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Individual Differences in Cooperation in a Circular Public Goods Game

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Abstract

Research using the public goods game to examine behaviour in the context of social dilemmas has repeatedly shown substantial individual differences in patterns of contributions to the public good. We present here a new method specifically designed to capture this heterogeneity in play and classify participants into broad categories or types. Players in groups of four made initial, simultaneous contributions to the public good. Subsequently, players were sequentially told the current aggregate contribution to the public good and allowed to change their decision based on this information. The game continued, with players updating their contribution decision until the game ended at an unknown point. By looking at the relationship between players' contributions and the aggregate value they observed, we were able to cleanly classify 82% of our players into three types: strong free riders (28%), conditional cooperators of reciprocators (29%), and strong cooperators (25%). We also found that scores on some of the personality dimensions we investigated (self-monitoring, self-esteem, neuroticism, and conscientiousness) correlated with player type. Finally, males were found to be more likely to be strong cooperators than females. Copyright © 2001 John Wiley & Sons, Ltd.

INTRODUCTION

Over the last three decades, individual differences have taken on greater importance in the context of group cooperation games. Whereas it used to be thought that players' 'dispositional qualities' would have only negligible effects in these environments (Pruitt and Kimmel, 1977), more recently, psychologists and economists have begun to take seriously the idea that individual differences among participants might be important in understanding and modelling behaviour in experimental games (see e.g. Liebrand, 1984; Yamagishi, 1986). Indeed, Rapoport and Suleiman (1993) suggested that

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researchers might do well 'to shift the focus of future research to identifying personality and attitude variables that allow the classification of subjects into different ''types'' whose decision behaviour in social dilemmas may be described by alternative models' (p. 193).

Our research is an attempt to shed light on the way individual differences impact play in social dilemmas, situations in which individually selfish behaviour leads to outcomes that are worse, in aggregate, for group members than if everyone had behaved cooperatively. A standard way to create social dilemmas in the experimental laboratory, and the one that forms the basis of our own experiments, is the public goods game. In this environment, players are given an endowment of tokens and must allocate them between a private account and a group account. Tokens in the private account yield a higher monetary return to the participant than tokens in the group account, but tokens in the group account improve the group's aggregate outcome. (For recent reviews, see Komorita and Parks, 1995; Ledyard, 1995.) This structure provides a relatively clean way to investigate how individuals trade off their own interests against those of a group.

The study of individual differences is becoming increasingly important in group-based games because of the emerging emphasis on the importance of reciprocity or 'conditional cooperation' in social dilemmas. Briefly, it has been suggested that many players in repeated social dilemma games condition their contributions (level of cooperation) on the play of others, contributing a greater fraction of their endowment as a positive function of their beliefs about others' contributions. Indeed, a consistent finding is that players' contribution decisions are correlated, sometimes very strongly, with players' expectations of others' contributions (Bornstein and Ben-Yossef, 1994; Croson, unpublished manuscript; Dawes, McTavish and Shaklee, 1977; Komorita, Parks and Hulbert, 1992; Messick, Wilke, Brewer, Kramer, Zemke and Lui, 1983; Wit and Wilke, 1992; Yamagishi and Sato, 1986).

This suggests that group dynamics might be strongly influenced by the composition of groups in terms of player types. If some players use reciprocal strategies, matching others' contributions, then the presence of players who contribute little or nothing to the public good (free riders) will lead to decreasing aggregate contributions over time as reciprocators match free riders' small contributions. Hence, in repeated or sequential games, a feedback system is created that is sensitive to the proportion of each strategy type within the group and, moreover, determines the extent to which a group is able to sustain cooperation. Thus, individual strategies that group members pursue ripple through the group over time.

This feedback loop can lead to strikingly varied dynamics. In a recent series of experiments by Kurzban, McCabe, Smith and Wilson (in press), participants interacted in a real time linear public goods environment in which players were able to change their contributions as they received information about what other members in their group were contributing. In a condition in which group members could only increase their contribution during the round and knew only the lowest current contribution to the group account, many players kept their contribution to the public good slightly above the observed lowest value. This generated a kind of upward spiral, enabling some groups to sustain high, occasionally perfect, levels of public good provisioning.

However, in this particular environment, the presence of a single free rider seems to have completely altered play dynamics. Some participants chose to keep their contribution at zero in this condition. Possibly because other (reciprocal) players observed that the lowest value never moved from zero, these groups generated almost no public good provisioning. What is odd about this result is that in this game, if all but one player in a

group were using a strategy of maintaining his or her contribution slightly above the current lowest contribution, the last player, the would-be strong free rider, would do better for himself or herself by following the same strategy instead of free riding. The persistence of free riding behaviour even when it was not a best response is puzzling, and the current investigation was in part motivated by this odd result.

