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The role of generalised reciprocity and reciprocal tendencies in the emergence of cooperative group norms☆

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ABSTRACT

Norms for cooperation are essential for groups to function effectively, yet there are often strong incentives for group members to behave selfishly. Direct and indirect reciprocity can help to discourage such uncooperative behaviour by punishing defectors and rewarding cooperators, but require explicit means for punishment and tally-keeping. What, then, encourages an individual to cooperate with their group when others cannot track the behaviour of others? We adapted the Bargaining Game to examine the emergence and maintenance of cooperation among 20 groups of six anonymous players (N = 120) who interacted amongst themselves over recursive bargaining exchanges. By estimating the expected utility that drives players' demands in these interactions, we demonstrate that their behaviour on each exchange reflects the demands placed upon them previously. Thus, we highlight the role of generalised reciprocity in such situations; that is, when an individual passes on to another member of their group the behaviour they have received previously. Furthermore, we identify four distinct behavioural types that differ in their expressions of generalised reciprocity: Some players converge quickly on cooperative demands regardless of the behaviour they received from their co-players, and are therefore characterised by low expressions of reciprocity. In contrast, individuals with strong reciprocal tendencies decrease their demands over successive interactions in response to the behaviour of their group. By simulating groups with different compositions of these player types, we reveal the strong influence of individual differences in reciprocal tendencies on the emergence of cooperative group dynamics.

1. Introduction

Norms, conventions, and notions of fairness emerge within communities through repeated interactions among constituent members (Young, 1993). There is no guarantee that a norm of cooperation will prevail, however; repeated interaction alone is insufficient to establish cooperative behaviour. This is the core of the social dilemma, wherein a collective group effort results in an optimal outcome

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value, but an individual group member benefits maximally by defecting – that is, from reaping the benefits of the value generated by the group without making any personal investment (Henrich, 2015). In such situations, cooperation tends to *decrease* over time; as group members begin to realise that the presence of defectors affects their earnings negatively, they adopt more defensive postures (Camerer & Fehr, 2006). How, then, can cooperation arise and be maintained within a group despite incentives to behave selfishly? One potential mechanism is reciprocity (Rockenbach & Milinski, 2006) – the process through which an individual conditions their own behaviour to that of their interaction partner(s). In this light, cooperation emerges through the reciprocal process of punishing defectors and rewarding co-operators. The present study explored the role of reciprocity in establishing and maintaining a cooperative group norm, and how individual differences in reciprocal tendencies among group members impact upon the cooperative group dynamics.

Direct reciprocity is behaviour aimed towards an immediate fellow interactant; put simply, what I do to you now is a direct response to what you did to me previously. An alternative is indirect reciprocity, whereby the knowledge of another's past actions towards others influences the future behaviour directed at them; I do to you now what I think is appropriate based on your reputation from prior interactions with others (see Stanca, 2009). When individuals can monitor the behaviour and reputations of others, a combination of punishment for defectors and reward for cooperators emerges through direct and indirect reciprocity (Rockenbach & Milinski, 2006). However, although reciprocal behaviour provides a powerful mechanism through which social norms and conventions for cooperation can be established and enforced, both direct and indirect reciprocity are cognitively demanding. The former requires us to identify an individual with whom we interacted previously and remember their behaviour towards us in order to respond later in kind, and the latter relies upon a memory of an individual's reputation (Rankin & Taborsky, 2009; Stevens & Hauser, 2004). With increasing group sizes, these mechanisms might become very costly to maintain. One form of indirect reciprocity that is relatively less demanding is Generalised Reciprocity (GR), whereby my behaviour towards you is shaped by the behaviour(s) I have received previously from another person (van Doorn & Taborsky, 2012). Since GR involves passing on prior behaviour without any need of knowing from whom that behaviour was received, nor their reputation, it circumvents the need for recognition or tally-keeping and provides an efficient mechanism for increasing group cooperation in various settings (Voelkl, 2015). This is true even in situations that preclude the possibility of tracking the behaviour and outcomes of other group members (Tsvetkova & Macy, 2014). One caveat is that GR requires repeated interactions to occur within a structured group – it facilitates cooperation only if individuals interact repeatedly among a subset of a population (Pfeiffer, Tran, Krumme, & Rand, 2012; van Doorn & Taborsky, 2012). This subset can be defined simply by spatial (e.g., geographical) positioning (Dreber, Rand, Fudenberg, & Nowak, 2008), or by arbitrary assignment to a small group, as is the case in most behavioural experiments.

To investigate the role of GR in establishing and maintaining a cooperative group norm, it is necessary to isolate it from indirect reciprocity. This can be achieved by ensuring that all group members remain unidentifiable and their prior interactions are untraceable (Tsvetkova & Macy, 2014), thereby negating any influence of reputation. Further, by minimising the number of members in a group, it is possible to ensure that repeated interactions will occur. To achieve this, the present study adapted the Bargaining Game introduced by Embrey et al. (Embrey, Fréchette, & Lehrer, 2013; see also Abreu & Gul, 2000), in which a pair of anonymous players must decide independently on the division of a pie between themselves and their co-player. If the personal demands of both players sum to more than the pie, the game proceeds to a concession stage; the respective demands continue to favour one player more than the other, but the overall payoff to both players decreases with increasing time until one of them concedes. Once a player concedes, the remaining division demanded by their co-player is paid out. Thus, any demand of more than half of the pie can be regarded as an uncooperative act, indicating that the player is willing to engage in conflict with their co-player in an attempt to maximise their own earnings. In our adaptation, individuals were assigned to small groups of six unidentifiable players and were paired randomly with another group member on each of 10 bargaining exchanges. This ensured that repeated interactions occurred between some group members, whilst also preventing any direct or indirect reciprocity; players were unable to identify the individual with whom they were interacting on any given exchange, nor track the prior behaviour (reputation) of that individual or any other member of their group. We expected to observe a gradual adoption of more egalitarian demands over repeated exchanges among groups of players, indicating that a cooperative joint behaviour had emerged. Crucially, players were not encouraged explicitly to adopt any strategy; with exchanges remaining anonymous, player demands are an indirect consequence of their prior interactions with other group members.

To assess the role of GR in the emergence of cooperation, we adapted a model of direct reciprocity based on Cox, Friedman, and Gjerstad (2007; see also Shaw et al., 2018, 2019). This model estimated player behaviour on our adapted Bargaining Game on the assumptions that those who make fair demands (exactly half the pie) are less likely to concede, and that players base their upcoming demand on the behaviour they received in previous rounds. In such artificial settings, the effect of receiving a un/cooperative act on our own subsequent behaviour towards others appears to be limited to the most recent interaction (Tsvetkova & Macy, 2014). Thus, an initial version of the model considered only the immediately preceding interaction. In contrast, Fictitious Play models (Berger, 2007; Brown, 1951) assume that players draw upon all prior experiences when forming and updating their expectation of a partner's behaviour. We therefore examined whether longer histories of interactions improved the accuracy of the model in estimating actual player demands.

