# Partner choice creates fairness in humans

**Stéphane Debove**[1,2*], **Jean-Baptiste André**[1,3], **Nicolas Baumard**[2]

[1]Institut de Biologie de l'Ecole normale supérieure (IBENS), INSERM 1024, CNRS 8197, Ecole normale supérieure - PSL Research University, Paris, France.

[2]Institut Jean-Nicod (CNRS - EHESS - ENS), Département d'Etudes Cognitives, Ecole normale supérieure - PSL Research University, Paris, France.

[3] Institut des Sciences de l'Evolution, Université de Montpellier, CNRS, IRD, EPHE, CC065, Pl. E. Bataillon, 34095 Montpellier, France.

*Correspondence: Stéphane DEBOVE, Institut de Biologie de l'Ecole normale supérieure, 46 rue d'Ulm, 75005 Paris, FRANCE. Email address: sd@stephanedebove.net

Data available from the Dryad Digital Repository: http://datadryad.org/resource/doi:10.5061/dryad.6v4c0 and on the first author's website: http://stephanedebove.net/?p=176

**Abstract**

Many studies demonstrate that partner choice has played an important role in the evolution of human cooperation, but little work has tested its impact on the evolution of human fairness. In experiments involving divisions of money, people become either over-generous or over-selfish when they are in competition to be chosen as cooperative partners. Hence, it is difficult to see how partner choice could result in the evolution of fair, equal divisions. Here, we show that this puzzle can be solved if we consider the outside options on which partner choice operates. We conduct a behavioral experiment, run agent-based simulations, and analyze a game-theoretic model to understand how outside options affect partner choice and fairness. All support the conclusion that partner choice leads to fairness only when individuals have equal outside options. We discuss how this condition has been met in our evolutionary history, and the implications of these findings for our understanding of other aspects of fairness less specific than preferences for equal divisions of resources.

**Keywords:** human fairness, human evolution, partner choice, ultimatum game, biological market, egalitarianism

**One Sentence Summary:** Partner choice leads to the evolution of fair divisions when individuals have the same outside options.

# 1 Introduction

Partner choice is a major force that has driven the evolution of cooperation in humans (Barclay, 2013). Experimental studies show that in situations where people choose others as cooperative partners, individuals try to outbid competitors by increasing their investment in cooperation (Barclay, 2004; Barclay and Willer, 2007; Sylwester and Roberts, 2013). Investing more in cooperation is costly but also leads to a good reputation: if partner choice is possible, the benefits of being a good cooperator can outweigh its costs (Barclay, 2006; Sylwester and Roberts, 2010). Theoretical models point in the same direction: incorporating partner choice in models of cooperation selects for cooperative behaviors (Sherratt and Roberts, 1998; Aktipis, 2004; McNamara et al., 2008). All of these studies support the theory of "competitive altruism" (Roberts, 1998; Barclay, 2004): when people monitor and choose others on the basis of their cooperative behaviors, costly cooperative behaviors can pay off.

Although the importance of partner choice for the evolution of human cooperation is clear, very little is known about its importance for the evolution of fairness. Most studies on partner choice are primarily concerned with how much people invest in cooperation and not how people *divide* the common goods produced through cooperation. The most famous experimental evidence of fairness in the division of a good comes from the ultimatum game (Güth et al., 1982; Güth and Kocher, 2013). In this two-player laboratory experiment, one of the players (the "proposer") makes an offer to the other (the "responder") on how to divide a sum of money. If the offer is accepted then both players receive the money, otherwise none of the players receives any money. Traditional game theory, which assumes players to be super-rational, predicts that responders will accept any offer, however small, because getting something is always better than getting nothing. Anticipating this, proposers should only offer the smallest possible amount. But experimental tests have not confirmed these theoretical predictions: proposers' modal offer usually falls between 40 and 50%, and responders are prepared to reject very low offers just for the sake of "fairness" (Hagel and Roth, 1995; Camerer, 2003).

To our knowledge, the only evolutionarily-minded paper studying the impact of partner choice on the fairness of money divisions is a study by Chiang (2010). Using a repeated ultimatum game, Chiang (2010) shows that partner choice increases offers from 42.20% to 46.28%, getting closer to the "fair" expected offer of 50% after 15 repetitions. Chiang (2010) concludes that his findings are "consistent with the predictions of competitive altruism theory" which is interesting because the predictions of competitive altruism theory in this case have not always been thoroughly discussed. Indeed, an interesting evolutionary question is to know up to what point people should attempt to appear generous when partner choice is possible. Some authors have argued that people will increase their generosity until the marginal costs of doing so exceed the marginal benefits, but what costs and benefits should be taken into account remains unclear.

Outside the evolutionary field, the consequences of partner choice for the evolution of fairness are studied in behavioral economics. In a seminal paper by Roth and Prasnikar (1991), nine proposers are in competition to make offers to a single responder. The responder then chooses an offer - and thus a single proposer. In this experimental setup, offers rose very rapidly to 99.5%. The same pattern of highly generous offers was replicated in Fischbacher et al. (2009), and a similar "runaway" effect of partner competition has been found in laboratory market experiments (Cason and Williams, 1990).

Interestingly, a few studies have showed that partner choice can also lead to the opposite pattern of offers - extremely selfish offers (Güth et al., 1998; Grosskopf, 2003; Fischbacher et al., 2009). In Fischbacher et al. (2009) for instance, two responders were in competition to access the offers made by a single proposer. After 20 repetitions of the game, the average offer decreased to 18.8%. The effect was even more dramatic when five responders were in competition to access the offer of a single proposer: proposers became increasingly selfish and offered an average of 13.8% in the last repetition.

In summary, a cross-disciplinary review reveals that partner choice leads to very unbalanced divisions of benefits in two opposite directions: the proposer either makes highly generous offers or highly selfish ones. In this paper, we aim to understand the origin of these opposite findings. We hypothesize that it is not partner choice in itself which is responsible for such unbalanced divisions, but rather unequal 'outside options.' Outside options are the individual's expected payoff in the same timespan if she had refused the current interaction. It is perfectly possible to be able to choose partners but only have bad options to choose from: in this case, it will be difficult to know whether unbalanced divisions are the result of the mere possibility to choose partners or of the existence of those bad outside options. We predict that when partner choice is possible, players should be "rewarded" according to their outside options: if proposers have better outside options than responders, runaway selfishness should be the result. If responders have better outside options than proposers, runaway generosity should be the result. Finally, and more importantly, we hypothesize that when proposers and responders have the same outside options, partner choice leads to a fair, 50/50 division.

We tested this hypothesis empirically and theoretically. In the behavioral experiment, groups of four participants played a modified version of the dictator game that allows for partner choice. We contrasted a condition in which proposers had better outside options than responders to a condition in which responders had better outside options than proposers. We predicted that offers would be over-selfish in the first case and over-generous in the second. In a third condition, we equalized the outside options of proposers and responders and predicted that fair offers would evolve. In the agent-based simulations and the game-theoretic model, we considered larger populations of agents and introduced a continuum of partner choice to demonstrate the robustness of the evolution of fairness when outside options are equal.