Our goals in the current experiment were twofold. The first was to develop a method that could cleanly distinguish different types of players in the public goods environment. A related but ancillary objective was to try to observe how the type distribution within groups affects play dynamics. Second, we were interested in correlating the different types of individual play observed in the public goods game with personality variables that might be correlated with cooperative behaviour. Much of the research on individual differences and cooperation is in the context of two-person games, and this experiment provided the opportunity to investigate variables that might be linked to cooperative play in group environments.

Individual differences in cooperation in groups

Types. The game theoretical concept of a 'type', meaning differences in agents' information, beliefs, and preferences, maps loosely onto the psychological concept of personality type. In both domains, the concept captures ways in which individuals systematically differ from one another. In economics, this is within the scope of a particular game theoretical environment, while in psychology the concept is designed to capture important ways in which people differ in their behaviour in consistent ways across settings.

Results from public goods games have repeatedly shown that there is a great deal of variation in the strategies that participants use, and a number of classification schemes designed to capture this variation have been suggested. Suleiman and Rapoport (1992), for example, suggested that there were three types of player: those who were concerned with equity, those who tried to maximize their utility, and those whose play defied easy categorization. Weimann (1994) proposed a scheme dividing players into cooperative types, strong free riders (who contribute zero to the public good in every round of play), and weak free riders (who contribute a positive amount to the public good, but not their entire endowment). More recently, Fischbacher, Gächter and Fehr (2001) suggested a four-part scheme in which players were classified as 'conditional cooperators', 'free riders', 'hump-shaped', and 'others'.

A consistent feature of these disparate classification schemes is that some, but not all, participants are classified as strong free riders. In addition, it looks as though at least some players are reciprocators, contributing as a positive function of their beliefs about others' contributions. However, to date, while there seems to be agreement that players use strategies that differ in systematical and discernable ways, there is no consensus on the correct classification scheme.

With the exception of Fishbacher *et al.* (2001), the descriptive schemes were not the result of a specific attempt to distinguish among types. Fischbacher *et al.* (2001) asked participants to indicate what their contribution would be given a set of hypothetical contributions from the participant's fellow group members. For most subjects, his or her answers to these hypothetical questions had no impact on their actual payment. Concerned that decoupling participants' decisions and their outcomes might compromise the reliability of participants' behaviour, we developed a new method for distinguishing player types.

Distinguishing types. To distinguish types of players in the public goods game, we designed an environment in which we could observe a large number of contribution decisions for each subject and, importantly, the way in which each subject conditioned his or her play on their information about others' contributions. To accomplish this, we developed a 'circular' public goods game that worked as follows. At the beginning of each round of play, participants simultaneously made an initial allocation of tokens between their private and group accounts. Subsequently, one player at a time was told the aggregate contribution to the group account and allowed to change his or her contribution. Play continued with each player in turn given a chance to change his or her contribution, ending at a pre-determined random point that was unknown to participants. At the end of the game, payoffs were determined by the final allocation of tokens to the group and private accounts.

With respect to the questions that motivate this paper, we believe that the design we use has several advantages over the standard, repeated public goods game in which moves are made simultaneously. For one, our method enables us to plot a player's contributions against the average contribution to the group account that they observed when they made their contribution. So, for example, conditional cooperators' contributions should cluster around the 45° line on this plot, while a strong free rider's contribution should be at zero regardless of the observed average contribution, and so forth for other possible player types.

A second advantage of this method is that it allows us to look at reciprocity in a way that most other public goods games do not. After the initial contribution, each player is making what might be a last move (because the game can end at any time) as well as a move that will potentially influence subsequent players. Because most public goods games are played with simultaneous contributions, it is not possible to observe how players condition their contributions on those of others.[1] For this reason, simultaneous games might be obscuring reciprocal play (Kurzban *et al.*, in press).

Finally, this design allows us to test the hypothesis that allowing the use of reciprocal strategies will lead to improved rates of provision of the public good. It has been argued that the simultaneous protocol leads to a downward spiral in contributions over the course of repeated rounds because players who are uncertain about others' contributions might be motivated to decrease their own contribution to avoid contributing more than others (see e.g. Kurzban, unpublished doctoral dissertation). Removing the uncertainty in contributions might lead to sustainable levels of cooperation, particularly if all members of the group are either strong cooperators or reciprocal types, because participants will be motivated by both reciprocating others' contributions and inducing reciprocal cooperation in others. Thus, we predicted that this method would allow some groups to avoid the decay in contributions over time observed in other public goods games.

