SCHOOL OF SCIENCE AND TECHNOLOGY

Behaviour in Common-Pool Resource Games: Investigating decision-making towards conservation and environmental issues.

A thesis submitted to Middlesex University in partial fulfilment of the requirements for the degree of Master by Research

Mario Bonfrisco
M00561231

January 2021

Abstract

Hardin's (1968) 'Tragedy of the commons', various fields, including economics, social sciences, conservation and environmental sciences have invested a great amount of effort to identify the characteristics that allow groups of individuals to administer and organise the use of common resources. The game used in the current study aimed to further analyse the dynamics found in social dilemmas such as Common-Pool Resources (CPRs). The game was an altered (with an amended matrix) version of a two-player Iterated Prisoner's Dilemma, where players had to make consumption decisions regarding a general resource that had the characteristics of a CPR – refreshable as well as depletable. A randomised probability of continuation (shadow of the future) was calculated and conveyed to the participants in each round. The analytical solution developed for the game suggested that players should conditionally cooperate when the probability was 69% or higher, whereas they should always defect, by taking the entire resource, when the it is lower than 69%. The game ended when the resource available was depleted by the players. A sample of 116 students and alumni voluntarily took part in the experiment. Participants were randomly allocated to either an anonymous ("Unseen") or non-anonymous ("Seen") condition. All participants were subjected to the same game structure, rules as well as pre and post-game questionnaires – Nature Relatedness (NR), Consideration of Future Consequences (CFC) and Index of Multiple Deprivation (IMD). The study had two main aims: (1) compare participants' behaviour within a strategic situation to its analytical solution and (2) investigate the psychological factors that influence the adoption of a cooperative or defective strategy. It was hypothesised that participants would follow the analytical solution. However, taking into account the idea of the Schelling points (Schelling, 1960), it was predicted that the switch point from cooperation to defection would be a more cognitively intuitive value – 50% - instead of 69%. Moreover, it was predicted that individuals with high NR, CFC, IMD as well as those in the Seen condition would play more cooperatively. These hypotheses were partially met. Participants did conditionally cooperate when the probability of another round was 69% or higher but did not always defect when it was lower than 69% - the Schelling points hypothesis was not supported. Moreover, only the manipulated condition had a significant effect on the participants' behaviour, in fact, those allocated to the Seen condition resulted to be more cooperative. Implications and limitations of the present research were discussed and suggestions for future studies are proposed.

Acknowledgements

The author of this paper would like thank Professor Mark Broom at City, University of London for developing the analytical proof relating to Nash Equilibria for the CPR game. Moreover, I would like to acknowledge Dr Yvan Russell for his contribution through discussing the topic area and assisting with interpretations and critical thinking and the Middlesex University staff for the technical support. Finally, I would like to express a special thanks to my supervisor, Dr Robert Spencer, for his support and guidance during the entire process.

Table of Contents

1. Introduction

1.1 Social Dilemmas

An individual faced with a dilemma has to make a decision between two (or more) available choices. Nevertheless, the outcomes for all choices are relatively negative or unpleasant in some way. Social dilemmas are situations where an individual, who is respectively part of a larger group ($N \geq 2$), must choose between alternatives with potentially negative consequences, wherein one option benefits the individual at a cost to the larger social group and the other choice benefits the social group but at some cost to the individual (Dawes & Messick, 2000). As such social dilemmas have a strategic interdependence element to them, however, they can also have a temporal element.

From a temporal point of view, the individually selfish choice benefits the individual in the immediate but potentially costs him or her when considering the lost future opportunity (it also costs the social group). The cooperative prosocial choice costs the individual in the immediate (he or she receives a lower payoff or outcome) but potentially results in greater future payoffs for both the individual and the rest of the social group. A difficulty for the individual in making a decision in the social dilemma is that future payoffs and outcomes are uncertain and not guaranteed, so outcomes are weighted and discounted based on the individuals' preferences as well as psychological understanding of the situation and group with whom they are interacting (Komorita & Parks, 1997).

On the other hand, if there is not a temporal aspect to the decision, knowledge and expectation of the social group (people with whom they are interacting) is an influencing factor. This introduces the issue of interdependence, making social dilemmas game-theoretical scenarios. In fact, it can be argued that a game-theoretical scenario is encountered, and a game is played, every time two or more individuals interact (Binmore, 2007).

Game Theory is a way of modelling and analysing the decisions of self-interested individuals in situations involving multiple individuals and the best way to behave requires taking into consideration what other individuals in that situation are doing. Since the publication of The

Theory of Games and Economic Behavior in 1944, by John von Neumann and Oskar Morgenstern, Game Theory has attracted much interest since it does not concern numbers, geometric figures or other abstract entities, but aims to outline a model of the behaviour of rational agents involved in some interaction with other rational agents. In other words, game theory intends to determine the best choice that a rational person should make, in a variety of situations, given his or her goals and beliefs (Hargreaves-Heap, 1994). In the game theory framework, there can be found cooperative and non-cooperative situations.

In cooperative situations, all individuals involved have, directly or indirectly, decided to work together towards a common aim (Maschler, 1992). Whereas, non-cooperative situations contain competitive interactions amongst individuals. In other words, in the latter, the subjects involved do not seek a supportive strategy that benefits the group, instead, they typically aim to achieve the optimal outcome for themselves. Therefore, each participant may obtain a very high or low payoff as consequences of their decision-making (Ritzberger, 2002) (see Appendix A for details).

Social dilemmas occur within non-cooperative situations and, in order to easily analyse them, they are conceptualised in strategic games, usually accompanied by adequate narratives. One of the narratives often used to simplify social dilemmas is the Prisoners' Dilemma (hereafter PD) (Kollock 1998). The PD is a two-person dilemma and involves, as the name suggests, two prisoners who must independently decide, unaware of the other prisoners' decision, whether to cooperate (C) with each other by not confessing their crime to the police or defect (D), testifying against each other (Luce & Raiffa, 1958). Their sentences will differ based on their decisions and level of cooperation, resulting in four possible outcomes (Figure 1) – the first is that one of the prisoners defects by confessing the crime to the police while the other prisoner decides to cooperate and thus stays silent (DC). In this case, as shown in Figure 1, the prisoner that defects will have the highest payoff available (5), whereas the prisoner that decided to cooperate (CD) receives the worst potential payoff (0). The second possible outcome is that both prisoners cooperate (CC), therefore, they both receive the same payoff (3). Such an outcome is also known as Pareto efficiency, which means that neither of the prisoners could receive a better payoff without making the counterpart worse off (Hahn, 1980). The third option is that both prisoners defect (DD), both receiving a payoff of 1 (Daniel, Arce & Sandler 2005). Therefore, rationally, the best decision is to defect because no matter what decision the other player makes, a player is always individually better off if they defect, although this will result in both prisoners defecting when they could have achieved a better outcome by mutually cooperating (therefore, DC > CC > DD > CD) (Kollok, 1998). Nonetheless, despite the value-based language contained in these labels, which of these behaviours is good or bad, and which is rational, will depend on the context and social group.

		Prisoner 2	
		C	D
Prisoner 1	C	3, 3	0, 5
	D	5, 0	1, 1

Figure 1*. Prisoner Dilemmas possible outcomes payoff (C = cooperation; D= defection).*

On the other hand, a common example of a multiple-person dilemma is portrayed by the Public Goods Game. A public good is a type of resource that every individual can use, regardless of their contribution for its preservation, construction or development (Dawes, 1991). In these situations, a person who uses the goods, but does not provide any kind of support, is generally called a ‘free rider’. When free-riders account for a small percentage of the group benefiting from a public good, the resource can be sustained. Conversely, if their number exceeds a certain threshold, the goodwill starts to perish and will eventually collapse. A common example of this dilemma is local public television. In fact, if only one individual makes a contribution to preserve it, such contribution does not make a large difference towards the success of the station, making a contribution rationally pointless. Essentially, the optimal scenario is becoming a free rider, thus, enjoying the local TV station without having any contribution costs while others do. Nonetheless, if all individuals within the group aim for the same selfish goal, the station will ultimately bankrupt and no one can benefit from it (Dawes & Messick, 2000). Hence, in Public Goods dilemmas, an individual meets an immediate cost that creates a profit shared by all the individuals within a certain group. This category of dilemmas is also called ‘social fence’ and one of their fundamental characteristics is that resources are non-excludable, which lead to the tempting behaviour of enjoying the resource without any contribution to its maintenance (Kollok, 1998). Furthermore, Public Goods differ from other dilemmas because they are commonly considered 'nonrival', meaning that one individual's usage does not decrease its availability to others (Cornes & Sandler, 1996).

Although the PD, as well as other similar dilemmas (e.g. Assurance Game, Chicken Game etc.), is fundamentally a two-person game, its attributes can be enlarged and applied to a larger group. However, Dawes (1980) suggests that doing so, will occur three profound alterations in the dynamics of the game – Firstly, in a two-person PD situation, each person involved will know how the other one behaved, thus, receiving relatively direct feedback. Whereas, within larger group anonymity increases as it becomes difficult to directly identify who made what level of contribution, and free riding may result unnoticed by others. The second main shift is that, in a two-persons situation, the cost of defection is concentrated entirely on another single individual, causing a more severe effect on the short term. Conversely, in a N-person situation, the cost of defecting is evenly spread across a larger number of individuals. Finally, the third important characteristic, which is altered by the change in the dynamics of the game, is the control over the other players. That is, in a two-person situation, one player has substantial control over the other player, thus, he or she could be able to influence the partner's actions in significant ways (Binmore, 1997). However, this does not occur in larger groups, where the single individual may have no direct control over the payoff other players obtain (Dawe, 1980). Nonetheless, though these are very common features to take into consideration, a N-person situation may not necessarily exhibit all the attributes mentioned above (Kollok & Smith, 1996).

1.2 The Tragedy of the Commons

Lloyd (1833) first discussed a category of N-persons dilemmas that differ from Public Goods in their attributes, analysing the overgrazing of cattle on village common areas. More than one-hundred years later, Hardin published a famous article in the Science journal, titled "The tragedy of the Commons" (Hardin, 1968). He revised Lloyd's idea in order to explain what occurs when a number of people use the same, limited, resource such as fishing space, grazing ground, clean air etc. In his paper, Hardin (1968) uses the example of a group of herders, each having their own cows, within a parcel of land to portray the tragedy of the commons dilemma. He argues that the overall grazing land has a certain capacity for cows to graze, therefore, each herder should limit such behaviour so that everyone can have his or her own share. However, it is in each individual herders' interest to graze a larger number of his own cows, regardless of the possible damage caused to the land. That is because the single herder obtains the benefits from the additional grazing while the negative effects of this (damage to the land) are shared to the whole group. Nonetheless, if all of the individuals from that group decide to act in the same way, the resource will perish and will soon be destroyed, causing everyone to suffer (Hardin, 1968). This happens because when individuals harvest over the suggested threshold and, thus, a resource does not have the chance to regenerate and it will be eventually exhausted (that is for renewable resource, different from non-renewable one as we shall see) (Kollock, 1998). Another real-life example could be behaviours found during pollution alerts. In such instances, residents may be asked by authorities to use bicycles instead of driving their cars. In this scenario, residents are better off ignoring such request and drive their car (since cycling or walking has a higher physical cost than driving), if the others will comply to the authorities' demand. However, when all residents think selfishly, they end up raising the pollution level and thus, getting a worse payoff (health damage etc.) (Dawes, 1980).

After Hardin's (1968) article there has been constantly increasing interest in behavioural mechanisms relating to the Tragedy of the Commons scenario. In fact, several studies have been conducted in the past sixty years, making social dilemma one of the most interdisciplinary fields with the contribution of researchers from psychology, economics, neuroscience, mathematics, anthropology and others (Ostrom, 2008). Many of the studies have focused on resources that include two main attributes that characterise Hardin's (1968) Commons – depletability and difficulty of exclusion – and are known with the technical name of Common-Pool Resources (CPRs).

Common-pool resources (CPRs) are types of goods available to a group or all individuals and they benefit from them through appropriation, meaning they take ownership or possession of the goods or quantities of them. In order for these goods to be considered CPRs, they need to have two main characteristics – the difficulty of exclusion and subtractability (Ostrom, 1990).

The difficulty of exclusion refers to the complexity of excluding a portion of individuals (appropriators) from accessing or profiting from a certain resource. Indeed, due to the nature of certain goods, restricting access to them can be, in some cases, impossible (Plott & Meyer, 1975). For instance, fencing a small area of the ocean to monitor and limit fishing activity is prohibitive. In other scenarios, the very act of restricting the usage of a certain good may make it more costly, due to monitoring mechanism instituted, than the actual benefits generated by the exclusion. In other instances, the exclusion is applicable within small communities, however, the same regulation may not be as effective for a bigger scale application (Ostrom et al., 1994).

The subtractability attribute indicates the degree to which an individual's usage of a resource affects the availability of the same resource for other individuals. For example, if a fisherman harvests a big amount of fish from a given area, those fishes are no longer available for others that also benefit from fishing in the same area (Gardner et al., 1990). In such a case we describe the resources available in a CPR as being rivalrous, indicating that once taken by one appropriator they are no longer available to be taken by other appropriators. This highlights a key difference between CPR's and Public Goods. The resource generated by a Public Good is not rivalrous as the usage of the Public Good need does not necessarily reduce the amount of the resource available for the use of others (see Appendix B for more information regarding CPRs structures).

1.3 Nash Equilibrium

In game theory, various formal rules are used to predict how a game should be played. These rules are known as solutions concepts. In non-cooperative games, a solution describes what strategy will be played by an individual and, thus, it predicts the result of the game. The main purpose of solution concepts in non-cooperative games is to find an optimal strategy by finding points of equilibrium, which indicate the most appropriate strategy given the absence of frameworks to support cooperation (Tadelis, 2013).

A very famous solution concept was first discussed by the mathematician John Nash, in 1950. He showed that every finite game (i.e. when there is a finite number of players and a finite number of strategies) must have no less than one equilibrium point (aka Nash equilibrium). The Nash equilibrium, within non-cooperative games, is reached when each player cannot gain any further benefit by changing his or her current strategy after considering others' possible choices (Binmore, 1994). In other words, Nash's concept is used to analyse the effects of strategic interactions in numerous circumstances, predicting the outcome of the choices of multiple individuals, not analysing the single decision but taking into account others' behaviour

as well. Therefore, the optimal choice is achieved when one cannot have a higher payoff when strategically accounting for the implications of the opponents' decisions (Binmore, 2007).
In certain interactions, such as the one portrayed by the PD, it can be observed the existence of a clear optimal strategy available to players involved, this is known as 'Pure Strategy Nash Equilibrium'. In the PD, as it was argued earlier, the rational and optimal response is to 'confess' (Defect) (see Figure 1) because it is the only strategy that offers the best payoff regardless of the other player's decision (Haurie, Krawczyk & Zaccour, 2012). However, a pure strategy equilibrium is not always available within the vast array of games. Nash (1951) argues that if no equilibrium exists in pure strategies, one must exist in mixed strategies – a mixed strategy, aka Randomised Nash Equilibria, is a probability distribution over two or more pure strategies. Nonetheless, there can be scenarios in which, due to their characteristics, are present multiple pure Nash equilibria. Those are usually not evenly compensating, and individuals involved do not randomise their decision-making but make their choice based on the information or expectation they have regarding others' behaviour (Skyrms, 2001) (see Appendix C for more details about mixed and multiple NE).

Regardless of the large number of games that have been generated in order to represent various social dilemmas, the PD has been the most used for the investigation of CPRs and Public Goods problems. The PD is considered to be reflective of a vast number of social and political questions, in regards of the relationship between members of a specific group (or worldwide) and their interaction towards common resources (Kuhn, 2007). However, as stated by Taylor (1987), using the 'one-shot' game (when a game involves only one round - also called static games) is an inadequate method of representation of real-life dilemmas. Indeed, when analysing field research that involves the usage of CPRs, it is possible to observe the existence of cooperation amongst individuals (e.g. Gardner et al., 1990), which would be close to unattainable if the characteristics of PD were reflected in those scenarios (Binmore, 2007). Therefore, the iterated games (with multiple rounds) can generate a more suitable representative of the conditions commonly encountered within CPRs and other commons dilemmas (Taylor, 1987). In fact, the requisites necessary in order to establish cooperation between players, which lack in static games, come into play when adding multiple rounds since they create future encounters. Consequently, it introduces the possibility of reciprocal punishment in future rounds for an individual who acts selfishly. This can foster cooperation and if the length of the game is unknown (how many times a player will have to interact with another player) it can make cooperative behaviour a beneficial and stable strategy.

The assumptions within the PD, which originally has only one pure Nash equilibrium strategy, are altered when the game is iterated. The iteration of the PD can be finite, infinite or indefinite (they can be represented by a tree diagram, see Figure 2). In the finite version, individuals play a specific number of rounds, therefore, they are aware of when the game will end. However, such knowledge defeats the argument that iteration can foster cooperation because the application of 'backward induction' will then become the only rational option (Kuhn, 2007). In other words, if players know the number of rounds (n-1), the last one becomes a 'one-shot' game and, thus, defecting will be the rational solution. Similarly, in the penultimate round (n-2) both players will know that even if they cooperate, they will defect in the next round, therefore, it is rational to defect. Hence, applying the same argument until the first round, it can be argued that the only Nash equilibrium strategy is always defection (Aumann, 1995; Luce & Raiffa, 1957) (however, some have suggested that such argument it is not as straightforward and cooperation could be established, for instance, if one believes they can influence the other with his or her decision – e.g. see Binmore 1997).

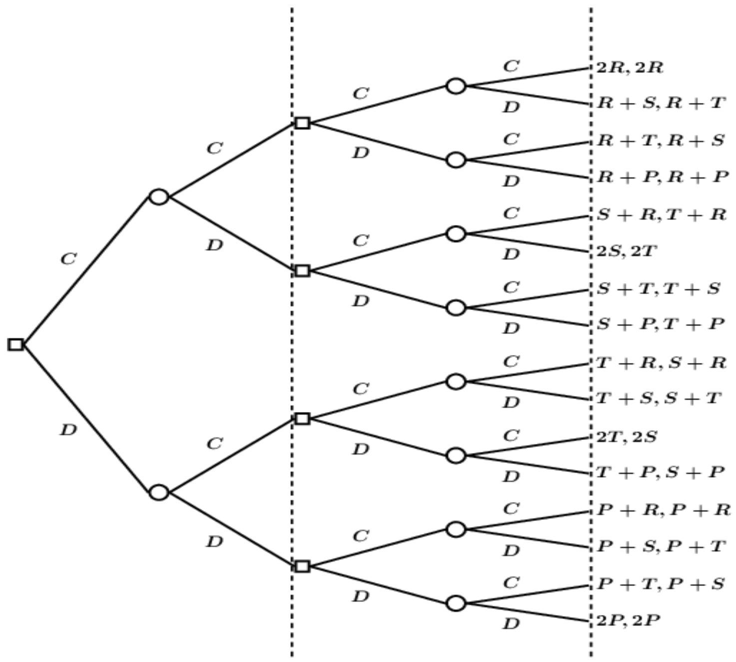

Figure 2. Tree diagram of finite IPD (Kuhn, 2007).

In order to avoid the possible effect of backward induction, an infinite repetition of the game is often introduced, which means that the game will continue for an unlimited number of rounds regardless of individuals' decisions or other influencing factors (Mertens, 1990). Although a true infinite iteration is certainly impossible for human beings, the absence of a last round generates the characteristics that may promote cooperation amongst agents (Press & Dyson, 2012). Nonetheless, for obvious reasons, infinite iterations are often considered unrealistic representatives of common scenarios and the average payoff for any given strategy reaches a certain limit when repeated infinitely (e.g. D, D = $[(1)(\infty)=\infty]$) (Binmore, 1992). Thus, an indefinite version of the iterated Prisoner's Dilemma (IPD) is usually preferred instead (Kuhn, 2007). In fact, the indefinite IPD is neither finite nor infinite but includes a certain probability p, which represents the 'shadow of the future', indicating the likelihood of another round. Alternatively, a 'discount factor' p can be applied instead, which aims to increase the value of present payoffs compared to future ones, thus, creating a geometric series (e.g. $x + \delta x + \delta^2 x + \delta^3 x + \dots \delta^n x$) (Spaniel, 2015). The probability of another round and the discount factor are treated similarly from a mathematical point of view, since what really impacts the chance of cooperation, in any stage of an IPD, is the prospect of meeting the other player for future rounds. Consequently, if p is close to zero, the IPD converts into a one-off PD game, favouring defection (Binmore, 1992).

To summarise, when the PD is indefinitely repeated, defection always remains a NE (subgame perfect equilibrium) strategy since the PD still retains the structure of a non-cooperative game, hence, players are not able to coordinate their decisions. As result, cooperation from the opponent is not guaranteed. Nevertheless, as displayed above, if two individuals are likely to meet in the future (the probability p of another round is relatively large) cooperation can become a NE as well. That is because they can each benefit from future cooperation but, mostly, one is likely to perish from the opponent's future punishment that is rationally caused by his or her current defection. In other words, the risk of a later, long term, punishment, can be a significant trigger for cooperation when the shadow of the future is large enough.

1.4 The Evolution of Cooperation

When the PD is indefinitely iterated, cooperation becomes a possible outcome. However, even if the probability p of a future encounter is relatively large, which is necessary for cooperation to emerge, this on its own is not a sufficient condition to guarantee cooperation. In fact, as already discussed, when the chance of meeting one's opponent is low or closer to zero, the rational decision is defection – the only best strategy available. Nonetheless, when the shadow of the future is large, there is no best strategy that assures an optimal outcome independently from what the other does. For instance, two individuals - player 1 and player 2 - find themselves in a PD scenario, with a good chance for them to meet again at some point in the future. If player 1 decides to defect on all of their encounters, then player 2's best move would be to defect as well. Instead, player 1 may decide to cooperate only if player 2 cooperates in return and defect forever if player 2 defects (aka GRIM or FRIEDMAN strategy). In this case player 2 is better off by cooperating. Nevertheless, that is true if the long-term payoff exceeds the one that he or she could obtain by defecting on the first encounter/round (Axelrod, 1990).

In general terms, a strategy is a set of rules that indicate what type of decision needs to be made, which, in an iterated PD, can be influenced by what the other agents' decisions are. An example is the GRIM strategy mentioned above, which starts by cooperating and keeps cooperating. However, if its opponent defects, then it switches to defection in every round until the game ends – thus, such a strategy takes into account the previous round and, conditionally, makes a decision based on the prior outcomes (Barron, 2013). Although most of the strategies that employ a conditional decision-making process tend to be NE (if the original structure of the IPD is assumed), not all strategies are necessarily NE. Hence, in order to be efficient, a strategy needs to be able to take into account the data collected during previous interactions as well as the likelihood of future interactions and act accordingly (Bearce, Floros & McKibben, 2009).

From an evolutionary perspective, a strategy is stable when no strategies can invade it since it generates a preferable outcome – these are known as Evolutionary Stable Strategies (ESS), also defined as refinements of NE (Huttegger & Zollman, 2012; Van Damme, 1992; Smith & Price, 1973). Commonly, if agents using an ESS invade a population of a weaker strategy, the EES is able to conquer the population and establish itself as a dominant strategy. For instance, a strategy that always cooperates is easily invaded by a strategy that always defects (Axelrod, 1990). However, although a strategy can follow the NE concepts of a game that is being played, a strategy can be considered an ESS only in relation to the rest of the strategies that are being used by other agents.

Axelrod (1980a) aimed to study the best strategy to employ in an indefinitely IPD scenario and invited several game theorists to submit a program (strategy) that contains a set of rules that trigger cooperation or a defection decision in every round. Interestingly, the winner of the tournament was one of the simplest strategies that were submitted – TIT FOR TAT (TFT). TFT starts by cooperating during the first interaction with another strategy, and thereafter copies what its opponent does. In other words, after the first cooperation, if the opponent strategy also cooperates, TFT cooperates again in the next round, otherwise, it will defect. The same results were found in the second tournament, even with a higher number of entries and their great sophistication (Axelrod, 1980b). It is suggested that the keys of TFT success are: (a) 'being nice' (it is never the first to defect), (b) retaliatory but forgiving (it punishes if the other defect, but it will start cooperating again if the other does too) and (c) clear (easy to predict its moves and, thus, adapt to it) (see Appendix D for more information regarding Axelrod's (1980a, 1980b) tournaments).