# 2 Behavioral experiment

## Methods

The experiments were conducted in March and May 2014 at the Nuffield Centre for Experimental Social Sciences (CESS). All conditions were approved by the CESS Ethics Review Committee. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007).

### Participants

A total of 120 participants were recruited from the University of Oxford using a web-based recruitment system. Participants were told that they would earn £4 for showing up and would earn additional money during the course of the experiment. The average earnings per subject were calculated to be at least £10 per hour.

### General Procedure

Participants were seated at computer terminals separated by partitions so that they could not see one another. We also ensured anonymity: the subjects did not have access to identifying information about the other players at any point during (or after) the experiment. Once seated, participants read instructions that explained the procedure. The instructions were then read aloud by the experimenter while participants read along. Participants then had time to ask questions. The participants first performed a practice round, followed by 30 experimental rounds. After the experiment, subjects answered a questionnaire about their behavior and thought process in the experiment.

The experiment included three conditions: competitive altruism (CA), runaway selfishness (RS) and equal options (EO). Each participant played in only one condition. Forty subjects took part in the CA condition, 44 in the RS condition, and 36 in the EO condition (differences are due to unequal show up rates between conditions). Conditions CA and RS present asymmetries of outside options between proposers and responders and should allow us to replicate the results of previous studies. They also serve as a baseline against which to compare results from the EO condition, in which outside options are equalized.

We start by describing the procedure common to all conditions before detailing procedures specific to each condition. In all conditions, subjects played 30 rounds of a four-player game. Groups of four were stable across rounds. At the beginning of each condition, subjects were randomly assigned to one of two roles ("proposer" or "responder"), and were informed of their role. In each round, proposers and responders could form partnerships to split a pool of money: proposers made offers, and responders could accept them. Subjects were informed that they would gain their average payoff across all rounds. Subjects did not know how many people were in their group, nor the number of proposers and responders in each round. The only information they had was whether or not one of their offers was accepted (proposers) or what offers remained available to them in the current round (responders). This enhanced the probability that the money divisions we observed in our experiment would result mechanically from each individual's outside options, and not from strategic thinking.

## Conditions

### Competitive Altruism (CA)

In the CA condition, there were three proposers and only one responder in each group of four subjects: proposers were thus in competition to be chosen by responders. Proposers and responders kept the same role for the entire 30 rounds. Each round proceeded in the following steps:

- Each proposer in a group decides what division of £10 with a responder from the group to propose.
- The one responder in the group chooses among the proposers' offers (with the obligation to choose one offer - she cannot refuse them all).
- Participants are informed of their own earnings for the round. The responder and the selected proposer receive the portions of the £10 corresponding to the chosen offer. The two proposers who were not chosen by a responder earn £0.

Because in this condition proposers are in competition to be chosen by responders, their outside options are worse than those of responders. We thus predicted that this asymmetry would lead to biased money divisions in favour of responders.

### Runaway Selfishness (RS)

The RS condition is similar to the CA condition, except that the number of proposers and responders in each group was reversed: three responders were in competition to access the offers made by a single proposer. Each round proceeded in the following order:

- The only proposer in the group makes an offer
- One responder in each group is randomly selected to accept this offer (as in a dictator game, the responder cannot refuse it)
- Earnings are reported to each participant. The two responders who were not selected for the offer in this round earn £0 in this round.

In this condition, responders had worse outside options than proposers, because they were in competition to gain access to proposers' offers. We thus predicted that partner competition would lead to biased money divisions in favour of proposers and ever-decreasing offers - runaway selfishness.

Note that subjects who participated in the CA and RS conditions received the exact same sheet of instructions. The only difference between the two conditions was the number of proposers and responders in each group, a parameter that was not communicated to subjects. Hence, any difference in behavior observed between these two conditions can only be attributed to the change in this parameter, and the resulting difference in the asymmetry of outside options between the conditions. Note also that if subjects knew their number of rivals, we would make the same predictions. We decided to give subjects as little information as possible to increase the probability that the effects we could observe would be the result of a "mechanical" effect of outside options, and not the result of strategic thinking (although we can not entirely rule out this possibility).

**Equal Options (EO)**

In the EO condition, all subjects had the same outside options. Although the condition began with two randomly selected proposers and responders in each group, subjects could decide to switch roles at the end of each round after having been informed of their payoff. Hence, proposers and responders who were not satisfied with their payoff could decide to play the opposite role in the next round. As before, subjects were not informed of the current number of proposers and responders in their group, nor were they informed of how many people were willing to change their role in the current round. In case all four subjects decided to play the same role, no partnership was concluded in the next round and all subjects received a null payoff.

We predicted that because outside options were equal in this condition, partner choice would lead to a stable "fair" equilibrium and the evolution of equal divisions. Note that having the same number of proposers and responders in each group but with *fixed* roles would not be enough to make this condition different from the RS condition: with an equal number of proposers and responders, proposers see their offers being accepted in each round, and should decrease their offers as in the RS condition.

## 2.1 Results

Figure 1 plots the evolution of the average offer accepted in each condition. We include the first round in this graph for informative purposes, but this round was a practice round and was not included in statistical analyses. Figure 1 confirms our predictions: each condition influenced the offers in the expected direction. In all rounds except the first (practice) round, mean accepted offers $\bar{o}$ followed the inequality $\bar{o}_{CA} > \bar{o}_{EO} > \bar{o}_{RS}$. Figure 1 also suggests an increasing trend over time in the CA condition and a decreasing trend over time in the RS condition.

We tested the significance of the differences between conditions using Mann-Whitney tests. We analyze each group as an N of 1 as a way of dealing with non-interdependence of decisions within a group. Significant differences were found between all conditions in pairwise comparisons: CA and EO (n1 = 9, n2 = 10, U = 90, $p < 0.001$), EO and RS (n1 = 9, n2 = 11, U = 17, $p = 0.012$), and RS and CA (n1 = 10, n2 = 11, U = 110, $p < 0.001$). An nptrend test (Cuzick, 1985) rejected the null hypothesis that there was no trend across conditions ($z = 4.65$, $p < 0.001$). Using data from the last ten rounds only, the differences between pairs of conditions CA and EO, EO and RS, RS and CA remained significant ($p < 0.001$ and U = 90, p = 0.028 and U = 21, $p < 0.001$ and U = 110 respectively), and the nptrend test was still significant ($z = 4.55$, $p < 0.001$). Differences were still significant at least at the 5 percent level when the last eight or twelve rounds were analyzed instead of the last ten.

Table 1 shows the results of a regression analysis of the average offer accepted in the round, pooling the three conditions CA, RS and EO, and setting EO as the omitted category. In Column 1, all rounds are considered and numbered from -29 to 0 so that the reported coefficients in the table represent effects in the last round of the experiment. In Column 2, only data from the last 10 rounds is used, and rounds are numbered from -9 to 0. The data were checked for linearity, normality, homoscedasticity, and autocorrelation.