Personality differences

A large body of evidence suggests that there are important in individual differences in personality and demographic variables that correlate with cooperativeness in experimental games (see below). Much of this evidence is from two-player games, especially the Prisoner's Dilemma, and there are reasons to believe that cooperation in groups differs in important ways from cooperation in dyads (see e.g. Kurzban and Leary, 2001). Some data,

[1]This argument only applies within rounds. In games with multiple rounds, there is the possibility of reciprocating contributions in one round with contributions in a subsequent round.

however, have been accumulated from group-based games as well. The size of this literature precludes investigating all previously examined personality dimensions, so we selected a small number that there was reason to believe might be correlated with cooperativeness.

Based on earlier findings, we chose to investigate the following: (1) Machiavellianism (Geis and Christi, 1970); (2) self-monitoring (see e.g. Boone, De Brabander and van Witteloostuijn, 1999a; Danheiser and Graziano, 1982); (3) the 'Big Five' personality dimensions (Lu and Argyle, 1991); (4) self-esteem (Lu and Argyle, 1991); and (5) locus of control (Boone, De Brabander and van Witteloostuijn, 1999b). In addition, given the conflicting findings in previous research (compare Brown-Kruse and Hummels, 1993, with Nowell and Tinkler, 1994, and Seguino, Stevens and Lutz, 1996, with Sell and Wilson, 1991), we were also interested in examining sex differences.

Machiavellianism. High scorers on the Maciavellianism (high Machs) scale developed by Christie (1970) are individuals who tend to be manipulative, opportunistic, and rational. Low Machs, in contrast, tend to be more emotional and more likely to conform to social norms rather than depart from them in order to pursue their self-interest. Meyer (1992), for example, found that low Machs refused low offers as the responder in an ultimatum game, suggesting that pursuing fairness norms was more important to them than the small gain they could have obtained by accepting the offer. High Machs, on the other hand, have been shown to be more likely to opportunistically exploit the trust of a counterpart (Gunnthorsdottir, McCabe and Smith, in press; Harrell and Hartnagel, 1976). Where high Machs tend to be competitive and exploitative, low Machs are, broadly, more cooperative than high Machs (Wilson, Near and Miller, 1996, 1998). Hence, we expected that high Machs would be particularly likely to cooperate in the first move of the game to elicit reciprocal cooperation from others, but more likely to free ride as the game progressed. We expected low Machs, in contrast, to follow the well known norm of reciprocity, and play a reciprocal strategy throughout the game.

Self-monitoring. Self-monitoring is a measure of the extent to which individuals change their behaviour depending on the current social context. High self-monitors are vigilant in their interactions, ensuring that the way that they present themselves is appropriate for each particular social context and creates the impression required to achieve their social goals. Low self-monitors tend to be less concerned with impression management and are less likely to change their presentational behaviour across social contexts.

In games of cooperation, it appears as though high self-monitors use cooperative moves to present a positive image to their counterparts. Danheiser and Graziano (1982) found that high self-monitors, unlike lows, increased their rate of cooperation in a two-person prisoner's dilemma game when they believed that they were going to have further social interaction with the other player in the game (see also Boone *et al.*, 1999a). So, while high self-monitors might be more likely to use others' contributions as a guide to what constitutes the 'correct' behaviour within each group, we expected that low self-monitors, being more cross-situationally consistent in their behaviour, would not be likely to condition their play on what others have done. Thus, we expected high self-monitors to be more likely to be classified as conditional cooperators than low self-monitors.

The Big Five. There are five factors or dimensions that seem to account for a great deal of between-individual variation in stable personality traits. There is debate on naming these

factors, but, broadly, these dimensions are extraversion, agreeableness, conscientiousness, neuroticism, and openness (see e.g. Benet-Martinez and John, 1998). The importance of the Big Five in personality research makes them an obvious candidate for continued empirical study.

Although we measured all five dimensions, three of them, extraversion, neuroticism, and agreeableness, have already been shown to relate to cooperativeness. Based on earlier research, we expected that extraversion (Lu and Argyle, 1991; but see Ashton, Paunonen, Helmes and Jackson, 1998) and agreeableness (see e.g. Lu and Argyle, 1991) would be positively correlated with cooperativeness, while neuroticism would be negatively correlated (Ashton *et al.*, 1998; Lu and Argyle, 1991). We had no predictions concerning the other two dimensions.

Self-esteem. Self-esteem plays a role in many different important processes, but its relationship to cooperativeness (and its counterpart, competitiveness), remains unclear. There is conflicting evidence on both the magnitude and direction of this relationship (Kagan and Knight, 1979; Lu and Argyle, 1991), and even which direction the arrow of causality points can be debated (see Meeker, 1990, for one view). Hence, we included a measure but remain agnostic as to its likely correlates with cooperativeness.