Importantly, the degree to which GR can maintain cooperative behaviour within a group depends entirely upon the reciprocal tendencies of its constituent members. The chain of GR starts with the spontaneous cooperative behaviour of one individual towards another in their group, and conditional reciprocators then carry over the cooperative act they have received onto others. Since the likelihood that a person will behave cooperatively increases after they have been at the receiving end of a cooperative act (Fowler & Christakis, 2010), or when they have observed one vicariously (Voelkl, 2015), the chain of GR affects the dynamics of an entire group by encouraging other reciprocal players to behave more cooperatively over time (Weber & Murnighan, 2008). However, this chain ends if cooperation is directed at a non-reciprocating type (Voelkl, 2015), and so cooperative behaviour cannot be perpetuated through

GR so effectively among groups comprising such individuals. To understand the role of GR in the emergence and maintenance of cooperative norms, it is therefore necessary to examine it at the level of both the group and its individual members.

Previous research has identified different types of player behaviour on economic games that are characterised partly by differences in reciprocal tendencies. In the Public Goods Game, for example, Titlestad, Snijders, Durrheim, Quayle, and Postmes (2019) identified three distinct behavioural types: while Responsive players cooperated or defected as a reaction to the behaviour of their group, Committed Cooperators grew increasingly cooperative over successive interactions and Reactive players remained the least likely to cooperate maximally with their group in all interactions, regardless of the behaviour they receive from others. Constant Contributors are also reported commonly (Weber & Murnighan, 2008) – players who always contribute to the collective payout. Interestingly, these behavioural types show consistency across different games (Peysakhovich, Nowak, & Rand, 2014; Poncela-Casasnovas et al., 2016) and remain persistent over long timescales (Mao, Dworkin, Suri, & Watts, 2017). Since these player profiles appear to reflect stable traits, such as other-regarding (cooperative) or self-interested (uncooperative) tendencies (Titlestad et al., 2019), we examined if such dissociable player types could be identified from varying expressions of reciprocity. Given such heterogeneity in player types, and that GR fails when directed towards unreciprocating individuals (e.g., Reactive players), we predicted that the distribution of demands among independent groups would vary as a result of player compositions vis-à-vis reciprocal tendencies. Further, we explored the role of personality factors in dissociable styles of reciprocal behaviour. It has long been known that affective reactions to violations of fairness norms can serve as a powerful determinant of whether or not such violations are reciprocated negatively (Fehr & Gächter, 2002; Hopfensitz & Reuben, 2009; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003), with those less angered by unfair behaviour also less inclined to punish it (e.g., McCall, Steinbeis, Ricard, & Singer, 2014). For this reason, we hypothesised that reciprocal tendencies will differ between people who are better able to regulate their affective state flexibly in pursuit of goals (action orientation) and those who ruminate and allow their emotions to influence their behaviour (state orientation; Kuhl & Goschke, 1994). It has also been shown that empathy for one's interaction partner can moderate the negative reciprocation of uncooperative actions (Batson & Ahmad, 2001; Kerr et al., 2009). Therefore, we predicted different patterns of reciprocal expression between individuals varying in their self-reported empathic tendencies.

2. Methods

In the following sections we report all measures, manipulations and exclusions. All experimental scripts and materials are available at https://osf.io/a4qtu/.

2.1. Subjects

A sample of 120 students (55 males; mean age = 21.5 years, SD = 2.01) took part in the experiment, all of whom were recruited from the participant database of the Faculty of Economics and Administration of Masaryk University, Czech Republic. This sample size was determined prior to any data analysis. Since it was unknown how many sub-groups would be identified, and given the novelty of the modelling technique (see below), there were no reliable grounds for formal sample size calculations. On the basis of similar research, however, it was expected that this relatively large sample size would allow us to identify a sufficient range of behavioural types in our single condition paradigm (see below; Titlestad et al., 2019). For 71 of these individuals, the main field of study was a discipline related to Economics. The experimental procedure was approved by the Research Ethics Committee of Masaryk University, and all participants provided written informed consent. Participation was recompensed with 200 CZK (approx. €7) and, based on a lottery method, players could earn an additional 60 CZK.

2.2. Procedure

The experiment took place in the Experimental Economics Laboratory of the Faculty of Economics, Masaryk University. On each of 5 separate sessions conducted over a single day, 24 participants sat at individual computer stations separated by dividers that prevented any form of communication. They first performed the Bargaining Game and then completed two self-report questionnaires. Importantly, the Bargaining Game comprised two separate blocks of 10 rounds presented in fixed order. Since the first 10 rounds were designed specifically for evaluating the hypotheses stated above, we focus only on this first block herein. The second block of 10 rounds were used to test a different hypothesis regarding the behaviour of participants in the presence of an unyielding behavioural type, and will be reported elsewhere.[1] Fully translated instructions can be found in Supplementary materials.

2.3. Bargaining Game

Participants were informed that they had been assigned randomly to a group comprising 5 other anonymous players, and that they

[1] The second block of rounds was designed specifically to provide pilot data for a subsequent investigation into the effect of observability; specifically, how individuals' behaviour on the Bargaining Game changes when they can observe their co-player's demands and concession times in previous rounds. For these pilot data, behaviour across the first and second block of rounds serve as the control and treatment group, respectively – block order was not randomized. The between-block comparison estimates the treatment effect on initial demands and concession times; no model of reciprocity was applied, and there is no overlap with the analyses presented in the current paper.

would play 10 rounds of bargaining exchanges with those members of their group. During the first stage of each round, players were paired randomly with an anonymous group member and both co-players made independent demands for a division of 30 points between them (d_i and d_j)). If their demands summed to 30 or fewer points, the round ended and each player received their demanded points plus half of any remaining points. If their demands summed to more than 30 points, the pair proceeded to a second 'concession' stage. During this second stage, players had three minutes to concede. With every second that elapsed, the total number of points for which players were bargaining decreased at a rate of 0.985; that is, d_i*0.985 ^{t} and d_j*0.985 ^{t}, where t is the number of seconds elapsed since the beginning of the concession stage. When player i conceded, their partner j was awarded the points they had demanded multiplied by the cost of time (d_j*0.985 ^{t}) and player i received the remainder (30-d_j)*0.985 ^{t}. If neither player conceded after 3 min, the game continued to the next round with no points awarded to anyone.