The estimated accepted offer in the last round of the EO condition was 4.67 (column 1, line 1), very close to the 50 % fair division. The negative coefficient in the RS condition and the positive coefficient in the CA condition, both significant, show that the predicted offers in these conditions differed in the expected direction. Offers in the CA condition are expected to be 4.8 units higher than in the EO condition, and offers in the RS condition are expected to be 2.4 units lower than in the EO condition. A comparison of column 1 with column 2 shows that there is no substantial difference of average offers accepted in the last 10 rounds compared to all rounds, controlling for time trends.

Time did not have a significant effect on the offers accepted in the EO condition (column 1 and column 2): offers remained stable across all rounds in this condition. On the contrary, significant interactions were found between time and RS and time and CA. The effect of time was especially large in the CA condition: offers increased by 0.12 units at each round. However, these interactions were no longer significant in the last 10 rounds (column 2), suggesting that offers ended up reaching a stable level in all conditions, as is already suggested by Figure 1.

# 3 Theoretical model

## Methods

We model a population of agents who have the same outside options and play ultimatum games repeatedly throughout their lifespan. Individuals meet each other in pairs at a constant rate $\beta$. When they meet, one individual is randomly selected to play the role of proposer, while the other plays the role of responder. The proposer makes a genetically encoded offer to the partner. If the offer is accepted, the two partners enter a cooperative interaction which is assumed to take time. During this cooperative interaction, they divide a resource of size 1 according to the accepted offer, until the end of the interaction which occurs at a constant rate $\tau$. If the proposer's offer is rejected, the two partners are separated without interacting and return to the population to find an unpaired partner.

At the end of their life, all individuals reproduce according to the amount of resource they have accumulated. Individuals pass on their offers and requests (the minimum offer they are ready to accept when they play the role of responder) to their offspring, with a small probability of mutation on these traits. The model is fully explained in SI section 2 and SI section 1.

When the encounter rate $\beta$ is high, it is easy to find a new partner in the population. When the split rate $\tau$ is low, interactions last a long time. Hence, when the $\frac{\beta}{\tau}$ ratio is high, partner choice is not costly, as rejecting an unfair offer does not mean that time will be wasted looking for a new partner. Moreover, because the roles of proposer and responder are assigned randomly in each new encounter, all individuals have the same outside options. In this environment where all individuals have the same outside options and can choose their cooperative partners, we observe what offers are made at the evolutionary equilibrium, which represent the fitness-maximizing offers. We also produce a resident-mutant analysis of the model, allowing us to pinpoint the offers that cannot be invaded by mutants once they have spread in the population. This analysis is detailed in SI section 1.

## Results

Our simulations show that the average offer accepted in the population tends toward 50% at the evolutionary equilibrium when partner choice is not costly (Fig. 2, plain lines). The resident-mutant analysis shows that a resident population cannot be invaded by mutants as long as the offer $p$ characterizing the population lies in the interval:

$$p \in \left[\frac{\beta/2}{\beta+\tau}, 1 - \frac{\beta/2}{\beta+\tau}\right] \tag{1}$$

Hence, when partner choice is not costly ($\beta >> \tau$), the range of evolutionary stable offers is restricted to $p \in \left[\frac{1}{2}, \frac{1}{2}\right]$. Analytical results are thus in perfect agreement with simulation results and confirm that partner choice in a context of equal outside options leads to the evolution of fairness.

On the other hand, simulations show that when partner choice is costly ($\beta << \tau$), the average offer accepted at the evolutionary equilibrium is very low (Fig. 2, dashed lines): proposers can afford to be selfish. This result holds whether we consider an initial population of "over-selfish" individuals offering 0% or an initial population of "over-generous" individuals offering 100% of the resource to their partner, showing that our results are not limited by the initial conditions of our model (Fig. 2, dashed lines).

# 4 Discussion

Our study shows that partner choice creates fairness, but only in a context of equal outside options. Partner choice is the mechanism that allows individuals to receive offers corresponding to their outside options; whether or not the offers will be fair depends ultimately on the equality of those outside options. This emphasis on outside options also helps explain why previous studies reported opposite effects of partner choice. Although the subjects in our CA and RS conditions received the exact same instructions, the inequality of outside options between the two conditions led to the evolution of offers in two opposite directions. Specifically, an asymmetry of outside options in favor of responders leads to runaway generosity, whereas an asymmetry in favor of proposers leads to runaway selfishness.

Although the importance of outside options may have been overlooked in evolutionary studies, it has already been investigated in behavioral economics (Cason and Williams, 1990; Knez and Camerer, 1995). A parallel could even be drawn between our results and the classical idea that an excess of supply or demand affects the price at which a commodity is exchanged (for a discussion of this parallel, see André and Baumard 2011b). Nonetheless, in behavioral economics, most studies fix outside options a priori and observe, once they are fixed, how they affect prices or bargaining outcomes. Here, on the contrary, we provide a condition in which equal outside options emerge endogenously from a partner choice-based environment. Hence, our work contains two main contributions to the literature. For scholars with a biological background, we draw attention to the prime importance of outside options when studying human partner choice and the evolution of fairness. And for scholars with an economics background, we show how the well-known effects of outside options are not limited to economic markets, but also have an impact over longer, evolutionary timescales, in "biological markets" (Noë et al., 1991; Noë and Hammerstein, 1995; Noë et al., 2001). In a nutshell, what we suggest is that the human sense of fairness is the result of natural selection optimizing human behavior in a market environment (without neglecting potential cultural or contextual effects, see Baumard et al. 2013).

Our work represents a number of methodological advances on previous related work. First, it uses a modified version of a dictator game, rather than an ultimatum game, to measure the fairness of money divisions: when only one offer is left, responders have no choice but to accept it. As divisions in the dictator game are known to be more asymmetric than those in the ultimatum game (Hagel and Roth, 1995; Camerer, 2003), the dictator game offers a more conservative way to observe the evolution of fairness. Second, we modified the dictator game so that it can be played not only between two players but in groups of four players, to introduce a first level of partner choice. A second level of partner choice is implemented by allowing subjects not only to choose their partner but also to change role between rounds. Finally, we observed behaviors on a longer timescale and with more independent observations than in previous studies.

The mechanism leading to fairness in our EO condition is easy to understand. When there are more proposers than responders in a group, offers start to increase following the predictions of competitive altruism. But as offers rise, proposers start to receive decreasing payoffs, which leads some of them to decide to play responder in the next round. This incentive to switch roles in turn leads to an excess of responders over proposers. At some point, the asymmetry of outside options is reversed, and responders want to change role and become proposers. These two forces working in opposite directions lead to the evolution of fair, balanced divisions which oscillate around 50%. The mechanism at play is similar in our theoretical study: proposers cannot make offers lower than 50%, as responders would reject them and prefer to play proposer. Conversely, proposers have no incentive to make offers higher than 50%, as they would be better off playing responder themselves to benefit from those generous offers.