Locus of control. Locus of control refers to the extent to which individuals believe that they control their fate. On one end of the scale, externals believe that their destiny is the result primarily of outside forces and influences. On the other end, internals believe that they actively shape the events that surround their lives (Rotter, 1966). Boone *et al.* (1999b) have recently provided evidence that internals in social dilemma situations are more likely than externals to play so as to try to influence the behaviour of other players in order to achieve their goals. In their experiments, the repeated prisoner's dilemma game, this meant cooperating early to encourage reciprocal cooperation from others later in the game, but defecting on the last move. In contrast, externals played less strategically, and showed less variation in their play. Based on this finding, we predicted that externals would be more likely than internals to be classified as either strong free riders or strong cooperators.

Participant sex. The effect of sex on cooperativeness in groups has been examined in a number of studies, but the evidence on this point is mixed. Some experiments have indicated that cooperativeness in public goods environments does not vary significantly as a function of sex (Caldwell, 1976; Dawes *et al.*, 1977, Experiment 1; McClintock and Liebrand, 1988; Yamagishi, 1986). Some studies suggest, however, that females in same-sex groups contribute more than participants in all-male groups (Nowell and Tinkler, 1994; Sell, 1997), at least under certain conditions (Dawes *et al.*, 1977, Experiment 2; Kurzban, unpublished doctoral dissertation), though the reverse has also been found (Brown-Kruse and Hummels, 1993). Mixed-sex groups have similarly yielded contradictory findings (compare Seguino *et al.*, 1996, in which females are more cooperative, with Sell and Wilson, 1991). In short, the mixed evidence of the effect of sex on cooperation allows us to make no firm predictions in the current experiment.

Summary. In summary, our predictions were as follows. With respect to absolute levels of contributions, we expected that high self-monitors, low Machs, and those who scored high on the extraversion and agreeableness scales would contribute more than other participants. We expected that high Machs, low self-monitors, and those with an external locus of control would be more likely than others to be classified as strong free riders, and that low self-monitors and externals would also be more likely than others to be strong

cooperators. Finally, we expected that low Machs and high self-monitors would be differentially likely to fit the reciprocator profile.

METHOD

Participants

Seventy-two participants, 50 males and 22 females, were run in three groups of 24 per session. Participants were recruited from the undergraduate population using the recruitment system in place at the Economic Science Laboratory as well as through classes at the University of Arizona.

Procedure

Participants arrived in the laboratory and were seated at computer terminals that are divided by partitions so that it is not possible to see anybody else's screen. Except for the instructions, which were printed on paper, the entire experiment was conducted by computer.

Once all 24 participants were seated, participants were told that they had already earned their show-up payment and that their decisions and earnings would be kept confidential. Subsequently, the instructions for the voluntary contribution mechanism, which closely followed Andreoni (1995), were distributed.

The instructions informed participants that they would be assigned to a series of groups, each consisting of four people, and that the members of these groups would be shuffled randomly over an unspecified number of games. Participants were told that they would receive an endowment of 50 tokens per game to divide between two exchanges, and that tokens in the individual exchange earned one cent per token, while tokens in the group exchange earned half of one cent for each player, making the marginal *per capita* return 0.5.

Each game consisted of all players simultaneously making an initial allocation of tokens between the two accounts. After this initial decision, there were a number of rounds during which one player in each group was provided the current aggregate contribution to the group exchange, and given the opportunity to change his or her allocation to the two accounts. Each person in the group was given a similar decision until the game ended at a point unknown to the participants. Participants were told that the only restriction on when the game could end was that each player would have at least one chance to change their contribution decision. It was emphasized that payoffs each round would be determined by the final allocation of all group members' tokens to the two exchanges. The composition of the groups, the order of play within groups, and the length of each game was generated randomly before the experiment and kept constant for all three sessions. Game lengths were generated by assigning a probability of 0.04 that the game would end after any given player's opportunity to change their allocation. This process generated the following game lengths: 6, 8, 4, 36, 38, 8, 21.

Because earlier research has indicated that there might be significant amounts of confusion in understanding instructions in the public goods game (Andreoni, 1995; Houser and Kurzban, in press) participants were required to complete a quiz before they were able to proceed. The quiz consisted of ten questions that could not be answered unless one understood the voluntary contribution mechanism. All ten questions had to be answered

correctly before players could proceed. Most participants were able to complete the quiz with little difficulty, and those that required additional help were assisted privately by the experimenter. The first round began once everyone had completed the quiz, and then subsequent rounds proceeded automatically after all groups had reached the end of the round.