There is not a best strategy that one can adopt; the outcome of an interaction is dependent on what other individuals do. For instance, using an ALL D strategy (always defecting) is beneficial when encountering an unconditionally cooperative strategy and it will not be exploited from another defective strategy. Indeed, a population of ALL D is usually evolutionary stable because it can be difficult to invade by other 'nicer' strategies (Axelrod, 1990). Nevertheless, cooperation seems to emerge when two or more agents are likely to meet for an indefinite number of times over an extended (also indefinite) period. Additionally, cooperation appears to remain stable when strategies adopted are based upon reciprocity and, in particular, when the individuals start an interaction by cooperating but will switch to defection as soon as the others do (Axelrod, 1990). Alongside Axelrod's (1980a, 1980b) tournaments, this pattern of cooperation was documented during World War I (Ashworth, 2000). As matter of fact, in WWI, differently from other types of combats, small units would face each other for long periods of times. This caused the initial one-shot PD situation (killing enemies presents a higher payoff in a one-off battle) to become iterated within most trenches, thus, resulting in a reciprocal truce between enemies (Axelrod, 1990). The formation of cooperative behaviour, in such extreme conditions, demonstrates that cooperation can be established at any time if some primary conditions (iterated encounters and reciprocal approaches) are met.

Many situations, occurring in a real-life setting, often have a PD structure. However, individuals involved are not always aware of the implications that their decisions may have on a short and long term. Nevertheless, within those interactions, they often are able to strategize thanks to various rules of thumb, as well as other influential factors that are believed to be highly valuable in one's existence and social status. One of the most discussed characteristics, which seems to greatly impact the development of cooperation, is the perceived reputation of one's interactor. In other words, if an individual is considered to be 'trustworthy' (likely to cooperate), others tend to start an interaction with him or her by cooperating (Barclay, 2004). In this regard, field research (which will be discussed in the next section) as well as computer simulations, have shown that altruism -or cooperative behaviour- is observed mostly when an individual has a significant chance to earn a good reputation status. Hence, the intention to build a good reputation for oneself is more likely to foster cooperation within an interaction when there is a third agent to witness it (or when there are the conditions for others to know, e.g. one of the persons involved in the interaction tells his or her opponent's behaviours to others) – aka 'indirect reciprocity' (Leimar & Hammerstein, 2001; Nowak & Sigmund, 1998a; Alexander, 1987). Therefore, differently from 'direct reciprocity' where an agent may act altruistic with another agent that has been cooperative to them in the past, indirect reciprocity can have wider effects and, consequently, be more beneficial (Barclay, 2004). Nowak and Sigmund (1998b) indicated that, within certain circumstances, individuals do not need to directly meet again for reciprocal cooperation to be established. Instead, he argued that cooperation through indirect reciprocity can become evolutionary stable when the probability of knowing another's reputation status surpass the cost-to-benefit ratio of the cooperative behaviour. Similar results have been also displayed by lab studies, where participants took part in experimental games and had to decide whether to cooperate or defect (e.g. donate or keep the money). Those studies have shown that players tend to be more cooperative towards players that have demonstrated to be altruistic towards others in general (Barclay, 2004; Milinski, Semmann & Krambeck, 2002). These findings confirm that having information about a person's reputation, regardless of the existence of previous direct interactions, can favour the emergence and sustain of cooperation.

1.5 Life History Theory

Another important factor, which may influence an individual's decision-making process during strategic interactions, concerns the extent to which people value the present as well as the future. Researchers have given various rationalizations to explain why people prefer present payoffs instead of future ones (or vice versa). It was first argued by Strotz (1956) that people tend to be more patient when they need to decide between two rewards that are both in the future (e.g. £100 in twelve months or £120 in thirteen months). However, when individuals are faced with a decision where they need to choose between a certain present payoff (e.g. £10 today) and a higher future payoff (e.g. £15 in one month), they tend to prefer the present reward (e.g. Benzion et al., 1989). This is known as 'discounted utility theory' (Loewenstein & Prelec, 1992; Fishburn & Rubinstein, 1982) and it is generalised in the 'temporal (future) discounting' argument applied on several behavioural phenomena, which do not only involve money decisions, but also behaviours that greatly impact one's health – e.g. smoking, use of drugs, unhealthy eating habits etc. (Dassen et al., 2015; Baker et al., 2003; Ainslie & George, 2001; Frederick et al., 2002). Most researchers that analysed the future discounting behaviour, have used monetary rewards as experimental tools for a variety of situations and applied a hyperbolic discounting model – value for later rewards decrease relatively fast in short term periods (e.g. within one week) but slower for more extended delay periods ($g(D) = \frac{1}{1 + kD}$) (Laibson, 1997). However, Reuben, Sapienza & Zingales (2010) demonstrated that individuals who exhibit short-term preferences for monetary payoffs, also do so for other types of payoff (e.g. food). Thus, the results observed in previous studies, where only monetary rewards were used, can potentially be applied on a vast array of real-life situations that involve other categories of goods, for instance, common resources such as CPRs.

Individual differences, such as personality traits, seem to significantly affect the level of future discounting (see Mishra & Lalumière, 2011; Joireman et al., 2003; Strathman et al., 1994). However, for the purpose of the current research, the focus will be directed to an evolutionary explanation - known as Life History Theory (LHT) - that takes into consideration environmental cues to which an individual is exposed during his or her life.

Evolution is the result of a developmental process where species compete to gain resources from the environment. Thereafter, individuals allocate those resources, gained through different procedures (hunting, cultivating, etc.), to activities and behaviours that favour reproduction and survival. However, obtaining those resources, which can be thought of as 'energy' for the agents of a species, comes with a cost. In fact, the harvesting of resources causes an expenditure of time and energy. Hence, selection generally favours those who can optimally allocate their energy, balancing their spend-gain ratio. In other words, every individual has a finite budget of energy (e.g. finite lives, a finite number of offspring, etc.), thus, must consider the optimal way to use the resources that the environment offers, since one cannot spend more resources than there are available. Such restricted budget poses an energy trade-off problem – one must decide how to spend available energy, however, a specific decision may preclude the possibility of spending that limited energy on something else – for instance, time spent in finding food, is time not spent in sleeping or if an individual spends time in parenting, it cannot spend the same amount of time in mating with new partners (Buss, 2005). Moreover, according to West and Gardner (2013), selection benefits those who allocate their energy to best increase their personal level of inclusive fitness, which promote their success over others. However, this optimisation is dependent on individuals' features and their environment. Indeed, the optimal way to allocate energy varies from a new-born to an adult, from a healthy individual to one affected by a disease and, very importantly, from a someone living in a stable environment to one living within unstable and unpredictable conditions (Del Giudice et al., 2016).

LHT assumptions were first proposed by MacArthur and Wilson (1967) and it suggests a framework that explains how, considering the implications caused by energy trade-offs, individuals should allocate their resources in order to maximise their fitness. The initial argument postulated by MacArthur and Wilson (1967) suggested that only the density of a species' population, within a definite area, regulates the demographic traits of its individuals. Such theory has been revised over time and later models suggested that evolutionary strategies differ based on population density as well as other ecological challenges, such as mortality and morbidity rates, consistency of such rates and availability of resources and the competitiveness around them (Ellis et al., 2009; Reznick et al., 2002). When organisms face trade-off decisions, mentioned above, they choose how much to invest into the somatic effort - improving and sustaining physiological traits and embodied capitals, such as skills etc. - and reproductive effort – investing into activities that are directly associated with sexual reproduction (courtship, competition over mates etc.). These trade-off decisions can be summarised in choosing between current and future reproduction (Preston, 2014; Hill & Kaplan, 1999). Therefore, individuals that tend to invest more in the somatic effort can be described as following a slower strategy and, consequently, reproduce later in life. Whereas, those who focus on reproductive effort adopt a faster strategy, resulting in earlier offsprings (Kaplan et al., 2000). The types of strategies adopted vary amongst species (e.g. organism with a short lifespan, reproduce earlier than those with a longer lifespan), nevertheless, research suggests that the unpredictability and harshness, within a given environment, are two highly influential ecological attributes that can be used to predict strategies adopted from a variety of species (Stearns & Hoekstra, 2000). In fact, an individual living in highly unpredictable and harsh conditions (e.g. recurrent natural catastrophises, predators' threats, scarce resources etc.) cannot benefit from long-term investments in the somatic effort, since environmental threats could wipe out such investments. Hence, the best option is to develop fast strategies, prioritising the quantity of offspring, by investing most of the energy in early reproduction to assure the survival of the gene. On the contrary, species develop a slower strategy, focusing on the development of a robust phenotype and quality offspring, when their environment is stable and does not exhibit recurrent threats (Griskevicius et al., 2011).

LHT has been widely used to explain how and why humans allocate their time and resources towards distinctive purposes throughout their lives. It is observed that, alongside life history strategy differences implemented between species, there is significant variability of those strategies amongst individuals of the same species. Humans, for instance, show a large level of variation in strategies used. Indeed, people generally have a long lifespan, make great investments in a relatively small number of offspring and have slow development periods – hence, they adopt a slow strategy. However, many individuals become sexually active and reproduce much earlier than others, as well as generating a larger amount of offspring compared to the average (Meij et al., 2009; Ellis, 2004; Kaplan et a., 2000). Such individual differences are believed to be caused by mortality cues that exist in one's environment. Additionally, mortality cues can be identified in different forms – unstable natural conditions (e.g. recurrent earthquakes), violence threats (high levels of criminality), low socioeconomic status leading to scarce resources etc. (Worthman & Kuzara, 2005).

Various studies have shown that mortality cues are strongly correlated with reproductive timing. For instance, Low et al. (2008) found that life expectancy accounts for 74% of the discrepancy in age at first birth over 170 nations - shorter life expectancy predicted earlier reproduction. Similar findings were observed by Wilson and Daly (1997) when comparing different neighbourhoods within Chicago. Moreover, the same results occurred when analysing the correlation between reproduction age and crime rates across 373 counties in the US (Griskevicius et al., 2010). Therefore, these results suggest that individuals adapt their strategies based on the analyses of their environment instead of having a pre-established strategy from birth.

A low socioeconomic status (SES) has been linked with a shorter life expectancy by several studies (for a review, see House, 1990). Because of this, it can be considered as one of the most influential mortality cues within the modern world. Conversely, a high SES can generate a safe and predictable existence for an individual. Indeed, Griskevicius et al. (2011) demonstrated that people who have lived within a 'resource-plentiful' environment, are less affected by sudden mortality cues (e.g. a murder in one's relatively peaceful neighbourhood).

Additionally, fast life strategies, calibrated as consequences of mortality cues - especially low SES – have been linked to future discounting behaviour such as unhealthy lifestyles (e.g. smoking) (Pepper & Nettle, 2014) risk-taking (Figueredo et al., 2005) and favouring present rewards (Gladden et al., 2009). Interestingly, Griskevicius et al. (2011) found that people who grew up in a low SES environment were highly affected by mortality cues, influencing their temporal preferences (e.g. they preferred $5 now rather than $10 later). Although analogous studies have observed similar patterns while analysing the effects of socioeconomic differences, little research has been done looking at the direct link between SES and decision-making processes within strategic interactions. Therefore, according to the large amount of evidence confirming the influential effect of mortality cues on life strategies adopted by humans, it can be expected that low SES, as mortality cue, may play an important role in strategic situations. However, except for Griskevicius et al.'s (2011) attempt of a direct investigation, currently, there are not enough findings available for a precise conclusion.

1.6 Nature Relatedness

As shown by earlier evidence, individuals' behaviour towards CPRs can be influenced by different factors. One of the variables that have been left relatively unexamined is the relation between one's attitude towards nature and his or her CPR appropriation decisions. The potential significance of nature relatedness is due to the characteristics of most CPRs. Indeed, dilemmas arise particularly when dealing with CPRs that are naturally present in the environment (Ostrom et al., 1990)

From an evolutionary perspective, human beings have an instinctive need to connect with other living things – this is known as biophilia (Kellert, 1995). Although in modern times individuals have started living in big cities, distancing themselves from the wilderness and natural environments, it is unlikely that the importance of nature embedded in human biology has been erased. In fact, traces can be observed through the tendency of opting for outdoors activities, the establishment of zoos in urban areas and the general fondness for natural landscapes (see Hartig et al., 1996, Kaplan, 1995 etc.). Nevertheless, there is substantial variability in how strongly people feel attracted by nature and how, in return, it affects their behaviour. Hines et al. (1986) conducted a meta-analysis of several studies that had looked at contributing factors of environmental behaviour. They found that personality and attitudes have an effect on environmentally responsible behaviour (ERB). Nisbet et al. (2009) argued that a nature relatedness construct captures most of those individual differences. Thus, they developed a scale -Nature Relatedness scale (NR hereafter) – to assess how an individuals' closeness to nature is reflected in their environmental behaviour. In two studies they proved the reliability and validity of the NR scale. Moreover, they found that those high in NR also showed more environmental concern, pro-environmental behaviour and greater exposure to natural environments (Nisbet et al., 2009).

Additionally, Van der Wal (2018), taking the evolutionary evidence from LHT and biophilia into consideration, explored the effects of natural compared to urban landscapes exposure on future discounting. They used two laboratory experiments, in which participants were shown either three natural or urban landscapes pictures on the screen of a computer, followed by a temporal discounting game (e.g. 100 euros now or 170 in 90 days). Furthermore, they conducted a field study in which participants were randomly allocated to the natural condition, meeting with the experimenter at the Amsterdam forest, or urban condition, meeting the experimenter in a built-up area of Amsterdam (Zuidas). After immersing themselves in the given environment, they were asked to play a temporal discounting game. All three studies showed a significant reduction of future discounting for the participants that were exposed to natural compare to urban landscapes.

These findings are important since, both ERB and future discounting, could determine how people behave towards environmental resources. However, little attention has been devoted to their impact on social dilemma scenarios. Moreover, there could be an interaction between nature relatedness and temporal discounting. In other words, individuals may tend to discount the future less, not only when they are directly exposed to natural landscapes, but also when they generally score higher in natural relatedness affinity.

1.7 Field and Experimental Background

Due to the constant growth of the world population and its consequent effects on common resources, there has been an increasing interest in researching and understanding issues regarding the use of CPRs. In the last few decades, since Hardin's (1968) seminal paper (the 'Tragedy of the commons'), various fields, including economics, social sciences, conservation and environmental sciences, have invested a great amount of effort to identify the design principles that allow groups of interdependent individuals to govern and organise the use of CPRs – thus, avoiding the tragedy of the commons. Indeed, despite Hardin's pessimistic view of human prospect (trapped into an unavoidable, selfish, behavioural cycle), the evolutionary framework has shown that cooperation can be established when certain criteria are met (Axelrod, 1990).

Interestingly, empirical findings have shown that government ownership or complete privatisation of a CPR, as suggested by Hardin (1968) to be the only solutions to avoid exploitation, are not always effective approaches and can be counterproductive in various situations (e.g. Sneath, 1998). The majority of field studies have looked at resources managed by group property systems, which are characterised by units of users who have the rights to use the resource and can exclude others – thus avoiding the tragedy of the commons without an external entity enforcing rules and imposing punishments (Larson & Bromley, 1990). Examples of these systems can be found for the management of irrigation systems (see Messerschmidt, 1986; Sengupta, 1991; Cox and Ross, 2011 etc.), forests management (see Acharya, 2002; Agrawal, 2001), groundwater basins (see Kumar, 2000; Blomquist, 1992) etc. However, although some of the field research findings can be transferred from smaller systems to the management of global resources (Worm et al., 2009), these are often limited due to their natural characteristics. For instance, the irrigation systems can be easily controlled by a group of users thanks to their small-scale usage (see Appendix E for extended information regarding studies and different CPRs management systems).

Therefore, the need for understanding people's behaviour towards CPRs is crucial, especially when considering those that are generally difficult to monitor (e.g. air pollution). In such circumstances, reputation is not a constant factor as uncooperative behaviour often goes unseen. In addition, future encounters are often uncertain or, depending on the characteristics of the CPR, they may not be as influential. Although the technology available nowadays (including social media) facilitates the act of monitoring each other, even when two or more individuals are not physically present, this is not always enough to guarantee the same results found in field research (Ostrom et al., 1999). Thus, several lab experiments have been generated in order to gather a more insightful comprehension of the incentives underlying people's decision-making processes in regard to cooperative or defective behaviours. Furthermore, empirical research involving experimental setting allows the study of precise variables and their impact on repeated controlled scenarios – gaining internal validity, compared to the external validity acquired by field research (Ostrom, 2006).

The social-interdependence in CPR problems makes them game-theoretical in nature, even when the resources under consideration are diffuse in their spatial and temporal distribution. Therefore, using a Game Theory framework can generate ideal conditions to optimally identify individuals' tendencies reflected in real-life scenarios (Ostrom et al., 1994). (It is important to mention that there are different issues related to the existence of CPRs -appropriation, assignment, provision, monitoring etc.-, however, for the purpose of the current paper, the discussion will focus on the appropriation issue). The modelling of an experiment is critical to properly capture a CPR dilemma. Gardner et al. (1990) suggested that in order to reproduce a CPR dilemma within a lab setting, four main conditions need to be met – resource substractability, multiple appropriators, suboptimal outcomes and constitutionally feasible alternatives.

Substractability (1), as discussed earlier, represents the feature that makes the amount of a certain resource available following extraction of resources by other users. In other words, the units used by one appropriator, are no longer available (or not fully) to another individual. This aspect needs to be reflected in the dynamics of the game used, otherwise, the game is accidentally portraying a public good scenario instead of a CPR dilemma. 'Multiple appropriators' (2) is another fundamental characteristic of a CPR dilemma and it simply implies that more than one individual will be playing the game. Moreover, the configuration of the game must contain the probability of suboptimal outcomes (3) as a result of a player's strategy. Finally, the game structure needs to allow different strategies, from which at least one is a more beneficial as well as feasible alternative (4) than the ones that usually lead to exploitation.

Conditions 3 and 4 are as important as the first two in order to depict a CPR dilemma, because if there are no suboptimal outcomes and no more than one strategy that an individual can adopt, there would not be a problematic situation, hence, no dilemma (Gardner et al., 1990).

Based on this conceptual framework, which reflects the variables found in real-life CPR dilemmas, various researchers have developed different games depending on the type of dilemma they were trying to analyse. Some experimental settings have been used as extensions of field studies and addressing a very specific CPR situation. For example, Tisdell et al. (2004) conducted a lab experiment to study the impact of information on the usage of water. The participants were university students, who acted as farmers and were asked to make some trading decisions that resembled real trading in the water markets. However, although experimental settings are often inspired by extensive field research (Ostrom, 2006), these do not specifically employ definite scenarios. Instead, generalised narratives are used with the purpose to recreate circumstances that share variables underlying a larger range of CPR dilemmas.

In a typical game-theoretical study, a number of participants make a consumption decision in a controlled setting and one of the aims is to see whether people's behaviour is similar to the one predicted by the Nash equilibrium. Ostrom et al. (1990) have conducted some influential CPR studies within lab settings, using a simple baseline situation to reproduce harvesting issues that can be generally found in CPRs, such as fisheries (see Gordon, 1954). A group of 8 participants took part in each experiment. Participants were given a set of tokens, which needed to be invested in one of two markets. Market 1 was an external market and had a fixed return. Whereas, market 2 played the function of a CPR, thus, returns were dependant on what other participants did – an example of this investment could be the invested time in fishing within a certain area. In fact, market 2 was more fruitful than market 1, nevertheless, if every participant invested all of their tokens in such a market, the payoff drastically decreased, and the outcome results counterproductive. On the other hand, the harvest from the CPR reaches a maximum net level when participants endow some, but not all, of their tokens in market 2. In the end, each round, players were told aggregate information regarding the general decision made by others (not individual decisions). Findings showed that participants overinvested in market 2 within the baseline experiments. However, in a repeated study, this overinvestment decreased substantially and approached the NE predicted for the game. Interestingly, when communication was introduced, the harvesting levels moved to higher cooperative patterns

(Balliet, 2010; Ostrom et al., 1994). Such game structures produced insightful findings, nonetheless, although market 2 was not pictured as a specific CPR, it can be argued that the structure reflects a limited access resource (e.g. local fisheries). Moreover, it tackles an 'allocation' problem rather than direct appropriation.

Game theory, as a discipline, has a history developing games known as atomic games. These are games that use simple scenarios to capture essential economics of complex problems with far-reaching real-world implications (e.g. dictator game, ultimatum game, PD etc.) (Ortmann, 2016). Given its simple application to a variety of situations, the (iterated) prisoner's dilemma structure is very often used for the study of CPRs problems. Indeed, the PD is just an abstract formula of a common circumstance, where what is best for the individual result in destructive outcome for the group. Therefore, the individual must decide whether to cooperate, benefiting the group, or defect, fulfilling self-interested goals. Axelrod (1990) argued that the PD has various features that make it ideal for the study of non-cooperative scenarios, however, two of those seems to be shared by many experiments that have been developed afterwards: (a) the payoffs do not need to be symmetrical for the all the players involved and (b) one cannot assume that participant will play rationally, trying to maximize their rewards. In fact, the strategies that are used during the game may be the result of instincts, imitation or rules of thumb. Additionally, decisions may not be made consciously, ignoring that a precise strategy is being used.

Some of the studies that have used the PD have kept its simple structure, due to its vast applicability, but modified its payoff matrix. Indeed, the PD implicitly involves the use of a specific payoff matrix (T>R>P>S), however, changing this structure can be beneficial in identifying and isolating the variable of interest (Gardner et al., 1990). For instance, Taylor (1987) suggested that the 'chicken' (T>R>S>P) and 'assurance' (R>T>P>S) game, which both require only small changes in the payoff matrix, can be a better representation of certain situations.

Other instructions and rules usually vary depending on the researcher's aim (Biel, 2000). For instance, participants may be allowed to talk before the experiment begins or not. This has been shown to affect the level cooperation during the game – when participants are allowed to talk, even if they do not coordinate their later decisions, they tend to be more cooperative afterwards

(Anderies et al., 2011). It has been suggested that one of the reasons for such an occurrence is the elicitation of group identity (Van Vugt, 2009; Dawes et al., 1990).

Another influential characteristic of a given game is uncertainty. Uncertainty can be introduced by unknown or unclear knowledge regarding other's appropriation behaviour. For instance, in a repeated game, players are told the results caused by the total consumption decisions of all participants involved, but do not know the specific amount harvested by a single individual. Nevertheless, such uncertainty is reduced if the number of participants is small (Dawes, 1980). Similarly, threshold uncertainty can lead to an overestimation of the resource, thus, leading to overconsumption (Budescu et al., 1990). Uncertainty can also be introduced, in repeated games, with a given probability of a future round (the shadow of the future). As matter of fact, Duffy and Ochs (2009) found that cooperation is increased when the probability of another round is higher, which momentarily decrease uncertainty.

Several studies have investigated the above variables using game-theoretical approaches. However, the majority of those contain methodological shortcomings. For instance, Murnighan and Roth (1983) conducted an experiment using an indefinitely repeated version of the PD, with different continuation probabilities, which could be considered a valid structure to analyse social dilemmas. However, participants played against the experimenter instead of against each other. There is a large possibility that this influenced participants' behaviours since the experimenter always played a specific strategy (Grim or TFT). In fact, the experiment showed mixed results that were later discussed in detail by Roth (1995). Moreover, many studies have focused on public good problems instead of CPRs (e.g. Dannenberg et al., 2015; Barrett & Dannenberg, 2012; Fehr & Gachter, 2000; Marwell & Ames, 1981 etc.). In fact, the similarities between CPR and Public Goods have led various researchers to treat both dilemmas as equivalent. However, they are not symmetric from an economical point of view (CPRs involve rivalry) as well as from the evolutionary biology account (Dionisio & Gordo, 2006). Therefore, experimental evidence is scarce and, in some cases, inconclusive.

Based on the evidence proposed, it can be argued that repeated games produce optimal conditions to reflects real-life dilemmas. A common setting involves two or more participants, who are provided with some general instructions regarding the use of a resource – stressing the interdependence factor. All participants are given a set of rules, including the consumption allowance in each round and the initial amount of resource available. An example of such a scenario can be observed in the experimental study conducted by Messick et al. (1983), who used groups of six people and asked them to make a consumption decision in each round. They were told that the resource had an initial size of 300 units and they were able to harvest between 0 to 10 units, individually, per round. The resource used was generalised and renewable if the sum of the harvesting in each trial was not exceeding a threshold calculated by the computer. Players were instructed to maximise their gains but, at the same time, trying to maintain the resource for as long as possible. At the end of each round, information regarding the remaining units was conferred. However, the study included some complex manipulations. For instance, players were led to believe that they were playing against each other, but in reality, they were playing individually on their assigned computer and were given bogus feedback about the rest of the group. Such manipulation was used to generate different conditions, such as high and low group consumption. Moreover, players were given the chance to keep the resource 'open-access' or close it and choose a group leader. The findings showed that participants in low consumption conditions tended to increase their harvest behaviour over time - taking advantages of other's (fictitious) low consumption. On the other hand, those in high consumption conditions, although tending to overconsume overall, kept a stable behaviour throughout the game. These results suggest interesting insights in people's behavioural patterns; however, they are not always generalisable as there was not a real interaction between the participants. In addition, changes in regulation (open or restricted access to the resource) are rarely as straightforward and, in some cases, impossible (Komorita, 2019).