Although the mechanism in our study is clear, it is interesting to ask what its biological equivalent in the real world might be. The roles of proposer and responder are a convenient way to model asymmetries of bargaining power in the lab: the proposer is in a strategically advantageous position because the responder has no choice but to accept her offer. Allowing subjects to change roles means removing this asymmetry from the game. Although it is hard to imagine a strict equivalent of the roles of proposer and responder in nature, asymmetries of bargaining power are plentiful. For example, a physically stronger individual could benefit from a local competitive advantage at the moment of sharing the benefits of cooperation. Weaker individuals cannot "choose" to become stronger in this situation, so what could be the ecological equivalent of being able to change role from proposer to responder and vice versa? We suggest it is a way to implement the variety of roles humans play across all their lifelong cooperative interactions, including interactions in which they are not the weakest anymore. This assumption is well justified by the empirical literature on human cooperation: humans cooperate frequently and in diverse contexts, both with kins and non kins (Hill, 2002; Hooper et al., 2014). In a review of the human social organisation, Kaplan et al. (2009) insist on the "high-quality, difficult to acquire resources" hunter-gatherers consume, which require "high levels of knowledge, skill, coordination". Because knowledge, skill, or coordination are not necessarily correlated with physical strength, weak individual can be good cooperators and have access to good outside options even if they are locally in a poor bargaining position. In a sense, we think it is interesting to reverse the question: what could be the ecological equivalent of playing a repeated dictator game when the roles of proposers and responders are fixed? Whereas it can probably adequately represent some situations in economics where the roles of sellers and buyers never change, it does not seem realistic for a hunter-gatherer to always be stuck in the same social role in all his lifelong interactions. Hence, without saying our paradigm is a perfect representation of humans' social life, we think it captures some interesting aspects of it, and is thus worth exploring.

Our study has a few important limitations. First, the small number of subjects in our groups means that the offers in each round may have been sensitive to noise. It would also be interesting to introduce asymmetries of outside options in a more natural way than by artificially fixing the number of proposers and responders in each group. In our theoretical study, we do not consider variations between individuals in outside options in the form of strong and weak individuals, for example. We also do not model the formation of reputation, as we suppose individuals have perfect information on the past behavior of other individuals. Examining if and how less-than-perfect information could prevent the evolution of partner-choice based fairness would thus be another way to extend our results.

Nonetheless, our study has interesting implications for our understanding of the evolution of human fairness as a whole. Whereas almost all theoretical studies of the evolution of human fairness have studied the evolution of equal divisions in the ultimatum game (Nowak et al., 2000; Page and Nowak, 2002; André and Baumard, 2011a), fairness in real life is not only characterized by equal divisions. People also consider unequal divisions as fair when they reflect inequalities of skills or talent, or an unequal investment of time, resources, and energy (Schokkaert and Overlaet, 1989; Konow, 2003; Cappelen et al., 2007). Our study offers hints as to why this would be the case. If the reason why humans evolved a sense of fairness is linked to the best way to reward social partners in a biological market (at the ultimate level), each social partner having to be rewarded according to her outside options, then maybe the reason why humans consider that the best contributors should get a bigger part of the benefits is that the best contributors have better outside options in a biological market. An interesting follow-up to our study would thus be to consider the fact that outside options can vary not only because of strength, but also because of skills, talents, effort, etc. Testing this prediction theoretically and empirically would also provide a good entry point to study fairness outside the ultimatum game and its associated always-equal divisions.

# 5 References and notes

# References

Aktipis, C. A., 2004. Know when to walk away: contingent movement and the evolution of cooperation. Journal of theoretical biology 231:249–60.

André, J.-B. and N. Baumard, 2011a. Social opportunities and the evolution of fairness. Journal of theoretical biology 289:128–35.

André, J.-B. and N. Baumard, 2011b. The evolution of fairness in a biological market. Evolution 65:1447–56.

Barclay, P., 2004. Trustworthiness and competitive altruism can also solve the "tragedy of the commons". Evolution and Human Behavior 25:209–220.

Barclay, P., 2006. Reputational benefits for altruistic punishment. Evolution and Human Behavior 27:325–344.

Barclay, P., 2013. Strategies for cooperation in biological markets, especially for humans. Evolution and Human Behavior .

Barclay, P. and R. Willer, 2007. Partner choice creates competitive altruism in humans. Proceedings. Biological sciences / The Royal Society 274:749–53.

Baumard, N., J. André, and D. Sperber, 2013. A mutualistic approach to morality: The evolution of fairness by partner choice. Behavioral and Brain Sciences 6:59–122.

Camerer, C., 2003. Behavioral game theory: Experiments in strategic interaction, vol. 32. Princeton University Press, Princeton, New Jersey.

Cappelen, A., A. Hole, E. Sø rensen, and B. Tungodden, 2007. The pluralism of fairness ideals: An experimental approach. American Economic Review 97:818–827.

Cason, T. and A. Williams, 1990. Competitive equilibrium convergence in a posted-offer market with extreme earnings inequities. Journal of Economic Behavior & Organization 14:331–352.

Chiang, Y.-S., 2010. Self-interested partner selection can lead to the emergence of fairness. Evolution and Human Behavior 31:265–270.

Cuzick, J., 1985. A Wilcoxon-Type Test for Trend. Statistics in Medicine 4:543–547.

Fischbacher, U., 2007. z-Tree: Zurich toolbox for ready-made economic experiments. Experimental Economics 10:171–178.

Fischbacher, U., C. M. Fong, and E. Fehr, 2009. Fairness, errors and the power of competition. Journal of Economic Behavior & Organization 72:527–545.

Grosskopf, B., 2003. Reinforcement and directional learning in the ultimatum game with responder competition. Experimental Economics 158:141–158.

Güth, W. and M. Kocher, 2013. More than thirty years of ultimatum bargaining experiments: Motives, variations, and a survey of the recent literature .

Güth, W., N. Marchand, and J. Rullière, 1998. Equilibration et dépendance du contexte. Une évaluation expérimentale du jeu de négociation sous ultimatum [Equilibration and context dependency : an experimental investigation of the ultimatum bargaining game]. Revue économique 49:785–794.

Güth, W., R. Schmittberger, and B. Schwarze, 1982. An experimental analysis of ultimatum bargaining. Journal of economic behavior & ... Pp. 367–388.

Hagel, J. H. and A. E. Roth, 1995. Handbook of experimental economics. Princeton University Press, Princeton, New Jersey.

Hill, K., 2002. Altruistic cooperation during foraging by the Ache, and the evolved human predisposition to cooperate. Human Nature 13:105–128.

Hooper, P. L., M. Gurven, and H. Kaplan, 2014. Social and Economic Underpinnings of Human Biodemography. in Sociality, Hierarchy, Health: Comparative Biodemography: Papers from a Workshop.

Kaplan, H. S., P. L. Hooper, and M. Gurven, 2009. The evolutionary and ecological roots of human social organization. Philosophical transactions of the Royal Society B. 364:3289–99.

Knez, M. and C. Camerer, 1995. Outside options and social comparison in three-player ultimatum game experiments. Games and Economic Behavior .

Konow, J., 2003. Which is the fairest one of all? A positive analysis of justice theories. Journal of economic literature XLI:1188–1239.

McNamara, J., Z. Barta, L. Fromhage, and A. Houston, 2008. The coevolution of choosiness and cooperation. Nature 451:189–192.

Noë, R. and P. Hammerstein, 1995. Biological markets. Trends in ecology & evolution 10:336–9.