After the last game, participants were asked to indicate their sex and age, and fill out a series of questionnaires. These included (1) the Mach IV Scale (Christie, 1970); (2) the Self-Monitoring Scale (Snyder, 1974); (3) the Big Five Inventory (BFI) (Benet-Martinez and John, 1998); (4) the Rosenberg self-evaluating scale (Rosenberg, 1965); and (5) Rotter's (1966) Locus of Control Scale.

The Mach-IV Scale assesses one's Machiavellian views, discussed above, and consists of 20 statements evaluated on a Likert scale from 'strongly agree' (7) to 'strongly disagree' (1), half of which are reverse coded. An example of an item on this scale is 'Never tell anyone the real reason you did something unless it is useful to do so'.

The Self-Monitoring Scale measures how much one is concerned with tailoring one's social presentation to the current social context. This scale consists of 18 items with which the participant either agrees or disagrees. As with the Mach-IV Scale, half of the items are reverse-coded. An example of one of the Self-Monitoring items (reverse coded) is 'I have trouble changing my behaviour to suit different people and different situations'.

The Big Five Inventory asks participants to indicate how much they agree with 44 statements on a scale of 1 (strongly disagree) to 5 (agree strongly), which yields one score for each of the five personality dimensions. As an example, one item on the extraversion scale is 'I see myself as somebody who is outgoing, sociable'.

The Rosenberg self-evaluating scale measures self-esteem. Participants indicate their agreement or disagreement with ten statements, with a scale ranging from 1 ('agree very much') to 5 ('disagree very much'). Example items include 'I take a positive view of myself' and 'I certainly feel useless at times' (reverse coded).

Finally, the Locus of Control Scale includes 29 pairs of statements for which the participant is asked to indicate which one they 'more strongly believe to be the case'. Six of the pairs are fillers, and are not scored. The remaining items are scored giving one point for each statement that indicates a stronger belief that one controls one's own fate. By way of example, one pair of statements was 'What happens to me is my own doing' and 'Sometimes I feel that I don't have enough control over the direction my life is taking', with greater agreement with the former being scored as a greater belief in an internal, rather than external locus of control.

Once the scales were filled out, participants were privately paid their experimental earnings, roughly $20 on average, and dismissed. The entire experiment lasted just under one and a half hours.

RESULTS

Contributions

Figure 1 describes the average contribution to the group exchange by round. Because different games end at different points, the averages are over different numbers of rounds. For example, all games included round one, so its average is over 126 observations, while there are only 18 observations to include in the round 34 average because it was reached only in game six. Figure 1 shows that, consistent with results from similar public goods

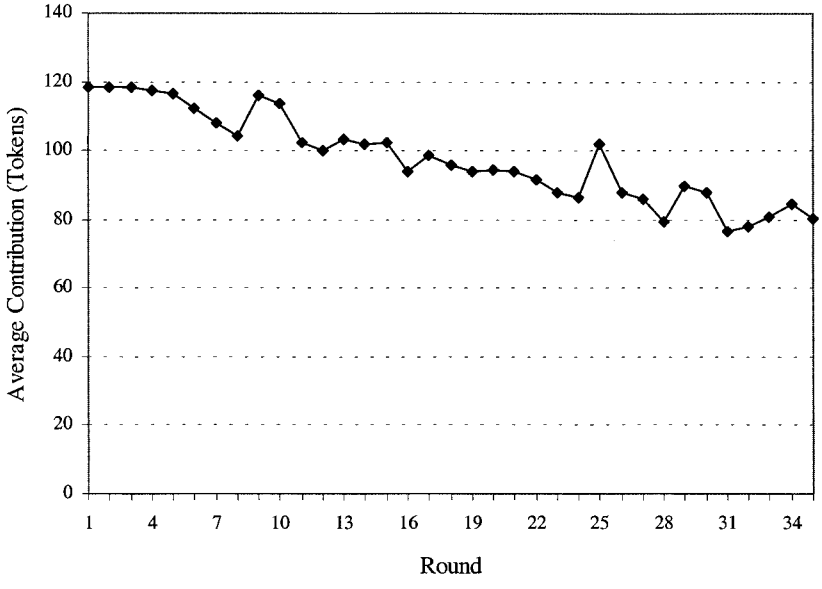

Figure 1. Contribution to group exchange by round

experiments, average contributions decayed over time from about 120 to about 80. Note, however, that these averages reported in Figure 1 mask important heterogeneity in group-level dynamics. The amount of decay in contributions depended on the composition of the group in terms of player types, discussed below, and in a number of cases there was little or no decay at all in contributions over the course of the game.