As mentioned earlier, indefinitely repeated games can produce more reliable results when investigating CPR dilemmas, this was further demonstrated by an important study conducted by Bó (2005). This experiment aimed at understanding the difference between indefinitely and finite game, investigate the effect of the shadow of the future in a controlled environment and gather insights regarding the influence of payoff matrix on players' behaviour. To do so, Bó (2005) used a common PD game, where players choose whether to cooperate or defect in each round. He set up two different conditions – one where participants knew exactly how many rounds were going to be played (1, 2 or 4) and a second one, where the game became indefinite due to a dice that was rolled at the end of each round in order to determine the continuation probability of the game ($\delta=0$, $\delta=1/2$ or $\delta=3/4$). Moreover, there were two additional conditions, where the payoffs changed slightly (these were called PD1 and PD2) – the main difference was that for probability $\delta=1/2$, the equilibria in PD1 were DD, CD, and DC, whereas in PD2 the equilibria were only DD and CC. Bó (2005) found that players cooperate more in the indefinitely repeated version of the game compared to the finite one. Furthermore, findings support the theoretical assumption that a greater shadow of the future results in higher cooperation between individuals; indeed, participants cooperated significantly more in δ=1/2 compare to δ=0 and when was δ=3/4 compared to δ=1/2. Finally, payoffs matrices seem to have an effect on people's decisions. Bó (2005) found that in PD2, where CC was one of the equilibria, there was higher cooperation than in PD1, where CC was not an equilibrium.

This latter study is crucial because, firstly, it implements some critical methodological correction to issues that were present in previous studies such as Murnighan and Roth (1983) mentioned earlier - but also several others (e.g. see Duffy & Ochs, 2009; Engle-Warnick & Slonim, 2006; Palfrey & Rosenthal, 1994). Additionally, it confirms the main factor in Axelrod's (1990) evolutionary theory of cooperation – the influence of the shadow of the future, which was translated as the probability of a future round. Finally, evidence gathered from this study, as well as many others, validated the postulation that an indefinitely repeated game model offers a realistic exemplification of everyday interaction and, thus, decisions that involve the use of a CPR.

1.8 The Effects of Anonymity

As shown in experimental studies (e.g. Milisnki et al., 2002) as well as computer simulations (Nowak & Sigmund, 2005), anonymity plays an important role for the occurrence of cooperation towards the usage of a CPR, due to the function of reputational consequences. Research has shown that when there are opportunities for the formation of reputation, the level of cooperation significantly increases (Fehr & Gächter, 2002). Reputation can be developed through direct or indirect interactions, thus, collecting information about another individual (past decisions). However, some studies have found that cooperation can also occur in circumstances of total anonymity. Meaning that individuals who have no information regarding others' actions (e.g. in single shot-games), nevertheless, behave altruistically (Gintis et al., 2003). Although these are striking results, since theoretically cooperation is highly irrational in such conditions, it also raises another question: what happens when individuals interact repeatedly, hence, having information regarding others' actions, but never see each other and do not know their identity (e.g. name or appearance)? In fact, it can be argued that such circumstances can be observed in real life, where people see the results of others' appropriation behaviours of a common good, but do not know the individuals with whom they are interacting.

This can be reproduced in experimental settings with various measures. For instance, Haley and Fessler (2005) were interested in understanding the effect of anonymity in economic games such as the 'dictator game'. In this game, there are usually two players. One player is the 'allocator', who is given a certain amount of money. He or she decides how much of this amount to offer to the second player, who is known as the 'responder', who does not play an active role. Simply, the responder receives any amount offered by the allocator, who keeps the rest – the equilibrium for this game is for the allocator to take everything since there are no consequences (Kahneman et al., 1986). Haley and Fessler (2005) used different manipulations to investigate whether auditory and visual stimuli affect the level of altruistic behaviour. Participants played the dictator game in a total anonymous setting, with private stations separating the two participants in each game. Experimenters referred to them as player 1 and player 2 and they were not allowed to talk. In order to recreate auditory anonymity, players were asked to use earplugs in a silent condition, whereas, visual anonymity was manipulated by adding two stylised eyes shapes on the desktop of the computer they were using. The control condition only showed a simple desktop image with the name of the laboratory – silent, non-silent, eyespots and no-eyes were crossed to produce four conditions. It was found that there was no significant effect of the auditory cues, however, those who were subjected to the presence of stylised eyespots showed significantly greater generosity.

Similarly, Charness and Gneezy (2008) studied the effect of knowing someone's name on the level of generosity. They used the dictator game as well as the 'ultimatum game'. The latter is a more strategic version of the dictator game as the responder must decide whether to accept the offer made by the allocator. Akin to the dictator game, if the responder accepts, he or she will receive the amount that was offered to them, while the allocator receives the rest. However, if the receiver rejects the offer, none of the parties will receive any monetary rewards. Assuming that both players aim to maximise their payoffs, the subgame-perfect equilibrium is for the allocator to offer a very minimum amount as the responder should be better off with a small amount compared to nothing (Güth et al., 1982). Charness and Gneezy (2008) used university students from two different universities and the games were played simultaneously online. The manipulation involved whether proposers, in both games, were disclosed the family name of their matched responders before the first move. Interestingly, the findings showed similar results as Haley and Fessler's (2005) for the dictator game. Nonetheless, no significant effect on behaviour was found in the ultimatum game, between those who know the responder's name and those who did not.

These results indicate that the knowledge of others' identity (e.g. via visual stimuli or, conceptually, their names), can affect the level of altruistic behaviour. Nonetheless, there is a clear need for further investigations, using other game-theoretical scenarios, to better understand the important implications of identity. Indeed, the dictator game portrays a situation where generosity can be considered as pure 'charity', whereas, CPRs dilemmas involve highly strategic decision-making processes (Frey & Bohnet, 1995).

2. The Current Research

Following the findings and postulations mentioned above, the current research investigates people's exploitation decisions around CPRs, using an economic game, where players make choices regarding how much of a generalised resource they would like to consume. The game draws on the strengths of previous studies. In fact, similarly to Messick et al. (1983), the game has multiple rounds and it involves participants making an appropriation from a number of units. The total amount of units available is conferred throughout the game. Moreover, based on Hardin's (1968) Tragedy of the Commons, the units refresh in each round if they are not overused. However, contrarily from Messick et al.'s (1983) study, participants will play against each other, therefore, creating a real interaction, instead of playing against a computer. Rules regarding units renewability are made clearer in the present study, whereas, Messick et al.'s (1983) research involved mathematical processes done by the computer at the end of each round. Furthermore, analogously to Bó (2005), the current study uses an indefinitely repeated game that has a similar structure of the PD but with a different payoff matrix (see Figure 3). Nevertheless, Bó (2005) uses only three different probability conditions to represent the shadow of the future (δ=0, δ=1/2 or δ=3/4), while the current paper applies a total randomised system of probability that ranges from 0 to 100 per cent in each round. Additionally, although most of CPRs problems implicate the interaction of several individuals, the present research will use a two-persons game, due to its simple structure and the great applicability of its results on larger groups (Gardner et al., 1990).

Player 2

Player 1		Cooperation	Defection
	Cooperation	25, 25	25, 75
	Defection	75, 25	50, 50

Figure 3. *Payoff matrix of the current two-persons indefinitely iterated game. (NB: this matrix assumes payoffs maximisation, treating each round as a single-shot game).*

The game is a two-player game in which participants simultaneously make an individual decision (without conferring) about the proportion of a generalized CPR resource they would like to consume (e.g. 20% of the resource). Participants will be aware of the total amount available of such resource and will earn points from their consumption decisions, but overconsumption can reduce the resource base available following rules set out to the participants before playing the game. In each round of the game, the experimenter will use a random number generator to generate a probability that the game will be played for a further round after the present one. This probability of the game continuing is communicated to the players before they make their consumption decisions.

Following Nash's (1951) theory, the current game must have at least one Nash equilibrium (NE) that prescribe how individuals who are playing rationally should play the game. Hence, an analytical solution for this game format was developed by Professor Mark Broom (Department of Mathematics, City University of London) (Appendix F gives the full proof of the analytical solution, which shows the existence of two pure Nash equilibria). The first solution suggests that cooperation is a NE if, and only if, the probability of another round is 69% (11/16) or greater. In that case, individuals should adopt a facultative conditionally cooperative strategy. Thus, where α and β are the consumption decisions of players 1 and 2 respectively, each player should cooperate if the other cooperated in the previous round

$\alpha \leq {}^{1}/_{4}$ is a NE if $p \geq {}^{11}/_{16}$ and Player 2 cooperated in preceding round

and defecting – taking everything - if the other player did not previously behave in a cooperative manner

The best reply to $\beta > {}^{1}/_{2}$ is $\alpha = 1$

Lastly, the second solution confirmed that defection – taking everything ($\alpha = 1$) – is always a NE, for any probability of a further round.

In other words, the first NE suggests playing the equivalent of a GRIM strategy when $p \geq .69$. In fact, similarly to GRIM, the NE states that a player should cooperate as long as the opponent player cooperates, and defect, by taking everything, if he or she defects. This will end the game and will not give the opportunity for the other player to correct his or her behaviour. Moreover, when $p < .69$, a player should always defect by taking the entire resource - this is the equivalent of the ALL D strategy, which starts with defection and it continues defecting until the end of the game.

The second NE states that during a game, defection (taking the entire resource) is always an optimal strategy regardless of the probability and the behaviour of the opponent player.

The present research has two main aims: Firstly, to compare participants' behaviour, during the iterated game, to the strategies prescribed by the analytical solution; and to investigate the extent of convergence/ divergence between plays and NE. Secondly, to investigate psychological factors (individual differences and life history traits) that influence the use of cooperative/sustainable strategies and competitive strategies when playing the iterated economic game - explanatory and predictive statistical approaches are used for the second aim. Moreover, to extend previous findings and further comprehend the implication of the psychological factor, the relationship between environmental cues and future discounting will be investigated.

In order to examine the individual differences that may have an impact on people's decision-making during the game, the level of nature relatedness and future discounting will be analysed. Furthermore, the assumptions proposed by the LHT – individuals living in harsh and unpredictable environments tend to prefer present reward, thus discounting the future more than individuals in stables and safe environments (Stearns, 1992) – will be tested by gathering Index of Multiple Deprivation (IMD) data.

When comparing the analytical solution to the strategies played by players during the game, one of the interests of the present study is to gather a deeper understanding of the role played by the anonymity factor. Drawings the results found by Haley and Fessler (2005) and Charness and Gneezy (2008), suggesting that the direct presence or the awareness of the identity of the other player can increase generosity, two conditions were developed. One involves players taking part in the experiment by being in the same room and, thus, seeing each other ('Seen' condition). Whereas, in the second condition participants are allocated to two different room, where they cannot see or hear each other before the end of the experiment ('Unseen' condition).

Finally, according to the analytical solution, when the probability of the next round is 69%, it acts as a switch point at which individuals change from defecting to cooperating. However, according to Schelling (1960), people coordinate their behaviour based on general conventions or personal biases. Schelling (1960) conducted various studies on this topic, one of which has become very famous and cited in the economic literature. He asked a group of undergrads to meet somewhere in New York without communicating or having any information about time and area. Although such a task may initially seem impossible to accomplish, the study showed that the most common answer was 'at noon' (time) and 'Grand Central Terminal' (place). These are known as Schelling points (or focal points) and they consist of a conventional time and place that are rationally shared by most individuals in that situation – the framing of the context is important since a person that is not familiar with New York would not be able to coordinate as well as a New Yorker (Binmore, 2007). Similarly, if two people are asked to choose between heads or tails and in order to win a prize, they need to choose the same, they are more likely to respond heads. That is because it is conventional to think about heads first when they are both mentioned (Shelling, 1960). More recent studies have shown that people tend to have Schelling point also when dealing with numbers and, especially, probabilities. Manski (2018) argues that the majority of responses to probabilistic expectation questions, with a scale ranging from 0 to 100%, tend to be around 50%. Therefore, similar inclinations could be observed while playing the current game, resulting in a different switching point from the one proposed by the NE.

2.1 Hypotheses

In relation to the first aim of the current study, it is believed that participants will follow the behaviour predicted by the analytical solution. Hence, they will conditionally cooperate – cooperating when the opponent player cooperates and defect by destroying the resource when the other participant defects - when the probability of another round is 69% or higher and move to a defective behaviour (destroying the resource) when the probability is lower than 69 per cent. Moreover, following the idea of Schelling points (Schelling, 1960), the true switch point from defection to cooperation may differ from the equilibrium solution (69%) and it will be a more cognitively intuitive value - 50%. Therefore, it is predicted that participants will play more cooperatively when the probability of another round is 50% or higher, whereas a greater number of defections will be played when the probability is lower than 50%.

Based on previous research as well as theoretical assumptions, it is predicted that (a) those who score higher in nature relatedness will play more sustainable strategies, (b) individuals that discount the future less steeply will play more sustainable strategies and (c) players in the 'seen' condition will use more sustainable strategies. Moreover, following the predictions of life history theory, (d) individuals who live in more deprived areas will experience greater cues of environmental stress and this will influence resource allocation strategies. Behaviourally this will result in individuals from stressed environments (low IMD) playing less sustainable strategies. Finally, it is predicted that (e) those who live in stressed environments will also discount the future more steeply.

3.Method

3.1 Participants

All participants were students or alumni from Middlesex University. All participants were volunteers. Psychology students were able to join the study by signing up through the university's participant recruitment system (SONA), whereas, for external participants the researchers organised experimental sessions through email. A total of 116 participants took part in the experiment and there were no exclusions during the screening of the data. Sixty participants were first year psychology students, who were accredited with one research credit towards their university course. The remaining 56 participants were students from different courses as well as alumni, who were recruited by the researcher through social, professional and friendship networks. As participation reward, participants (except for the first-year psychology students, who received course credit) entered a prize draw that involved 12 Amazon vouchers with a value of £5 each. Participants were 37 males and 79 females, with age ranging from 18 to 44 (M=21.92, SD=4.79) There were no specific eligibility criteria apart from an adequate level of English proficiency.

3.2 Design

There were two parts to the study. The first involved the collection of participants' data on age, sex, postal address (as a proxy of IMD and life history cues) and the completion psychological scales measures (NR-6 and CFC)

The second part of the study involved participants in pairs playing an economic game where, over a number of rounds, they make individual consumption decisions, exploiting a generalised Common Pool Resource. Two conditions were used for the economic game: In the first, participants played in the same room, so they were face to face with their opponent (Seen). In the second, participants played the game in separate rooms and never encountered their opponent face to face (Unseen). These conditions were a between-subjects factor.
The IVs were the psychological scales, life history cues and game conditions. The DVs were players consumption decisions within rounds and the total number of cooperation decisions within games.

3.3 Game and Materials

The current study employed an economic game, for which a mathematical proof (Appendix F) had been developed, in order to investigate the extent to which the behaviour of real players corresponds to the equilibria predicted by the mathematical solutions. It was a two-player game in which participants simultaneously made an individual decision (without conferring) about the proportion of a generalised CPR resource they would like to consume (e.g. 20% of the resource). Participants earned points from their consumption decisions, but overconsumption could reduce the resource base available following rules set out to the participants before playing the game. In other words, every game starts with reward value (V) of 100 units available to both participants from which they make consumption decisions – α and β. Each player could choose to take any amount from the units available (e.g. if V is 100, one can make an appropriation that ranges from 1 to 100 – with no decimals values). After players' decisions, the reward value maintains the same number of units retained at the beginning of a round only if the sum of the appropriations is 50% or less of the initial amount, following inequality (1):

$$\text{if } \alpha + \beta \leq {}^{1}/_{2} \text{ of } V\text{, then } V \text{ stays } 1 \qquad (1)$$

However, if the total consumption exceeds 50% of the units available at the beginning of a round, the resource will not refresh, and the consumption will be subtracted from the available units. This means that each player cannot take more than 25% of the units available in order for the resource to refresh as shown in (2):

$$V(1 - \alpha - \beta) \text{ if } {}^{1}/_{2} < \alpha + \beta < 1 \qquad (2)$$

The game ends when the consumption equals or exceeds the available resource (inequality (3)):

$$V \text{ becomes 0 if } 1 \leq \alpha + \beta. \qquad (3)$$

The game was iterated and in each round of the game the experimenter used a random number generator (https://www.random.org) to generate a probability, ranging from 0 to 100 percent, of another round. In other words, how probable is the occurrence of another round after the present one. This probability was communicated to the players before they made their consumption decisions in the current round.

The analytic solution developed for this game shows the existence of two possible Nash equilibria. The first solution suggests that if the probability of there being another round is ~69% (11/16) or greater, then individuals should adopt a conditionally cooperative strategy. Such a strategy follows a simple concept: cooperate if the second player cooperated in the previous round and defect, by taking all the available resource units, if the second player did not behave in a cooperative manner. Conversely, if the probability of there being another round is less than 69% then players should always defect (by taking all the resource units), thus, playing a more selfish strategy. The second Nash equilibrium indicates that it was always rational to defect, regardless the probability of next round and previous behaviours from opponent players (See Appendix F).

Participants were sequentially assigned to two different conditions of the game: (1) "Seen" (N=60), where two players were allocated in the same room while playing the game, and (2) "Unseen" (N=56), where participants were allocated to different rooms, avoiding any visual or auditory contact between them.

Prior to the game, all participants were asked to complete a questionnaire scale relating to how connected they feel to nature, the NR-6 nature relatedness scale (Nisbet & Zelenski, 2009), which is a 21 items paper-and-pencil questionnaire and uses a 5-point Likert scale that range from 1, disagree strongly, to 5, agree strongly. The scale includes statements such as "I enjoy being outdoors, even in unpleasant weather" or "My feeling about nature do not affect how I live my life". Moreover, the Consideration of Future Consequences (CFC) scale (Strathman et al. 2013) was used to assess the degree to which participants discount future rewards. This is a 12 items paper-and-pencil questionnaire, using a 5-point Likert scale that range from 1, extremely uncharacteristic, to 5, extremely characteristic. Statements such as "My convenience is a big factor in the decisions I make or the actions I take" and "I only act to satisfy immediate concerns, figuring the future will take care of itself" are presented in this scale. Participants were also asked to provide their current, and previous postcode (if applicable), with at least five year of residency. These were used to collect the indices of multiple deprivation data, at the neighbourhood level, associated with each postcode. Personal details, including names, were not required for this research and all data was anonymised. The multiple deprivation data was analysed as an indicator of life history cues regarding levels of environmental stressors.

3.4 Procedure

The study was granted ethical approval by Middlesex University Research ethics Committee (Application N. 8122 (Appendix H)). Before the experiment, participants were instructed via email about the location and timing of the experiment. When a pair of participants were assigned to the Seen condition, they were asked to go to the same location and at the same time and were given a desk in the same room. On the other hand, when a pair of participants was assigned to the Unseen condition, they were asked to go to the same location but at slightly different times, to avoid contact prior to the start of the experiment. They were then guided to different rooms, where they took part in the experiment in complete anonymity.

Participants were first presented with an information sheet containing some general information regarding the study, followed by a consent form. Subsequently, the two questionnaires - NR-6 and CFC - were presented. The pre-game phase ended with a second information sheet explaining the rules of the game. When both participants had completed all questionnaires and read all information relevant to the experiment, the researcher summarised the rules to participants before beginning the game.

In the Seen condition, the researcher was in the same room with participants, from the start to the end of the game. Whereas, in the Unseen condition the researcher was in a separate room and communicated with the players mainly through walkie-talkies that were installed in the rooms.

On each round, the researcher announced the units available and the probability of a next round. Participants wrote their decision - number of units they wanted to consume - on a piece of paper, which was handed to the experimenter (in the Unseen condition, the researcher would go and collect those from each room). A datasheet was used by participants to record their consumption decisions for each round of the game. After each round the researcher calculated the sum of the units taken by both participants. If the sum was 50% or lower than the available units, these were refreshed for the next round, whereas if is the sum exceeded 50%, only the difference (available units minus consumption) was left for the next round. In both cases, this information was communicated to participants. The game continued until the resource was destroyed, meaning that the available units reached zero. A debrief with a unique code was handed to the participants at the completion of the experiment. (An example of the data collection pack used by participants is shown in Appendix I).

3.5 Statistical Analysis

The data was analysed using IBM SPSS version 25 (IBM Corp., 2017). Table 1 shows descriptive statistics for number of games played and number of total rounds played across all games.

Table 2 gives descriptive statistics for the number of games in the Seen/Unseen conditions and frequency counts for the number of rounds played when the probability of another round was greater than 69% or less than 69%.

3.5.1 Investigation of the analytical solution

The first part of the analyses investigated one of the key questions of the current research – How participants' behaviour differs from the analytical solution of the game.

As stated previously, the analytical solution suggests that there are two possible Nash equilibria (NE): (1) conditionally cooperation if the probability (p) of a next round is 69% or more and (2) defect, by taking the entire resource available, when p is less than 69 percent. However, the latter is always a NE, regardless of the probability.

Table 1. *Total number of games and rounds played.*

	N
Games	58
Rounds	588

Strategies played in each round were coded into a binary variable (0 for defection and 1 for cooperation). A second binary variable was also coded to analyse whether cooperations were NE, thus conditional (i.e. cooperate only when the opponent player cooperated in the previous round) – 0 for Non-Nash and 1 for NE. This second variable also accounted for whether defections were NE, which occurred only when participants defected by taking the entire resource and, as result, ending the game (any other defection was not considered as NE). Finally, given the purpose of the analysis, Probability was also coded into a binary variable – 0 for $p < 69$ and 1 for $p \geq 69$. (from hereafter Probability and Nash Equilibrium are used to refer to the variables used in the models).

Table 2. *Number of rounds in each Probability level ($p \geq 69$, $p < 69$) and number of games in each Condition level (Seen, Unseen)*

		Frequency counts (N)	Percentile (%)
Probability	$p \geq 69$	256	44
	$p < 69$	332	56
Condition	Seen	30	52
	Unseen	28	48

A set of cross-tabulations and binary logistic generalized estimating equations (GEE) models were used to analyse the data. The application of GEE accounts for non-independence of data points in the response variable, which is caused by repeated observations within each participant over the multiple rounds played during a game. Moreover, GEE is generally a robust method of analysis and focuses on the population-average in terms of the coefficients effect, rather than subject-specific as it occurs in mixed-models (Hubbard et al., 2010).

In order to examine participants behaviour against the analytical solution over the various rounds played throughout the 58 games, the three variables (Strategy, Probability, Nash Equilibrium) were added to the models, depending on the analysis. Three main steps were undertaken:

(1) Investigation of the extent strategies played in each round (cooperation – defection) were affected by Probability ($p < 69$ – $p \geq 69$).

(2) Examination of the effect of Probability and Strategy on the occurrence of NE plays. (e.g. do people play more NE when $p \geq 69$ compare to $p<69$? Or, do people play more NE when they cooperate compared to when they defect?).

(3) Lastly, since there were two possible NE when p was 69% or higher (contrary to $p < 69$), Investigation of the effect of Strategy on Nash Equilibrium when $p \geq 69$ (e.g. when $p \geq 69$, do people play NE more when they cooperated or when they defect?).

Additionally, as suggested by Manski (2018), the majority of responses to probabilistic expectation questions, with a scale ranging from 0 to 100%, tend to be around 50%. A similar predisposition is expected to be found during the game scenario of the current research. Indeed, as the Schelling Theory proposes, 50% is assumed to be more cognitively intuitive than 69% - the latter is relatively specific, and some individuals could consider it still significantly high. Therefore, in order to test the hypothesis that strategies played will tend to follow the Schelling point (i.e. participants would switch from cooperation to defection when p is under 50% instead of 69%) another nominal binary variable was generated (Probability 2) – coded 0 for $p < 50$ and 1 for $p \geq 50$. As for the analyses described above, another binary logistic GEE model was performed.

3.5.2 Explanatory and Predictive modelling of influential factors

The second part of the analyses aimed to answer the second research question of the current study – what are the individual differences and environmental factors that predict people's behaviour in the strategic situation presented by the CPR economic game.

Four predictors were considered for this investigation: NR (continuous variable generated using the mean score of the Nature Relatedness scale for each participant), CFC (continuous variable generated using the mean score of the Consideration of Future Consequences scale for each participant), IMD (continuous variable generated using the Index of Multiple Deprivation for each participant) and Condition (binary nominal variable, coded 0 for the Seen – where participant were in the same room - and 1 for the Unseen – where participants were allocated to different rooms).

In order to develop a complete comprehension of the implication of these four predictors, two different methods were undertaken – explanatory and predictive.