Noë, R., J. V. Hooff, and P. Hammerstein, 2001. Economics in nature: social dilemmas, mate choice and biological markets. Cambridge University Press, Cambridge, England.

Noë, R., C. Schaik, and J. Hooff, 1991. The market effect: An explanation for pay-off asymmetries among collaborating animals. Ethology 87:97–118.

Nowak, M. a., K. M. Page, and K. Sigmund, 2000. Fairness versus reason in the ultimatum game. Science 289:1773–5.

Page, K. M. and M. a. Nowak, 2002. Empathy leads to fairness. Bulletin of mathematical biology 64:1101–16.

Roberts, G., 1998. Competitive altruism: from reciprocity to the handicap principle. Proceedings of the Royal Society B: Biological Sciences 265:427–431.

Roth, A. and V. Prasnikar, 1991. Bargaining and market behavior in Jerusalem, Ljubljana, Pittsburgh, and Tokyo: An experimental study. The American Economic ....

Schokkaert, E. and B. Overlaet, 1989. Moral Intuitions and Economic Models. Social choice and Welfare Pp. 19–31.

Sherratt, T. and G. Roberts, 1998. The evolution of generosity and choosiness in cooperative exchanges. Journal of Theoretical Biology Pp. 167–177.

Sylwester, K. and G. Roberts, 2010. Cooperators benefit through reputation-based partner choice in economic games. Biology letters 6:659–62.

Sylwester, K. and G. Roberts, 2013. Reputation-based partner choice is an effective alternative to indirect reciprocity in solving social dilemmas. Evolution and Human Behavior 34:201–206.

# 6 Data accessibility

Source code for the simulations and data for the simulations and behavioral experiment are archived online on the first author's website http://stephanedebove.net/?p=176 and on datadryad.org http://datadryad.org/resource/doi:10.5061/dryad.6v4c0"

# 7 Competing interests

We declare no competing interests.

# 8 Authors' contributions

S.D. designed the behavioral experiment, collected data, carried out the statistical analysis, developed the agent-based simulations, and wrote the manuscript. J.-B.A. designed the behavioral experiment, built the analytical model, and coordinated the study. N.B. designed the behavioral experiment and coordinated the study. All authors gave final approval for publication.

# 9 Acknowledgments

SD thanks the *Région Ile-de-France* for funding this research through a *2012 DIM "Problématiques transversales aux systèmes complexes"* grant, the *Institut des systèmes complexes*, and the doctoral school Interdisciplinaire Européenne Frontières du Vivant ED 474, Programme doctoral Bettencourt, Universities Paris Descartes and Paris Diderot for their support. This work was supported by ANR-11-0001-02 PSL* and ANR-10-LABX-0087. The experiments reported in this paper were conducted at Nuffield CESS (Nuffield College Centre for Experimental Social Sciences). We would like to especially thank John Jensenius and Akitaka Matsuo for their excellent research assistance, and Mark Sheskin for helpful corrections on the manuscript.

## 10 Figure and Table Legends

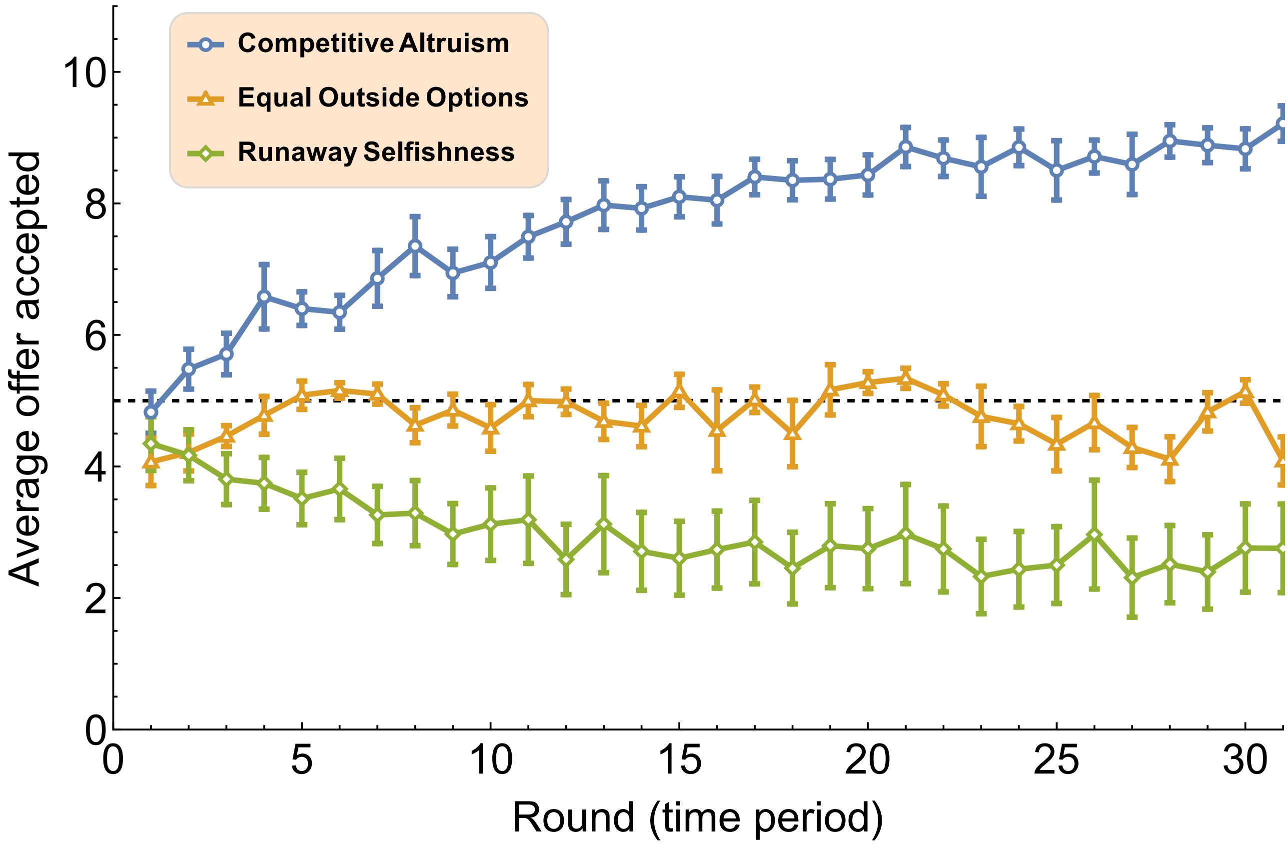


Figure 1: Evolution of the average offer accepted by responders in each of the three conditions. In the Competitive Altruism condition, responders have better outside options than proposers. In the Runaway Selfishness condition, proposers have better outside options than responders. In the Equal Outside Options condition, proposers and responders can choose partners and have the same outside options. Round 1 is a practise round. Error bars represent standard errors.

.