Player types

To assign players to types, we assumed that each subject was one of four possible types: (1) free-riders, who contribute zero, (2) cooperators, who contribute 100%, (3) conditional cooperators, who cooperate at the same level as the average current contribution, and (4) 'triangle' cooperators, who behave like conditional cooperators until average contributions reach the 50% level, and then contribute the difference between 100% contribution and the average contribution (after Fishbacher *et al.*, 2001). We assigned to each subject the type that was consistent with the greatest number of their moves.[2] Our design ensures that each contribution decision except the first is conditional on the contributions of the other members of the group. Suppose that in round t the average contribution of the group is X. Then, for example, a conditional cooperator should also contribute about X, while a free-rider should contribute very little and a strong cooperator a lot, independent of X's value. We simply counted the number of decisions consistent with each type and then assigned to the subject the type that agreed with the greatest number of their moves.

Following this typing strategy requires precise assumptions about how each type behaves. Again, suppose that X is the average contribution of the group observed by the subject before her contribution decision. We label a contribution as consistent with the conditional cooperator type if it is within five tokens of X. Similarly, a contribution is

[2]A rigorous statistical foundation for this approach to typing subjects is provided by El-Gamal and Grether (1995). We do not pursue the formalization here.

consistent with the triangle type if it is within five tokens of that type's 'ideal' contribution level. A contribution is consistent with the free-rider type if it is less than 20% of the endowment independent of X. To be consistent with the cooperator type requires the contribution to be 80% of the per-round endowment.

A given contribution decision might be consistent with zero, one, or more than one of the types. Consider a case where the average contribution is 25 and the participant chooses to contribute 15. This is too low to be consistent with the conditional cooperator, triangle, or strong cooperator types, and too high to be consistent with free-rider, making this decision consistent with no type. On the other hand, if the average public contribution is zero, then if the subject chooses to contribute zero, it is consistent with free-riding, conditional cooperation, and the triangle type. We are able to identify each subject's type because they play the game seven times, which induces substantial variation in the average contributions of others that each subject observes. Over the course of seven games, each subject makes seven initial (and unconditional) contribution decisions and from 36 to 38 conditional contribution decisions, depending on their random placement in the groups. Only the conditional contributions are used in our typing analysis.

Of the 72 subjects who completed our experiment, 61 could be cleanly classified by our procedure in the sense that at least one-third of their moves were consistent with one of the types, while 11 subjects did not satisfy this criterion. We dropped the 11 subjects that were difficult to classify from the remainder of the analysis. Among the 61 who could be classified easily, there were two subjects whose moves were equally well described by conditional cooperation and triangle play, and one subject whose moves were equally well described by conditional cooperation and free riding. In each of these three cases we labelled the subject as a conditional cooperator.

Table 1 indicates the results of our classification procedure. Overall, 60% of subjects' moves were consistent with their assigned types. At the individual level, some subjects' moves are perfectly consistent with their type while others are consistent only one-third of the time. Both the aggregate error rate and the variation at the individual level are similar to what others have found when using classification procedures similar to ours (see e.g. El-Gamal and Grether, 1995, Walker and Shachat, 1997). Very generally, our classification procedure seems to do very well at capturing general tendencies of the different types, but there is also substantial heterogeneity in each type's play. For example, free-riders occasionally contribute their entire endowment to the group account, while cooperators occasionally contribute nothing.

Two important and related group outcomes often examined in the VCM literature are the final contribution to the public good and the cooperative decay, which is the amount by

Table 1. Number of each type and fraction of correctly predicted choices

	Number of participants	Fraction of participants	Fraction of choices predicted correctly		
			Mean	Min	Max
Cooperator	18	0.30	0.65	0.39	1.00
Free-rider	20	0.33	0.62	0.33	1.00
Conditional Cooperator	21	0.34	0.53	0.33	0.76
Triangle	2	0.03	0.51	0.47	0.54
Total	61	1.00	0.60	0.33	1.00

which the final contribution differs from the initial contribution. To examine the effect of group composition on these outcomes we scored each group's 'cooperativeness' by giving two points for each cooperator, one point for each conditional cooperator and zero points for each free-rider and triangle type in the group. Hence, a group of four cooperators would score eight, while a group with four conditional cooperators would score four. We then examined the relationship, across all groups without unclassifiable subjects, between each outcome variable and the cooperativeness score.