For the explanatory approach, the influence of the four predictors was investigated using consumption decisions as the dependent variable. Consumption was a continuous variable, which included every consumption decision made by participants in each round (N=588). A One-Sample Kolmogorov-Smirnov Test, as well as the examination of a Q-Q plot of the residuals, indicated that the data was not normally distributed. On the other hand, for the predictive approach, Number of Cooperations was used as the dependent variable. This was a count variable that involved the sum of all the cooperations played during a game by each participant (these also included cooperation that were not NE).

To investigate the effect of the predictors on Consumption, a Gamma GEE model with log link was employed to account for the non-normal distribution of the data as well as the non-independence of data points. The four predictors were adjusted to allow a within-subject analysis. Additionally, a further simple linear regression, adding CFC as dependent variable and IMD as independent variable, was used in an attempt to replicate the findings observed in previous studies where environmental cues had a significant effect on individuals' degree of future discounting. This aimed to gain a better understanding of the implication of these predictors on participants' behaviour.

For the predictive approach - using Number of Cooperation as response variable - data was analysed using a series of generalized linear models (GLM). Due to observed overdispersion in the count data point ($\chi 2/df = 2.640$) when entered into an intercept-only Poisson loglinear GLM, a Negative Binomial (NB) model with a log link function was used. The NB accounts for the overdispersion by loosening the restrictive assumption of the Poisson model that the data variance needs to be equal to the mean (Hilbe, 2011).

4. Results

4.1 Players' behaviour as function of probability and strategy as predicted by the analytical solution

Table 3 shows the descriptive statistics for Strategy and Nash Equilibrium, indicating the total number of NE (and Non-NE) plays as well as cooperations and defections occurred throughout the 58 games. Results portrayed a considerable difference between NE and Non-NE plays, where only 152 play (out of 588) resulted to be NE. However, there was not a large difference between cooperations and defections played.

Table 3. *Total frequencies within rounds for Strategy (Cooperation, Defection) and Nash Equilibrium (NE, Non-NE).*

		Frequency counts (N)	Percentile (%)
Strategy	Cooperation	287	49
	Defection	301	51
Nash Equilibrium	NE	152	26
	Non-NE	436	74

4.1.1 Investigation of the extend strategies played in each round (cooperation – defection) were affected by Probability ($p < 69$ – $p \geq 69$).

In order to assess the first step of the analyses an initial binary logistic GEE analysis was conducted using Strategy as response variable and Probability as predictor (Table 4). This indicated a non-significant effect of Probability on Strategy played, Wald $\chi 2(1)=2.058$, $p=.151$. Therefore, there was no significant difference between cooperation and defection, regardless the probability of another round.

Table 4. *Frequency occurrence of Strategy (Cooperation, Defection) within Probability (($p \geq 69$, $p < 69$)*

		Strategy	
		Cooperation N (%)	Defection N (%)
Probability	p < 69	153 (46%)	179 (54%)
	p ≥ 69	134 (52%)	122 (48%)

4.1.2 Examination of the effect of Probability and Strategy on the occurrence of NE plays.

A second GEE analysis was performed, adding Nash Equilibrium to the model as the dependent variable, whereas, Strategy and Probability were added as predictors (Table 5). This was used to investigate a possible influence of Probability and Strategy on the probability of playing a NE in each round. The results suggest a main effect of Probability on Nash Equilibrium, Wald $\chi 2(1)=91.667$, *p<.001*. Specifically, the GEE outcomes show that the odds of playing a NE, instead of a Non-NE, when p ≥ 69 are estimated to be exp(3.032)=20.732 times the corresponding odds of when p < 69. In other words, when p ≥ 69 there is a 95% probability of playing a NE, whereas, when p < 69, the probability of playing a NE is only 32% - the odds ratio (i.e. exponentiated coefficient) was converted into probability dividing the odds by one plus the odds. Table 4 shows that when p ≥ .69, 52% of the plays were NE, while only 6% of the plays were NE when p < .69.

In addition, there is a significant main effect of Strategy on Nash Equilibrium, Wald $\chi 2(1)=45.289$, *p<.001*. In fact, when people cooperate the odds of playing a NE are estimated to be exp(1.767)=5.854 times higher than when people defect. Precisely, when individuals cooperate there is 85% probability of playing a NE, compared to a 15% probability when they defect instead.

Table 5. *Frequency occurrence of Nash Equilibrium (NE, Non-NE) within Strategy (Cooperation, Defection) and Probability (p ≥ 69, p < 69).*

		Nash Equilibrium	
		NE N (%)	Non-NE N (%)
Strategy	Cooperation	112 (39%)	175 (61%)
	Defection	40 (13%)	261 (87%)
Probability	p ≥ 69	132 (52%)	124 (48%)
	p < 69	20 (6%)	312 (94%)

4.1.3 Investigation of the effect of Strategy on Nash Equilibrium when p ≥ 69.

Lastly, to specifically investigate the effect of Strategy on Nash Equilibrium when p ≥ 69, a further GEE analysis was conducted holding p ≥ 69 constant and adding Nash Equilibrium as the dependent variable and Strategy as predictor to the model (Table 6). The findings demonstrated a significant main effect of Strategy, Wald $\chi 2(1)=92.883$, *p<.001*. In details, when p is 69% or higher, the estimated odds of playing a NE when participants cooperate are exp(3.257)=25.954 higher than when the play defection. In other words, when p ≥ 69, there is a 96% chance that individuals who cooperate will also play a NE, whereas, if they defect there is only a 3% chance they will play a NE.

Table 6. *Frequency occurrence of Nash Equilibrium (NE, Non-NE) within Strategy (Cooperation, Defection) when p ≥ 69.*

		Nash Equilibrium	
		NE N (%)	Non-NE N (%)
Strategy	Cooperation	112 (84%)	22(16%)
	Defection	20 (16%)	102 (84%)

4.1.4 Analysis of Strategy employed, within rounds, by each player in relation to the opponent's behaviour.

A crosstab investigation was conducted to analyse the number of cooperations and defections that occurred as results of conditional play, independently from the NE. Results showed that 82% of all cooperations were conditional to the other player's behaviour, whereas, 62% of all defections followed a defective behaviour initiated by the opponent agent.

4.1.5 Investigation of players' behaviour against the Schelling point hypothesis

In order to test the Schelling point hypothesis, similarly to the previous analyses, a binary logistic GEE model was performed. This included Strategy as response variable and Probability as predictor. However, p was entered as two different variables. In fact, apart from the nominal variable ($p < 50 - p \geq 50$) (Table 7), a continuous version was utilised in order to examine a general effect of probability on strategies played. The GEE results indicated that there is no significant main effect of Probability 2, as nominal variable, on Strategy, Wald $\chi2(1)=.878$, *p<.712*. Moreover, there is a no significant main effect of Probability as continuous variable, Wald $\chi2(1)=.000$, *p<.998*.

Table 7. *Frequency occurrence of Strategy (Cooperation, Defection) within Probability 2 (p ≥ 50, p < 50)*

		Strategy	
		Cooperation N (%)	Defection N (%)
Probability(2)	p < 50	90 (43%)	118 (57%)
	p ≥ 50	197 (52%)	183 (48%)

4.2 Individual differences and environmental factors as predictors of cooperation and mean consumption.

Table 8 shows the descriptive statistics for CFC and NR-6 scores and IMD. Mean and Standard Deviation are reported for the overall data as well as by Conditions (Seen, Unseen). Results indicate minor differences between conditions. Therefore, any implication of Condition will not be the result of confounding interactions with the other IVs.

***Table 8**. Descriptive statistics for NR, CFC and IMD, by Condition and overall.*

	Total M (SD)	Seen condition M (SD)	Unseen condition M (SD)
NR	3.33 (.580)	3.32 (.582)	3.34 (.583)
CFC	3.59 (.524)	3.53 (.520)	3.65 (.521)
IMD	12673.2 (7000.7)	13197.4 (7304.5)	12112.2 (6679.9)

4.2.1 Generalized Estimating Equations within game with Consumption as response variable.

A GEE Gamma model with log link was performed to assess the effect of individual differences and environmental factors on the consumption decisions made by participants in each round. NR, CFC, IMD and Consumption were added to the model as main effects, whereas Consumption was added as response variable. The results display a non-significant effect of NR, Wald $\chi 2(1)=2.225$, *p=.136;* a non-significant effect of CFC, Wald $\chi 2(1)=.539$, *p=.463;* and a non-significant effect of IMD, Wald $\chi 2(1)=.022$, *p=.882.* However, there was a significant effect of Condition, Wald $\chi 2(1)=5.882$, *p=.015.* In detail, when participants are in the Unseen condition, it is expected for their consumption decisions to be exp(.190)= 1.209 times (21%) higher than those in the Seen condition (see Figure 4)

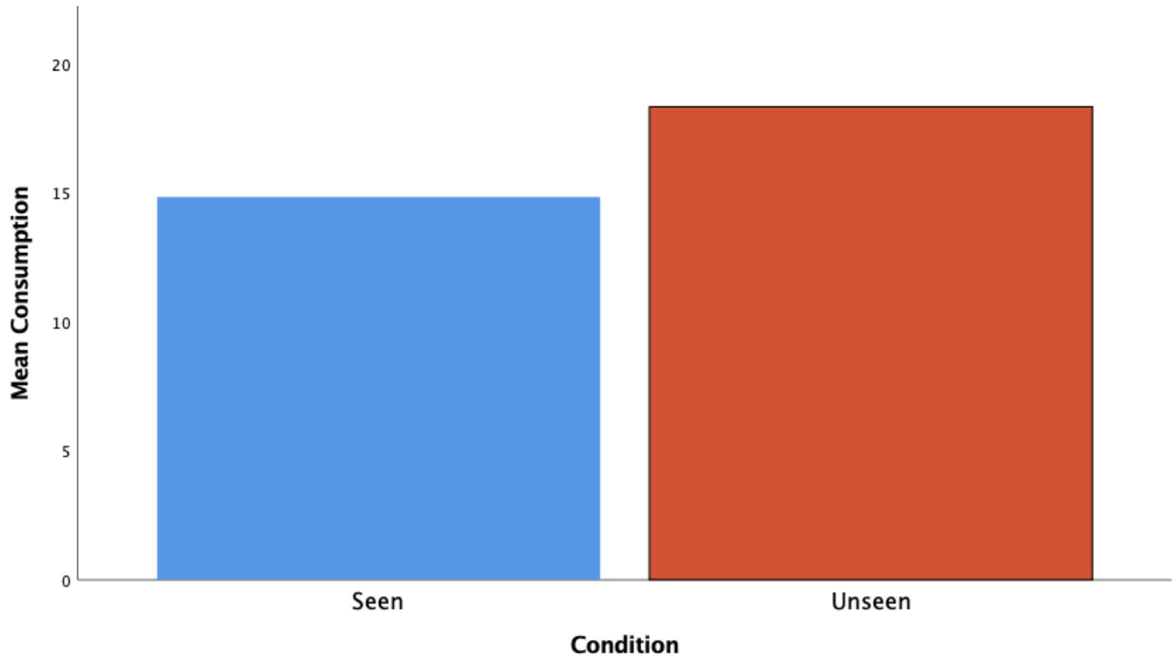

Figure 4. *Relationship between mean consumption and condition levels.*

4.2.2 Simple Linear Regression between IMD and CFC

A simple regression was used in order to analyse the effect of IMD on CFC. The findings show a non-significant effect of IMD (F(1, 114)=.651, p = .421, R^2 = .006). Therefore, participants' degree of evaluation of future consequences was not influenced by their IMD.

4.2.3 Generalized Linear models with Number of Cooperations as response variable

A series of Generalized Linear Models (N=45), using a Negative Binomial model with log link and a parameter set at .5, were developed to investigate the main effects and interactions between the four independent variables - NR, CFC, IMD and Condition - and the outcome variable Number of Cooperations. A sequential approach was taken where predictor variables and interactions were added to the models one at a time. The first criterion used for model selection was the consideration of associated Akaike Information Criterion (AIC) value. The AIC is a measure of the goodness of fit, normally implemented using a lower is better approach (Zeileis, Kleiber & Jackman, 2008). An initial selection of ten models with lowest AIC values was made (details of these models, ordered as they were originally generated, are outlined in Appendix G). Moreover, as shown by the Omnibus test (likelihood-ratio chi-square test), only three of the 45 models were significantly better than an intercept only model. These were part of the initial ten selected models (model 8, 9 and 10) and were the ones that yielded the lowest AIC values (see Table 9).

Table 9. Summary of generalised linear models using a Negative Binomial model with log link. *Exploring the effects on Number of Cooperations, of NR, CFC, IMD and Condition. Model 8 was retained as the best fitting model.*

Model	95% Wald CI	Std. Error	P	Deviance	Df	Omnibus Test(Sig.)	AIC
8				126.26	112	.024	478.26
NR	[.1176, 1.1346]	.2594	.150				
Condition			.				
Seen	[.7209, 5.1540]	1.1308	010				
Unseen							
Condition:NR							
Unseen:NR	[-1.4208, -.1252]	.3305	.021				
Seen:NR	[.1176, 1.1346]	.2594	.150				
9				123.35	111	.015	477.36
Condition							
Seen	[.7465, 5.284]	1.1577	.009				
Unseen	.	.	.				
IMD	[-.000003, .000046]	.000012	.078				
NR	[.0978, 1.137]	.2652	.222				
Condition:NR							
Unseen:NR	[-1.4739, -.1456]	.3387	.017				
Seen:NR	[.0978, 1.137]	.2652	.222				
10				122.20	110	.019	478.20
IMD	[-.000002, 0.000047]	.000013	.077				
NR	[.07833, 1.100]	.2656	.315				
Condition							
Seen	[.8856, 5.3631]	1.1633.	.007				
Unseen	.		.				

CFC	[-.1673, .5812]	.1946	.284
Condition:NR			
Unseen:NR	[-1.4913, -.1833]	.3400	.025
Seen:NR	[.07833, 1.100]	.2656	.315

This led to a final selection, which accounted for significance of the variables included as well as the overall simplicity of the model. Indeed, Model 8 contained NR and Condition as main effects as well as an interaction between Condition and NR. From the main effects, NR was not significant at the p=.151, while Condition as well as the interaction between Condition and NR resulted significant at the p=0.010 and p=0.021 respectively. Model 9 included three main effects – Condition, IMD and NR – and the interaction between Condition and NR. However, while Condition and the interaction between Condition and NR were significant (see Table 8), IMD (albeit trend level) and NR resulted to be non-significant at the p=.089 and p=.222 respectively. Model 10 included all four main effects as well as an interaction between Condition and NR. However, the model contained three non-significant main effects: IMD at p=.075, CFC at p=.284 and NR at p=.315. Similar to Model 8 and 9, Condition and the interaction between Condition and NR were significant (see Table 9). This suggested that the more complex models, adding three or four main effects, were no better at accounting for information in the data than the simpler model. On this criterion Model 8 was retained as the best fitting model.

Nevertheless, examining the Tests of Model Effects table generated by the GLM analysis, NR was found to be non-significant towards the model, which suggests that including NR in the model does not significantly increase its fit. Therefore, NR, as main effect, was subsequently excluded from the final model, which only included Condition and the interaction between Condition and NR – this yielded almost the same AIC value and lower standard errors (see Table 10).

Table 10. Final Model. *Simplified Model 8, including Condition as main effect and interaction between Condition and NR.*

Model	95% Wald CI	Std. Error	P	Deviance	Df	Omnibus Test(Sig.)	AIC
8a				127.36	112	.039	478.36
Condition							
Seen	[.2300, 2.1369]	.4864	015				
Unseen	.	.	.				

Condition:NR			
Unseen:NR	[-.2270, .1077]	.0854	.024
Seen:NR	[.0317, .4581]	.1087	.485

In the final model (Model 8a), condition showed a significant main effect, Wald $\chi2(1)=5.919$, *p=.015*. Specifically, when the condition is Seen, the number of cooperations played by participants are expected to be exp(1.184)=3.266 times (227% increase) higher than the Unseen condition.

However, it is important to take into account that Condition as main effect becomes significant only after the interaction with NR is added to the model (see Appendix G). From the interaction it can be observed a negative relationship between the Seen condition and NR, however, this is not significant, Wald $\chi2(1)=.488$, *p=.485*. Nevertheless, there was a significant relationship between the Unseen condition and NR, Wald $\chi2(1)=5.070$, *p=.024*. Differences between the two sites, and their interaction with NR, were investigated graphically by plotting Number of Cooperation against NR in two graphs divided by Condition, as shown in Figure 5. A positive correlation was apparent between Number of Cooperation and NR when the condition was Unseen. On the other hand, the scatterplot representing the Seen condition confirms the non-significant interaction mentioned above.

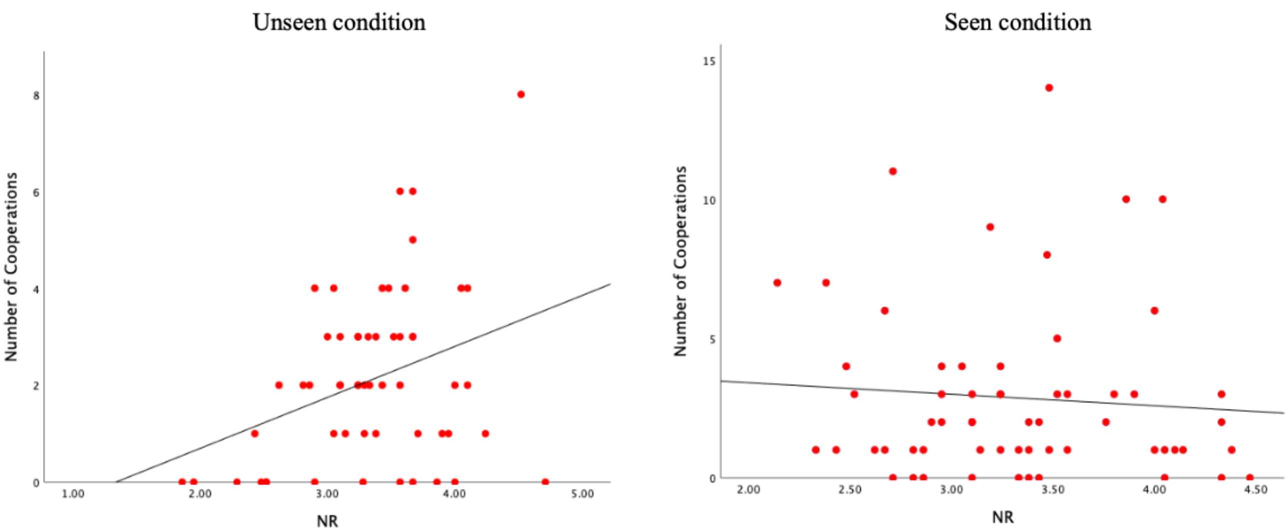

Figure 5. NR means plotted against Number of Cooperations. *Plots shown for Unseen and Seen condition with fitted regression lines.*

In summary, it can be observed that when the condition is Unseen individuals tend to cooperate significantly less compared to the Seen condition. However, Figure 5 shows that, when the condition is Unseen, players who score higher in the NR scale are also likely to play more cooperations compared to those who scored lower.

5. Discussion

The present study aimed to investigate individuals' behaviour in strategic situations. For this purpose, an iterated game was developed, and players' consumptions were recorded in every round to analyse how these differ from the analytical solution. Moreover, there was an interest in identifying the factors that promote cooperative and defective behaviour.

The first part of the study tried to empirically investigate how people behaved within rounds, thus, four GEEs with binary logistic models were used. Results showed a non-significant effect of probability on strategy played. This indicates that there was no significant difference between the number of cooperations and defections played, independently of whether the probability of another round was lower or higher than 69 per cent. Similar results were yielded by the investigation of 50% (probability) as a switch point from defection to cooperation. Indeed, a non-significant effect was found and, thus, there was no significant difference between the number of cooperations and defections played in either $p < .50$ or $p > .50$. Interestingly, probability of another round had a non-significant effect even when considered as a continuous variable. In other words, as probability increased, the number of cooperations did not significantly increase, and defections did not decrease accordingly (or vice versa). However, a significant main effect of Probability on Nash Equilibrium was found. When the probability of a further round was equal or higher than 69 per cent, the odds of playing a Nash Equilibrium was much higher compared to when the probability was less than 69 per cent. Moreover, analysing the descriptive statistics, it was observed that when $p \geq .69$, 52% of the plays were NE, whereas when $p < .69$ only 6% of the plays were NE (overall, 26% of the plays were NE). Finally, a main effect of Strategy was also observed, suggesting that when players cooperated, they were also more likely to play a Nash Equilibrium compared to when they defected. When considering only rounds with probability equal or higher than 69 per cent, the analysis confirmed a significant effect of strategy played on Nash Equilibrium. Meaning that when $p \geq 69$, participants who cooperated were drastically more likely to play a Nash Equilibrium compared to those who defected.

The hypotheses proposed for this first part of the study were partially met. The first hypothesis predicted that participants would follow the Nash Equilibria suggested by the analytical solution. Thus, when $p \geq .69$, they would cooperate when the opponent player cooperated and defect, by taking the entire resource if the opponent player happened to defect in a previous round. Moreover, when $p < .69$ the significant majority of the plays were expected to be defection (by taking everything). The results, as outlined above, show that only 26% of all the plays were NE. These results were further supported by the non-significant effect of Probability on strategy played, which suggests that when $p < .69$, players did not play only defections, as it was predicted, but cooperated almost as equally as they defected. The additional analysis conducted to investigate the divergence from the analytical solution shows a significant difference between $p \geq .69$ and $p < .69$ in number of NE played (52% of the plays were NE when $p \geq .69$ and only 6% were NE when $p < .69$). Although this does not support the hypothesis, which assumes that the number of NE played should be equally high in both categories, it is not surprising if taking into account the characteristics of the NE. In fact, while $p \geq .69$ included two possible NE (cooperate or defection), $p < .69$ allowed only defection as NE. Additionally, in order to be considered a NE, defection had a narrower requirement (taking the entire resource) compared to cooperation (any amount within ¼ of the available resource). Further analysis confirmed a significant effect of Strategy - participants were more likely to play a NE when they cooperated compare to when they defected.

As suggested, an explanation for such findings could be attributed to the narrowed characteristic required to play an "optimal" defection. Indeed, it can be argued that this could have made the NE a far less intuitive option and participants were not able to cognitively reach such solution within a certain amount of time. Fudenberg and Levine (1993) suggested that often NE is the result of learning from past observations. However, defecting by taking the entire resource available is an irreversible maximisation of one's outcome since it causes the game to end. Therefore, there cannot be a recurrence of the same behaviour and, consequently, the learning factor is unavailable. Moreover, previous research has shown that individuals' behaviour tends to differ from the predicted NE when this assumes that players care only about their self-interest, thus trying to maximising the outcome at all times (Wolff, 2015). This relates to the assumption of the NE in the current study, which presumes that individuals will maximise their consumptions regardless of the negative consequences that such behaviour may cause to the opponent player (i.e. future unavailability of the resource due to its destruction). Evidence found in various studies support this idea, suggesting that individuals tend to behave cooperatively even in situations where the only NE is defection; e.g., one-shot PD (Dreber et al., 2013; Dreber et al., 2008; Becker et al., 2006). The conjecture of complete rationality, (Homo Economicus) from agents in a strategic situation, has been often disproven. This indicates that, in order to be evolutionarily successful, behaviour does not need to be necessarily selfish (Camerer, 2011). Due to the mathematical nature of the Nash Equilibrium theory, social preferences tend to be overlooked (Fehr & Fischbacher, 2002). Nevertheless, experiments from different countries and with different game structures, have found that in addition to the factual payoff, participants express an unequivocal tendency to care about fairness while playing the games (Henrich et al., 2005). That is not to say that individuals always cooperate unconditionally even when it is not reciprocated. In fact, punishment for defective behaviour has been very commonly observed. For instance, the current experiment shows an equal number of cooperations and defections played overall - 80% of all cooperations were played as a response to the opponent's cooperative behaviour and 64% of all defections followed a previous defection played by the other agents in the game. These insights denote a variation in behaviour within rounds as a result of continuous adaptation to the opponent's actions. Therefore, even if some individuals show more defective behaviour than others, they may still try to avoid a complete maximisation due to fairness principles (Henrich et al., 2005). It is also important to take into consideration that, although players would make their consumption decisions simultaneously, the knowledge of previous rounds behaviour was available to participants. Thus, for instance, if a player has acted cooperatively in previous rounds, the opponent player may decide to test his or her reaction to a sudden defection, without ending the game at once, since that would prevent higher payoffs obtainable with the occurrence of future rounds. Moreover, when the resource available regenerated, players did not know how much the opponent participant consumed. Hence, if one believes that the other would take less than the ¼ limit, he or she may decide to take a slightly higher share to exploit a presumably cooperative agent, while trying to keep the resource regenerating at the same time. Such reasoning can be much more beneficial than the NE.