For each player, the goal of the game was to earn as many points as possible in order to increase their probability of receiving the bonus payoff of 60 CZK in a lottery at the end of the game. The total number of points earned by a player over the course of the game was divided by the maximum attainable. A random number was then drawn and compared to the percentage of points earned by a player; if the number drawn was smaller than the percentage of points, the player was awarded the bonus to induce risk of neutral preferences (Roth & Malouf, 1979).

2.4. Generalised reciprocity model

Using the demands, frequency of concessions, and length of concession periods (seconds) for all players comprising the sample (N = 120), we calculated an estimate of expected utility that drives player demands in the Bargaining Game.

We define the utility function of players at any given round as:

$$U_i(m_i, m_j) = m_i + \theta mj \tag{1}$$

Here, m is the payoff for paired players i and j, and θ is a parameter dependent on the cooperativeness of a partner's demand. In other words, θ represents other-regarding tendencies – the value a given player places on increasing or decreasing their co-player's payoff (Titlestad et al., 2019). Positive and negative θ values represent players who value increasing or decreasing their co-player's payoff relative to their own (kindness or unkindness, respectively). On every trial:

$$\theta = \theta_0 + \alpha(1/2 - d_j) \tag{2}$$

In the above equation, θ_0 is the level of un/kindness and α is a time-invariant, player-unspecific reciprocity parameter indicative of the general reaction to uncooperative demands. θ_0 and α are estimated by a maximum likelihood procedure.

The game is then solved by backwards induction. In the concession stage, a player uses a mixed strategy (concede/not concede) with a probability expressed by the exponential probability density function:

$$f(t) = he^{-ht} \tag{3}$$

Here, h is the constant hazard rate, or the risk of an event happening at a particular point, with time, t, being continuous. In equation (3), h is defined as:

$$h_i = \frac{r(1 - d_i + \theta_E d_i)}{(d_j + d_1 - 1)(1 - \theta_E)} \tag{4}$$

Now, θ_E is the *expected* θ of the co-player, and r is the discount rate (0.015).

In the concession stage, players' demands maximise their expected utility:

$$U_i = d_i\frac{h_j}{r + h_j} + \theta d_E\frac{h_i}{r + h_i} \tag{5}$$

The term $d_i\frac{h_j}{r+h_j}$ expresses the expected equilibrium monetary payoff of player i given demand d_i. Expected demands depend on the history of previous demands. One model utilised the demand made against the partner in the immediately preceding round, $d_E(t) = d_j(t-1)$. We will refer to this as the Last Round Model. An alternative model considered expectations as contingent upon *all* previous rounds, as in Fictitious Play solutions (Brown, 1951; see also Berger, 2007); that is, players choose the best response to an observed distribution of demands across all preceding rounds. We refer to this as the Fictitious Play model.

The model was then estimated in two steps: First, we used stopping times and a theoretical mixed strategy distribution to estimate θ_E by maximum likelihood. Then, we substituted the estimated θ_E into the utility function and estimated the parameters θ_0 and α by maximum likelihood. Thus, the model predicts that a player will make demands based upon their expectations that are contingent on the demands made upon them in the previous round(s). Additionally, for incompatible demands that initiate the concession stage, it predicts that players with the more cooperative demand (closer to 15) are less likely to concede. We then compared the fit of the Last Round and Fictitious Play model using Akaike Information Criteria (AIC), which arrives at the most parsimonious model by penalising the number of parameters included in the likelihood calculations.

2.5. Model comparisons

To evaluate the fit of the Generalised Reciprocity (GR) Model, we compared its AIC to that achieved by a variety of alternative models. First, we compared it to a nested model in which the reciprocity parameter was fixed to $\alpha = 0$. This represents a self-regarding model that assumes players care only about their own immediate monetary payoff, regardless of their prior experiences. We then compared it to a three-parameter Reinforcement Learning Model (Erev & Roth, 1998) to assess whether player demands reflect learning processes over multiple bargaining exchanges rather than reciprocal reactions to their co-players. In brief, this alternative model estimated player demands in the initial demand stage of each round (prior to any subsequent concession stage) by considering their initial propensity for each possible demand, a reward function, a rule for updating their propensities, and a probabilistic choice rule. Finally, we performed a comparison between both the Last Round and Fictitious Play models against one in which the θ parameter updated upon each subsequent round on the basis of all preceding observations (e.g., the estimation in round 5 is based on observations from the concession stages in rounds 1 to 4, and the estimation in round 10 is based on observations from the previous 9 rounds). Full details of the model specifications are provided in the Supplementary Materials.

2.6. *Cluster analysis*

On the assumption that reciprocal players should make demands that align gradually with those made by others in their group, we identified dissociable patterns of player behaviour by applying Gaussian Mixture Model (GMM) to four aspects of demands: each player's mean and standard deviation of demands in the early (1–5) and late rounds (6–10). The fit of this clustering model was then estimated by maximum likelihood – we estimated models for different numbers of clusters, and identified the best-fitting model with Bayesian Information Criteria. The clustering analysis was performed in R 3.6.3 (R Core Team, 2017), using the *mclust* package (Scrucca, Fop, Murphy, & Raftery, 2016). Using the model described above, separate reciprocity parameters were then estimated for each of the clusters emerging from the optimal GMM solution.

2.7. *Group simulations*

To assess the influence of different compositions of player type on group dynamics, we performed simulations of demands over 10 rounds among 480 groups of six players from the same or different clusters (homogenous or heterogenous groups, respectively) emerging from the GMM procedure. This number of groupings was selected to be sufficiently high to ensure that the results of the simulations do not depend heavily on random initial demands due to the law of large numbers. Using the *plyr* library (Wickham, 2011) in R 3.6.3 (R Core Team, 2017), simulations were performed as follows: First we defined a group of players by selecting a set of six demands randomly from the observed distribution. These players were then matched randomly for the initial round, just as they were in the experiment. Players then made a demand that maximised their expected utility, which involves an expectation of their co-player's demand formed from previous experiences (see equation (5)). This procedure was repeated for 10 periods, as it was in the experiment.

