The effect of their previous choice was also significant for the second trials before (current choice -2). Moreover, the interaction between participants' own previous choices and their partner's previous choices showed more cooperation following previous mutual defection.

The effect of a partner's previous responses on a participant's decision, supports findings from Study 4 (Chapter 6). In Chapter 6 it was discussed how reciprocal altruism (Trivers, 1971) and reciprocation (Axelrod & Hamilton, 1981) provides an explanation for the emergence of cooperation between non-related individuals in social dilemmas.

Literature on reciprocation and cooperation have mostly focused on the effect of one's partner's decision on their decision (Cimini & Sánchez, 2014). Whilst the current study provides support for reciprocation, it adds an additional dimension to the consideration. In this study, the effect of ones' own previous decisions on a participant's current decision was also considered, in addition to their partner's previous decisions. *A priori* model (model P) shows the effect of one's own previous decision as being stronger than their partner's previous decision on their current decision. This shows that it is not just the reciprocation that motivates participants to cooperate or to defect, but also that their own previous decisions affect their decisions. Cimini and Sánchez, (2014) called this Moody Conditional Cooperation (MCC), meaning that cooperation of the player also depends on the mood that they are currently in.

Findings from participants' previous choices also show that if they themselves defected in the trial before and if their partner also defected in the previous trial, they were more likely to cooperate in the current trial. This finding is similar to findings from Study 4 (Chapter 6). In Chapter 6, it was discussed how emotions act as commitment devices (Frank 1987, as cited by Ketelaar & Tung Au, 2003) and "affect-as-information" (Schwarz & Clore, 1983) can impact an individual's cooperation followed by defect, e.g., through feeling guilty. It was also speculated that participants could have tried to avoid falling into a mutual defect trap by cooperating after mutual defect.

In summary, whilst reciprocation (Bolton & Ockenfels, 2017) or conditional cooperation (Cimini & Sánchez, 2014) seem to be the simple answer for the effect of a partner's previous choices on participants' current decisions, the importance of a participant's own previous choices on their current decision, the Moody Conditional Cooperation (Cimini & Sánchez, 2014) should not be undermined. It is worth noting that the effect of choice will diminish moving forwards in time, so the biggest effect is by most recent choices. These findings highlight the importance of the cognitive adaptation modules that humans have developed to retain social maps of their social situations, in order to guide them through their decisions in social dilemmas (Kiyonari, Tanida, & Yamagishi, 2000).

7.6.2 Trials and block numbers based on a priori model and model with first choice

Findings from *a priori* model (model P) shows that participants were more likely to cooperate in early trials and less likely to cooperate in later trials within each block. There was no effect of trial numbers when considering the first choice in the model, model F. Findings from model P show that participants initially begin the game more cooperatively within each block, and towards the end of the block they diverted from cooperation and began to defect. This finding is in line with previous studies that showed participants initially establishing a cooperative pattern and then starting to deviate from this initial cooperative pattern as the game approached its end (Selten & Stoecker, 1986) - the so called non-cooperative end effect. The end effect was said to be applicable to finite PDG. Although, in our meta-analysis, some of the studies had a fixed number of trials (e.g., 4 players 16 trials fixed across each block) and others had a random number between 13 to 17 trials. Participants, however, did not know the number of trials they played in each block. It is likely that participants could anticipate the end approach of the block based on their experiences in the previous blocks. In line with the end effect, it has been shown that people learn about strategic cooperation or conditional cooperation early in the game and that they converge from the cooperative strategy from then onwards (Embrey, Frechette, & Yuksel, 2014). Based on findings from *a priori* model, it is likely that in our study participants started with conditional cooperation earlier on within the block and began to defect more in the later trials towards the end of the block through learning and experience.

In addition to the effect of trial number, *a priori* model shows an effect for block number, with participants more likely to cooperate in later blocks during the game. Based on the end effect, it would be expected to see the same decline in cooperation towards the later blocks as was seen with the trials. Interestingly, the model with first choice shows different results with more cooperation in early blocks as compared to less cooperation in later blocks, supporting the end effect. These findings are intriguing as they show contrasting results when looking at participants' first choice only, as compared to a repeated interaction. It is possible that when looking at the repeated interactions, participants have established a decision pattern that is less influenced by the end effect or conditional cooperation unlike and the model with first choice.

Overall, findings highlight the importance of the length of the game and how it affects cooperation during a repeated interaction or a one-shot game.

7.6.3 The effect of social context

Social context was varied and based on interaction type: face-to-face vs non-face-to-face, partner type: human vs computer, p-cooperative and p-defecting, study type: 2 players vs 4 players. Findings from these are discussed in the following section.

7.6.3.1 Partner type, human or computer, based on a priori model (model P) and model with first choice (model F)

Findings from both *a priori* model (model P) and model F, based on the first choice, show that participants were more likely to cooperate with a human partner as compared to a known computer partner. In our studies, participants received an instruction at the beginning of each block and were informed of the partner type that they would play with in the respective block. This was done consistently across all blocks and all four studies. More cooperation with a human partner as compared to the computer partner could be therefore affected by a participant's expectation of their computer partner's behaviour. Based on our post experiment debriefing from our participants, they mostly believed that the computer strategy was played randomly and they believed that would not be able to influence the computer choice, whilst they believed that they can influence their partner's decision. This finding is consistent across all four studies and supports the literature on the effect of the actual and perceived partner's on participants' decision, based on the instruction that was given to them (Miwa & Terai, 2012a). In Chapter 6, it was discussed that participants saw computers as being incapable of producing adaptive behaviour like humans, for example, in response to either cooperation or defection. Hence, it was suggested that participants did not expect to fall into mutual distrust with a computer partner (Miwa

& Terai, 2012a). This finding also supports the cognitive adaptation of social map (Cosmides & Tooby, 1992), as it is possible that participants expected their human partner to reciprocate based on their social map, and in the case of a computer, they see the computer as non-social and incapable of cognitive adaptation or retaining a social map.