Moreover, the results from this experiment demonstrate that individuals made the most optimal economic decisions from a behavioural economic viewpoint (i.e., decisions most beneficial to the entire group) when they played cooperatively rather than defectively. This occurred even in instances where defecting could be more beneficial to the individual. This is supportive of the theory that human decision-making has evolved to incorporate a learned tendency towards prosocial behaviour and altruism. Gintis (2007) has highlighted the tendency for economic and sociological theorists to neglect the perspectives of the other, the former favouring a purely rational model of decision-making while the latter proffers the importance of social roles and cultural beliefs. Seeking to reconcile the two, Gintis (2007) argues that game theory could be used to explain many behavioural phenomena if it would include analytic constructs for both common knowledge (i.e., the semantic common knowledge model) and informational asymmetry (i.e., the Harsanyi doctrine), which are required to form both common and divergent beliefs. The Harsanyi (1968) or 'common priors' doctrine has been demonstrated to be violated in most games, especially as the number of players increases (Nyarko, 2010). While groups benefit from prosocial behaviour, the cost of prosocial behaviour falls disproportionately on helpers, thus reducing the evolutionary fitness of helpers in comparison with egoists without non-random benefits to helpers (Richerson & Boyd, 2008). However, Hamilton's (1964) inclusive-fitness theory demonstrates how altruism towards kin results in selection for prosocial traits: if siblings help each other, the benefits of prosocial behaviour is now randomly directed toward those carrying the same gene, thereby selecting for prosocial traits. Using Darwinian methods, Richerson and Boyd (2008) have argued that, while cultural evolution is subject to the rules of natural selection, cultural evolution itself has changed the social environment such that individual natural selection favours altruism. Wilson (1997) further explains the complex interactions of cultural and natural selection through multi-level selection theory, which shows how the elements of phenotypic variation, heritability, and fitness consequences work together to facilitate the evolution of altruism necessary for group-level adaptation. When both between-group and within-group selection are included in this conceptualisation, altruism is not restricted to genealogical relatives. Wilson's (1987) re-analysis of Maynard Smith's (1964) haystack model demonstrates that Mendelian populations derived from sibling groups favour altruism more than the sibling groups alone. Multi-level selection theory proposes that the concept of group mind, well documented in the insect kingdom, can also be applied to humans. Indeed, Gintis et al. (2003) have demonstrated that strong reciprocity, a tendency to cooperate with others and punish those who defect from the social norm, is an evolutionarily stable strategy. Bowles and Gintis (2003) have used simulations to demonstrate that the proliferation of strong reciprocators under conditions 100,000 years ago is extremely high, yielding high levels of sustainable cooperation and not requiring relatedness or group extinction. Gintis et al. (2003) cite evidence from the labour market and several experimental games that are consistent with the findings of the current study, showing the individuals will make sacrifices to contribute to the economic well-being of the group.

The second hypothesis - that there would be a switch point from defection to cooperation at 50% probability of another round, rather than 69% - was also not met. Participants played a nearly equal number of cooperations and defections independently of whether the probability was higher or lower than 50%. What is even more surprising, examining the effect of probability on a continuum (from 0 to 100%) it was found that probability had no effect on the strategy employed in each round. Hence, contrarily to the analytical solution, participants often cooperated even when the probability of another round was very low (e.g. 10%). This is also in contrast with previous findings. For instance, Bó (2005) found that the number of cooperation significantly increase along with the shadow of the future. Indeed, he found that, when the probability of a future round was low, around 9% of the plays were cooperations. The substantial difference between Bò's (2005) results and the present findings could be attributed to the disparity in the methodology used. The probability of continuation communicated to the participants in the current study utilised a continuous, randomised, approach. Whereas, Bó (2005) adopted a categorical approach, although still randomised, which presented only three treatments - δ=0, δ=1/2 or δ=3/4. It can be argued that this simplification may have favoured the understanding of the shadow of the future and, consequently, promote more rational and strategic decisions during the game. Hope and Kelly (1983) suggested that probability plays an important role in every society, however, probabilistic reasoning can be hard to master. Earlier, Slovic et al. (1982) found that even after specific instructions, individuals have significant difficulties in developing a good intuition about central ideas of probability. As a consequence, they tend to fail in tasks that involve probable events. More recent studies have tested population's understanding of probabilistic weather forecasts (e.g. "30% chance of rain") and found that probabilities are interpreted by individuals in multiple, mutually contradictory ways (Gigerenzer et al., 2005). This may confirm the assumption that participants' decision-making during the game was influenced by a difficulty in understanding the probability of another round communicated to them, thus, unable to fully comprehend its implications on the continuation of the game. On the other hand, Bò's (2005) approach simplified such process, limiting individuals' cognitive workload and leaving more room for strategic thinking.

Lastly, Skaperdas and Syropoulos (1996) suggest that agents' evaluation of the future (independently from the discount factor) plays an important role in the strategy adopted. This implies that an individual may decide to defect even if there is a high chance of a next encounter or vice versa. Thus, although less likely compared to the other arguments mentioned above, could be that for some players the possibility of continuation of the game seems more appealing in regards of future rewards, even it if the probability is low.

The second part of the research aimed to understand what are the psychological and environmental factors that influenced participant behaviour while playing the game. This analysis was undertaken in two different approaches: explanatory and predictive.

For the explanatory purpose, a GEE analysis with Gamma log link model was used to account for non-normality and non-independence of the data. Following the theoretical background, within rounds consumptions were used as dependent variable and NR, CFC, IMD and Conditions were entered in the model as main effect variables (IVs) – lower consumption was taken as an indication of cooperative behaviour, whereas higher consumption suggested defective tendencies. It was hypothesised that high scores in NR, CFC and IMD would significantly lower participants' consumptions. Moreover, it was expected that those living in a less stressed environment (high IMD) would also score lower on the CFC scale. Finally, in regard to the two different Conditions, it was assumed that when participants do not have visual or auditory cues of the other player (Unseen condition), they would play more defectively, compared to the Seen condition, by consuming more units of the shared resource.

These hypotheses were only partially met. Indeed, only Conditions resulted to have a significant effect on the amount of consumption during the game. Specifically, when players were in the Unseen conditions (two different rooms), the amount of their consumption was 21% higher compared to when they were in the Seen condition. These findings support the results of previous studies that have looked at the effect of anonymity in strategic interactions. For example, Haley and Fessler (2005) found that while playing the dictator game, participants tended to play more altruistically simply by adding 'stylised eyes' (visual cue) as a background image of the desktop they were using. Similarly, Charness and Gneezy (2008) used the ultimatum game to analyse the extent to which anonymity affects cooperation. They recruited students from two universities, in two different cities, in order to avoid any possible identification. Surprisingly, they found that by only revealing the surname of the receiver player, although they had never met the person and were not familiar with the surname, this promoted altruistic behaviour in the allocator. As mentioned, in the dictator game, any sign of cooperation can be translated as pure altruism since a defective move can't cause future repercussion. Whereas, the current study adds additional insight into the topic: cooperation is harmed by anonymity, regardless of the occurrence of repeated encounters between two individuals. Therefore, although other studies (e.g. Milisnki et al., 2002; Nowak & Sigmund,

2005) have shown that cooperation can occur through the direct and indirect formation of one's reputation, it can be argued that in certain strategic situations, involving the usage of CPRs, two individuals may interact in complete anonymity, without external observers and subsequent implication of one's reputation. The increase of defective behaviour in such situations must be taken into consideration when dealing with the administration of a common resource.

Unexpectedly, the findings displayed a non-significant effect of NR, CFC and IMD on participants' consumption within rounds. Such results were surprising, especially the lack of a significant implication of IMD and CFC, as they contrast some important evidence found in previous research. LHT suggests that individuals living in a stressed environment, which can have different forms of mortality cues, tend to favour short-term reward due to future uncertainty (Worthman & Kuzara, 2005). The present research used the IMD as an indicator of participants' economic status as well as mortality cue since it takes into consideration some crucial factors of a given neighbourhood - income, employment, health, crime etc (Payne & Abel, 2012). Hence, the lower the IMD linked to one's neighbourhood, the higher the number of mortality cues are assumed to occur in his or her life. For instance, while comparing different neighbourhoods of the same city, Wilson and Daly (1997) found that the median age of women giving birth was 22.6 years in those neighbourhoods with low life quality, compared to a median of 27.3 years in a wealthier neighbourhood. Moreover, IMD and CFC were taken as two factors directly related since, following the findings of earlier studies (e.g. Griskevicius et al., 2011), it was assumed that IMD would impact players' time preference - their consideration of future consequences - (i.e. low IMD equals to low CFC). However, a non-significant effect of IMD on CFC was also observed.

Although several studies have looked at the effect of low socioeconomic status (SES) and its negative consequences (e.g. Pepper & Nettle, 2014; Figueredo et al., 2005; Gladden et al., 2009), this is the first attempt to link it to strategic thinking. Therefore, it can be arduous to carry out a precise comparison and analyse the cause for such discrepancy between findings. Nevertheless, Griskevicius et al. (2011) attempted to understand how an individual's SES influenced by the impact of mortality cues and, as consequence, the tendency to take risks as well as time preference. For two of the three experiments used in the Griskevicius et al. (2011) study, participants were asked to report their current and childhood SES by asking about their subjective experience - fixed statements with a 7-point scale (e.g. "I have enough money to buy things I want" or "I felt relatively wealthy compared to other kids in my school"). In order to reproduce mortality cues, participants were asked to read a fictitious article, formatted like the New York Times, which portrayed current trends towards violence and death. Following the article, they were asked to make financial choices that tested risk aversion and time preference (e.g. "Do you want a 50% chance of getting $800 OR get $100 for sure?" or "Do you want to get $100 tomorrow OR get $200, 90 days from now?". Results showed that individuals who reported higher childhood SES were less influenced by mortality cues, thus, taking less risk and preferring greater future rewards rather than short-term rewards. Moreover, it was found that contrarily to childhood SES, current SES had little or no effect on the people's decision-making during the study. In the third experiment, they opted for a more objective measure -childhood household income- in order to strengthen the result of the previous two experiments. The same results were observed – low childhood SES corresponded to high risk-taking and more future discounting; and vice versa. The important influence of childhood SES also found in previous experiments (see Griskevicius et al., 2010) suggests that individuals may unconsciously calibrate their life history strategy towards daily occurrences during a 'critical period' in childhood. When comparing the present study to the one described above, it can be argued that the difference between the findings presented may be due to a multitude of factors. First, the current study did not take into consideration participants' childhood SES, but only the current one. As seen from Griskevicius's et al. (2011) result, the current seems to have no impact on how people are affected by mortality cues. Second, during the present experiment, the IMD was taken as an indicator of one's SES as well as an indirect indicator of mortality cues occurring in participants' lives. However, since the experiment was conducted in a lab environment, it is likely that, without specific stimuli (as used in Griskevicius's et al. (2011) study), mortality cues are not perceived in such a controlled setting. Third, IMD may not be a good indicator of an individual's economic status since it involves an average of different aspects found within a neighbourhood, hence, one could hold a low SES but living in an area with a moderate/high IMD (or vice versa). This may be especially true for those who reallocate for educational and working purposes since the present experiment considered only participants' past five years of residency. Lastly, Griskevicius et al. (2011) analysed the influence of mortality cues, as a consequence of one's SES, on time preference. On the other hand, the present experiment was interested in understanding whether players had a preconditioned level of CFC, as a result of their environment, and how this would impact their strategic decisions. It could be argued that the lack of a significant effect of CFC in the present study is due to the difference in methodology when compared to Griskevicius's et al. (2011), who actively manipulated the exposure to mortality cues during the experiment. This might have created a more vivid experience, within a lab setting, of what an individual may encounter in his or her daily life. However, the use of CFC, instead of any other time preference indicators, was motivated by the hypothesised measuring of a stable construct (Strathman et al., 1994). In fact, according to Strathman et al. (1994), the various measures developed during the years to analyse time preference (e.g. Future Time Perspective, Stewart Personality Inventory, Time Perspective Inventory etc.) typically test a general preoccupation with the future or worry towards future events. However, the CFC indicates the extent to which people reflect on probable distant outcomes, caused by their current behaviours, and the degree to which they are impacted by these potential outcomes. It embodies an internal struggle between present behaviour and its connection to immediate and future outcomes - one's decision to favour present or future is hypothesised to be a stable feature. Thus, it was assumed that being a stable feature, participants should be influenced in their decision independently from the existence of experimental stimuli, as shown in the previous study that has used the CFC scale (see Joireman, Van Lange, & Van Vugt, 2004; Lindsay & Strathman, 1997; Joireman, Lasane, Bennett, Richards, & Solaimani, 2001). Researchers have also argued that young individuals are less able to understand and judge future consequences of present actions as well as less able to hypothesise possible risks and benefits (Kaser-Boyd, Adelman, & Taylor, 1985; Lewis, 1981; Mann, Harmoni, & Power, 1989). This would make the CFC scale not valid enough when using samples of students as occurred for the present research. Nevertheless, according to Rappange et al. (2009), who used a large sample of 2,006 young adolescents, the average CFC score between young and older individuals (50 to 69 years old) is not significantly different.

Due to the lack of previous experiments using CFC in a complex strategic situation such as the one used in the current study, it is difficult to draw any precise conclusion from these results. That is because a certain situation could involve different levels of decision-making processes, which, as consequence, shadow the influence of other individual differences such as temporal discounting and temporal preference. Moreover, as argued by Wischniewski et al. (2009), the contextual situation plays a crucial role in how people behave and make decisions. In other words, there are scenarios when almost anyone would cooperate, and others when most individuals would defect, regardless of their general tendencies. However, a visual analysis of the IMD data collected from the participants showed a linear spreading of the neighbourhood deprivation level reported (ranging from 1618 to 28084). Thus, the lack of correlation between

IMD and CFC, and consequently the non-significant effect of CFC, should not be caused by similar economic statuses experienced by participants.

Therefore, the lack of significant results can be caused by a variety of other factors. For instance, the lab setting in which the study was conducted may have made it difficult to establish a high ecological validity, therefore, the mortality cues assumed from one's IMD could not be perceived while taking part in the study. Hence, direct manipulation, to highlight risks of mortality, may be needed to elicit the influence of participants' environmental status. Moreover, as found by Griskevicius's et al. (2011), childhood SES, compared to one's current SES (i.e. IMD), has a greater impact on how individuals perceive mortality cues. Thus, the use of IMD only may not be the optimal representative tool of people's approach toward temporal decision-making. That is because the economic status experienced during some critical year of childhood (similar to other developmental theories) tend to remain a stable adaptation element even if adulthood presents improved circumstances. Finally, as mentioned, there can be situations when an individual cooperates or defects due to contextual features (Wischniewski et al., 2009). For example, the presence of a large amount of resource may result in higher cooperation compared to when there is a scarce availability and, consequently, more competition to gather those resources necessary to preserve an individual's survival (Aquino et al., 1992). Furthermore, as seen in the first part of the current experiment, most of the consumption decisions followed the reciprocity approach – participants cooperated when their opponents played cooperatively and defect when they played uncooperatively (aka conditional cooperation). Such behavioural strategies have been well studied and shown to be a crucial aspect of most evolutionary models as it avoids the proliferation of "free-riders" within a social group (Hammerstein and Leimar, 2006; Fehr and Fischbacher, 2004; Trivers, 1971). As a result, there is a fair possibility that the implication of the level of CFC, during the games, was shadowed by the presence of these strategic aspects that were at the core of every round. Thus, in order to better understand whether CFC is a stable feature, as well as an important aspect that must be considered during decision-making processes occurring within complex strategic situations, further investigations are essential.

Similar to CFC, the non-significant effect of NR found in the analysis could also be attributed to an ecological validity issue. In fact, nature relatedness is believed to define an individual's cognitive and affective connection with nature. As results, high levels of NR should predict sustainable approaches and behaviours. In other words, a person who feels connected to the natural environment wants to preserve it. These beliefs follow the assumptions of Wilson's (1984) biophilia hypothesis, which argues that humans, since they have lived and evolved in natural environments for a great number of years, have an innate connection with rural areas and everything that represents the wildness of nature (e.g. plants, animals etc.). Exposing oneself to nature fulfils this innate need and it fosters general well-being (Kellert, 1997). However, although the resource used during the game had the same properties of a CPR, for the purpose of the current study the researchers referred to a generalised resource (i.e. the type of resource was not identified), which participants had to consume in term of 'units'. While such design is beneficial for various reasons, especially to avoid confounding effects caused by subjective perceptions towards a specific resource, it can be argued that NR specifically predicts pro-environmental behaviour, whereas the resource used for the current study lacks the descriptions necessary to be perceived as an environmental resource.

In science the difference between explanatory and predictive designs have been long discussed and, initially, the two approaches were considered equal in their nature (Hempel & Oppenheim, 1948). Nevertheless, recently it has become clear that the two are concerned with distinct types of uncertainty regarding the understanding of a new notion. The difference lies in the fact that quantifiable data, in most cases, is not a precise depiction of its underlying constructs. Hence, the disparity arises between the capacity to explain occurrences at a theoretical level and the ability to produce predictions at a quantifiable level (Simon, 2001). To obtain a complete understanding of the subject tackled in the current study, both designs were used to examine the data.

Predictive modelling is a process that involves the application of a statistical model to data in order to predict new or future observations. The main goal is to predict an output value (Y) for future observations using some initial input values (X). This comprises temporal forecasting, which uses observations until time t to forecast new values at time $t + k$, $k > 0$ (Shmueli, 2010).

A series of GLMs with the negative binomial model were employed to observe what are the factors that best predict cooperation in strategic situations. Results show that Conditions – Seen and Unseen – as well as their interaction with NR score is a significant predictor of the number of cooperations played. Indeed, there was a significant effect of Condition, indicating that, all other things being equal when individuals are in a Seen condition, they are expected to play more cooperations compared to when they are in an Unseen condition. Additionally, the significant interaction observed between Condition and NR suggests that when a participant is in an Unseen condition, although individuals are expected to have a less cooperative behaviour (compared to the Seen condition), the number of cooperations increase if he or she scores high in the NR scale. However, there was a non-significant interaction between the Seen condition and NR. Hence, there is no significant difference in the number of cooperations between those who score high and those who score low in NR when the condition is Seen.

These findings support the result of the explanatory approach portrayed above. In fact, Condition was showed to be a good predictor of cooperation in both approaches. This also supports previous evidence, which suggests that reputation – direct or indirect - plays an important role in strategic situations. That is because if an individual is considered to be 'trustworthy' others tend to be more cooperating during the interactions with him or her (Barclay, 2004; Leimar & Hammerstein, 2001; Nowak & Sigmund, 1998a; Alexander, 1987). Moreover, as found by Haley and Fessler (2005) and Charness and Gneezy (2008), having some information – visual, auditory or just representative, such a name - about the opponent agent, in a strategic situation, significantly increase the chances of cooperation even when the only rational behaviour should be defecting (e.g. dictator game). Thus, compared to complete anonymity (Unseen Condition), the mere presence of another individual (Seen Condition) benefiting from the same resource (i.e. someone who can see or hear you) does encourage a cooperating behaviour even if there is no communication between the agents. Interestingly, a significant interaction between the Seen condition and NR appeared as a predictive factor. Similar to the explanatory model, there was no significant effect of NR as the main effect, however, its interaction with the Unseen Condition suggests a possible implication of people's concern towards environmental preservation. Hence, it is predicted that when an individual anonymously consumes a certain CPR, tends to be more cooperative with others if his or her level of NR is high. Although a predictive design cannot be taken as ultimate evidence, it still is an important outcome that confirms the need for further investigations into NR and its potential consequences on one's behaviour.

The current study uses an original game set up to analyse people's behaviour in strategic situations. The game has been developed to capture the dynamics found in different dilemmas involving CPRs. Most of the previous studies that have been conducted around this topic were field research. Although these can be very insightful when investigating the characteristics of a certain resource as well as people's behaviour towards them, often the results cannot be generalised to a wider range of situations. On the other hand, the current study aimed to recreate a setting that includes some of the main features shared by most of CPRs. In other words, fields studies are interested in individuals' behaviours towards a specific situation (or resource), whereas a lab study, such as the current one, aims to look into the behaviour occurring within those strategic situations that include dynamics shared by a larger umbrella of resources. Therefore, it can be argued that the use of a general resource, which was refreshable as well as depletable, gave the opportunity to gather insights applicable to a broader variety of dilemmas. Moreover, the rules established in the game – e.g. resource refreshed if players consumed 50% or less of the amount available in each round - fairly recreated the natural cycle of resources found in nature, such as oil, wood etc. Finally, while many researchers use Public Goods game and PD indifferently for resources from the same categories, it was shown that the two have different fundamental traits. For instance, contrarily to the PD, Public Goods games represent situations where individuals are non-excludable and they are considered nonrival, meaning that one individual's usage does not decrease its availability to others (Cornes & Sandler, 1996). These characteristics do not portray those of CPR dilemmas and, thus, it is believed that the PD is better suited for such investigation. In fact, according to Kuhn (2007), the PD is considered to be reflective of a vast number of social and political questions, in regards of the relationship between members of a specific group (or worldwide) and their interaction towards common resources.

Nonetheless, there are some limitations that may have caused significant data distortion. For example, when participants were instructed on the rules of the game, they were explained (although not explicitly) that taking ¼ of the available resource would cause this to refresh for a next round. Merely following these instructions could have facilitated the play of NE when $p \geq .69$, therefore, it could be argued that the procedure may have fostered a more cooperative behaviour overall. In fact, having more information regarding the punishment of taking more than ¼ of the resource, when $p \geq .69$, made the choice of cooperating more straightforward, thus, avoiding the effort expenditure occurring during complex cognitive processes. According to Todd and Benbasat (1994), incorporating direct or indirect decision aids to a certain task will modify the relative effort necessary to implement available strategies. As a consequence, this will also have an impact on strategy selection by the decision-maker. Additionally, previous studies have shown that decision-makers adapt their evaluation of a strategy based on the features of certain task and clues that may lead towards an optimal decision, however, always trying to minimise the level of cognitive effort (Todd and Benbasat, 1991). Thus, following the cost-benefit framework suggested by Payne (1982), which argues that the objective of an individual is to maximise decision quality and minimise effort, it is suspected that the participants of the current research were, to some extent, influenced by the features of the game and the unavoidable instructions given to allow a basic understanding of the rules. This could explain why many participants have cooperated even in conditions where defection was the only rational decision.

Moreover, as one of the main aims of this study was to analyse the effect of anonymity on strategy played, participants were randomly divided into two conditions – one in the same room where they could see and hear each other and a second one, where participants were allocated into two different rooms, avoiding any type of visual or auditory stimuli. However, it must be taken into consideration that most of the participants were part of the same psychology department at Middlesex University. Hence, there is the possibility that regardless the precautions taken in order to guarantee a suitable level of anonymity for the Unseen condition, some participants were somehow aware of the identity of the person in the other room. This could have happened, for instance, by meeting or seeing a fellow student from one's same course going to the location where the experiment was taking place. In such a case, the study manipulation risked being partly invalidated since the requirements for the manipulation would not be met. There are no clear proofs that such incongruity occurred, nevertheless, further studies need to carefully consider this possibility. What is more, since, as just mentioned above, most of the participants were recruited from the same university department as well as from the same course year, there could be another confounding factor involving both Unseen and Seen conditions. Indeed, participants could have been influenced, not only by the potential punishment occurring while playing the game, in case of a defective behaviour, also by the prospect of forming a negative reputation outside the experimental setting. This is because players could have forecasted possible encounters within the department during the academic year, fearing additional punishment in case of another interaction. In addition, the use of only university students is not an ideal representation of the population, particularly when dealing with economic matters since they may embody a portion of the population that is more privileged compared to those who did not have the opportunity to pursue education. Moreover, individuals who already have professional experiences in various fields could have different approaches to strategic situations due to more developed skills in critical thinking. Another limitation related to a university sample is the age range. Although in the present study participants' age ranged between 18 to 44 years old, the mean age was 21.92 and the mode 19.

Meaning that the majority of the students who took part in the experiment were relatively young.

Furthermore, the use of a totally randomised probability of a further round, although theoretical, recreated a more realistic representation of the dynamics an individual can find in his or her real life. However, while a non-significant effect of probability was found in the current study, such randomisation can also generate inequality regarding the opportunity for learning the optimal strategies to adopt in the various circumstances faced within the game. For instance, if in one scenario (A) the randomiser gives a very low probability of continuation in the first round, whereas in another scenario (B) the probability given by the randomiser is relatively high for ten rounds, the participants in scenario B will be more likely to play longer than those in scenario A. Consequently, they would be more advantaged as they are able to interact more and possibly be subject to an evolutionary learning curve. Future studies should take this into consideration as a potential confounding factor when analysing the data as well as a focus of study to better understand if and how evolutionary learning occurs.