2.8. *Self-report measures*

2.8.1. *Emotion regulation*

The Action Control Scale (ACS; Kuhl, 1994) was administered as an explicit measure of emotion regulation. This self-report instrument measures an individual's ability to regulate affective states quickly and flexibly in response to environmental demands (action orientation) rather than fixating on them in a change-preventing, volitional mode that allows them to impact upon behaviour (state orientation). The 36-item questionnaire consists of three sub-scales, each measured by 12 items: action orientation after failure versus preoccupation (AOF); demand-related action orientation versus hesitation (AOD); and action orientation during activity performance versus volatility (AOP). Each item presents an everyday situation (e.g., "*When I am told that my work has been completely unsatisfactory*"), and participants select one of two possibilities – one indicative of action orientation ("*I don't let it bother me for too long*") and the other of state orientation ("*I feel paralysed*"). Since AOD and AOF index emotional reactions to the outcomes of a behaviour, we focus only on these two dimensions herein. These two sub-scales achieved acceptable reliability (Cronbach's $\alpha > 0.79$).

2.8.2. *Empathic tendencies*

The Interpersonal Reactivity Index (IRI; Davis, 1983) was administered as an explicit and multidimensional measure of trait empathy, which has been shown consistently to be valid and highly reliable across a range of populations (e.g., mid to late adolescence; Hawk et al., 2013) and various European countries (de Corte et al., 2007; Gilet, Mella, Studer, Grühn, & Labouvie-Vief, 2013). This 28-item instrument consists of four seven-item sub-scales that measure discrete empathic tendencies: Perspective Taking (adopting spontaneously the psychological perspective of others) and Fantasy (transposing oneself imaginatively into the feelings and actions of fictitious characters) are measures of the cognitive component of empathy, while Empathic Concern (adopting "other-oriented" feelings of sympathy and concern) and Personal Distress (having "self-oriented" feelings of personal anxiety and unease in tense interpersonal settings) measure the affective component. Participants indicated their answer for each item on a five-point Likert scale (1 = "*Does not describe me well*", 5 = "*Describes me very well*").

3. Results

3.1. Sample behaviour

The overall behaviour across our entire sample is depicted in Fig. 1. This shows that while a large proportion of the demands was for exactly half of the pie across all rounds, the frequency of these demands was lower, and those for 20 or more was higher, in the first compared with the second half of rounds. To examine this more formally, we performed a McNemar's χ^2 test to compare the change in proportions of demands for 15 or less and 20 or more between the first and last rounds. This revealed significant differences ($\chi^2 = 7.42$, df = 1, $p < 0.050$), confirming that demands of exactly 15 became increasingly more common over the latter half of rounds, culminating in a minimal mean demand in the last round. The hazard rate was calculated based on the distribution of concession times. Over 80% of all concession stages were resolved within 20 s. The probability density function in equation (3) was calculated from these times (Fig. 1D).

As shown in Table 1, demands of 15 were the most versatile across the sample – they performed better than all other demands by resulting in the highest mean payoff and lowest proportion of concessions.

3.2. Reciprocity modelling

The parameters for the Fictitious Play and Last Round models estimated across the entire sample are presented in Supplementary Table S3. The former model fit the observed data better than the latter (AIC = −5297 *vs.* −2235) – that is, players made demands according to their experiences across all previous rounds. When comparing the alternative versions of these models in which the θ parameter was updated on each successive round, the Fictitious Play model again fit the data better than the Last Round Model (AIC = −5092 *vs.* −4304) but no more so than the reference base model. We therefore proceeded with the Fictitious Play model with a fixed θ parameter estimated over all rounds in the analyses that follow. An AIC comparison also revealed that this version of the GR model outperformed the nested monetary model (AIC = −5297 *vs.* −4928). To assess whether the greater versatility of demands for 15 can explain the increased frequency of this demand over successive rounds more than reciprocal expressions, we compared the GR model to a three-parameter Reinforcement Learning model (Erev & Roth, 1998; $s = 1$, $\rho = 0.05$, $\in = 0.91$). This alternative model estimated players' increasing propensity for a given demand in response to non-zero monetary payoffs for that demand. Interestingly, the GR model outperformed this Reinforcement Learning model (AIC = −5297 *vs.* 2884, respectively).

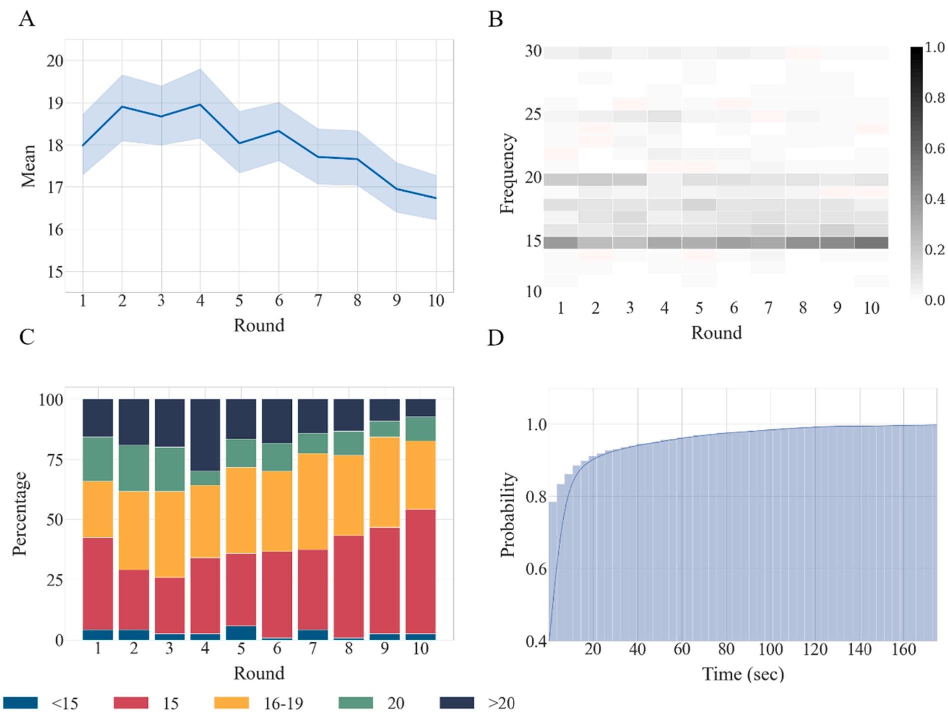

Fig. 1. Sample-wide behaviour. *A*: Mean (±SD) demand on each round. *B*: Heatmap illustrating the frequency of demands in each round. *C*: Percentage of binned demands on each round. *D*: Cumulative distribution of concession times.

Table 1
Versatility of demands.

Demand	Concession	Unresolved	Concede %	Payoff Mean (SD)
<15	14	0	21.4	12.81 (1.93)
15	229	0	13.1	14.03 (2.42)
16–19	388	2	49.7	13.02 (3.83)
20	143	5	62.9	11.39 (5.44)
>20	196	11	80.1	10.63 (6.33)

3.3. *Sub-group behaviour*

Although the behaviour of the sample as a whole demonstrated an overall decrease in demands, the heatmaps in Fig. 2 reveal that the interaction of player demands resulted in stark inter-group differences in demand dynamics. While some of the groups seemed to converge on a cooperative norm in early rounds, with demands concentrated around the equal division of the pie, the demands made in other groups remained high even in the second half of rounds.