Overall, findings show that participants cooperated more with their human partner as compared to the computer partner. This highlights the importance of the social identity of the partner, as perceived by participants, and its effect on their behaviour, based on the expectation that they have from their partner's behaviour.

7.6.3.2 The effect of cooperative or defecting partner based on a priori mode

In this meta-analysis, only in one study, the 4 players study; 100 participants played the PDG game with a pretend-cooperative and with a pretend-defecting partner, in addition to a human and a known computer partner. Overall, findings show the likelihood of a participant cooperating with a cooperative partner and defecting with a defecting partner was consistently higher.

These findings show that participants' decisions were strongly influenced by their partner's behaviour (being cooperative or defecting), confirming Rabin's (1993) fairness equilibrium and reciprocation (Komorita et al., 1991). In Chapter 6 it was discussed how observing a partner's repeated cooperative or defecting behaviours, could be inferred by participants as the social rules of the given situation (Biel & Thøgersen, 2007; Chen et al., 2007), and this could give rise to the reciprocation becoming the social norm of the situation (Biel & Thøgersen, 2007).

7.6.3.3 The effect of the type of interactions, face-to-face vs. non-face-to-face, based on a priori model and the model with the first choice

In our meta-analysis, three of the four studies were conducted whilst participants played the PDG during a non-face-to-face interaction, and in one study, fifty participants played the game face-to-face. Whilst the 'no verbal communication' was an experimental condition for both the non-face-to-face and the face-to-face interaction (to exclude the effect of the linguistic channel), the face-to-face situation allowed for identified interaction. From the *a priori* model, participants showed less cooperation during the face-to-face interaction as compared to when they played the game in a non-face-to-face situation. Model F with first choice (excluding the effect of previous responses) shows no significant effect of interaction type (face-to-face vs anonymous). These results are unexpected and are in contrast with our *a priori* hypotheses and the current literature.

Whilst typically most past experiments are conducted in an anonymous (non-face-to-face) situation, previous studies on the effect of interaction type on cooperation however, mostly focused on the effect of direct communication (e.g., written and verbal or video communication) as compared to indirect communication, (or non-verbal acts, e.g., gaze, smiling) (Van Lange, Joireman, Parks, & Van Dijk, 2013). Findings from both direct communication e.g., pre-play communication (Attanasi, García-Gallego, Georgantzís, & Montesano, 2013) and indirect communication, show a bias for more cooperation (Bohnet & Frey, 1999). Our experiment was conducted during a face-to-face interaction, but participants were not allowed any kind of verbal or written communication. This type of non-anonymous or non-face-to-face interaction was called identified silence by Bohnet and Frey, (2002). Bohnet and Frey (2009) found that mutual silent identification increases cooperation in the PDG. They suggested that the increase in cooperative behaviour is due to the decrease in social distance, that was achieved by identifying one's partner by seeing them without any communication being exchanged. Contrary to the finding by Bohnet and Frey, findings from our *a priori* model showed more defection in the face-to-face interaction. One possible reason for more defection by participants during the face-to-face interaction might be the fact that all the participants in the face-to-face experiment were young students. Based on the uncontrolled social utility hypothesis, the social environment that is created by face-to-face interaction is hard to control. As is suggested by Roth, (1995) people bring their social learning and expectations into their interaction. This is also called mannerism. In our face-to-face experiment, all fifty subjects were recruited from the student population. Therefore, it is likely that they expected more competition when they faced a partner from the same cohort. Moreover, participants did not know the other person in advance, (we confirmed this through questionnaires, e.g., that they were not friends). One social norm that is known between the students is competition, and this could be activated as the norm of the game through the face-to-face interaction, seeing the other person is a student like themselves.

The social distance theory by Elizabeth Hoffman et al. (1996) suggest activating the social norms through decreasing the social distance and empathy (Bohnet & Frey, 1999). Interestingly, when excluding the effect of previous choices from the model, the finding of more defection in the face-to-face interaction becomes non-significant. This could mean that participants developed defection as their social norm after the first few interactions.

Overall, findings show that silent face-to-face interaction or silent identification does not increase cooperation as suggested by the literature. This could be due to reasons such as the activation of cultural norms, e.g., being a student and competitive.

7.6.3.4 The effect of the type of study, 4 players vs. 2 players, or the effect of group size, based on the a priori model and model F with first choice

In this meta-analysis, in three of the four studies, the PDG was played in groups of two, whilst in the last study (hereafter 4 players), the game was played in groups of four. In the same way as in the 2 players study, in the 4 players study participants were introduced to the game whilst they were all seated in the same room, and they were told that they would play against one computer and all the other human partners (three humans in 4 players). When considering the effect of the type of study, 2 players vs. 4 players in *a priori* model, findings show that participants were more likely to defect when they played the game in groups of 4 as compared to the 2 players study. This finding is in line with previous literature showing that as the group size increases, the likelihood of cooperation decreases and participants in bigger groups show more defecting behaviour (Dawes, 1980). It is rational to see less cooperation during the 4 players study as compared to the 2 players study. In our studies, (both 2 player and 4 player), participants initially saw each other when they were introduced to the game in the same room. The aim was that participants see whom they would interact with to increase the ecological validity of our experiment. However, no communication was allowed before and during the game. Participants remained anonymous to each other by not showing any name or label indicating who they were going to interact with, and only calling their partner a human partner. Keeping the interaction anonymous has therefore increased the similarity of 4 players situation to that of N-players suggested by Dawes (1980).