Finally, there are two more points that need further attention. The first is the absence of monetary compensation for the participants. Most of the previous studies that have investigated strategic scenarios using game-theoretic settings have also used monetary payoffs for players' decisions while playing a game (for instance, see Bó, 2005). Contrarily, the current research did not use direct decision-making rewards or participation payments, instead, it accredited course credit for first-year psychology students and gave the chance to win one of 12 Amazon vouchers, with a £5 value each, by entering a price draw that occurred at the end of the experimental period. It can be argued that the absence of a monetary incentive can cause a lack of interest, resulting in lower effort employed in order to reach the best result for oneself and the group. Such an assumption is supported by a study conducted by Gumber et al. (1969), who found that, while playing the PD, participants who played for real money were greatly more competitive than those who played for imaginary money. The important influence of monetary rewards has since been confirmed by other researchers (see Azrieli et al., 2018). Lastly, when using self-reported questionnaires, it is always appropriate to consider the possible impact of social desirability (Thomas & Kilmann, 1975), especially when using questionnaires that involve environmental topics (e.g. NR-6) since it currently is a highly debated matter and people may try to avoid feeling judged for their non-interest toward pro-environmental behaviours. Social desirability is even greater within young people (Mwamwenda, 1995), which represent the sample used for the current research.

Following these suggested limitations, future studies should look into a different game instructing approach to avoid a potential confounding effect on strategy selection while playing the game. In addition, a larger and more variegated sample is needed in order to better investigate age and background differences in decision-making during strategic situations. Using students from different departments, and different institutions, as well as participants from other professional fields and backgrounds, can help prevent issues caused by preoccupation towards the prospect of future punishments that go beyond the experimental setting. Moreover, further research should use monetary rewards to incentivise motivation during the game and attempt to analyse the possible impact of a learning curve by letting participants play the game multiple times - this could also solve the problem created by the randomisation of the probability of a next round (i.e. future encounter). Finally, so as to improve the exploration of nature relatedness and its effects, a specific CPR may be used as the focus of investigation rather than a generalised resource, since the latter may cause a conceptual disconnection with its surrounding issues. Ultimately, besides NR and CFC, it can be worthwhile to consider other individual differences such as personality traits, pro-social values etc.

In conclusion, the current findings did not strictly follow the analytical solution, which assumed conditional cooperation when $p \geq .69$ and full depletion of the recourse when $p \leq .69$. Participants seem to have played conditionally to the behaviour of the opponent player when $p \geq .69$. However, although most of the cooperations were NE, only 12% of the defections were optimal plays. Moreover, there was no significant difference between the number of cooperations and defections played when the probability was lower or higher than 69 per cent. Further analysis showed that there was no significant impact of the shadow of the future (i.e. probability of a future round) towards the selection of strategies in every round. This does not support previous findings, which suggested that cooperation in social dilemmas is mainly established thanks to the prospect of a future encounter. The explanatory analysis found a significant impact of anonymity, supporting the initial hypothesis and confirming that having some information (visual or auditory) regarding other users of a resource can increase the chance of cooperative behaviour. Nevertheless, the rest of the hypothesis were not met, in fact, there was no significant effect of IMD, NR and CFC. The predictive analyses also yielded similar results, confirming anonymity as a main significant predictor of individuals' behaviour in strategic situations. Interestingly, a significant interaction was found between Conditions and NR, implying the need for further investigations. Understanding how different factors, such as the shadow of the future, NR and CFC, influence people's decision-making is of crucial importance considering the current issues regarding environmental resources as well as manmade usage of common resources. These, together with the exploration of other aspects that influence the individual can be valuable during the process of making new regulations that aim at the administration and/or preservation of a certain CPR. Thus, further research should attempt to implement the methodological changes earlier discussed, as well as using a more suitable sample of participants, in order to expand the current results and enlarge the knowledge of CPRs dilemmas.

References

Acharya, K. P. (2002). Twenty-four years of community forestry in Nepal. *International Forestry Review*, *4*(2), 149-156.

Agrawal, A. (2001). Common property institutions and sustainable governance of resources. *World development*, *29*(10), 1649-1672.

Ainslie, G., & George, A. (2001). *Breakdown of will*. Cambridge University Press.

Alexander, R. D. (1987). *The biology of moral systems*. Transaction Publishers.

Alston, L. J., & Mueller, B. (2008). Property rights and the state. In *Handbook of new institutional economics* (pp. 573-590). Springer, Berlin, Heidelberg.

Anderies, J. M., Janssen, M. A., Bousquet, F., Cardenas, J. C., Castillo, D., Lopez, M. C., ... & Wutich, A. (2011). The challenge of understanding decisions in experimental studies of common pool resource governance. *Ecological Economics*, *70*(9), 1571-1579.

Aquino, K., Steisel, V., & Kay, A. (1992). The effects of resource distribution, voice, and decision framing on the provision of public goods. *Journal of Conflict Resolution*, *36*(4), 665-687.

Arce M, D. G., & Sandler, T. (2005). Counterterrorism: A game-theoretic analysis. *Journal of conflict resolution*, 183-200.

Ashworth, T. (2000). *Trench Warfare, 1914-1918: the live and let live system*. Pan Macmillan.

Aumann, R. J. (1995). Backward induction and common knowledge of rationality. *Games and Economic Behavior*, *8*(1), 6-19.

Aumann, R. J., & Dreze, J. H. (1974). Cooperative games with coalition structures. *International Journal of game theory*, *3*(4), 217-237.

Axelrod, R. (1980). Effective choice in the prisoner's dilemma. *Journal of conflict resolution*, *24*(1), 3-25.

Axelrod, R. (1980b). More effective choice in the prisoner's dilemma. *Journal of Conflict Resolution*, *24*(3), 379-403.

Axelrod, R. (1990). *The Evolution of Co-operation.* Penguin

Azrieli, Y., Chambers, C. P., & Healy, P. J. (2018). Incentives in experiments: A theoretical analysis. *Journal of Political Economy*, *126*(4), 1472-1503.

Baker, F., Johnson, M. W., & Bickel, W. K. (2003). Delay discounting in current and never-before cigarette smokers: similarities and differences across commodity, sign, and magnitude. *Journal of abnormal psychology*, *112*(3), 382.

Baker, J. M. (1997). Common Property Resource Theory and the" Kuhl" Irrigation Systems of Himachal Pradesh, India. *Human Organization*, 199-208.

Baland, J. M., & Platteau, J. P. (1996). *Halting degradation of natural resources: is there a role for rural communities?*. Food & Agriculture Org..

Balliet, D. (2010). Communication and cooperation in social dilemmas: A meta-analytic review. *Journal of Conflict Resolution*, *54*(1), 39-57.

Barclay, P. (2004). Trustworthiness and competitive altruism can also solve the "tragedy of the commons". *Evolution and Human Behavior*, *25*(4), 209-220

Barrett, S., & Dannenberg, A. (2012). Climate negotiations under scientific uncertainty. *Proceedings of the National Academy of Sciences*, *109*(43), 17372-17376.

Barron, E. N. (2013). *Game theory: an introduction* (Vol. 2). John Wiley & Sons.

Bearce, D. H., Floros, K. M., & McKibben, H. E. (2009). The shadow of the future and international bargaining: The occurrence of bargaining in a three-phase cooperation framework. *The Journal of Politics*, *71*(2), 719-732.

Beaufils, B., Delahaye, J. P., & Mathieu, P. (1997, July). Our meeting with gradual, a good strategy for the iterated prisoner’s dilemma. In *Proceedings of the Fifth International Workshop on the Synthesis and Simulation of Living Systems*(pp. 202-209). MIT press.

Becker, T., Carter, M., & Naeve, J. (2005). *Experts playing the traveler's dilemma*. Inst. für Volkswirtschaftslehre, Hohenheim University.

Benin, S., & Pender, J. (2006). Collective action in community management of grazing lands: the case of the highlands of northern Ethiopia. *Environment and Development Economics*, *11*(1), 127-149.

Benzion, U., Rapoport, A., & Yagil, J. (1989). Discount rates inferred from decisions: An experimental study. *Management science*, *35*(3), 270-284.

Biel, A. (2000). Factors promoting cooperation in the laboratory, in common pool resource dilemmas, and in large-scale dilemmas. *Cooperation in modern society: Promoting the welfare of communities, states, and organizations*, 25-41.

Binmore, K. (1994). *Game theory and the social contract: just playing* (Vol. 2). MIT press.

Binmore, K. (1992). Fun and Games: A Text on Game Theory Lexington. *Massachusetts: DC Heath and Company*.

Binmore, K. (1997). Rationality and backward induction. *Journal of Economic Methodology*, *4*(1), 23-41.

Binmore, K. (2007). *Game theory: a very short introduction* (Vol. 173). Oxford University Press.

Binmore, K. (2015). Why All the Fuss: The Many Aspects of the Prisoner's Dilemma. *Peterson (ed.)*, 16-34.

Blomquist, W. (1992). *Dividing the waters: governing groundwater in Southern California*. ICS Press Institute for Contemporary Studies.

Blomquist, W., & Ostrom, E. (1985). Institutional capacity and the resolution of a commons dilemma. *Review of Policy Research*, *5*(2), 383-394.

Bó, P. D. (2005). Cooperation under the shadow of the future: experimental evidence from infinitely repeated games. *American economic review*, *95*(5), 1591-1604.

Bowles, S., & Gintis, H. (2004). The evolution of strong reciprocity: cooperation in heterogeneous populations. *Theoretical Population Biology*, *65*(1), 17-28.

Bromley, D. W. (1992). The commons, property, and common-property regimes. *Making the commons work*, 3-16.

Brusca, R. C. (Ed.). (2010). *The Gulf of California: biodiversity and conservation*. University of Arizona Press.

Budescu, D. V., Rapoport, A., & Suleiman, R. (1990). Resource dilemmas with environmental uncertainty and asymmetric players. *European Journal of Social Psychology*, *20*(6), 475-487.

Buss, D. M. (Ed.). (2005). *The handbook of evolutionary psychology*. John Wiley & Sons.

Camerer, C. F. (2011). *Behavioral game theory: Experiments in strategic interaction*. Princeton University Press.

Charness, G., & Gneezy, U. (2008). What's in a name? Anonymity and social distance in dictator and ultimatum games. *Journal of Economic Behavior & Organization*, *68*(1), 29-35.

Coll, M., Libralato, S., Tudela, S., Palomera, I., & Pranovi, F. (2008). Ecosystem overfishing in the ocean. *PLoS one*, *3*(12).

Cornes, R., & Sandler, T. (1996). *The theory of externalities, public goods, and club goods*. Cambridge University Press.

Cox, M., & Ross, J. M. (2011). Robustness and vulnerability of community irrigation systems: The case of the Taos valley acequias. *Journal of Environmental Economics and Management*, *61*(3), 254-266.

Dannenberg, A., Löschel, A., Paolacci, G., Reif, C., & Tavoni, A. (2015). On the provision of public goods with probabilistic and ambiguous thresholds. *Environmental and Resource Economics*, *61*(3), 365-383.

Dassen, F. C., Houben, K., & Jansen, A. (2015). Time orientation and eating behavior: Unhealthy eaters consider immediate consequences, while healthy eaters focus on future health. *Appetite*, *91*, 13-19.

Davis, M., & Maschler, M. (1965). The kernel of a cooperative game. *Naval Research Logistics Quarterly*, *12*(3), 223-259.

Dawes, R. M. (1980). Social dilemmas. *Annual review of psychology*, *31*(1), 169-193.

Dawes, R. M. (1991). Social dilemmas, economic self-interest, and evolutionary theory. In *Frontiers of mathematical psychology* (pp. 53-79). Springer, New York, NY.

Dawes, R. M., & Messick, D. M. (2000). Social dilemmas. *International journal of psychology*, *35*(2), 111-116.

Dawes, R. M., Van de Kragt, A. J., & Orbell, J. M. (1990). Cooperation for the benefit of us—Not me, or my conscience.

Del Giudice, M., Gangestad, S. W., & Kaplan, H. S. (2016). Life history theory and evolutionary psychology. In D. M. Buss (Ed.), *The handbook of evolutionary psychology: Foundations* (p. 88–114). John Wiley & Sons Inc.

Dionisio, F., & Gordo, I. (2006). The tragedy of the commons, the public goods dilemma, and the meaning of rivalry and excludability in evolutionary biology. *Evolutionary Ecology Research*, *8*(2), 321-332.

Dreber, A., Ellingsen, T., Johannesson, M., & Rand, D. G. (2013). Do people care about social context? Framing effects in dictator games. *Experimental Economics*, *16*(3), 349-371.

Dreber, A., Rand, D. G., Fudenberg, D., & Nowak, M. A. (2008). Winners don't punish. *Nature*, *452*(7185), 348-351.

Duffy, J., & Ochs, J. (2009). Cooperative behavior and the frequency of social interaction. *Games and Economic Behavior*, *66*(2), 785-812.

Ellis, B. J. (2004). Timing of pubertal maturation in girls: an integrated life history approach. *Psychological bulletin*, *130*(6), 920.

Ellis, B. J., Figueredo, A. J., Brumbach, B. H., & Schlomer, G. L. (2009). Fundamental dimensions of environmental risk. *Human Nature*, *20*(2), 204-268.

Engle-Warnick, J., & Slonim, R. L. (2006). Inferring repeated-game strategies from actions: evidence from trust game experiments. Economic theory, 28(3), 603-632.

Faysse, N. (2005). Coping with the tragedy of the commons: Game structure and design of rules. *Journal of economic surveys*, *19*(2), 239-261.

Fehr, E., & Fischbacher, U. (2002). Why social preferences matter–the impact of non-selfish motives on competition, cooperation and incentives. *The economic journal*, *112*(478), C1-C33.

Fehr, E., & Fischbacher, U. (2004). Social norms and human cooperation. *Trends in cognitive sciences*, *8*(4), 185-190.

Fehr, E., & Gachter, S. (2000). Cooperation and punishment in public goods experiments. *American Economic Review*, *90*(4), 980-994.

Fehr, E., & Gächter, S. (2002). Altruistic punishment in humans. *Nature*, *415*(6868), 137-140.

Figueredo, A. J., Vásquez, G., Brumbach, B. H., Sefcek, J. A., Kirsner, B. R., & Jacobs, W. J. (2005). The K-factor: Individual differences in life history strategy. *Personality and individual differences*, *39*(8), 1349-1360.

Fishburn, P. C., & Rubinstein, A. (1982). Time preference. *International economic review*, 677-694.

Frederick, S., Loewenstein, G., & O'Donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of economic literature*, *40*(2), 351-401.

Frey, B. S., & Bohnet, I. (1995). Institutions affect fairness: Experimental investigations. *Journal of Institutional and Theoretical Economics (JITE)/Zeitschrift für die gesamte Staatswissenschaft*, 286-303.

Fudenberg, D., & Levine, D. K. (1993). Steady state learning and Nash equilibrium. *Econometrica: Journal of the Econometric Society*, 547-573.

Gardner, R., Ostrom, E., & Walker, J. M. (1990). The nature of common-pool resource problems. *Rationality and society*, *2*(3), 335-358.

Gigerenzer, G., Hertwig, R., Van Den Broek, E., Fasolo, B., & Katsikopoulos, K. V. (2005). "A 30% chance of rain tomorrow": How does the public understand probabilistic weather forecasts?. *Risk Analysis: An International Journal*, *25*(3), 623-629.

Gintis, H. (2007). *Bayesian rationality and social norms*. Mimeo. Accessed on 9 Sept. 2020 from http://papers.economics.ubc.ca/legacypapers/gintis.pdf

Gintis, H., Bowles, S., Boyd, R., & Fehr, E. (2003). Explaining altruistic behavior in humans. *Evolution and human Behavior*, *24*(3), 153-172.

Gladden, P. R., Figueredo, A. J., & Jacobs, W. J. (2009). Life history strategy, psychopathic attitudes, personality, and general intelligence. *Personality and Individual Differences*, *46*(3), 270-275.

Griskevicius, V., Delton, A. W., Robertson, T. E., & Tybur, J. M. (2010). Environmental contingency in life history strategies: the influence of mortality and socioeconomic status on reproductive timing. *Journal of personality and social psychology*, *100*(2), 241.

Griskevicius, V., Tybur, J. M., & Van den Bergh, B. (2010). Going green to be seen: status, reputation, and conspicuous conservation. *Journal of personality and social psychology*, *98*(3), 392.

Griskevicius, V., Tybur, J. M., Delton, A. W., & Robertson, T. E. (2011). The influence of mortality and socioeconomic status on risk and delayed rewards: a life history theory approach. *Journal of personality and social psychology*, *100*(6), 1015.

Gumpert, P., Deutsch, M., & Epstein, Y. (1969). Effect of incentive magnitude on cooperation in the Prisoner's Dilemma game. *Journal of Personality and Social Psychology*, *11*(1), 66.

Güth, W., Schmittberger, R., & Schwarze, B. (1982). An experimental analysis of ultimatum bargaining. *Journal of economic behavior & organization*, *3*(4), 367-388.

Hahn, F. (1980). General equilibrium theory. *The Public Interest*, 123.

Haley, K. J., & Fessler, D. M. (2005). Nobody's watching?: Subtle cues affect generosity in an anonymous economic game. *Evolution and Human behavior*, *26*(3), 245-256.

Hamilton, W. D. (1964). The genetical evolution of social behavior: I and II. *Journal of Theoretical Biology*, *7*, 1-52.

Hammerstein, P., & Leimar, O. (2006). Cooperating for direct fitness benefits. *Journal of Evolutionary Biology*, *19*(5), 1400-1402.

Hardin, G. (1968). The tragedy of the commons. *science*, *162*(3859), 1243-1248.

Hargreaves-Heap, S. (1994). *The theory of choice: A critical guide*. Blackwell Publishers.

Harsanyi, J. C. (1968). Games with incomplete information played by Bayesian players, Parts I, II, III. *Management Science 14*, 159–182, 320–334, 486–502.

Hartig, T., Böök, A., Garvill, J., Olsson, T., & Gärling, T. (1996). Environmental influences on psychological restoration. *Scandinavian journal of psychology*, *37*(4), 378-393.

Haurie, A., Krawczyk, J. B., & Zaccour, G. (2012). *Games and dynamic games* (Vol. 1). Singapore: World Scientific.

Hempel, C. G., & Oppenheim, P. (1948). Studies in the Logic of Explanation. *Philosophy of science*, *15*(2), 135-175.

Henrich, J., Boyd, R., Bowles, S., Camerer, C., Fehr, E., Gintis, H., ... & Henrich, N. S. (2005). “Economic man” in cross-cultural perspective: Behavioral experiments in 15 small-scale societies. *Behavioral and brain sciences*, *28*(6), 795-815.

Hilbe, J. M. (2011). *Negative binomial regression*. Cambridge University Press.

Hill, K., & Kaplan, H. (1999). Life history traits in humans: Theory and empirical studies. *Annual Review of Anthropology*, *28*(1), 397-430.

Hope, J. A., & Kelly, I. W. (1983). Common difficulties with probabilistic reasoning. *The Mathematics Teacher*, *76*(8), 565-570.

House, J. S., Kessler, R. C., & Herzog, A. R. (1990). Age, socioeconomic status, and health. *The Milbank Quarterly*, 383-411.

Hubbard, A. E., Ahern, J., Fleischer, N. L., Van der Laan, M., Satariano, S. A., Jewell, N., ... & Satariano, W. A. (2010). To GEE or not to GEE: comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology*, 467-474.

Huttegger, S. M., & Zollman, K. J. (2012). Evolution, Dynamics, and Rationality: The Limits of ESS Methodology. *Evolution and rationality: Decisions, cooperation and strategic behaviour*, 67-83.

IBM Corp. (Released, 2017). IBM SPSS Statistics for Macintosh, Version 25.0. IBM Corp, Armonk, NY.

Ireson, W. R. (1995). Village irrigation in Laos: traditional patterns of common property resource management. *Society & Natural Resources*, *8*(6), 541-558.

Joireman, J. A., Lasane, T. P., Bennett, J., Richards, D., & Solaimani, S. (2001). Integrating social value orientation and the consideration of future consequences within the extended norm activation model of proenvironmental behaviour. *British Journal of Social Psychology*, *40*(1), 133-155.

Joireman, J. A., Van Lange, P. A., & Van Vugt, M. (2004). Who cares about the environmental impact of cars? Those with an eye toward the future. *Environment and Behavior*, *36*(2), 187-206.

Joireman, J., Anderson, J., & Strathman, A. (2003). The aggression paradox: Understanding links among aggression, sensation seeking, and the consideration of future consequences. *Journal of Personality and social Psychology*, *84*(6), 1287.

Kahneman, D., Knetsch, J. L., & Thaler, R. H. (1986). Fairness and the assumptions of economics. *Journal of business*, S285-S300.

Kaplan, H., Hill, K., Lancaster, J., & Hurtado, A. M. (2000). A theory of human life history evolution: Diet, intelligence, and longevity. *Evolutionary Anthropology: Issues, News, and Reviews: Issues, News, and Reviews*, *9*(4), 156-185.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of environmental psychology*, *15*(3), 169-182.

Kaser-Boyd, N., Adelman, H. S., & Taylor, L. (1985). Minors' ability to identify risks and benefits of therapy. *Professional Psychology: Research and Practice*, *16*(3), 411.

Kellert, S. R. (1995). *The biophilia hypothesis*. Island Press.

Kellert, S. R. (1997). *The value of life: Biological diversity and human society*. Island Press.

Kendall, G., Yao, X., & Chong, S. Y. (2007). *The iterated prisoners' dilemma: 20 years on* (Vol. 4). World Scientific.

Kollock, P. (1998). Social dilemmas: The anatomy of cooperation. *Annual review of sociology*, *24*(1), 183-214.

Kollock, P., & Smith, M. (1996). Managing the virtual commons. *Computer-mediated communication: Linguistic, social, and cross-cultural perspectives*, 109-128.c

Komorita, S. S. (2019). *Social dilemmas*. Routledge.

Komorita, S. S. & Parks, C. D. (1997). *Social dilemmas*. Boulder, CO: Westview

Kuhn, S. (2007). Prisoner dilemma: in The Stanford Encyclopedia of Philosophy.Need to check whether I need to cite it as website

Kumar, M. D. (2000). Institutional framework for managing groundwater: A case study of community organisations in Gujarat, India. *Water Policy*, *2*(6), 423-432.

Laibson, D. (1997). Golden eggs and hyperbolic discounting. *The Quarterly Journal of Economics*, *112*(2), 443-478.

Lam, W. F. (1998). *Governing irrigation systems in Nepal: institutions, infrastructure, and collective action*. Institute for Contemporary Studies.

Larson, B. A., & Bromley, D. W. (1990). Property rights, externalities, and resource degradation: locating the tragedy. *Journal of Development economics*, *33*(2), 235-262.

Lee, A. J., DeBruine, L. M., & Jones, B. C. (2018). Individual-specific mortality is associated with how individuals evaluate future discounting decisions. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1880), 20180304.

Leimar, O., & Hammerstein, P. (2001). Evolution of cooperation through indirect reciprocity. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *268*(1468), 745-753.

Lewis, D. (1981). Causal decision theory. *Australasian journal of philosophy*, *59*(1), 5-30.

Lindsay, J. J., & Strathman, A. (1997). Predictors of recycling behavior: an application of a modified health belief model 1. *Journal of Applied Social Psychology*, *27*(20), 1799-1823.

Lloyd, W. F. (1833). *Two Lectures on the Checks to Population: Delivered Before the University of Oxford, in Michaelmas Term 1832*. JH Parker.

Loewenstein, G., & Prelec, D. (1992). Anomalies in intertemporal choice: Evidence and an interpretation. *The Quarterly Journal of Economics*, *107*(2), 573-597.

Low, B. S. (2017). Sex, wealth, and fertility: Old rules, new environments. In *Adaptation and Human Behavior* (pp. 323-344). Routledge.

Luce, R. D. & Raiffa, H. (1957). *Games and Decisions.* New York: Wiley

Luce, R. D., & Raiffa, H. (1958). Games and decisions: Introduction and critical survey. *New York*.

MacArthur, R. H., & Wilson, E. O. (1967). *Island biogeography*. Princeton.

Mann, L., Harmoni, R., & Power, C. (1989). Adolescent decision-making: The development of competence. *Journal of adolescence*, *12*(3), 265-278.

Manski, C. F. (2018). Survey measurement of probabilistic macroeconomic expectations: progress and promise. *NBER Macroeconomics Annual*, *32*(1), 411-471.

Marwell, G., & Ames, R. E. (1981). Economists free ride, does anyone else. *Journal of public economics*, *15*(3), 295-310.

Maschler, M. (1992). The bargaining set, kernel, and nucleolus. *Handbook of game theory with economic applications*, *1*, 591-667.

Maynard Smith, J. (1964). Group selection and kin selection. *Nature, 201*, 1145-1147.

McCay, B. J. (2002). Emergence of institutions for the commons: contexts, situations, and events. *The drama of the commons*, 361-402.