As anticipated, this analysis indicates that the final group contribution is increasing in the group's cooperativeness. Highly cooperative groups sometimes obtain perfect cooperation by the end of the game, while groups with very low cooperativeness tend to end with low contributions to the group exchange. A regression of cooperation on group cooperative score predicts that replacing a group's cooperator with a free-rider will reduce final group contributions by about 40 tokens. In addition, cooperative decay tends to decrease as a group's cooperativeness increases. A regression of decay on group cooperative score predicts that replacing a cooperator with a free-rider will increase cooperative decay by about 30 tokens.

Personality types

To analyse the link between personality scores and behavioural types we focused on the participants whom we classified cleanly as cooperators, conditional cooperators, and free-riders. We excluded triangle types because there were too few in our sample to allow compelling inference. We lost two of the 59 remaining subjects because of a recording error that assigned these subjects to the same seat, leaving it impossible to match their survey results to their game play. Our final sample includes 57 subjects, 18 cooperators, 20 conditional cooperators, and 19 free riders, and a total of 15 females and 42 males.

We examined how subjects' gender and scores on nine personality variables correlated with their behavioural type. We began with a simple correlation analysis, the results of which guided our specification of the subsequent multinomial logit model. The purpose of the correlation analysis was to reduce the number of covariates to consider, since we have only 18–20 subjects in each type category but ten explanatory variables. Note that the type variable takes value one if the subject is assigned that type, and zero otherwise.

Table 2 reports the simple correlation between types and our covariates. In the subsequent analysis we choose to exclude all those covariates that did not have a correlation of at least 0.2 in magnitude with at least one type variable. Thus, we retain for further analysis five of the original ten covariates: self-monitoring, conscientiousness, neuroticism, self-esteem, and sex. A formal, likelihood-ratio based approach to model selection results in the same exclusions.

We analysed the impact of personality on behavioural type with a multinomial logit regression. A thorough overview of this technique can be found in, for example, Greene (2000). Multinomial logit is used to draw inferences about the way category probabilities vary with observed characteristics. In our case, we attempted to learn about the way that different personality characteristics affect the probability of adopting different behaviours in our experiment.

The result of a multinomial logit regression with type as dependent variable and a constant and the five covariates mentioned above as regressors is reported in Table 3. Note that we have chosen conditional cooperators as the baseline type. The fit of the model is statistically significant ($\chi^2(10) = 18.88$, $p = 0.04$). Most of the coefficients are not

Table 2. Correlation of personality score and type

Variable	Type		
	Conditional cooperator	Cooperator	Free-rider
Machiavellianism	− 0.12	0.05	0.07
Self-monitoring	0.05	− 0.22	0.17
Extraversion	0.18	− 0.08	− 0.10
Agreeableness	0.15	− 0.18	0.03
Conscientiousness	0.06	− 0.22	0.15
Neuroticism	− 0.07	0.22	− 0.14
Openness	− 0.16	0.18	− 0.02
Self-esteem	0.28	− 0.19	− 0.09
Locus of Control	− 0.11	0.13	− 0.02
Sex	− 0.15	0.23	− 0.08

Table 3. Multinomial logit regression results

Variable	Coefficient	*p*
Cooperators		
Self-monitoring	− 0.17	0.16
Self-esteem	− 0.07	0.21
Conscientiousness	− 0.04	0.63
Neuroticism	0.08	0.27
Sex	2.26	0.03
Constant	1.94	0.56
Free-riders		
Self-monitoring	0.07	0.52
Self-esteem	− 0.12	0.03
Conscientiousness	0.08	0.27
Neuroticism	− 0.03	0.60
Sex	0.24	0.76
Constant	1.83	0.55

estimated precisely, which is not surprising given our sample size. The estimates suggest that sex and self-monitoring affect the probability of being a cooperative type, while self-esteem seems to be a determinant of free-riding.

Table 4 describes the relationship, implied by the model's estimated coefficients, between changes in the covariates and the probability of being a cooperator, conditional cooperator, and free-rider.[3] Holding the distribution of personality scores fixed at the sample distribution, the model predicts that 41% of males would be cooperators as compared to 11% of females. Specifically, these results are found by first using the estimated model to predict the probability of each type for each subject in our sample but under the (sometimes counterfactual) assumption that they are male. Then, the same predictions are made under the assumption that everyone is female. The 41% figure is the average probability, over the 57 subjects in our sample, that they will be cooperators conditional on all of them being male but holding fixed their other observed

[3]In Table 4, 'Low' refers to the lowest possible measured score, and 'High' refers to the highest possible measured score, for each variable that we consider.