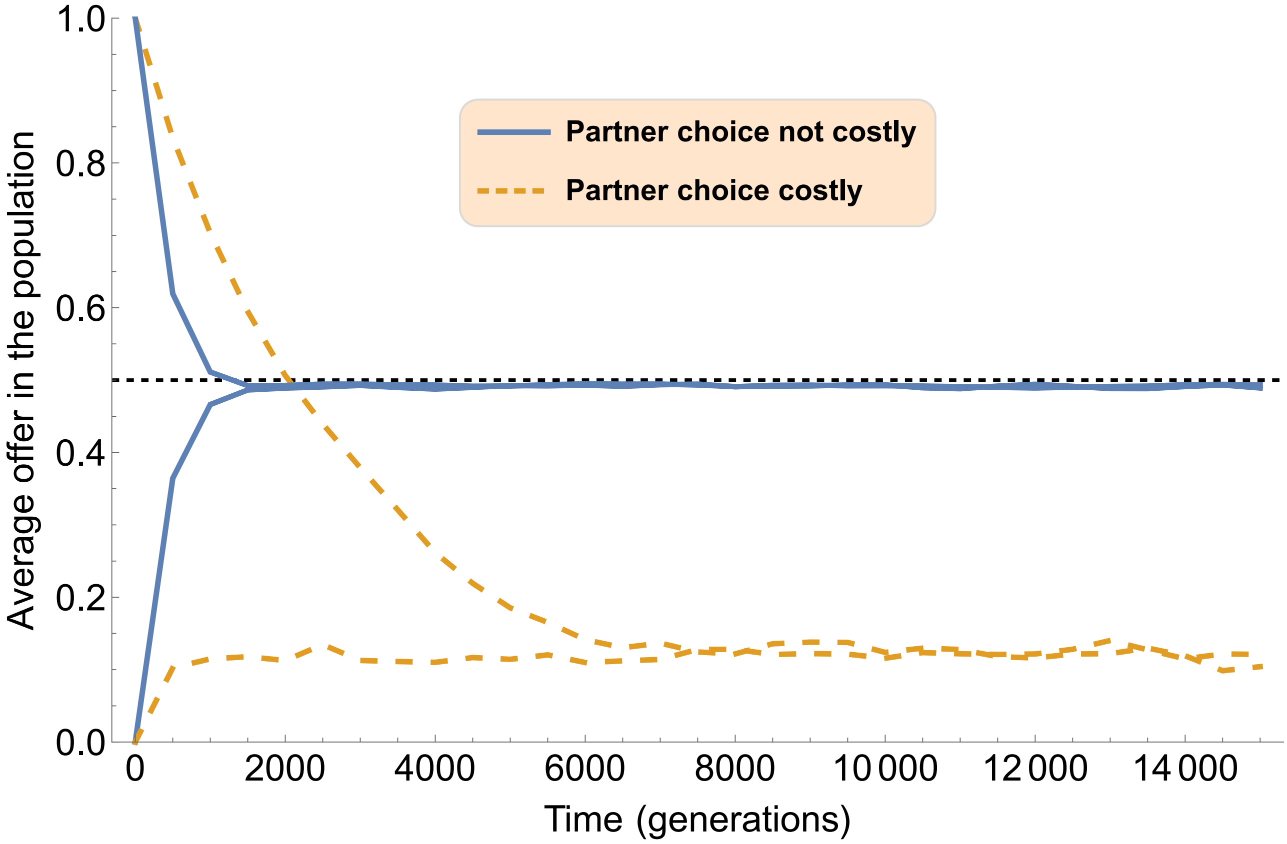


Figure 2: Evolution of the average offer in the ultimatum game when individuals have the same outside options and for two different costs of partner choice (simulation results). Two starting points (0 and 1) are used for each cost of partner choice. Each curve represents an average over 20 simulation runs. Parameter values used for these simulations can be found in SI section 2.2.

| | All rounds | Last 10 rounds |
|---|---|---|
| *Constant* | $4.669^{**}(0.171)$ | $4.375^{**}(0.299)$ |
| RS | $-2.366^{**}(0.228)$ | $-1.741^{**}(0.398)$ |
| CA | $4.779^{**}(0.233)$ | $4.622^{**}(0.407)$ |
| time | $-0.006(0.0102867)$ | $-0.046(0.055)$ |
| time x RS | $-0.036^{*}(0.013)$ | $0.060(0.074)$ |
| time x CA | $0.115^{**}(0.013)$ | $0.095(0.075)$ |
| $N$ | 878 | 295 |
| $R^2$ | 0.71 | 0.76 |
| $F$ | 429.054 | 188.731 |
| $Prob > F$ | 0.000 | 0.000 |

Table 1: Pooled regression predicting the average accepted offer. Reported numbers are ordinary least squares coefficients. Numbers between parentheses are standard errors. The left column gives a regression using data from all rounds. In the right column, only data from the last 10 rounds were used.

RS = Runaway Selfishness.
CA = Competitive Altruism
* = Significance at the 0.01 level
** = Significance at the 0.001 level

Supplementary information for paper

# "Partner choice creates fairness in humans"

**Stéphane Debove**[1,2*], **Jean-Baptiste André**[3], **Nicolas Baumard**[2]

[1]Institut de Biologie de l'Ecole normale supérieure (IBENS), INSERM 1024, CNRS 8197, Ecole normale supérieure - PSL Research University, Paris, France.

[2]Institut Jean-Nicod (CNRS - EHESS - ENS), Département d'Etudes Cognitives, Ecole normale supérieure - PSL Research University, Paris, France.

[3] Institut des Sciences de l'Évolution, UMR 5554 - CNRS – Université Montpellier 2, Montpellier, France.

*Correspondence: Stéphane DEBOVE, Institut de Biologie de l'Ecole normale supérieure, 46 rue d'Ulm, 75005 Paris, FRANCE. Email address: sd@stephanedebove.net

# 1 Analytical model

## 1.1 Social life and fitness: a general framework

We consider a population of individuals taking part in any kind of pairwise social interaction. We follow a focal individual and aim to derive that individual's cumulated payoff throughout her entire life as a function of (i) her probability of successfully interacting when she meets a potential partner, (ii) the expected duration of each of her social interactions, (iii) her expected payoff from each interaction, and (iv) her payoff when she is solitary (a baseline payoff).

Consider a population of $N$ individuals $i$ from 1 to $N$. Individuals undertake pairwise social interactions, one at a time. Each individual $i$ can be in one of two states at any given time: solitary or paired with a partner. When solitary, individual $i$ encounters other solitary individuals at a given rate $\beta$. Certain pairs of partners are mutually compatible, others are not. This may depend on various properties of the individuals and of the interaction at hand (see below).

In expectation, each time individual $i$ is paired with a given random partner, there is a probability $\alpha_i$ of their being mutually compatible. Therefore, individual $i$'s effective rate of social encounter is $\rho_i = \beta\alpha_i$. We assume interactions have exponentially distributed duration: i.e., for individual $i$, interactions stop at a constant rate $\tau_i$. The duration of an interaction can be interpreted as the duration of the actual social event, or it can be interpreted as a refractory period after each interaction during which an individual is not "in need of" social interactions. In either case, during this period the individual is not available for other social interactions.