Meij, J. J., Van Bodegom, D., Ziem, J. B., Amankwa, J., Polderman, A. M., Kirkwood, T. B. L., ... & Westendorp, R. G. J. (2009). Quality–quantity trade-off of human offspring under adverse environmental conditions. *Journal of evolutionary biology*, *22*(5), 1014-1023

Meinzen-Dick, R., Raju, K. V., & Gulati, A. (2002). What affects organization and collective action for managing resources? Evidence from canal irrigation systems in India. *World development*, *30*(4), 649-666.

Mertens, J. F. (1990). Repeated games. *In Game Theory and Applications* (pp. 77-130). Academic Press.

Messick, D. M., Wilke, H., Brewer, M. B., Kramer, R. M., Zemke, P. E., & Lui, L. (1983). Individual adaptations and structural change as solutions to social dilemmas. *Journal of personality and social psychology*, *44*(2), 294.

Milinski, M., Semmann, D., & Krambeck, H. J. (2002). Reputation helps solve the 'tragedy of the commons'. *Nature*, *415*(6870), 424-426.

Mishra, S., & Lalumière, M. L. (2011). Individual differences in risk-propensity: Associations between personality and behavioral measures of risk. *Personality and Individual Differences*, *50*(6), 869-873.

Murnighan, J. K., & Roth, A. E. (1983). Expecting continued play in prisoner's dilemma games: A test of several models. *Journal of conflict resolution*, *27*(2), 279-300.

Mwamwenda, T. S. (1995). Age Differences in Social Desirability. *Psychological Reports*, *76*(3), 825–826.)

Nash, J. (1951). Non-cooperative games. *Annals of mathematics*, 286-295.

Nash, J. F. (1950). Equilibrium points in n-person games. *Proceedings of the national academy of sciences*, *36*(1), 48-49.

Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2009). The nature relatedness scale: Linking individuals' connection with nature to environmental concern and behavior. *Environment and behavior*, *41*(5), 715-740.

Northcott, R., & Alexandrova, A. (2015). Prisoner's Dilemma doesn't explain much.

Nowak, M. A., & Sigmund, K. (1998a). The dynamics of indirect reciprocity. *Journal of theoretical Biology*, *194*(4), 561-574.

Nowak, M. A., & Sigmund, K. (1998b). Evolution of indirect reciprocity by image scoring. *Nature*, *393*(6685), 573-577.

Nowak, M., & Sigmund, K. (1993). A strategy of win-stay, lose-shift that outperforms tit-for-tat in the Prisoner's Dilemma game. *Nature, 364*(6432), 56-58.

Nyarko, Y. (2010). Most games violate the common priors doctrine. *International Journal of Economic Theory, 6*(1), 189-194.

Olson, M. (2009). *The Logic of Collective Action: Public Goods and the Theory of Groups, Second Printing with a New Preface and Appendix* (Vol. 124). Harvard University Press

Ortmann, A. (2016). Episodes from the early history of experimentation in economics. In *The Making of Experimental Economics* (pp. 195-217). Springer, Cham.

Ostrom, E. , Dietz, T. E., Dolšak, N. E., Stern, P. C., Stonich, S. E., & Weber, E. U. (2002). *The drama of the commons*. National Academy Press.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge university press.

Ostrom, E. (2006). The value-added of laboratory experiments for the study of institutions and common-pool resources. *Journal of Economic Behavior & Organization*, *61*(2), 149-163

Ostrom, E. (2008). Tragedy of the Commons. *The new palgrave dictionary of economics*, *2*.

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the commons: local lessons, global challenges. *science*, *284*(5412), 278-282.

Ostrom, E., Gardner, R., Walker, J., Walker, J. M., & Walker, J. (1994). *Rules, games, and common-pool resources*. University of Michigan Press.

Palfrey, T. R., & Rosenthal, H. (1994). Repeated play, cooperation and coordination: An experimental study. The Review of Economic Studies, 61(3), 545-565

Payne, R. A., & Abel, G. A. (2012). UK indices of multiple deprivation—a way to make comparisons across constituent countries easier. *Health Stat Q*, *53*(22), 2015-2016.

Pepper, G. V., & Nettle, D. (2014). Socioeconomic disparities in health behaviour: An evolutionary perspective. In *Applied evolutionary anthropology* (pp. 225-243). Springer, New York, NY.

Pinkerton, E. W. (1994). Local fisheries co-management: a review of international experiences and their implications for salmon management in British Columbia. Canadian journal of fisheries and aquatic sciences, 51(10), 2363-2378.

Plott, C., & Meyer, R. (1975). The technology of public goods, externalities, and the exclusion principle. In *Economic analysis of environmental problems* (pp. 65-94). NBER.

Press, W. H., & Dyson, F. J. (2012). Iterated Prisoner's Dilemma contains strategies that dominate any evolutionary opponent. *Proceedings of the National Academy of Sciences*, *109*(26), 10409-10413.

Preston, S. D. (2014). *The interdisciplinary science of consumption*. MIT Press.

Rapoport, A., Seale, D. A., & Colman, A. M. (2015). Is tit-for-tat the answer? On the conclusions drawn from Axelrod's tournaments. *PloS one*, *10*(7).

Rappange, D. R., Brouwer, W. B., & Van Exel, N. J. A. (2009). Back to the consideration of future consequences scale: Time to reconsider?. *The Journal of social psychology*, *149*(5), 562-584.

Reuben, E., Sapienza, P., & Zingales, L. (2010). Time discounting for primary and monetary rewards. *Economics Letters*, *106*(2), 125-127.

Reznick, D., Bryant, M. J., & Bashey, F. (2002). r-and K-selection revisited: the role of population regulation in life-history evolution. *Ecology*, *83*(6), 1509-1520.

Richerson, P. J., & Boyd, R. (2008). *Not by genes alone: How culture transformed human evolution*. Chicago: University of Chicago Press.

Ritzberger, K. (2002). Foundations of non-cooperative game theory. *OUP Catalogue*.

Roger, B. M. (1991). Game theory: analysis of conflict. *The President and Fellows of Harvard College, USA*.

Safina, C. (1994). Where have all the fishes gone?. Issues in Science and Technology, 10(3), 37-43.

Schelling, T. (1960). The Strategy of Conflict. *Cambridge, MA, Harvard University Press*

Schmeidler, D. (1969). The nucleolus of a characteristic function game. *SIAM Journal on applied mathematics*, *17*(6), 1163-1170.

Sengupta, N. (1991). Managing common property: irrigation in India and the Philippines. Sage Publications India Pvt Ltd..

Shmueli, G. (2010). To explain or to predict?. *Statistical science*, *25*(3), 289-310.

Simon, H. A. (2001). Science seeks parsimony, not simplicity: Searching for pattern in phenomena. *Simplicity, inference and modelling: Keeping it sophisticatedly simple*, 32-72.

Skaperdas, S., & Syropoulos, C. (1996). Can the shadow of the future harm cooperation?. *Journal of Economic Behavior & Organization*, *29*(3), 355-372.

Skyrms, B. (2001). The Stag Hunt. *Proceedings and Addresses of the American Philosophical Association, 75*(2), 31-41.

Skyrms, B. (2004). *The stag hunt and the evolution of social structure*. Cambridge University Press.

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1982). Why study risk perception?. *Risk analysis*, *2*(2), 83-93.

Smith, J. M., & Price, G. R. (1973). The logic of animal conflict. *Nature*, *246*(5427), 15-18.

Sneath, D. (1998). State policy and pasture degradation in Inner Asia.

Spaniel, W. (2015). *Game theory 101: the complete textbook*. CreateSpace.

Speck, F. G., & Hadlock, W. S. (1946). A report on tribal boundaries and hunting areas of the Malecite Indian of New Brunswick. *American Anthropologist*, *48*(3), 355-374.

Stearns, S. C., & Hoekstra, R. F. (2000). *Evolution, an introduction*. Oxford University Press.

Strathman, A., Gleicher, F., Boninger, D. S., & Edwards, C. S. (1994). The consideration of future consequences: weighing immediate and distant outcomes of behavior. *Journal of personality and social psychology*, *66*(4), 742.

Strathman, A., Gleicher, F., Boninger, D. S., & Edwards, C. S. (1994). The consideration of future consequences: weighing immediate and distant outcomes of behavior. *Journal of personality and social psychology*, *66*(4), 742.

Tadelis, S. (2013). *Game theory: an introduction*. Princeton University Press.

Taylor, M. (1987). *The possibility of cooperation.* Cambridge: Cambridge University Press.

Thomas, K. W., & Kilmann, R. H. (1975). The social desirability variable in organizational research: An alternative explanation for reported findings. *Academy of Management Journal*, *18*(4), 741-752.

Tisdell, J. G., Ward, J. R., & Capon, T. (2004). Impact of communication and information on a complex heterogeneous closed water catchment environment. *Water Resources Research*, *40*(9).

Todd, P., & Benbasat, I. (1991). An experimental investigation of the impact of computer based decision aids on decision making strategies. *Information Systems Research*, *2*(2), 87-115.

Todd, P., & Benbasat, I. (1994). The influence of decision aids on choice strategies: an experimental analysis of the role of cognitive effort. *Organizational behavior and human decision processes*, *60*(1), 36-74.

Trivers, R. L. (1971). The evolution of reciprocal altruism. *The Quarterly review of biology*, *46*(1), 35-57.

Tucker, C. M., Randolph, J. C., & Castellanos, E. J. (2007). Institutions, biophysical factors and history: an integrative analysis of private and common property forests in Guatemala and Honduras. *Human Ecology, 35*(3), 259-274

Van Damme, E. (1992). Refinements of Nash equilibrium. In *Advances in Economic Theory, 6th World Congress* (Vol. 1, pp. 32-75).

Van der Wal, A. J., Schade, H. M., Krabbendam, L., & Van Vugt, M. (2013). Do natural landscapes reduce future discounting in humans?. *Proceedings of the Royal Society B: Biological Sciences*, *280*(1773), 20132295.

Van Vugt, M. (2009). Triumph of the Commons. *New Scientist*, *203*(2722), 40-43.

Von Neumann, J., & Morgenstern, O. (1944). Theory of games and economic behavior. Princeton university press.

Wilson, D. S. (1987). Altruism in Mendelian populations derived from sibling groups: the haystack model revisited. *Evolution, 41*(5), 1059-1070.

Wilson, D. S. (1997). Altruism and organism: Disentangling the themes of multilevel selection theory. *The American Naturalist*, *150*(S1

Wilson, E. O. (1984) Biophilia. Cambridge, MA: Harvard University Press

Wilson, M., & Daly, M. (1997). Life expectancy, economic inequality, homicide, and reproductive timing in Chicago neighbourhoods. *Bmj*, *314*(7089), 1271.

Wilson, W. (1971). Reciprocation and other techniques for inducing cooperation in the Prisoner's Dilemma game. *Journal of Conflict Resolution*, *15*(2), 167–195.

Wischniewski, J., Windmann, S., Juckel, G., & Brüne, M. (2009). Rules of social exchange: Game theory, individual differences and psychopathology. *Neuroscience & Biobehavioral Reviews*, *33*(3), 305-313.

Wolff, I. (2015). When best-replies are not in equilibrium: Understanding cooperative behaviour.

Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C. & Jensen, O. P. (2009). Rebuilding global fisheries. *science*, *325*(5940), 578-585.

Worthman, C. M., & Kuzara, J. (2005). Life history and the early origins of health differentials. *American Journal of Human Biology*, *17*(1), 95-112.

Yu, H., Jiang, S., & Land, K. C. (2015). Multicollinearity in hierarchical linear models. *Social science research*, *53*, 118-136.

Appendix A

In cooperative games all individuals involved have, directly or indirectly, decided to work together towards a common aim (Maschler, 1992). Examples of such coalitions could be a group of people agreeing on how to divide the amount that each of them should pay from a restaurant bill or, on a bigger scale, various nations acting together in order to prevent a severe economic crisis. Cooperative games are not always straightforward and much research has been done to understand how individuals create effective coalitions, when everyone is free to decide how and with whom to cooperate, as well as how much each player should benefit from such collaboration (*see* Davis & Maschler, 1965; Schmeidler, 1969; Aumann & Dreze, 1974; etc.).

In contrast, *non-cooperative games* contain competitive interactions amongst individuals, which commonly result in "winners" and "losers". Meaning that subjects involved do not seek for a supportive strategy that benefit the group, instead, they typically aim to achieve the optimal outcome for the themselves. Therefore, each participant may obtain a very high or low payoff as consequences of their decision-making (Ritzberger, 2002). The PD is an example of this category of games as well as other variations, such as the 'Assurance game', 'Chicken game' and other situations that generate a social dilemma (Kollock, 1998). These games are also considered non zero-sum games because a player's gain of utility does not necessarily result in another player's loss of utility, which it is what occurs in zero-sum games (Roger, 1991).

Appendix B

A CPR resource is composed by a *facility*, which makes possible the existence of a stock of units, and the *flow*, which is the actual available units that appropriators can benefit from their extraction. If fishing is taken as an example, the fishing grounds are the CPR's facilities whereas the tons of fish are the extractable flows. However, this applies to many other resources that can be found in nature or were specifically constructed by other individuals in order to create a useful service (e.g. parking spaces, where a parking garage is the facility, while its parking spaces are the flow). (Blomquist & Ostrom, 1985).

Furthermore, another distinction between CPRs is their simultaneous renewable and exhaustible nature. In the case of fish stocks, if the total amount of fishing is contained within a certain resource patch throughout time, fish will be able to reproduce and, thus, the flow will be constantly refreshed to a minimum threshold amount. However, if an overfishing occurs (exceeding a certain threshold), the flow will not be able to renew and it will start to deplete, resulting in an eventual destruction of the resource. On the other hand, there are also resources that do not have a renewable attribute, therefore, units appropriation will inevitably lead to their depletion (e.g. oil pools) (Ostrom, 1990).

In their extensive work, Ostrom et al. (1994) suggested that although CPR situations tend to share common characteristics, issues faced by appropriators using a certain resource may vary significantly from those using another CPR. Therefore, Ostrom, Gardner and Walker (1994) argued that it is analytically useful to group CPR problems in two main general types – *appropriation* and *provision.* For appropriation problems the attention is focused on the flow of a CPR, hence, various means are introduced with the intention of excluding possible appropriators to optimise the allocation of the available flow. Whereas, provision problems concern the conservation of the facility and, thus, they are associated with preserving or enhancing the production potentials of a resource. In other words, interventions regarding the provision issues aim to preserve the facility of a CPR and avoid its destruction due to different factors, but mainly as consequences of appropriation.

Appropriation problems may result to be very complex to resolve. In fact, different factors need to be taken into account, beside establishing the efficient level of appropriation, such as optimal timing, technologies used and site of appropriation. Therefore, appropriation problems can be further differentiated in three subcategories - appropriation externality, assignment problems and technological externalities. (1) Appropriation externality concerns the issue of overuse by one individual and the impact of such behaviour upon other appropriators' return. Indeed, Gordon (1954) showed that fishers increase fishing inputs until the average return eventually meets the marginal cost occurred during fishing activity. This result in a situation beneficial for the singular individual since the marginal return increase for him/her, however, the average return for the group decrease creating a negative externality. (2) Assignment problems consider the lack of homogeneity of a resource. Many CPRs are characterised by heterogeneous distribution of their units and thus, the yield within one spot may diverge significantly from another spot. Consequently, adequate assignments of the 'good patches', meaning an equal allocation of the CPRs flows, are needed in order to guarantee a non-discriminatory distribution of the resource and avoid conflicts over those patches. In many cases assignment issues are solved by large variety of local rules, which have shown to be very effective in forming an appropriation order and maintaining a fair distribution of a resource. Messerschmidt (1986) demonstrated this by showcasing examples of irrigation conflicts, within Nepali communities, solved by introducing an irrigation system that involve the reversing of the order by which fields were irrigated during the year. In other words, one of the major crops was watered from the north fields downwards and for the other major crop the order was reversed. This system guaranteed that the farther fields were watered first. This rule has become such an established tradition within Nepali communities that they have a rhyme handed down through generation: "*kar vaalaa, nhaa mhalaa,* meaning "barley from the top, buckwheat from the bottom"" (Messerschmidt, 1986, p. 463). Finally, (3) technological externalities, similarly to assignment problems, concern heterogeneity of the technology used by different appropriators within the same given CPR flow. An example of distribution rules, intended to resolve the existence of technological diversity, is the division of costal fishery into separate fishing areas, so that each area is devoted to one type of fishing technique which involve the use of a specific technology (Cordell, 1972).

Furthermore, provision problems can be tackled from two different perspectives – *demand-side* and *supply-side.* Interventions designed to improve the demand-side aspect aim to change appropriation behaviours that affect the productive ability of a CPR facility (Blomquist, 1992). Whereas, supply-side interventions aim to alter appropriators' activity in order to enhance cooperative behaviour towards the maintenance of a CPR facility (*see* Easter and Welsch, 1986).

Appendix C

In certain interactions, such as the one portrayed in the PD, it can be observed the existence of a clear optimal strategy available to the players involved, this is known as 'Pure Strategy Nash equilibrium'. In the PD, as it was argued earlier, the rational and optimal response is to 'confess' (*see Figure 1)* because it is the only strategy that offers the best payoff regardless of the other player's decision (Haurie, Krawczyk & Zaccour, 2012). However, a pure strategy equilibrium is not always available within the vast array of games. Nash (1951) argues that if no equilibrium exists in pure strategies, one must exist in mixed strategies – a mixed strategy, aka Randomised Nash Equilibria, is a probability distribution over two or more pure strategies. An example of such situation can be given by the 'matching pennies' game. In the matching pennies game, two players simultaneously choose to put two pennies, facing up or down, on a table. If the coins match (both are heads or both tails), player 1 needs to pay £1 to the opponent, whereas the opposite happens in the case that the pennies mismatch – player 2 must pay £1 to player 1 (*see Figure 2*). In this scenario, one player's optimal strategy is strictly depended on the other player's strategy. Indeed, if player 1 believes that player 2 will choose heads, he or she is better off playing tails, however, if player 2 believes that player 1 will pay tails, he or she is better off by switching to tails – such reasoning will continue infinitely and will never lead to a singular pure strategy. Therefore, taking into account the two equally compensating strategies -heads or tails-, the mixed equilibrium (or Mixed Nash equilibria) is to flip the coin and randomise one's decision. Doing so, each player has a 50% percent chance to receive the higher payoff (1) (Spaniel, 2015).

Player 1 \ Player 2	Heads	Tails
Heads	1, -1	-1, 1
Tails	-1, 1	1, -1

Figure 2. Matching Pennies payoff matrix.

Nonetheless, there can be scenarios in which, due to their characteristics, are present multiple pure Nash equilibria. Those are usually not evenly compensating, and individuals involved do not randomised their decision-making but make their choice based on the information they have about the other participant or based on their expectation regarding the other's behaviour (Skyrms, 2001). An example of such circumstance is the Stag Hunt game (aka Assurance game). The Stag Hunt displays a situation where two hunters go out and try to catch some meat and there are two rabbits in the hunting range as well as one stag. However, the hunters can only bring the equipment necessary to catch one type of animal, thus, they must choose between stag or rabbits without knowing what the other person will be hunting. The stag has more meat (higher payoff) than the rabbits combined, but it requires both hunters to chase the stag (they need to cooperate). On the other hand, each hunter could catch the rabbits by themselves. Interestingly, if one of the hunters decide to go after the stag and the other one goes out hunting a rabbit, the one who is hunting the rabbit will get both of the rabbits within the range, while the other hunter will not be able to get anything. This information can be converted in a payoff matrix in order to find the Nash equilibrium for this specific game (*see Figure 3)*.

Hunter 2

Hunter 1		Stag	Rabbit
	Stag	3,3	0,2
	Rabbit	2,0	1,1

Figure 3. The Stag Hunt payoffs matrix

As it was mentioned above, in this scenario can be observed two pure Nash equilibria. Indeed, if Hunter 1 decide to after the stag, Hunter 2 is better off by going after the stag too, and vice versa. Similarly, if Hunter 1 decide to hunt the rabbits instead, Hunter 2 is better off by hunting the rabbits too, and vice versa. Therefore, although rabbit-rabbit (1,1) is a sub-optimal outcome, thus resulting in a lower payoff than stag-stag (3,3), which is an optimal outcome, they are both pure Nash equilibria.

This is similar to the PD as if the individuals involved behave rationally, they will likely follow one of the two Nash equilibria, with a good chance of playing the sub-optimal strategy, due to the often lack of trust in the other player (choosing to hunt rabbit it is the safe choice regardless the lower payoff). Whereas, in the prisoner's dilemma there is only one Nash equilibrium, which also is sub-optimal.

Usually, for the interactions portrayed by the Stag Hunt, it is assumed a certain amount of coordination amongst the individuals involved (although the actual occurrence of such coordination is not guaranteed), whereas, PD lack such feature. That is, if two individuals cooperate in the PD, there are both opting for a smaller payoff rather than a potentially higher one. Therefore, there is a divergence between common benefit and rational choice for the individual. Contrarily, in the stag hunt, cooperation can be more beneficial than defection ($R>T>P>S$) and thus, what is considered as rational decision is based on one's belief regarding the other's possible choice (Skyrms, 2004).

Appendix D

A famous experiment that looked into the emergence of cooperation was conducted by Axelrod and first published in 1980. He aimed to study the best strategy to employ in an indefinitely IPD scenario, through the use of a computer tournament. In fact, Axelrod (1980a) invited several game theorists to submit a program (strategy) that contains a set of rules that trigger a cooperation or a defection decision in every round. Furthermore, considering the nature of an IPD, each strategy was allowed to take into account the history of previous rounds and make a decision based on such data. The strategies submitted were then paired to each other, to their own twins and to a strategy called RANDOM, which randomly cooperated or defected. Interestingly, the winner of the tournament (after a total of 120,000 moves) was one of the simplest strategies that was submitted – TIT FOR TAT (TFT). TFT starts by cooperating during the first interaction with another strategy, and thereafter copies what the its opponent does. In other words, after the first cooperation, if the opponent strategy also cooperates, TFT cooperates again in the next round, otherwise it will defect. Such a strategy of reciprocation was already well known within game theory and studies of cooperation, being able to stimulate a considerable level of cooperation when played by human beings (*see* Wilson, 1971). When comparing the structures of the different strategies submitted (fourteen in total), one specific feature seems to be the distinguishable factor between TFT, and low-scoring strategies – 'being nice', meaning, never being the first to defect. Moreover, another factor that may have affected the results was its forgiving nature. As matter of fact, it was the most forgiving between the 'nice' strategies (Axelrod, 1990). Additionally, TFT has two more main characteristics beside being nice and forgiving, which seems to also promote its effectiveness: it is retaliatory (it punishes if the other defect) and clear (easy to predict its moves and, thus, adapt to it) (Kuhn, 1997).

Axelrod (1980b) repeated the tournament for a second time and the same results were obtained, despite the higher number of entries (sixty-two) from different disciplines and the complete information available to everyone about the previous tournament. In spite of the presence of very sophisticated strategies (e.g. taking into consideration multiple previous rounds or being able to modify their decision-making process during the game) as well as those that attempted to improve TFT (e.g. TIT FOR TWO TATS etc.), TFT again proved to be the highest-performing strategy, thus, winning the tournament. Therefore, it demonstrated its evolutionary stability, it was an ESS, within a noticeably large variety of different strategies, since it is able to invade other populations (even ALL D when the number of invaders is sufficiently large) whereas others were not able to invade it.

Nonetheless, after the publication of Alxelrod's (1980a, 1980b) papers, several studies have been conducted in order to demonstrate that TFT is not necessarily the best strategy. Examples of notorious strategies, proposed as improvement from TFT, is Nowak and Sigmond's (1993) PAVLOV or 'Gradual Tit for Tat' (Beaufils et al., 1997). However, these strategies, as many other ones that have been proposed, were not tested in the conditions of Axelrod's (1980a) original tournaments. Thus, their superior effectiveness cannot be safely assumed. Other critiques have highlighted the possibility that the success of TFT was partly determined by Axelrod's setup of the tournament, hence, different settings are needed to best capture the true performing ability of a given strategy (*see* Binmore, 2015; Northcott & Alexandrova, 2015; Rapoport et al., 2015). Nevertheless, as shown by earlier studies, the success of a strategy is strictly related to its environment. Therefore, existing strategies as well as minor changes in the payoff matrix can have a significant impact on the overall gain and stability of a given strategy (Kendall et al., 2007).

Appendix E

Empirical findings have shown that the solutions proposed by Hardin (1968) - government ownership of a resource or, similarly, their complete privatisation- do not always results in optimal answers to exploitation issues. In fact, studies, such as Sneath (1998), have shown that such solutions are not the only available ones and, instead, they can be counterproductive, generating unwanted outcomes. Observing grassland degradation, Sneath (1998) found that in northern China and southern Siberia, the level of degradation was significantly greater than in Mongolia. Interestingly, China and Russia had adopted a government management of the resource, whereas Mongolia had allowed herders to maintain their traditional group property system – group property institutions are characterised by units of users who have the rights to use the resource and can exclude others (Larson & Bromley, 1990).