Interestingly, however and similar to findings from interaction type, face-to-face vs non-face-to-face study, when excluding the effect of previous choices from the model, (model F) the results show no significant effect of study type, 4 players vs 2 players (or the group's size) on cooperation. This highlights the effect of previous interaction that was included in the model and made the effect of the study type, 2 players vs. 4 players, to be significant. This could mean that the effect of learning and experience changes participants' reactions to the social context, here the group size. In another words, when considering first choice, group size does not influence cooperative decision during the PDG.

7.6.4 Environmental context and cooperation based on a priori model

In three of the four studies participants played the game in three (negative, neutral, positive) environmental contexts. The 4player study was conducted with only the negative and neutral environmental contexts. Because participants were not informed about the environmental context of the blocks until after playing the first trial, environmental context was not expected to affect a participants' decision in the first block and hence it was not included in model with first choice.

Finding from the *a priori* model shows, that participants cooperated less in the negative environmental context as compared to the neutral environmental context, whilst there was no effect of positive environmental context on participants' cooperation. These results partially support previous findings, findings from Study 2 and Study 4, (see Chapter 4 and 6) whilst in Study 1 and Study 3, (see Chapter 3 and 5) we found that the negative environment increases cooperation in the PDG (Taheri et al., 2018; Taheri et al., 2020, under review). Previously, it was discussed how introducing random monetary losses and gains may trigger emotions such as happy or sad, frustration or anger or other negative and positive emotions in the negative or positive blocks repeatedly (Taheri et al., 2018). On the other hand, when including the past interaction, it was argued how variation in reinforcement slows down participants' learned cooperative behaviour (Bereby-Meyer & Roth, 2006).

One main difference between the current study and the previous studies (Study, 3, 4 and 5), is that we included participant's own and their partner's previous choices in the analysis (similar to Study 6). This could mean that the effect of learning and experience changes participants' reaction to the environment.

7.6.5 Individual differences and cooperation based on the *a priori* model and model of first choice

7.6.5.1 The effect of relational attachment style and cooperation

Individuals attachment data were collected from participants in all four studies. It was expected that cooperation would vary based on individuals' attachment style. Findings from the *a priori* model did not show any effect for attachment style, when including the past two responses in the model. However, the *a priori* model showed an interaction of partner type, p-defecting with avoidant attachment style with a higher likelihood of defection for participants with higher avoidant scores when playing with a defecting partner. This is in line with previous studies that shown a partner's strategies affect participants' decisions (e.g., see Van Lange & Visser, 1999). Lange and Visser, (1999) used the term locomotion to describe how people adapt to their partner's strategy and adjust their level of interdependence based on the interaction between their partner strategy and their own individual differences. They showed specifically, that non-cooperative partners elicit the least cooperation, but also have lower levels of interdependence (more avoidant). As discussed before, the Interdependence Theory (IT) suggests that interdependency between the partners in social dilemmas is also affected based on their attachment style (Rusbult & Van Lange, 2003a). It seems therefore natural for participants with higher scores in relational avoidant to seek lower a level of dependency with their defecting partner as compared to the rest of the participants. When a partner is consistently defecting, it is expected to trigger the internal working model of avoidant individuals which leads to even lesser dependency with their defecting partner.

When including the first choice in the model, interestingly attachment scores showed different results. Findings from model F show that an anxiously attached individuals cooperated more with their computer partner as compared to a human partner, whilst they also showed more defection overall. Avoidant attached individuals on the other hand showed more defection in the early blocks as compared to the later blocks. Based on the attachment working model, it is expected that both anxious and avoidant attached individuals have difficulties in trusting others during an interpersonal situation (Mikulincer et al., 2003). Hence, when only considering the initial trials and blocks where participants are still learning about their partner's behaviour, it is expected that anxious and avoidant individuals start with distrusting behaviour, or defection. Moreover, avoidant attached individuals seem to show more cooperation as the game moved on into the later blocks, whilst an anxious attached individuals seem to be less trusting overall and in particular with a human as compared to a computer partner.

In summary, findings highlight how individual differences in relational attachment style affect decision making, especially in the initial encounter when they have not yet learned about their partner's potential behaviour.

7.6.5.2 The effect of age and cooperation based on the a priori model and model with first choice

Findings from the *a priori* model and model F show no effect of age on cooperation. However, when considering participants' previous choices, age was shown to modulate the effect of environmental context, with older participants to showing more cooperation in the negative environment. This finding is partially in line with the literature. Whilst it was expected to see overall more cooperation as participants' age increased, we did not find an effect of age on cooperation. However, as the literature suggests, decision making in older adults is shown to be of a different quality as compared to younger people. This could be because of the effect of experience, motivation, and incorporating emotional content (McGillivray, Friedman, & Castel, 2012). Older adults are suggested to have better ability for emotional regulation (Charles, 2011) and to cope with uncertainty (Meeks & Jeste, 2009).

In summary, the findings highlight the importance of considering the role of age within the context, as manifested by the environment and the recent experience of participants in the previous trials.

7.6.5.3 The effect of gender and cooperation based on a priori model and model with first choice

Findings from the *a priori* model show more cooperation by female participants as compared to male participants, whilst findings from the model with first choice did not show any effect of gender on cooperation. This finding is interesting, as it shows how the effect of gender can vary based on experience, e.g., when only considering the first choice or when including the last two choices. Findings from the *a priori* model, (when considering previous choices), is partially in line with previous studies, showing that women are more cooperative than men (Ortmann & Tichy, 1999; Stockard et al., 1988). However, the results from the PDG is mixed, e.g., some studies found that men played in pairs cooperate more (e.g., see Colman, Pulford, & Krockow, 2018; Kurzban & Houser, 2001). It is noteworthy that in our study, participants were not paired randomly whilst majority of the participants were female they were not always paired with the same gender. It is, therefore, important not to overstate gender differences and their effect on cooperation, in particular in the current study, where male participants were under-represented (only a fourth of the sample were male participants).