Table 4. Adjusted type probabilities by covariate

Type	Variable									
	Male	Female	Low self-esteem	High self-esteem	Low self-monitor	High self-monitor	Low conscient-iousness	High conscienti-ousness	Low neuroticism	High neuroticism
Cooperator	0.41	0.10	0.22	0.28	0.67	0.09	0.59	0.16	0.13	0.64
Conditional	0.29	0.49	0.02	0.52	0.22	0.35	0.36	0.26	0.36	0.24
Free-rider	0.30	0.40	0.75	0.19	0.11	0.56	0.05	0.58	0.51	0.13

Note: This table provides the model's prediction of the fraction of each 'variable' in the population that will be each type. For example, the model predicts that 41% of males in the population will be cooperators, after adjusting for all of the other covariates. These predictions have standard errors which are available on request.

characteristics. Similarly, 11% is the sample average probability of being a cooperator conditional on everybody being female.

On the other hand, an analogous procedure reveals that nearly half of females would be conditional cooperators, as opposed to 30% of males. Large changes in self-esteem seem to have corresponding large changes on the probability of being a free-rider. In particular, holding the distribution of other covariates fixed, about three-quarters of subjects with the lowest possible self-esteem would choose to free-ride, while less than one-fifth of those with highest self-esteem would make that choice. Self-monitoring also seems to have a substantial impact. Subjects who score very low on the self-monitoring scale are very likely to cooperate, while high self-monitors are likely to free-ride.

DISCUSSION

The circular public goods game that we introduce here provides an opportunity to observe players' contribution decisions conditional on information about others' current contributions. This allows us to begin to look in detail at a number of important elements of participant play in these games.

First, the results we obtained indicate that there is, as expected, sizable and significant heterogeneity in play. While some players contribute almost nothing to the public good even when others are contributing a great deal, other players contribute nearly their entire endowment even when others are free-riding. More importantly, these differences are consistent in a way that allowed us to capture this heterogeneity in a systematic way. Thus, players who were strong free riders in one group of four players tended to pursue this strategy with another group of four players. Taken together, heterogeneity between players coupled with homogeneity in behaviour for a given player across groups lends weight to the conclusion that the concept of player types can be important in understanding results of public goods games.

More specifically, the existence of player types seems to have important effects on the dynamics within groups. The number of strong free-riders in a group influences the path that groups take over the course of time during a game. Without free-riders, groups are capable of sustaining high levels of contribution to the public good. The presence of free-riders, however, puts the group in a spiral toward lower and lower levels of contributions.

This feature of group dynamics lends weight to arguments that the decay in contributions typical of public goods experiments is due to what Andreoni (1995) termed

'frustrated attempts at kindness'. That is, the fact that the presence of free riders not only decreases the final value of contributions to the public good, but actually produces a decline from initial contributions to subsequent contributions, suggests that decay is due to conditional cooperators decreasing their contributions in response to their observation of low aggregate contributions in the group.

It should be noted, however, that one's type is clearly not an absolute. Free-riders occasionally contribute significant amounts to the public good, and strong cooperators occasionally contribute relatively little. This suggests either that players make errors, or that our type classification scheme is too simplistic to capture more complex behavioural regularities in play. Future work should be aimed at developing more sophisticated type designations to extend this approach. This might also help to capture the cases that did not fit easily into our analysis.

The relationship between types and personality variables were relatively weak and did not fit in nicely with previous findings in the experimental literature. Our results implicated sex, self-monitoring, neuroticism, conscientiousness, and self-esteem as correlates of cooperative decision making. The finding that males are less likely to be strong free-riders is consistent with some (Sell and Wilson, 1991), but inconsistent with other previous results (Seguino *et al.*, 1996). While the indication that high self-monitors are more likely to be conditional cooperators is in the predicted direction, the fact that those that score high on neuroticism were more likely to be cooperative conflicts with earlier findings (Ashton *et al.*, 1998). Because these relationships between personality measures and cooperative type tend to be inconsistent, we believe these results should be treated with some caution.

An interesting feature of the circular design is that it allowed some groups to achieve substantial levels of cooperation over a large number of rounds, a result that contrasts sharply with the typically observed decay in contributions over time. One possible reason is that the circular game affords reciprocity in a way that other versions of public goods games do not. Conditional cooperators, for example, cannot condition their play on others' contributions when play is simultaneous, as it is in most public goods games. The sequential nature of the circular game might allow reciprocal cooperative behaviour that would otherwise be obscured (see Kurzban *et al.*, in press, for a more detailed discussion).

We have presented here a new method to assess individual differences in public goods game behaviour. We believe this method can be refined to develop more sophisticated models both of individual behaviour in these games and of group dynamics that take into account the type composition of a given group. If better personality predictors can be found, it should ultimately be possible to predict the dynamics of a given group by knowing the kinds of individuals that it contains. Though this goal seems a distant one, we believe that the work presented here lays some of the groundwork for achieving it.

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