Individual property is conceptually similar to group property, as they can be comparable forms of privatisation, and involve a set of rules regarding how to regulate a resource as well as who can benefit from it (Alston & Mueller, 2008). Nevertheless, individual (firms) privatisation differs from traditional group management, since the latter often encompasses set of traditional rules that are rooted into several generations and, usually, does not have specific monitoring programs that aim to regulate the provision and extraction of a resource (Faysse, 2005). Finally, 'open-access' property describes a condition where a certain resource is not monitored or regulated by the government, a private firm or a group of users - which lead to the occurrence of CPR dilemmas.

Interestingly, free access to a CPR, without any form of regulation, should rationally lead to exploitation and destruction of the resource. However, it has been observed that individuals are able to cooperate, generating group property systems, where they self-regulate their appropriation levels and avoid depletion (Ostrom et al., 1990). Such instances are noteworthy because people are able to avoid the tragedy of the commons without an external entity enforcing rules and imposing punishments for misbehaviours. Therefore, the understanding of the dynamics of such occurrence in real-life scenarios could ultimately lead to the recognition of strategies, which can be implemented to foster a sustainable behaviour, hence, helping individual to enjoy joint benefits from the use of a CPR, without falling into the temptation of defection.

When considering the strategies submitted for Axelrod's (1980a,1980b) computer simulations, similar strategy patterns can be found in the behaviours of those individuals dealing with strategic situations, such as the use of a CPR. In fact, people can be generally distinguished between (1) those who always defect, behaving in a narrow, self-interested manner (aka ALL D); (2) those that do not cooperate unless they have some sort of guarantee that other will not defect (this can involve different influential factors and mixed strategies); (3) those that start interaction by cooperating and hope for others to do the same (akin TFT); and finally, (4) those that are inherently altruistic and always cooperate regardless the others' behaviour (Ostrom et al., 1999).

A classic instance of CPRs, which are often managed by a common property system, are irrigation systems. Different studies have reported successful scenarios, where farmers cooperate in order to efficaciously share water resources. An example was already mentioned in the earlier section dedicated at the CPRs, which showed how Nepali communities were able to self-manage the distribution of the water, throughout different seasons, as result of farmers' collaborative behaviour (Messerschmidt, 1986). Analogous evidence was found by Sengupta (1991) when studying irrigation systems in India and Philippines, by Cox and Ross (2011) in New Mexico and others (*see* Tucker et al., 2007; Lam, 1998; Baker, 1997; Ireson, 1995 etc.). Nonetheless, the establishment of this sort of cooperative schemes are not restricted to irrigation systems but are well-known to be successful for other types of CPRs as well (Baland & Platteau, 1996). Another example is forests management. Indeed, different studies have demonstrated that when forests are controlled by a community of local individuals, deforestation diminishes or, in many cases, stops (Acharya, 2002; Agrawal, 2001). Thus, similarly to the administration of irrigation systems, community-based arrangements were able to successfully avoid common exploitation. Instead, they improved the maintaining, as well as the regeneration, of forests. Additionally, field research has shown comparable outcomes for a variety of other CPRS, such as groundwater basins (Kumar, 2000; Blomquist, 1992), grazing lands (Benin & Pender, 2006) etc., that are generally managed by a group of local people. Therefore, it can be argued that the emergence of instinctive cooperation is achievable and beneficial – compared to the often-unsuccessful government regulations (Ostrom et al., 1999).

Common property systems, within a relatively small group of people, are at times regarded as cooperative in nature due to the recurrent interaction between the users of CPR. Thus, the idea of any form of monitoring coercion seem redundant. However, on closer examination, those systems involve a compliance to the often-unspoken internal rules that coordinate the allocation and/or appropriation of a CPR – creating a structure of rights and duties to which most individuals must adhere in order to maintain an overall state of cooperation (Bromley, 1992). Hence, in order for cooperation to emerge, the probability of recurrent interaction must be relatively large due to two main factors, already discussed earlier – reputation and risk of future punishment (Axerlod, 1990). In fact, it has been shown that when non-locals have temporary access to an open access (or more likely, common property regime) CPR , they tend to exploit the resource as result of the lack of knowledge regarding the traditional rules in use; but mainly, the exploitation is caused by the lack of benefit that cooperation normally produce for the members of the group that indefinitely use the resource and interact with each other. Moreover, when this happens, those who were previously managing the commons cooperatively, can fall into the tragedy of the commons, joining the race to exploit the resource (Safina, 1994; Speck & Hadlock, 1946).

Therefore, although some of the field research findings can be transferred from smaller systems to the management of global resources (Worm et al., 2009), these are often limited due to their natural characteristics as well as the dynamics found in relatively small communities. For instance, the irrigation systems can be easily controlled by a group of users thanks to their scale and usage characteristics. In fact, it is usually created for a limited amount of people and aimed for a specific area. Only individuals permanently living in such region can benefit from it and it is impossible for strangers to secretly exploit it. Thus, due to its restricted use, it can be easily monitored, and eventual defectors are promptly punished by the other members (Meinzen-Dick et al., 2002; Fehr & Gachter, 2000). Nevertheless, not all CPRs have such small-scale usage. For instance, more complicated circumstances involve the overfishing prevention. Indeed, it has been observed that fisheries can be regulated by a reciprocal cooperative behaviour within small fishing areas – e.g. the Gulf of California (Brusca, 2010; McCay, 2002; Pinkerton, 1994). However, as monitoring, and repetitive encounters, becomes more arduous in larger areas, the likelihood of overfishing increases. Hence, it is undeniable that the understanding of fishing behaviour found in small areas, by field studies, is essential to understand global fishing issues. Nonetheless, such insights are not sufficient for a suitable generalisation to open ocean contexts, where overfishing trends have kept a steady increase since the 1950s (Coll et al., 2008).

Appendix F

Common-Pool Resource Appropriation Game: 2 players known reward value

Reward starts a value V. If I take proportion α, my opponent proportion β, then the reward maintains its value if $\alpha + \beta \leq 1/2$, goes to $V(1 - \alpha - \beta)$ if $1/2 < \alpha + \beta < 1$ and becomes 0 if $1 \leq \alpha + \beta$.

Picking the same α, β in every round, with the probability of another round occurring given the following expected payoffs for playing α against β.

$$R[\alpha,\beta] = \alpha V(1 + p + p^2 + \cdots) = \frac{\alpha V}{1-P} \qquad \alpha + \beta \leq 1/2$$

$$= \alpha V(1 + (1 - \alpha - \beta)p + \cdots) = \frac{\alpha V}{1-(1-\alpha-\beta)p} \qquad 1/2 < \alpha + \beta < 1$$

$$= \frac{\alpha V^*}{\alpha+\beta} \qquad 1 < \alpha + \beta$$

*here $(\alpha + \beta)V$ is taken but this is $> V$, so it is divided in proportion to the attempted seizure.

For given β, what is the best α? Allowable β values are $0 \leq \beta \leq 1$.

For $\beta > 1/2$, $\alpha = 1$ gains $\frac{V}{1+\beta}$, is clearly better than any other $\alpha > 1 - \beta$.

The payoff for $\alpha < 1 - \beta$ is $\frac{\alpha V}{1-(1-\alpha-\beta)p}$.

This is $< \frac{V}{1+\beta}$ if $\frac{\alpha V}{1-(1-\alpha-\beta)p} < \frac{V}{1+\beta} \Rightarrow \alpha(1 + \beta) < 1 - (1 - \alpha - \beta)p$

$\Rightarrow (1 - \alpha - \beta)p < 1 - \alpha - \alpha\beta$ which is true for $p \leq 1$.

Thus, the best reply to $\beta > 1/2$ is $\alpha = 1$. Playing 1 is a Nash Equilibrium and no other strategy for $1/2 < \beta < 1$ is.

For $\beta \leq 1/2$, $\alpha = 1$ gets $\frac{V}{1+\beta}$ and is better than any other $\alpha > 1 - \beta$,

$\alpha = 1/2 - \beta$ gets $\frac{(1/2-\beta)V}{1-p}$ and is better than any other $\alpha < 1/2 - \beta$,

$1/2 - \beta < \alpha < 1 - \beta$ gets $\frac{\alpha V}{1-(1-\alpha-\beta)p}$ and is $< \frac{V}{1+\beta}$ as before.

Thus the best response to $\beta < 1/2$ is 1 if $\frac{V}{1+\beta} > \frac{(1/2-\beta)V}{1-p}$ and is $1/2 - \beta$ otherwise.

Thus no strategy $\beta \leq 1/2$ is a Nash Equilibrium unless $1/2 - \beta = \beta \Rightarrow \beta < 1/4$.

$\beta < {}^{1}/_{4}$ is a Nash Equilibrium if $\frac{({}^{1}/_{2} - {}^{1}/_{4})V}{1-p} \geq \frac{V}{1+{}^{1}/_{4}} \Rightarrow \frac{1}{4(1-p)} \geq {}^{4}/_{5}$

$\Rightarrow \frac{16(1-p)}{5} \leq 1 \Rightarrow 1 - p \leq {}^{5}/_{16} \Rightarrow p \geq {}^{11}/_{16}$.

In summary we have $\boldsymbol{\beta = 1}$ is always a Nash Equilibrium, $\boldsymbol{\beta = {}^{1}/_{4}}$ is a Nash Equilibrium if $\boldsymbol{p \geq {}^{11}/_{16}}$

■

Appendix G

The table shows the first selection of 10 models (from the initial 45 models developed during the sequential approach) with the lowest AIC, for Number of Cooperation as response variable. Negative Binomial model with log link (Parameter set at .5)

Model	Coefficient [95% Wald CI]	SE	P	Deviance	Df	Omnibus Test(Sig.)	AIC
1				132.70	114	.087	480.71
Condition							
Seen	[.0807, -.0200]	.0807	.087				
Unseen	.	.	.				
2				131.71	113	.135	481.72
Condition							
Seen	[-.021405, .6812]	.1792	.066				
Unseen	.	.	.				
NR	[-.1555, .4757]	.1610	.320				
3				133.38	113	.070	479.97
Condition							
Seen	[-0.079, 0.613]	.176	.137.				
Unseen	.	.					
IMD	[0.000012, - 0.000003]	.000012	.093				
4				128.85	112	.076	480.85
Condition							
Seen	[-.0681, .6406]	.1808	.113				
Unseen	.	.	.				
IMD	[-.000003, .000046]	.000013	.085				
CFC	[-.1783, .5553]	.1871	.314				
5				129.21	112	.090	481.21
Condition							
Seen	[-.0684, .6433]	.1815	.113				
Unseen	.	.	.				
IMD	[-.000005, .000044]	.000013	.115				
NR	[-.1873, .4500]	.1625	.419				
6				128.85	112	.076	480.85
Condition							
Seen	[-.0681, .6406]	.1808	.113				
Unseen	.	.	.				
IMD	[-.000003, .000046]	.000013	.085				
CFC	[-.178355, .5553]	.1871	.314				
7				128.51	111	.121	482.51
Condition							
Seen	[-.0582, .6560]	.1822	.101				
Unseen	.	.	.				
IMD	[-.000004, .000045]	.000013	.102				
NR	[-.2300, .4258]	.1673	.558				
CFC	[-.2160, .5395]	.1927	.401				
8				126.26	112	.024	478.26
NR	[.1176, 1.1346]	.2594	.150				
Condition			.				
Seen	[.7209, 5.1540]	1.1308	010				
Unseen							

Condition:NR							
Unseen:NR	[-1.4208, -.1252]	.3305	.021				
Seen:NR	[.1176, 1.1346]	.2594	.150				
9				123.35	111	.015	477.36
Condition							
Seen	[.7465, 5.284]	1.1577	.009				
Unseen	.	.	.				
IMD	[-.000003, .000046]	.000012	.078				
NR	[.0978, 1.137]	.2652	.222				
Condition:NR							
Unseen:NR	[-1.4739, -.1456]	.3387	.017				
Seen:NR	[.0978, 1.137]	.2652	.222				
10				122.20	110	.019	478.20
IMD	[-.000002, 0.000047]	.000013	.077				
NR	[.07833, 1.100]	.2656	.315				
Condition							
Seen	[.8856, 5.3631]	1.1633.	.007				
Unseen	.		.				
CFC	[-.1673, .5812]	.1946	.284				
Condition:NR							
Unseen:NR	[-1.4913, -.1833]	.3400	.025				
Seen:NR	[.07833, 1.100]	.2656	.315				

3				**132.70**	**114**	**.087**	**480.71**
Condition							
Seen	[.0807, -.0200]	.0807	.087				
Unseen	.	.	.				

Appendix H

Psychology REC

The Burroughs
Hendon
London NW4 4BT

Main Switchboard: 0208 411 5000

24/07/2019

APPLICATION NUMBER: 8122

Dear Robert Spencer and all collaborators/co-investigators,

Re your application title: Empirical tests of Nash Equilibria in Common Pool Resource games

Thank you for submitting your application. I can confirm that your application has been given APPROVAL from the date of this letter by the Psychology REC.

The following documents have been reviewed and approved as part of this research ethics application:

Document Type	File Name	Date	Version
Aims, objectives and hypotheses	Ethics Aims and Research Questions Spencer 8122	24/07/2019	1
Methods and data	CPR New Ethics (3 games) Summary of the research study and rationale	24/07/2019	1
Materials	Participant Data Collection Pack CPR Game 1 V1	24/07/2019	1
Materials	Experimenter Datasheet CPR Game 1 V1	24/07/2019	1
Materials	Participant Data Collection Pack CPR Game 2 V1	24/07/2019	1
Materials	Experimenter Datasheet CPR Game 2 V1	24/07/2019	1
Materials	Participant Data Collection Pack CPR Game 3 V1	24/07/2019	1
Materials	Experimenter Datasheet CPR Game 3 V1	24/07/2019	1
Participant Information Sheet	Information Sheet & Consent Form Game 1	24/07/2019	1
Participant Information Sheet	Information Sheet & Consent Form Game 2	24/07/2019	1
Participant Information Sheet	Information Sheet & Consent Form Game 3	24/07/2019	1
Debriefing Sheet	Participant Debrief Sheet CPR Game 1 V1	24/07/2019	1
Debriefing Sheet	Participant Debrief Sheet CPR Game 2 V1	24/07/2019	1
Debriefing Sheet	Participant Debrief Sheet CPR Game 3 V1	24/07/2019	1

Although your application has been approved, the reviewers of your application may have made some useful comments on your application. Please look at your online application again to check whether the reviewers have added any comments for you to look at.

Also, please note the following:

1. Please ensure that you contact your supervisor/research ethics committee (REC) if any changes are made to the research project which could affect your ethics approval. There is an Amendment sub-form on MORE that can be completed and submitted to your REC for further review.

2. You must notify your supervisor/REC if there is a breach in data protection management or any issues that arise that may lead to a health and safety concern or conflict of interests.

3. If you require more time to complete your research, i.e., beyond the date specified in your application, please complete the Extension sub-form on MORE

Appendix I

Information Sheet

18/07/2019
Robert Spencer
Psychology Department,
Faculty of Science & Technology,
Middlesex University,
London, NW4 4BT.

Consumption decisions around Common Pool Resource in an economic game scenario

Thank you for your interest in this project, which is concerned with how people make decisions about the consumption or exploitation of resources when other individuals are simultaneously exploiting those resources. Before you decide to participate it is important to understand why the research is being done and what it will involve. Please read the following information carefully. Please ask a member of the project team who are running the study if anything is unclear to you and you would like further information.

All resources on this planet are finite and in many cases we have to make use of those resources at the same time as they are being exploited by other people. In addition to this some resources, particularly environmental resources, are available for all people to make use of and it is often not possible or desirable to control access to such resources or exclude people from using them. Such resources are called Common Pool Resources. Common Pool Resources are interesting because multiple individuals are exploiting them at the same time and both this and the amount of the resource available influences the decisions people make when exploiting those resources. Your participation in this study will help us to understand the consumption decisions people make when exploiting Common Pool Resources at the same time as another individual whose consumption choices you are unaware of.

If you choose to take part in this study you will be asked to complete three short questionnaires dealing with aspects of your personality and how connected you feel to urban and natural environments. Following this you will play an economic game against one other person where you individually make decisions about the quantity of a resource you wish to consume. Following the game you will be provided with further information about the aims of the study.

Participating in the study should take around 30 minutes depending on how many rounds the economic game lasts.

- Participation in this research is entirely voluntary.
- No information from which you can be personally identified (name, email address) will be shared at any time, used in the analysis of the results or published in research outputs arising from the project.
- Your privacy will be respected at all times. All participants are given a unique reference number for participating so all data collected will be anonymised.
- You will not receive personalised feedback about the questionnaires you complete.
- You will receive copies of the consent form, information sheet and debrief sheet via email.
- If you change your mind about participating you have the right to stop at any time without giving a reason.
- Even if you consent to participate in the research you have the possibility to withdraw the data you provided from the study at the end of the project (to do so please contact the Principle Investigator shown below).
- No risks or benefits to you as an individual are anticipated as a result of your participation in this research.

The project is being conducted at Middlesex University in the UK. All research projects involving human participants are reviewed and must be approved by an Ethics Committee before they can proceed. The Middlesex Department of Psychology Ethics Committee have reviewed and approved this research project. The Principle Investigator is Dr Rob Spencer (r.spencer@mdx.ac.uk; Department of Psychology, Faculty of Science & Technology, Middlesex

University, Town Hall, The Burroughs, Hendon, London, NW4 4BT) and the research project team are: Mario Bonfrisco (MB1981@live.mdx.ac.uk)

If you have any queries please contact a member of the project team in the first instance. If you have any complaints, please contact the Principle Investigator.
If you have read the above information and give your consent to participate in this study, please tick the ‘I agree’ box on the consent form. Thank you for reading this information sheet.

Middlesex University
Department of Psychology
Faculty of Science & Technology

Written Informed Consent

Title of Study/ Research Project:
Consumption decisions around Common Pool Resource in an economic game scenario
Researcher:
Mario Bonfrisco
Principle Investigator:
Dr Robert Spencer

I understand the details of the research as outline din the participant information sheet and explained to me by the researcher and confirm that I consented to participate in the study.
I have been given contact details for the Principle Investigator and members of the project team in the information sheet.
I understand that my participation is entirely voluntary, that data collected during the research will not be identifiable and I have the right to withdraw from the study at any time without any obligation to explain my reasons for doing so.
I further understand that the data I provide will be may be used for analysis and subsequent publication and provide my consent that this might occur.

I agree.

☐

Date:

Note for participants: Data may be inspected by the chair of the Psychology Ethics Panel at Middlesex University, if required by institutional audits about the correctness of procedures. Although this would happen in strict confidentiality, please tick the below box if you do not wish the data you provide to be included in this type of ethics audit.

☐

URN:

Participant Questionnaire

Age:

Sex:

Please provide the postcode for your last 2 home addresses in the boxes below (If your permanent home address and term time address differ, please provide the postcode for your home address. If you have lived at the same home address for the last 5 years or more just provide one postcode. **Why are we asking for this?** This information will not be used to identify you or your home address it will simply be used to look up economic data at the neighbourhood level on the Office for National Statistics website):

Nature Relatedness Scale

Instructions: For each of the following, please rate the extent to which you agree with each statement, using the scale from 1 to 5 as shown below. Please respond as you really feel, rather than how you think "most people" feel.

1 Disagree strongly	2 Disagree a little	3 Neither Agree or disagree	4 Agree a little	5 Agree strongly

1. I enjoy being outdoors, even in unpleasant weather. ____
2. Some species are just meant to die out or become extinct. ____
3. Humans have the right to use natural resources any way we want. ____
4. My ideal vacation spot would be a remote, wilderness area. ____
5. I always think about how my actions affect the environment. ____
6. I enjoy digging in the earth and getting dirt on my hands. ____
7. My connection to nature and the environment is a part of my spirituality. ____
8. I am very aware of environmental issues. ____
9. I take notice of wildlife wherever I am. ____
10. I don't often go out in nature. ____
11. Nothing I do will change problems in other places on the planet. ____
12. I am not separate from nature, but a part of nature. ____
13. The thought of being deep in the woods, away from civilization, is frightening. ____
14. My feelings about nature do not affect how I live my life. ____
15. Animals, birds and plants should have fewer rights than humans. ____
16. Even in the middle of the city, I notice nature around me. ____
17. My relationship to nature is an important part of who I am. ____
18. Conservation is unnecessary because nature is strong enough to recover from any human impact. ____
19. The state of non-human species is an indicator of the future for humans. ____
20. I think a lot about the suffering of animals. ____
21. I feel very connected to all living things and the earth. ____

Consideration of Future Consequences Scale

For each of the statements below, please indicate whether or not the statement is characteristic of you. If the statement is extremely uncharacteristic of you (not at all like you) please fill-in a "1"; if the statement is extremely characteristic of you (very much like you) please fill-in a "5". Use the numbers in the middle if you fall between the endpoints. Please keep the following scale in mind as you rate each of the statements below.

1=extremely uncharacteristic
2=somewhat uncharacteristic
3=uncertain
4=somewhat characteristic
5=extremely characteristic

___1. I consider how things might be in the future, and try to influence those things with my day to day behavior.
___2. Often I engage in a particular behavior in order to achieve outcomes that may not result for many years.
___3. I only act to satisfy immediate concerns, figuring the future will take care of itself.
___4. My behavior is only influenced by the immediate (i.e., a matter of days or weeks) outcomes of my actions.
___5. My convenience is a big factor in the decisions I make or the actions I take.
___6. I am willing to sacrifice my immediate happiness or well-being in order to achieve future outcomes.
___7. I think it is important to take warnings about negative outcomes seriously even if the negative outcome will not occur for many years.
___8. I think it is more important to perform a behavior with important distant consequences than a behavior with less-important immediate consequences.
___9. I generally ignore warnings about possible future problems because I think the problems will be resolved before they reach crisis level.
___10. I think that sacrificing now is usually unnecessary since future outcomes can be dealt with at a later time.
___11. I only act to satisfy immediate concerns, figuring that I will take care of future problems that may occur at a later date.
___12. Since my day to day work has specific outcomes, it is more important to me than behavior that has distant outcomes.

Instructions for playing the Common Pool Resource economic game

Please read the below instructions and then wait for further guidance from the experimenter

Instructions for players:

In this game you have access to a resource. The total amount of this resource that exists is 100 units. You accumulate points by consuming units from this resource and your aim is to accumulate as many points as possible in the game. The game lasts for a number of rounds, you will not be told how many rounds the game is going to last but, in each round prior to making your consumption decision, you will be told the actually probability of there being another round after the current round.

You are playing the game against one other player, they have access to the same resource you are consuming, so the resource is shared and anything you consume is not available for them to consume.

In each round of the game you have to choose how much of the resource you would like to consume. The minimum you can take is 1 unit in a round and the maximum is the total resource available (100 units).

When making your choice about how much to consume in a given round you should be aware of the following rules of the game.

Once all players have made their consumption choices in a round, the experimenter will add up the consumption choices of all players:

- If that total consumption is less than or equal to 50% of the total resource available then the resource will refresh back to the starting value for the next round.
- If that total is greater than 50% of the total resource available but less than all of the resource, the resource will be reduced by the amount extracted by all players and the value of the resource in the next round will be this reduced value (e.g. if the value of the resource in round one is 100 units and the total consumed by all players was 80 units then the resource available in the next round would be 20 units). The experimenter will state the actual reduced value of the resource at the start of the next round. If players then use less than 50% of this reduced resource in the next round then the resource will refresh to the reduced value. (e.g. If the resource is reduced to 40 units and the total consumption of all players in the next round is 20 units or less, then the resource will refresh to 40 units in the following round but not back to the original starting value of 100 units).
- If the total consumption for all players is equal to or greater than the total amount of the resource available then the game ends and the points accumulated by a player are totalled up to give their final score for the game.
- Prior to making their consumption decisions in a round players will be told the exact probability that there will be another round after the one being currently played.

Your task during the game is to complete the participant datasheet by recording how much of the resource you would like to consume in that round in row 1 under the column consumption decision. You will then write your consumption decision on a separate piece of paper and discreetly pass it to the experimenter without communicating that information to the other player in the game. You make your decision without conferring or knowing what choice the other player will make.

Participant Datasheet:

Date:	Location:
Player URN:	Game:
Round:	Consumption Decision:
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	

URN:

Post-game questionnaire

Was your behaviour/ consumption decisions influenced by what you thought other would do?
Y/N

Did you think that other players would overuse the resource?

Y/N

Did you know the person against whom you were playing?

Y/N

Are you friends with the person against whom you were playing?

Y/N