When an interaction does take place, individual $i$ receives a payoff $g_i$ per unit of time in the interaction, a constant that is independent of $\tau$. When in the solitary state, individual $i$ gains a non-social payoff $\sigma_i$ per unit of time. Individuals are born in the solitary state and they live a certain length of time $L$ in expectation.

Here, we aim to derive the expected total social payoff of individual $i$ over her lifespan. In this aim, call $S_i(t)$ the probability that individual $i$ is solitary at age $t$ ($I_i(t) = 1 - S_i(t)$ is the probability that $i$ is involved in an interaction at time $t$). We have $\dot{S}_i = \tau_i I_i - \rho_i S_i$, with the initial condition $S_i(0) = 1$ (individuals are born solitary). Integrating this differential equation gives us the probability that individual $i$ is solitary at age $t$:

$$S_i(t) = 1 - \frac{\rho_i}{\tau_i + \rho_i}(1 - e^{-(\tau_i+\rho_i)t}) \tag{1}$$

The cumulated (social and non-social) benefit of individual $i$ at age $t$ is denoted by $G_i(t)$, with the initial condition $G_i(0) = 0$ and the rate of increase $\dot{G}_i(t) = g_i(1 - S_i(t)) + \sigma_i S_i(t)$.

We integrate this equation to obtain the total gain at age $L$:

$$G_i(L) = \frac{\sigma\left(\rho - e^{-L(\rho+\tau)}\rho + L\rho\tau + L\tau^2\right) + g\rho\left(-1 + e^{-L(\rho+\tau)} + L(\rho+\tau)\right)}{(\rho+\tau)^2} \tag{2}$$

For the sake of simplicity, we assume that the lifespan ($L$) of individuals is always very large relative to the durations of both social interaction and solitary periods. Therefore from equation (1) the fraction of time spent by an individual in the solitary state is approximately $\frac{\tau_i}{\tau_i+\rho_i}$. Without loss of generality, we also assume that the lifespan of individuals is equal to unity $L = 1$. Therefore, we approximate the cumulative lifetime payoff of individual $i$ as

$$G_i = \frac{g_i \rho_i + \sigma_i \tau_i}{\rho_i + \tau_i} \tag{3}$$

## 1.2 A resident/mutant analysis in the ultimatum game

We assume that all individuals are characterized by the same rate of interaction cessation $\tau$, and the same rate of solitary benefits $\sigma$. We consider that individuals interact in an ultimatum game in which the proposer and responder are chosen randomly. The total resource per unit of time is 1 and it must be divided into two shares.

By assumption, the social interaction must be at least possible in an evolutionarily stable state. This implies that the solitary gain $\sigma$ is less than 1/2 (otherwise, no interaction can be mutually acceptable).

Individuals are genetically characterized by two variables: $p$, the offer they make when they play the role of proposer, and $q$, the minimal offer they are ready to accept when they play the role of responder.

Assume that the population is fixed with a resident strategy $(p, q)$. Call $G$ the total cumulative payoff of resident individuals (proportional to their fitness). When a focal resident individual is paired with another resident, we call $\alpha$ the probability that the interaction eventually takes place (mutual acceptance). In this case, we call $g$ the expected payoff of the focal individual. From equation (3), the expected payoff of residents can be written $G = \dfrac{g\beta\alpha + \sigma\tau}{\beta\alpha + \tau}$.

Here we aim to derive the necessary conditions on the resident strategy such that no rare mutant is favored (first ESS condition). For any focal mutant, we call $\alpha'$ the probability that she eventually ends up interacting when she is paired with a resident. In this case, we call $g'$ the expected payoff of the mutant. From equation (3), the expected payoff of the rare mutant can be written $G' = \dfrac{g'\beta\alpha' + \sigma\tau}{\beta\alpha' + \tau}$.

Three types of resident can be delineated.

The two first types are not very interesting. The third is the only significant one.

1) *The resident strategy is fixed with $(p, q)$ such that $p > q$.* In this case, resident individuals are making an unnecessarily high offer. It is then easy to show that any mutant offering $p' \in [q, p]$ is strictly favored (as its offer is always accepted and yet lower than the resident's).

2) *The resident strategy is fixed with $(p, q)$ such that $q > p$.* In this case, interactions among two residents are never accepted ($\alpha = 0$). The payoff of residents is thus $G = \sigma$. In this case we need to consider two types of mutants.

A less demanding mutant, accepting $q' = p$, has a probability $\alpha' = 1/2$ of successfully interacting in each social encounter and then receives a benefit $g' = p$. Therefore, the mutant payoff is $G' = \dfrac{p\beta/2 + \sigma\tau}{\beta/2 + \tau}$. It is then easy to show that the mutant is neutral or counter-selected whenever $p \leq \sigma$. In other words, individuals will accept a proposer's offer whenever the social gain is larger than the solitary gain.

Similarly, a more generous mutant, offering $p' = q$, is neutral or counter-selected whenever $q \geq 1 - \sigma$. Individuals will make the effort to propose enough whenever their potential social gain $(1 - q)$ is larger than their solitary gain.

Therefore, a resident with $q > p$ can be evolutionarily stable (at least according to the first ESS condition) only if both $p \leq \sigma$ and $q \geq 1 - \sigma$, i.e., offers must be too low to be worth accepting and requests must be too high to be worth meeting. In this case, we can remain "blocked" in a situation in which social interactions are impossible and no rare mutant can increase in frequency.

3) *The resident strategy is fixed with* $(p, q)$ *such that* $p = q$. In this case, the residents are always certain to interact ($\alpha = 1$) and they always receive $g = 1/2$ in expectation. From equation (3), the expected payoff of residents can thus be written $G = \dfrac{\beta/2 + \sigma\tau}{\beta + \tau}$.

In this case, there are four types of mutants: more generous or less generous, and more demanding or less demanding. Double mutants need not be considered as mutants are assumed to be infinitely rare in our analysis and therefore selection on the two traits is completely independent.

It is easy to show that more generous mutants cannot be favored by selection as they would be unnecessarily over-generous. It is also easy to show that less demanding mutants are neutral, and therefore cannot be favored by selection.

Therefore, we really need to consider two types of mutants. More demanding mutants can be favored if the resident offer is too low and not worth accepting. Less generous mutants can be favored if the resident request is too high and not worth accepting. This gives us two conditions for the resident strategy to be an ESS (first ESS condition only).

(i) Consider a mutant more demanding than the residents ($q' > p$), but characterized by the same offer $p$. In practice, in the resident population, this mutant only plays the role of a proposer, and therefore interacts with probability $\alpha' = 1/2$, gaining $g' = 1 - p$. This gives the mutant a payoff of $G' = \frac{(1-p)\beta/2+\sigma\tau}{\beta/2+\tau}$. It is then easy to show that the mutant is neutral or counter-selected whenever $p \geq \dfrac{\beta/2 + \sigma\tau}{\beta + \tau}$.

(ii) Consider a mutant that is less generous than residents ($p' < p$), but characterized by the same demand $q$. In practice, in the resident population, this mutant only plays the role of a responder, and therefore interacts with probability $\alpha' = 1/2$, gaining $g' = p$. This gives the mutant a payoff of $G' = \frac{p\beta/2+\sigma\tau}{\beta/2+\tau}$. It is then easy to show that the mutant is neutral or counter-selected whenever $p \leq 1 - \dfrac{\beta/2 + \sigma\tau}{\beta + \tau}$.