7.8 Conclusions

The aim of this meta-analysis was to understand the effect of extrinsic (environmental and social contexts), and intrinsic (individual differences) variables, as well as previous choices and their interactions, on cooperation during the PDG across the four empirical studies. Based on the findings from Linear Mixed Effect fitted models, when studying cooperation in conflict, the predicting variables can be categorised into three domains. The learning and experience dimension, the social and environmental contexts aspect, and the individual differences dimension. Whilst the current models offered by theories, such as the Interdependence Theory, have discussed some of these domains in depth, there seems to be a gap within the current literature. One main finding of the current study is the influence of learning and experience on cooperation that is beyond reciprocation. Moreover, whilst the partner type has a strong effect on cooperation, individual differences add additional variance into the equation. Similarly, whilst the effect of age and environment on cooperation is currently understudied, the interaction of the two is shown to be important when studying cooperation.

To conclude, the framework represented here is a simplified model that works as an umbrella, for studying cooperation in dilemmas, with other variables falling under it. It was shown that studying cooperation in conflict, without considering various aspect of the so-called situation and the different variables contributing to it, lacks validity and reliability.

8 SUMMARY AND FUTURE DIRECTIONS

8.1 Introduction

Cooperation in conflict is affected by various factors including, but not limited to, environmental and social contexts and individual differences. Although decades of research have provided us with valuable insights in this area, the impact of each of these variables and how they interact with each other is still unclear. The purpose of this dissertation was to investigate the effect of extrinsic (environmental and social context) and intrinsic variables (individual differences) on cooperation during social conflict and during the repeated PDG interaction. In this chapter, the summary of the main findings is discussed, and the limitations presented along with suggestions for future research directions.

In Chapter one, the literature on cooperation in dilemma and factors that affect cooperation was presented. It was argued that most studies on cooperation have narrowly considered one or two of these variables and have studied them in isolation. This is a limited view of studying human behaviour. Therefore, the objective of my research was to set a framework to include both the external and internal factors that affect cooperation, and design experiments to investigate these variables and their interactions both in separate study and across the studies. To study the effect of environmental and social contexts (external factors) on cooperation, I added variations into the environmental uncertainty by adding blocks, in which participants would lose extra money independent of their decision outcome (negative context), and blocks in which they were given additional money, independent of their decision outcome (positive context) as compared to the blocks where their payoff was not manipulated (neutral context). The social context was varied through investigating participants' decisions during two different interaction types, the non-face-to-face interaction and the face-to face interaction. In addition to the interaction type, social partners were also varied by introducing pretended cooperative partners and pretended defecting partners, in addition to the real human partner and a computer partner. By controlling the behaviour of the partner, it made it possible to investigate the individual's decisions independent of their partner's decisions. Amongst the individual differences, attachment style was studied, as it has been shown to affect intrapersonal and interpersonal relationships and behaviour (Van Lange, Otten, Bruin, & Joireman, 1997), plus the effect of attachment style on cooperation is understudied in social decision making. Likewise, the literature on decision making and cooperation is mostly biased by the focus on studying younger adults (based on availability and convenience). There are fewer studies on cooperation across the adulthood lifespan (Lim & Yu, 2015). Hence, one aim of this research was to include middle age and older participants and to study how age affects cooperation in the PDG as a between subject variables. Another variable that has been consistently shown to affect cooperation is individual prosocial orientations. Hence, individual prosocial trait was also included in the study. Finally, by looking across the four empirical studies through conducting a meta-analysis, both the random and mixed effect of the above variables and their interaction were investigated in an attempt to better understand how cooperation is a function of interactions between external and internal variables.

The major findings of my work are, that environmental and social contexts both impact the way that participants interact with each other during the conflict situation of the PDG. In addition to these external factors, the effect of environmental and social factors depends on between subject variables, such as their attachment style, age, and cooperativeness trait. Last but least, it was found that decisions should be studied within the context of the recent history of interactions, however the effect of experience was shown to disappear as moving forward in time. These results imply that we must consider all aspects of the situation and individual differences when studying factors affecting cooperation in conflict.

In the next section the results from each chapter are briefly presented and factors that affect cooperation are outlined, based on my findings from the five studies.

8.2 Summary of results

The first empirical chapter, (chapter 3) investigated the effect of environmental uncertainty and individual differences in attachment style and their impact on cooperative behaviour during a non-face-to-face interaction of PDG. This chapter was published in *PLoSONE* journal, (Taheri et al., 2018).

Theories on environmental uncertainty and cooperation suggests that environmental uncertainty can affect participants' decisions' during interdependent situations (Kelley et al., 2009a). Findings on the effect of environmental uncertainty (resource uncertainty) show mixed results, with most studies showing more cooperation during environmental uncertainty, depending on the context in which cooperation has been studied (e.g., see Bendor et al., 1996, 2017; de Kwaadsteniet, Rijkhoff, & van Dijk, 2013). Moreover, based on the way that the negative and positive environmental contexts were introduced (losing or gaining additional random money), it was expected that this type of environmental uncertainty would trigger negative (sad) or positive (happy) emotions in participants during the respective blocks. Emotions are suggested to affect behaviour through an indirect effect on their decision making, e.g., using emotion as a feedback system (Baumeister et al., 2007; Frank, 2011). Studies on the effect of emotions on cooperation have also shown mixed results, with most studies suggesting a bias for increased cooperation under negative emotions (Hertel, Neuhof, Theuer, & Kerr, 2000b; Kjell & Thompson, 2013). In Study 1, it was found that overall cooperation increased during negatively uncertain environment as compared to the neutral and positive environmental contexts, meaning that when participants randomly lost money, they cooperated more (Taheri et al., 2018).