3.3.1. *Cluster analysis*

The optimal solution of the GMM procedure identified 4 dissociable clusters of player behaviour (BIC = −1051). With the GR model, we then estimated specific reciprocity parameters for each of these 4 clusters. The number of players, means and standard deviations of demands, and estimated parameters for each cluster are presented in Table 2.

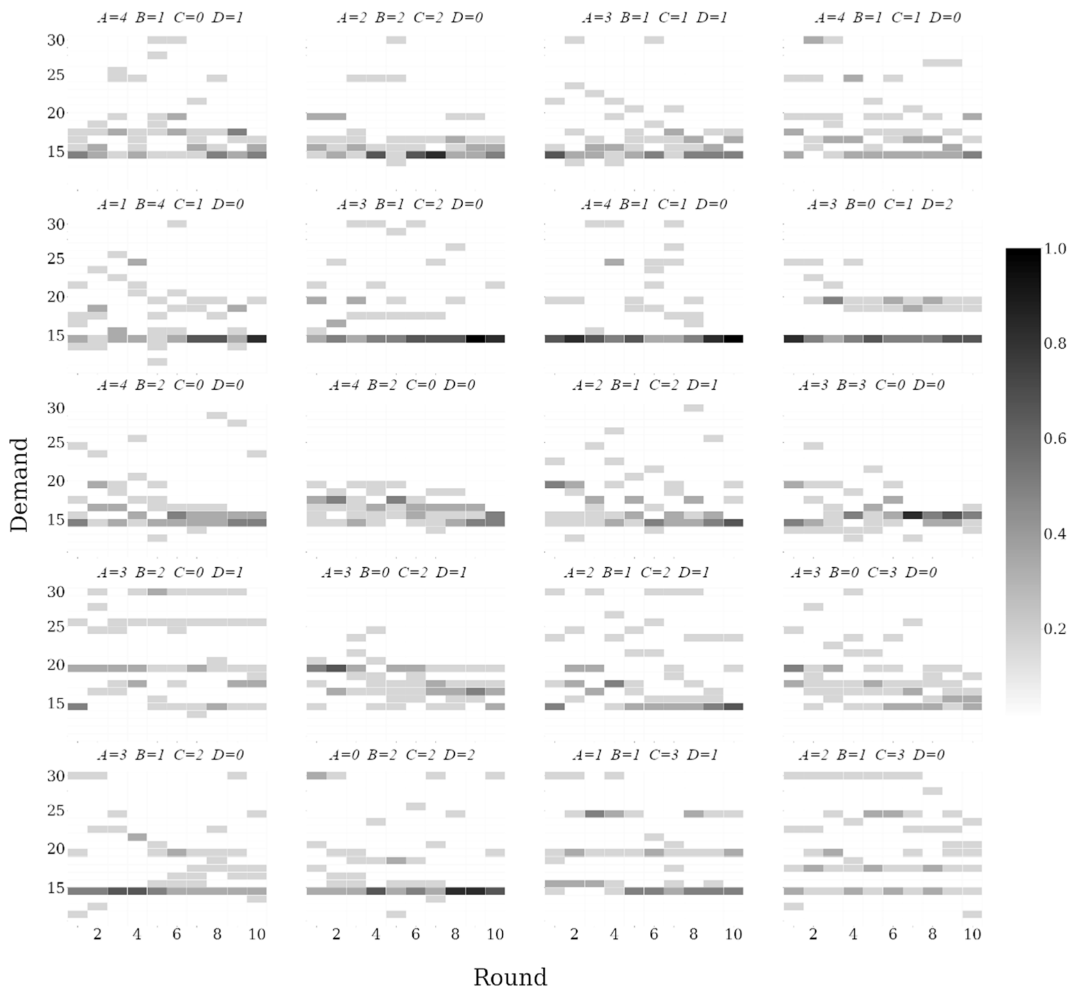

Fig. 2. Proportions of demands in each of the 10 rounds across the 20 groups. This illustrates how the increase in demands of 15 over successive rounds that was expressed in the sample overall was observed in some but not all groups. The values above each graph state the numbers of constituent players classified into each of the behavioural types revealed by the cluster analysis (see below).

Table 2
Cluster parameters.

Cluster	N	Early		Late		θ	α	Emotion regulation		Empathy	
		Mean	***SD***	***Mean***	***SD***			***AOF***	***AOD***	***Cognitive***	***Affective***
A	54	18.8	2.64	17.0	1.37	0.03	0.17	5.74 (2.82)	6.66 (3.10)	34.94 (8.48)	28.22 (7.13)
B	27	15.8	0.76	15.2	0.17	0.02	0.09	5.77 (2.87)	6.48 (3.33)	32.88 (8.25)	30.88 (6.94)
C	28	20.1	3.55	21.5	4.77	0.03	0.22	6.32 (2.86)	6.67 (2.85)	37.78 (6.72)	31.96 (6.62)
D	11	19.6	6.07	15.1	0.28	0.02	0.05	4.81 (1.66)	5.45 (3.17)	31.81 (7.31)	27.63 (4.86)

Note: The α parameter is the estimate of reciprocity from the Fictitious Play version of the GR model. *Abbreviations*: AOF = action-orientation after failure; AOD = action-orientation after hesitation; SD = standard deviation.

3.3.2. Empathy and emotion regulation

Table 2 also presents mean scores for players belonging to the different clusters. Due to the small and uneven number of participants comprising individual clusters, non-parametric analyses were employed to compare self-reported emotion regulation and empathic tendencies (ACS and IRI scores, respectively). A Kruskal-Wallis *H* test revealed that the four clusters did not differ in either subscale of the ACS (AOF: $\chi^2(3) = 2.32$, $p = .510$; AOD: $\chi^2(3) = 1.55$, $p = .670$). Although the clusters demonstrated comparable cognitive empathic tendencies ($\chi^2(3) = 7.73$; $p = .052$), they appeared to differ slightly in self-reported affective empathy ($\chi^2(3) = 7.93$; $p = .047$). Follow-up Kolmogorov-Smirnov tests did not reveal any statistically significant differences, however ($p \geq 0.068$; $r \leq 0.19$). This likely reflects the low power in these comparisons; sensitivity power analysis performed in G*power (Faul, Erdfelder, Lang, & Buchner, 2007) determined that a critical χ^2 value of 7.81 would be required to detect differences between these groups with 80% power.