Attachment theory has been used as a conceptual framework to study individuals' intrapersonal and interpersonal behaviours by many psychologists. Studies on the effect of attachment style on decision making however is a new area. Only a handful studies have explored its effect on cooperation during conflict (Vrtička & Vuilleumier, 2012). Findings from these studies mostly show ambivalence behaviour by anxiously attached individuals during the dilemmas, (McClure et al., 2013), whilst the effect of avoidant attached style on cooperation is less clear. Based on attachment theory and affect regulation, individuals develop different proximity-seeking behaviour depending on their attachment style (Mikulincer et al., 2003). It was therefore expected that anxiously and avoidantly attached individuals would react differently during the negative and positive environmental contexts. In this study, when factoring attachment style into the analysis, the effect of environmental context was reversed. This means that cooperation decreased in both anxious and avoidant individuals during the negative environmental context, as compared to increased cooperation during negative contexts by participants overall. These results show that the environment affects individuals differently based on their attachment style. This was discussed using attachment theory and evolutionary theory and affect as a source for information processing.

The second empirical chapter, (Chapter 4) replicated the first study, however this time participants played the game during a face-to-face interaction. The aim was to see how individuals would react differently during a non-verbal face-to-face interaction as compared to the non-face-to-face interaction (Study 2). In addition to this, it was aimed to study how individuals with anxious and avoidant attachment styles would react differently during the face-to-face interaction. Whilst findings from Study partially supported the finding from Study 1, these finding was interesting as the face-to-face interaction changed the impact of the environmental context. Overall, cooperation increased during a positively uncertain environment as compared to the negative and neutral environment, whilst the results across the pairs showed that insecure pairs cooperate less during the negative environment. Findings from of Study 1 and Study 2 showed how environmental uncertainty affected participants differently in the two different set ups, e.g., more cooperation in the negative environment whilst playing the game in a non-to-face condition whilst it was the opposite when the game was played in a face-to-face condition. Findings was discussed based on affect information processing, (Bless & Fiedler, 2006; Hertel et al., 2000a). Additionally, it was found that anxious and avoidant individuals cooperated less across the board during the uncertain environment, mutually insecure individuals' betrayal was magnified during the face-to-face condition. These findings discussed based on the decrease in social distance during the face-to-face interaction (Bohnet & Frey, 2002) and how individuals with anxious and avoidant attachment style will be affected by distressing situation (Mikulincer & Shaver, 2007) during the uncertain environment.

The third empirical study was an extension to the first study by including a wider range of adults, ranging from above 30 up to 86 years old to investigate the effect of environmental uncertainty on cooperation across adulthood. The finding from the third study was consistent with the first study in terms of the effect of environment on cooperation, with an increase in cooperation during the negatively uncertain environment. Participants from the middle age group (age 30 to 60) were found most cooperative and participants from the young group were found least cooperative whilst the older participants were the least flexible in changing their strategies when they played against a computer or a human partner. This finding was discussed based on socioemotional theory (Carstensen, Isaacowitz, Derek M, 1999) and positivity bias theory (Mather & Knight, 2005). This chapter is reviewed and resubmitted to the *Journal of Aging and psychology*, (Taheri et al., 2020).

The fourth and the final empirical study was set to control for the confound effect of a partner's behaviour on cooperation. Therefore, two type of social partners were introduced, pretend-cooperative (p-cooperative) and pretend-defecting (p-defecting) partners, in addition to the real human partner. The two p-cooperative and p-defecting partners were in fact computer programs and played the game 80% cooperatively or 80% defecting respectively, based on participants' previous responses, to measure for the impact of partner type on cooperation. Individual differences in their cooperativeness trait was also measured using questionnaires. The environmental uncertainty was only studied using the negative and neutral environmental contexts, since the positive environment was not found to impact cooperation during the non-face-to-face interaction. The results showed that participants cooperated most with their p-cooperative partner whilst they also defected most with their p-defecting partner. It was also found that participants were faster and more stable in adopting a cooperative strategy with their p-cooperative partner. The environment affected participant's cooperation when they played with their real human partner as well as the cooperative and defecting partner (social context), but not when they played with the computer (non-social context). Importantly, the effect of environment on cooperation was changed with a decrease in cooperation during the negatively uncertain environment, relative to the neutral environment. Moreover, findings from Linear Mixed Effect model showed strong dependency of participants current decisions on their own and their partner's previous choices. It was also found that high scores in cooperativeness made participants less likely to defect and more likely to cooperate with the p-cooperative partner in the negative environmental context. Importantly, by controlling for partner's strategy, it was shown this was not just because of the partner's behaviour. Therefore, whilst previous studies did not permit to fully rule out the role of the partner's behaviour, Study 4 showed when controlling for partner's behaviour, factors including participant's recent choices, partner type, and participants' cooperativeness trait as well as the environmental contexts to affect cooperation in the repeated PDG. Findings from Study 4 suggests that cooperation is favourable, however it is not unconditional, and defect would be a preferred decision if the partner did not reciprocate cooperation. These results highlight the importance of not only the environmental and the social contexts in which the decisions are made, but also the importance of the recent history of interactions and the effect of individual differences in their cooperativeness on cooperation in the repeated PDG.

Chapter 7 is a meta-analysis of all four empirical studies. I used Linear Mixed Effect analysis and included all the factors from the four studies to investigate for both the random effects and the mixed effects of the variables across the studies. Based on the findings from the meta-analysis, it was shown that learning and experience, the social and environmental contexts, and the individual differences to affect cooperation. It was shown that the influence of learning and experience on cooperation is beyond reciprocation and whilst the social context, e.g., partner type, interaction type and study type, and the environmental context has strong effects on cooperation, individual differences add additional variance into the equation. Importantly, these effects may also vary based on the context of the game and whether we look at a one-shot game or a repeated interaction.

8.3 Food for thought

Did we recruit more cooperative or prosocial individuals as volunteers in our experiments or, were they mostly motivated by the money? Van Lang et, al. (2011) reported that participants vary in their motivation when participating in experiments, for example prosocials were more likely to volunteer in psychology experiments. Moreover, their social value orientation was also linked to the course of study they chose, e.g., Economics students were more likely to be individualistic whilst Psychology students to be more prosocial (Van Lange, Schippers, & Balliet, 2011). Hence, as they argued, samples used in psychological experiments could systematically vary in their motivations, whilst this variation could be linked incorrectly to their individual differences and pro-sociability.

8.4 Limitations of the research

One limitation of the research is the generalizability of its sample. In this research, most participants were students and female, and this could bias the finding by gender and culture and age.

Whilst this research was set to study cooperation, it is possible that certain types of people sign up for research. Similarly, I did not measure participants' motivation for participating in research, but it is likely that the older and younger participants have different motivations for their participation in research.

Although, I made sure that all the participants, young and old comprehended the task fully before running the experiment, however, the plain instruction that was given to the participants (Biel & Gärling, 1995), may have affected their understanding of the experiment as also, for example, the payoff matrix based on their differences in memory and cognitive abilities. In all the experiments, participants were instructed to play the game and try to maximize their income. Based on Dawes (1980) this kind of framing reflects an implicit assumption by most researchers that human nature is egoistic (Biel & Gärling, 1995). Our framing may have affected participants' decisions. e.g., based on their age. On a similar note, participants' understanding of how to maximise their income can interfere with their cooperation (Burton-Chellew, El Mouden, & West, 2016)

Whilst the aim of the environmental manipulation was to trigger participants' emotions through creating negative or positive environmental contexts as in real life, however, using monetary losses and gains might have diluted this.

Finally, in this research it was attempted to create an ecologically valid social environment, e.g., participants sat with their partner/partners in the same room during the instruction to make it more real for them. However, the experimental labs are not the best environment to study social problems.

8.5 Conclusion

Studying cooperation in a social dilemma is both fascinating and challenging, due to its multi dimensionality. Whilst researchers have conducted over 1000 studies using the Prisoner's Dilemma Game, the effect of environmental and social contexts and individual differences on cooperation are less clear. This thesis shows that environmental uncertainty and social context do affect cooperation in the PDG, but also that these effects are modulated by individuals' attachment style, their age, and their cooperativeness. Importantly, findings from this research show that recent experience impacts individuals' cooperation in the PDG differently, based on their attachment style and the social and environmental context that they interact in.

8.6 Future direction

Cooperation is an important aspect of our human society. We face crises and uncertainties constantly, for example, political instability in the Middle East, climate change and the pandemic of Covid-19. Therefore, when implementing strategies and polices to increase cooperation within individuals and between societies, it is important to consider the various aspects of the dilemmas and the factors affecting cooperation.

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APPENDICES

Chapter 5 Supplementary materials

Effects of Intra-Individual variability in decision times

For each condition and each participant, we computed the standard deviation of decision times and divided this by the average decision time for this condition, to obtain the coefficient of variance measure of intra-individual variability (CoV-IIV). The impact of the factors on CoV-IIV was tested using a mixed ANOVA with partner, environment, and age as factors. As stated in the main text, similar to the analysis of the decision times, we observed a main effect of age, which did not correlate with any of the repeated factors. Here we focus on reporting the other effects.

Main effect of partner. Participants were more variable in their decision speed when playing with a human than with a computer F (1,129) = 3.90, p = .05, $p\eta^2$ = .03.

Main effect of environment. The environment also affected the variability, F (2,258) = 3.15, p = .04, $p\eta^2$ = .02. Similar to the decision time analysis, variability was larger in the uncertain block (Negative: .55, .021 SEM; Positive: .57, .027 SEM) than in the certain neutral blocks (.49, .02 SEM).

Interaction partner by environment, F (2,258) = 12.03, p <.001, $p\eta^2$ = .08. Follow up analysis showed that the environment effect was larger when playing with a human F (2,262) = 10.64, p <.001, $p\eta^2$ = .07; than with the computer F (2,262) = 3.53, p = .031, $p\eta^2$ = .03. The pattern of the effect was also reversed. When playing with another human, decision time variability was larger in negative than neutral blocks, t (131) = 3.47, p = .001, d = .30 and during the positive versus the neutral blocks t (131) = 4.28, p <.001, d = .37, Variability was also larger in the positive than the negative blocks, t (131) = 1.94, p = .054, d =.17. When playing with a computer, there was no difference in variability between negative and neutral blocks, t (131) = -.27, p =.784, d = .02;

though positive blocks were associated with less decision time variability compared with neutral blocks, t (131) = -2.55, p =.012, d = .22, as well as negative blocks t (131) = 2.54, p = .012, d = .22.

Overall, the results showed that participants were more variable when playing with a human than a computer, though this depended on the environment. They were least consistent in the time taken to decide in an uncertain negative environment when playing with a human. But were most consistent when playing with a computer during the negative uncertain and certain neutral environments.

Table S1: CoV-IIV results 1

Age	Partner	Environment	Mean-CoV-IIV	*SE*
Young	Human	Negative	0.62	0.05
		Neutral	0.41	0.03
		Positive	0.8	0.08
	Computer	Negative	0.60	0.04
		Neutral	0.60	0.04
		Positive	0.49	0.02
Middle	Human	Negative	0.64	0.06
		Neutral	0.49	0.04
		Positive	0.74	0.10
	Computer	Negative	0.56	0.05
		Neutral	0.56	0.06
		Positive	0.49	0.03

Elderly	Human	Negative	0.43	0.05
		Neutral	0.41	0.03
		Positive	0.51	0.08
	Computer	Negative	0.45	0.04
		Neutral	0.49	0.04
		Positive	0.41	0.02

First Trial Analysis

To be able to compare our results to a single-shot trial we analysed the first trial in each condition.