3.3.3. Simulations

3.3.3.1. Homogeneous groups. Using the α and θ parameters estimated for each cluster, and substituting them in equation (2), we simulated the behaviour of 480 groups with a random sampling of initial demands corresponding to the observed distribution of initial

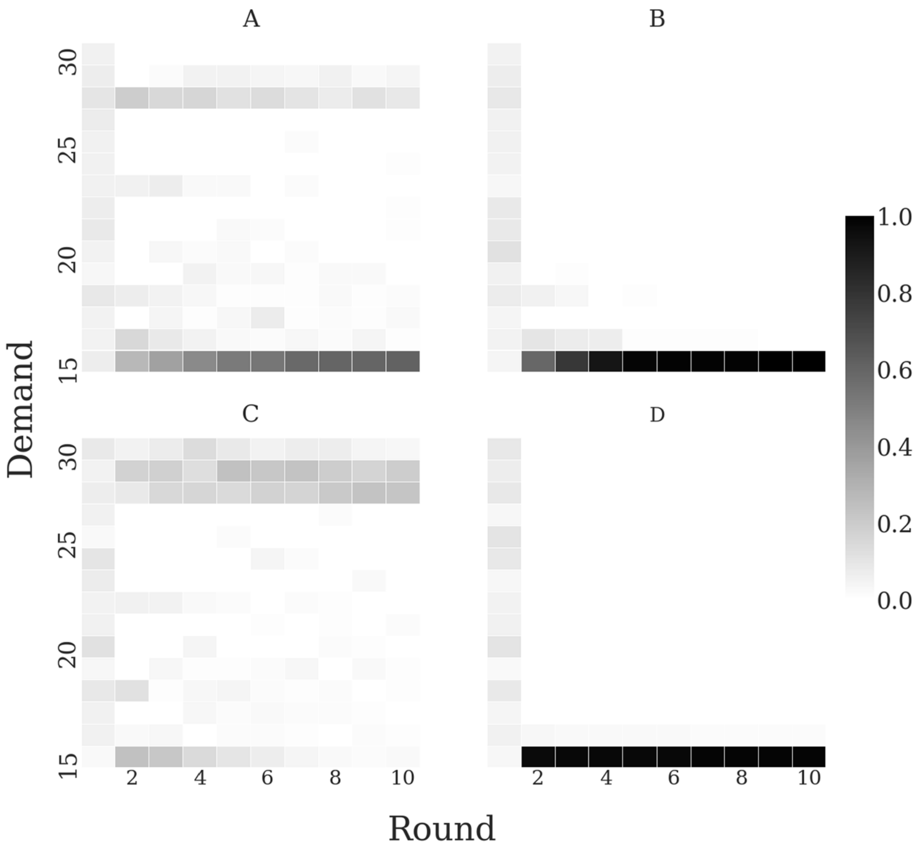

Fig. 3. Simulated data of homogeneous groups, comprising 6 players of the same cluster. *A:* Responsive Type. *B:* Conditional Cooperators, *C:* Reactive Type, *D:* Constant Cooperators.

demands in our sample. The simulations presented in Fig. 3 represent demand trajectories estimated for homogenous groups consisting of only one of the four player types identified by the cluster analysis. In clusters A and B, the simulations resulted in a group dynamic that involves an overall decrease in demands. The demands of the group in the last round are of particular interest, as they can be