Methods: For each participant we took the first response in each human or computer condition collapsed across the environmental conditions (as these were only revealed throughout the trials after participants made their response).

We computed a Chi-square to assess whether the frequency of cooperation choices was affected by the knowledge of the other player (**Table S2**). This was done separately for each version and each age group. Two versions of the order of the conditions were used, in one version participants started with a human and in the second with a computer.

Results

Overall participants selected to cooperate more in the first trial when playing against a human or a computer (Supp Table 1), independent of whether they faced the computer or human in the first block (no block order effect). Participants also cooperated more with a human than with a computer, although there were a few exceptions. The young group did not show a clear preference for response (cooperate/betray) when facing a computer or a human in the first trial of the game. The difference between age groups who played the same experiment version was significant when playing with a human and trended significance when playing with the computer. The elderly group who played with a computer after playing with a human first also did not show a clear preference pattern for cooperating/betraying in the first trial, though the difference between the age groups was not significant.

Table S2: Cooperation /Betrayal choices in the first trial

CONDITIONS	GROUP	COOPERATE/BETRAY	CHI-SQUARE (P)
HUMAN 1^{ST} (VER-B)	Young	13/7	1.8 (.180)
	Middle	11/0	*>4.455 (<.035)*
	Elder	24/2	*18.615 (.000)*
χ^2 AGE EFFECT			*8.896 (.012)*
HUMAN 2^{ND} (VER-A)	Young	28/5	*16.03 (.000)*
	Middle	18/2	*12.8 (.000)*
	Elder	17/5	*6.545 (.011)*
χ^2 AGE EFFECT			1.294 (.524)
χ^2 ORDER EFFECT			2.074 (.150)
COMPUTER 1^{ST} (VER-A)	Young	18/15	.273 (.602)
	Middle	17/3	*9.8 (.002)*
	Elder	16/6	*4.545 (.033)*
χ^2 AGE EFFECT			5.628 (.060)
COMPUTER 2^{ND} (VER-B)	Young	15/5	*5 (.025)*
	Middle	9/2	*4.455 (.035)*
	Elder	16/10	1.385 (.239)
χ^2 AGE EFFECT			1.862 (.394)
χ^2 ORDER EFFECT			.839 (.360)
χ^2 1^{ST} PARTNER EFFECT		106/26	*5.617 (.018)*

χ^2 2ND PARTNER EFFECT	96/35	*4.71 (.041)*
χ^2 PARTNER EFFECT	202/62	*8.432(.004)*

The results of this analysis mirror the pattern observed in the cooperation ratio assessed in the iterated prisoner's dilemma game. It showed that already at the first trial participants opted to cooperate more with a human than with a computer partner. The pattern of results was similar across age groups, though, like in the cooperation ratio results reported in the main text, the middle age group were most consistent in their cooperation decisions, while both the young and elderly groups in some conditions showed no clear pattern of decision.

The significant difference between interacting with a human and a computer partner, shows that as a group, participants understood the partner manipulation, and adjusted their decisions according to the partner. It also suggests that a relatively large proportion of betrayals in the young and elderly groups may emerge from different reasons. More young participants chose to betray as their first decision in the game independent of whether they played a human or a computer. In the elderly group, more individuals chose to betray a computer only after playing with a human first. These results should be interpreted with caution as they rely on a relatively small number of participants and hence need to be replicated.

Pairwise Analysis

In the current experiment, participants played with other participants in half the trials. This means that like in real life, the behavior of any given participant depended to a degree on their partner's and the relationship they formed in the game. In other words, participants cannot be considered as fully independent samples, as their responses were dependent on the pairing. The lack of independence violates ANOVAs assumptions and may have led to inflation of the degrees of freedom. To ensure the pattern of results was not affected by this procedure, we ran additional analysis where the averaged pair performance was the random variable.

Cooperative response ratio of 58 pairs (Young = 22, Middle = 12, Elderly = 24) were averaged. We excluded participants who played with a partner from a different age group. A mixed ANOVA with the factors partners and environment as repeated factors and age as a between factor revealed a similar pattern to the results observed when using the individual participant as the random variable.

The results are presented in supplementary figure 1. The pattern of the averaged pair results matched the analysis of the individuals, though the effects were not always significant, potentially due to the reduced power.

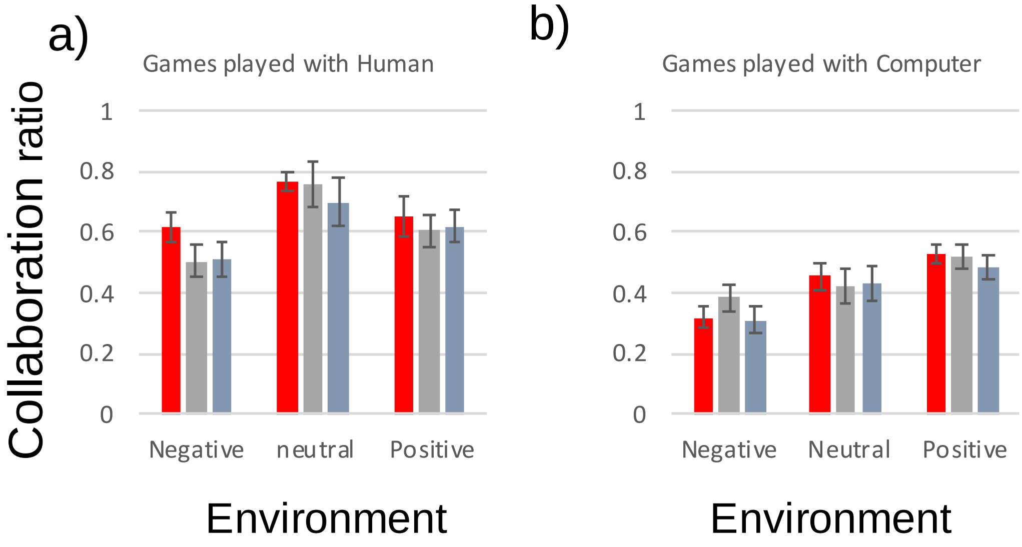

Figure S1: Cooperation ratio by partner

Cooperation ratio averaged over the pair. Red: young, Light grey: middle-aged, Dark grey: elderly. a) When playing against a human or b) against a computer