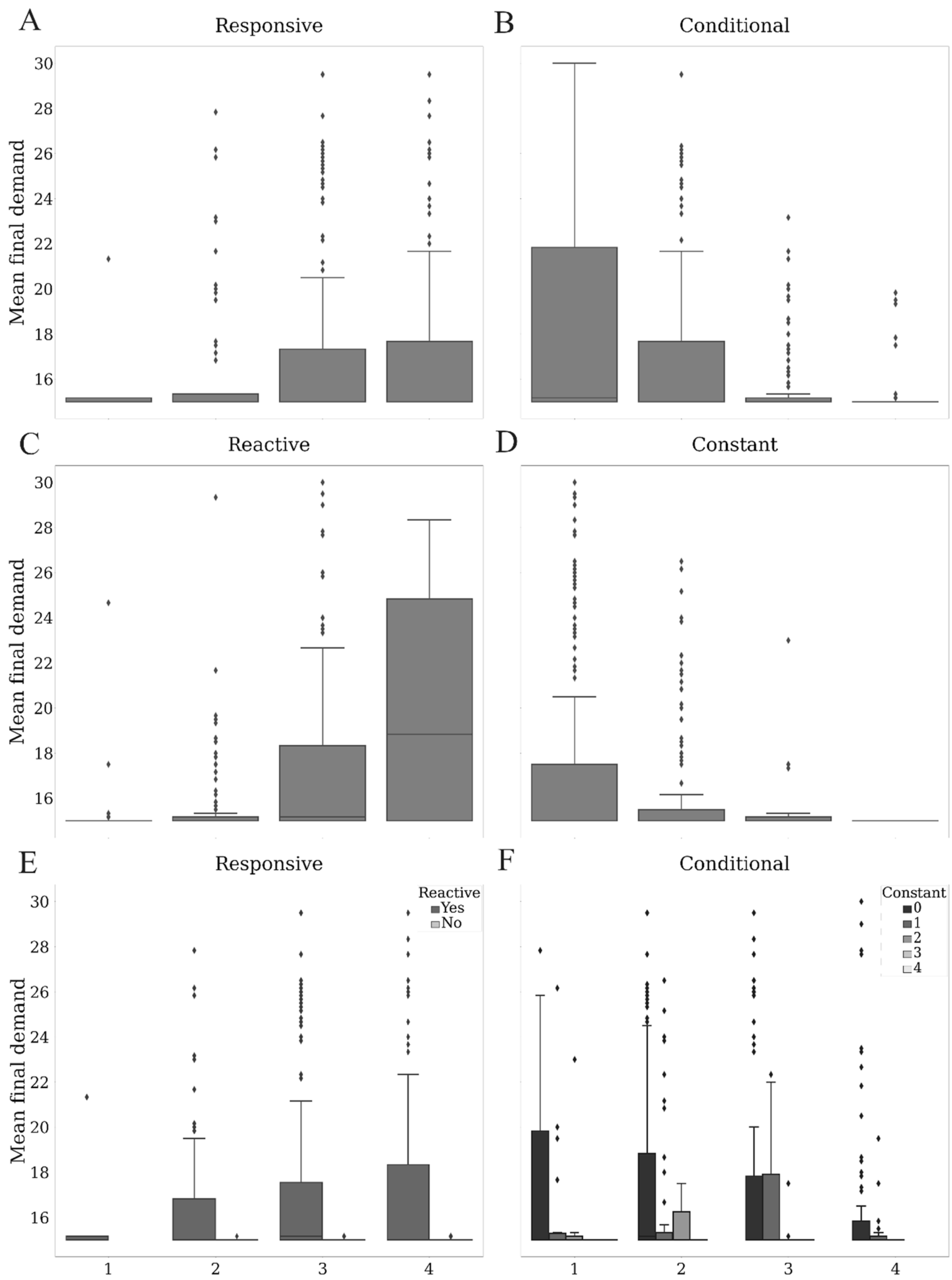

Fig. 4. The influence of group composition on group dynamics. All plots present the mean demand in the tenth round from 480 simulated heterogeneous groups comprising different player compositions. The x-axes indicate the number of players in groups of six that are classified as one of the four behavioural types. In panels *A-D*, the rest of the group consists of a random assortment of all other player types. Panel *E* shows how different concentrations of Responsive players influence the ultimate group dynamic in the presence of at least one Reactive player. Panel *F* illustrates how the ultimate group dynamic is shaped by different proportions of Conditional and Constant Cooperators.

considered to reflect the group norm that has developed over the course of ten interactions. Both clusters B and D converge quickly to an equal division of the pie. These clusters are characterised by low estimates of reciprocity – that is, they comprise players who do not necessarily react to the demands of the other members of the group. Players of these types are analogous to Constant and Conditional Contributors observed in the Public Goods Game. In contrast, clusters A and C are highly reciprocal; the former has a tendency to decrease their demands over successive interactions, while the latter continues to place high demands right through to the final round. These behavioural patterns resemble the Reactive and Responsive player types observed elsewhere. We therefore adopt this nomenclature hereafter for the clusters emerging from the GMM procedure.

3.3.3.2. Heterogeneous player parameters. We used the observed distribution of player types to simulate heterogeneous groups of different player compositions. Fig. 4 displays the mean demands of 480 groups on the tenth round, and the effect of each player subtype in the group. As expected from the simulations above, groups with higher numbers of Constant and Conditional Cooperators converge largely on demands of 15 in the final round; that is, the presence of these players tends to decrease the mean demand to some maximally cooperative value. Since Conditional and Constant Cooperators generally make demands of 15 in the later rounds, the interactions between Responsive and Reactive Cooperators are particularly interesting (see Fig. 4); when no Reactive players are present in a group with Responsive players, the mean demand in the last round converges to an equal (cooperative) demand, regardless of the number of Responsive players.

4. Discussion

This study investigated if Generalised Reciprocity (GR) serves as a mechanism through which cooperation emerges as a group norm from repeated interactions among constituent members in the absence of any direct enforcement mechanisms, such as punishment or reputation building. Furthermore, we examined the extent to which individual differences in reciprocal tendencies among group members result in inter-group variability in the establishment and maintenance of cooperative norms. To do so, we developed a model of GR and applied it to the behaviour of individuals engaged in a Bargaining Game within small groups of anonymous players who were given no explicit instruction or incentive to cooperate with one another. Our findings reveal that cooperative-like behaviour can evolve within a group even if players are aware only of their own outcomes and those of their immediate partner; individuals were unaware of the dealings and outcomes of any other member of their group. Therefore, the resulting cooperative-like behaviour was driven at least partly by GR. Moreover, individual differences in expressions of reciprocity result in marked variability in group dynamics; cooperation within heterogeneous groups is possible only if at least some of the constituent members have a reciprocal disposition.

To assess the role of GR, we adapted a model of direct reciprocity (Cox et al., 2007; Shaw et al., 2018, 2019) and applied it to the behaviour of individuals who bargained with anonymous members of their small group. This paradigm extended our earlier findings of direct reciprocity in dyadic interactions (Shaw et al., 2018, 2019) to the level of group dynamics, and prevented the formation of reputation by precluding the possibility of tracing a source interactant's behaviour. As such, the frequent emergence of group cooperation that we have observed cannot be interpreted in terms of conformity to a norm since players were blind to the dealings and outcomes of other exchanges among their group members, and therefore could not imitate previous behaviours (Romano, Balliet, Yamagishi, & Liu, 2017). The superior fit of our GR model compared to that of a reinforcement learning also suggests that cooperation was not achieved coincidentally as a result of players learning strategies to optimize their payout. Further, since the fit of our GR model was improved significantly by incorporating the entire history of demands made against a given player, rather than just the preceding exchange, it provides evidence for an adaptive decision-making process that goes beyond an immediate reaction to the last demand (Tsvetkova & Macy, 2014). Thus, in most cases, players' demands appear to reflect a deliberate consideration of past exchanges with their group members rather than a reflective action, as predicted by Fictitious Play models (Berger, 2007). It is worth noting that the comparison between the Fictitious Play model with a fixed theta parameter yielded a better fit to the data than its alternative version with an updating theta value. We take this to indicate that the theta parameter reflects a stable estimate of un/kindness, and it is sufficient to update only the expected equilibrium monetary payoff of a player given the history of interactions up to a specified time.

Interestingly, we found no evidence of a relationship between players' reciprocal expressions and their empathic or emotion regulation tendencies. This might simply reflect the lack of statistical power resulting from comparisons among data-defined behavioural types, however, and future studies should assess the reliability of this result by examining larger groups of these types. Another potential explanation is the lack of counterbalancing; since the primary focus of this study was on the role of reciprocity in the emergence and maintenance of co-operative group dynamics, we decided to administer the self-report questionnaires after the Bargaining Game to avoid the former influencing the latter. However, it is entirely possible that behaviour on the game influenced participants' responses on the self-report questionnaires. Further research is also needed to examine alternative factors that might drive individual differences in the proclivity to reciprocate, such as the avoidance of reciprocal situations (Xiong, Guo, Gu, Huang, & Zhou, 2018). Previous studies report that a player's negative affective state decreases their altruistic tendencies (Rudolph, Roesch, Greitemeyer, & Weiner, 2010), and such transient factors might influence reciprocal tendencies more than the stable traits we have measured subjectively.