Mirroring the individual results, there was a significant effect of age, *F* (1, 55) = 7.08, *p* =.002, $p\eta^2$ = .20. Young pairs (*M* = 0.44, CI: .385 - .498) cooperated less than middle age pairs (*M* = 0.58, CI: .512 - .665) *t* (32) = -2.83, *p* = .008, *d* = 1.06; and less than the older pairs (*M* = 0.56, CI: 514 - .622), *t* (44) = -3.17, *p* = .003, *d* = 0.93. Middle age and older pairs did not differ in their overall cooperation ratio, *t* (34) = .52, *p* = .604, *d* = 0.18.

Partner type affected the pairs' decision, *F* (1, 55) = 36.19, *p* <.001, $p\eta^2$ = .40. Participants cooperated more with a human (*M* = 0.63, CI: .579 - .696) than with a computer (*M* = 0.42, CI: .386 - .468). There was only a weak trend of interaction between partner and age, *F* (2, 55) =2.41, *p* = .099, $p\eta^2$ =.08. Following this interaction trend, we computed separate analysis for games played with human and a computer.

When playing with a human, there was a significant effect of age, *F* (2,55) = 3.37, *p* = .042, $p\eta^2$ = .11. Young pairs showed less cooperation than middle age pairs, *t* (32) = -2.22, *p* = .033, *d* = .868. Young and older pairs did not differ, *t* (44) = -1.29, *p* = .203, *d* = .41. While middle age pairs tended to collaborate more than older pairs, *t* (34) = 1.86, *p* = .072, *d* = .61.

When playing with a computer partner, age had a large effect on the cooperation ratio, *F* (2,55) = 7.38, *p* = .001, $p\eta^2$ = .22. On average young pairs cooperated less but not significantly different than middle age, *t* (32) = -1.69, *p* = .101, *d* = .62. Young cooperated less than older pairs, *t* (44) = -3.91, *p* = .000, *d* = 1.15. Middle age cooperated less than older pairs, but the effect was not significant *t* (34) = -1.606, *p* = .117, *d* = .56.

Was the impact of partner type on decision modulated by age? The averaged pair decisions showed an inverted 'U' shape of cooperation when playing with human, and a linear increase of cooperation when playing with a computer.

The environment affected pairs' behavior, F (2,110) = 2.90, p = .059, pη^2 = .05, this was a linear effect, F (1,55) = 6.12, p = .017, pη^2 = 1.00: negative > neutral > positive. Specifically, independent of partner and age, pairs made on average more cooperative decisions when playing in an uncertain negative environment (M = .55, CI: .517 -.596) than positive environment (M = .50, CI: .461 - .557), t (57) = 2.64, p = .011, d = .35. Proportion of cooperative decisions in the negative environment was larger but not significantly different than decision made in the certain neutral environment (M = .53, CI: .491 -.574), t (57) = 1.25, p = .215, d = .16. Proportion of cooperative decisions in neural-certain environment was larger but not significantly different than decisions made in the positive environment, t (57) = 1.30, p = .200, d = .170. There was no interaction between the partner and environment, p = .269, pη^2 = .024; age did not interact with the environment, p = .994, pη^2 = .002; nor was there a three-way interaction, p = .295, pη^2 = .043.

The results showed that the behavioral pattern of the pairs was similar to that of the individuals, suggesting that the results reported in the main text were not driven by inflated degrees of freedom.

Participants who played across aged groups

Eight pairs were of mixed age-groups. In these pair participants from the young (M = 26.3, range 22 – 29 years) group played with middle-aged (M = 34.3, range 30 – 40 years) participants. The pairing was opportunistic, as participants signed up anonymously to the same testing slot, using the research participation scheme of the School of Psychology at University of Birmingham, which is open to students only.

To ensure that those who played across our age group definitions were not different than those who played with a partner of similar age, we computed a separate mixed ANOVA for the young and middle age groups. The factors were: 2 (partner: computer, human) x 3 (negative, neutral, positive) and same/different age group as a between-subject factor.

Young participants (*M* = .62, CI: .486 .762) who played with participants from the middle age range overall cooperated more than young adults (*M* = .43, CI: .385 - .492). who played with other young adults, F (1,51) = 6.345, p = .015, $p\eta^2$ = .111. No other factor interacted with the type of age pairs, all Ps >.219, $p\eta^2$ < .029. Middle-aged participants who were paired with younger participants did not differ from their peers who played with other middle-aged participants on any of the factors, all *p*s > .353, $p\eta^2$ < .032.

The results highlight the importance of taking the partner into consideration. It is possible that the overall more cooperative middle-aged group encouraged cooperation within younger participants. It is also possible that young participants were more likely to comply with a cooperative strategy when facing a more mature player than they were with an equally young peer. Recall that participants met each other before the experiment started. However, these results should be interpreted with caution. First dividing a continuous measure, like age, into categories had some participants assigned different categories despite being very similar in age, some middle-aged participants were in their early thirties (especially those who played in the mix pairs), while some in the young category were in their late twenties. Second, the number of players who played with participants from a different age group was very small.

Therefore, further research is needed to first assess the reliability and replicability of these findings and to carefully examine factors that drive participants to behave differently when facing peers of different ages.