The overall decrease in demands that we observed across the entire sample converges with the increased cooperation reported recently by Titlestad et al. (2019) in a Public Goods Game (PGG). Moreover, the patterns of player behaviour that we have observed in our Bargaining Game resemble the behavioural types that these authors report in the PGG, and align closely to those identified in other types of economic exchange (Baumgartner, Dahinden, Gianotti, & Knoch, 2019; Chaudhuri, Paichayontvijit, & Smith, 2017; Peysakhovich et al., 2014; Weber & Murnighan, 2008). When simulations were performed with homogeneous groups representing each of the four player types emerging from our data, three resulted in decreased demands over time: Two (Constant and Conditional Co-operators) converged to equal demands almost immediately, whilst the third (Responsive players) expressed a rapid decline in demands after the fifth round. Research on the emergence of cooperation in the PGG shows that players who identify with others, even arbitrarily, have a tendency to cooperate more readily (Titlestad et al., 2019). That is, homogeneity can have a positive effect when the context encourages cooperation explicitly. Our experiment extends this finding by demonstrating that it is not necessary to encourage cooperation explicitly in certain types of groups. Simulations with the Responsive players indicated that demands depend strongly on the initial conditions, however; when the first overall demand of a homogenous group of Reactive players was high, subsequent demands remained high through a chain of retaliation. When faced with an unfair offer, a strongly reciprocating individual will respond with a strong negative reaction. Negative effects of reciprocity in homogeneous groups, like those in one of our simulations, are similar to the outcomes of repeated Dictator Games, whereby players appear to take turns in punishing one another when given the chance (Vandermeer, Hosey, Epley, & Keysar, 2019). As Postmes, Haslam, and Swaab (2005) expresses succinctly, "Solidarity and homogeneity are not incompatible, neither are homogeneity and disunity". Importantly, however, such repeated Dictator Games serve to encourage retaliatory behaviour. In our Bargaining Game, there was no direct possibility for punishment because demands were made to an unknown member of the group.

Social Value Orientation (see Balliet, Parks, & Joireman, 2009) mentions an additional Competitive player type, whose behaviour is focused on outperforming others. We believe this player type, characterised partly by a unique competitive style of reciprocity, to be a subset of the Reactive players that we have observed. Unfortunately, the size of this cluster hindered a more granular division of this player type. Future research should consider further subdividing the specific player types we have observed to achieve more accurate descriptions of behaviour.

The current study is certainly not the first to demonstrate the importance of group composition in the emergence and maintenance of cooperative behaviour. The influence of Constant Contributors in the PGG is a clear example of the positive effect that one player can have on the speed at which cooperation is established; in a four-person group comprising three reciprocating players, the presence of a Constant Contributor can increase cooperative behaviour by up to 40% in comparison to groups comprising a free rider (Böckler, Tusche, & Singer, 2016). Likewise, in large groups of players who interact with one another in a repeated Prisoner's Dilemma, the presence of a Constant Contributor can stabilise cooperation (Mao et al., 2017). In the present study, nearly a third of the sample comprised such players, and our simulations demonstrate the influence they can exert on the overall behaviour of their respective group. It is suggested that the influence of this behavioural type operates through an updating of the beliefs with which other players start their group interactions (Martinangeli, 2021; Poncela-Casasnovas et al., 2016). Any player, but particularly a Conditional Cooperator, who comes into contact with a Constant Cooperator will update their optimistic or pessimistic beliefs in a more cooperative direction. An opposing influence is observed for Reactive players; when paired with other reciprocal types, these individuals have a tendency to increase the overall demands. In Embrey et al.'s (2013) study, once players were made aware of the presence of an unyielding behavioural type (a computer), they expected others to adopt a similar posture and modified their own behaviour accordingly. The simulations we performed of behaviour on our Bargaining Game present a similar scenario, and further portray the complexity of the interaction between player types; in groups with one or more Responsive players, the presence of a single Reactive individual is enough to increase the mean demand at the end of the game.

It is important to stress that expressions of GR estimated with the model developed in this study captured historical interactions between individuals and the group to which they belong – a feature common to all social groups. Although these estimates were unrelated to two aspects of personality – namely, emotion regulation and empathic tendencies, previous studies have found that behavioural types are stable across different paradigms and persistent through time (Peysakhovich et al., 2014). These social preferences or beliefs are then carried into the early group interactions in a given task. An interactive model of social identity formation (Postmes et al., 2005; Thomas, McGarty, & Mavor, 2016) proposes that individuals internalise an identity or the behaviour that they believe to be expected of them through communication and action. In turn, individual role fulfilment contributes to the construction of a social identity for the group as a whole, which is reached after implicit or explicit negotiations (Reicher & Hopkins, 2001). This bottom-up induction is, in our case, manifested in the tendency to converge on cooperative (equal) divisions of the pie over time. The presence of egalitarian demands at the onset of the game is consistent with the social heuristic hypothesis (SHH; Rand et al., 2014): under the time pressure imposed on our Bargaining Game, players might have defaulted intuitively to an equal division due to their prior experiences of advantageous outcomes from cooperative behaviour. Importantly, however, a number of studies question this central premise of the SHH; the causal effect of time pressure on cooperative intuitions fails to replicate (e.g., Bouwmeester et al., 2017), possibly reflecting its reliance upon emotion-induction manipulations (Kvarven et al., 2020), participants with strong prosocial tendencies (Alós-Ferrer & Garagnani, 2020), and samples that are inexperienced with economic games (Arechar & Rand, 2022).

It is important to acknowledge that we investigated only 20 different groups, which resulted in a broad yet limited set of possible group dynamics. Further, our results are likely to be specific to the size of the groups we have investigated; across ten interactions, players were likely to interact with every other member in their group and so the degree to which their behaviour can influence one specific member is reduced. In smaller groups, it is likely that a group norm be established earlier because the probability of repeated interactions with each member increases. Since the length of a reciprocal chain increases disproportionately as the size of a group increases (Peña, Pestelacci, Berchtold, & Tomassini, 2011), the opposite might be expected of larger groups. Future studies should attempt to assess the reliability of our findings in other independent groups of varying sizes.

In conclusion, expressions of generalised reciprocity (GR) during bargaining among anonymous individuals resulted in the overall egalitarian outcome of our sample. This indicates that GR does indeed provide a parsimonious explanation for the emergence of cooperative-like behaviours observed in group interactions. Variable compositions of distinct behavioural types resulted in marked differences among constituent groups, however, demonstrating that the posture adopted by players is the result of the interplay between their own reciprocal tendencies and those of the group with which they interact. Expressions of GR were independent of emotion regulation or empathic tendencies, and might therefore reflect a deliberate response to the observed behaviour of the wider group. Individual differences in reciprocal tendencies mean that, even in anonymous settings, group composition exerts a strong influence on the outcomes of the group as a whole; if at least some of the group members are cooperative, then a cooperative norm can unfold as players modify their expectations of one another's intentions and adjust their own behaviour accordingly.

Data Availability Statement

All data and experimental materials are publicly available at https://osf.io/a4qtu/.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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