Overall, therefore, we find a range of resident strategies that can be ESS (with respect to the first condition only), characterized by an offer

$$p \in [\frac{\beta/2 + \sigma\tau}{\beta + \tau}, 1 - \frac{\beta/2 + \sigma\tau}{\beta + \tau}] \tag{4}$$

Recall that we assumed that social interactions are possible at an ESS (i.e. $\sigma < 1/2$) which entails that the range is non-empty (i.e. $\frac{\beta/2+\sigma\tau}{\beta+\tau} < 1/2$ ).

It is interesting to note that the minimum offer acceptable in this range is $p_{min} = \frac{\beta/2+\sigma\tau}{\beta+\tau}$ which is equal to the resident payoff $G$. This makes perfect sense. $G$ can be seen as an individual's average payoff per unit of time, and it cannot be evolutionarily stable to accept a social offer that is lower than one's average payoff per unit of time.

In the main paper, we interpret equation (4) with the simplifying assumption that $\sigma = 0$ (there are no solitary benefits). We can make the same interpretation without this assumption, which does not change the results.

(i) When the rate of social encounters is very low relative to the rate of interaction cessation ($\beta << \tau$), the expected duration of each interaction is very low relative to the time it takes to enter into a new interaction. In this case, the range of evolutionarily stable offers is approximately $p \in [\sigma, 1-\sigma]$.

In this case, individuals will never take the risk of refusing an interaction in hopes of subsequently finding a better one. This is because interactions are very brief relative to the rate of new pair formation, and therefore accepting an unfavorable offer has no cost: i.e., by accepting an offer one does not significantly reduce one's chances of interacting later. In other words, social opportunities are not "in competition" with each other. Therefore, individuals will always accept any proposed interaction, as long as it is better than their solitary option (both partners must receive at least $\sigma$). This is a situation in which partner choice/switching does not take place in practice.

(ii) When the rate of social encounters is very large relative to the rate of interaction cessation ($\beta >> \tau$), the expected duration of each interaction is very large relative to the time it takes to enter into a new interaction. In this case, the range of evolutionarily stable offers is approximately $p \in [1/2, 1/2]$.

In this case, individuals will be extremely picky and never accept an unfavorable offer. This is because interactions are long relative to the rate of novel pair formation. Therefore, by accepting an offer an individual is giving up alternative interactions that one could have had in the meantime. In other words, social opportunities are in perfect "competition" with each other. Therefore, individuals will accept an interaction in a given role only in case it is just as good as an interaction in the opposite role (both partners must get half of the pie). This is a situation in which partner choice/switching truly takes place.

### 1.3 Novelty of the analytical model

Compared to our previous theoretical work on the evolution of fairness (André and Baumard, 2011a,b), the analytical model presented here incorporates a new and more realistic way to model partner choice. In our previous papers, we were using an explicit parameter $c$ or $\delta$ to represent the cost of changing partner: each time an individual decides to change partners, her payoff would be discounted by $\delta$. In the current model, all costs are implicit: an individual pays a cost for changing partner because it takes time to find a new one ($\beta$ is low) or because the rejected interaction wouldn't have lasted a long time anyway ($\tau$ is high), and so accepting an "unfair" offer would not have led to a high fitness cost anyway. We are thus introducing "opportunity costs" in the current model which represents an important step towards building a more ecological and realistic model.

## 2 Agent-based simulations

### 2.1 Methods

The agent-based simulations exactly reproduce the social life described by the analytical model presented above. They extend the simulations presented in André and Baumard (2011b) by using an encounter rate $\beta$ to model encounters in the population.

All simulations were coded in Netlogo (Wilensky, 1999) and run on a dedicated cluster of computers managed by HTCondor (University of Wisconsin–Madison, 2013). Mathematica (Wolfram Research, 2012) was used for data analysis and the production of graphical representations. The code for all simulations and data analysis is freely downloadable on Github.com and the first author's personal website, and is also available on request from the first author.

## 2.2 Parameter values

The following parameter values were used in the simulations:

- population size: 500
- number of generations: 15000
- lifespan: 1000
- $\beta$: 1 for the "partner choice not costly" condition. 0.001 for the "partner choice costly" condition.
- $\tau$: 0.01
- mutation rate: 0.002 for the "partner choice not costly" condition. 0.02 for the "partner choice costly" condition.
- mutation standard deviation: 0.02
- $\sigma$: 0

  The mutations were drawn from a normal distribution centered around the trait value. The mutation rate was increased for the "partner choice costly" condition so that the evolution of selfish offers could be plotted on the same graph as the graph for the evolution of fair offers. Using a higher mutation rate doesn't change the endpoint of evolution, only the time necessary to reach it.

# 3 Behavioral experiment

## 3.1 Supplementary analysis

SI Table 1 shows the average accepted offers and their standard deviations for each group and condition. Columns 1 to 3 use data from all rounds, while columns 4 to 6 are restricted to the final ten rounds. Rows 1 to 11 show the average offer per group, while row 12 shows the average offer across all groups. SI Table 1 confirms the trends over time which were apparent on visual inspection of Figure 1. With a few exceptions, average offers made in the CA condition were higher than those made in the EO condition, which were in turn higher than those made in the RS condition. The average accepted offer across all rounds (row 12, columns 1 to 3) was 7.9 in the CA condition, 4.8 in the EO condition, and only 2.9 in the RS condition.

| | All rounds | | | Last 10 rounds | | |
|---|---|---|---|---|---|---|
| Group | CA mean (s.d.) | EO mean (s.d.) | RS mean (s.d.) | CA mean (s.d.) | EO mean (s.d.) | RS mean (s.d.) |
| 1 | 7.5 (1.0) | 4.6 (0.7) | 5.0 (0.0) | 8.4 (0.3) | 4.9 (0.5) | 5.0 (0.0) |
| 2 | 8.2 (1.3) | 4.9 (0.5) | 4.3 (0.5) | 9.4 (0.2) | 4.9 (0.3) | 3.8 (0.2) |
| 3 | 8.7 (1.3) | 4.9 (0.6) | 1.2 (1.1) | 9.6 (0.2) | 4.8 (0.9) | 0.0 (0.1) |
| 4 | 8.8 (0.8) | 5.3 (0.6) | 4.1 (0.5) | 9.5 (0.2) | 4.9 (0.7) | 4.0 (0.4) |
| 5 | 7.5 (1.3) | 4.4 (1.3) | 1.3 (2.0) | 8.6 (0.2) | 4.5 (0.9) | 0.0 (0.0) |
| 6 | 6.7 (1.2) | 5.1 (0.8) | 4.5 (2.0) | 7.0 (1.5) | 5.2 (0.9) | 4.4 (2.4) |
| 7 | 7.3 (1.9) | 4.9 (1.2) | 5.0 (0.0) | 9.1 (0.4) | 4.1 (1.4) | 5.0 (0.0) |
| 8 | 6.9 (0.9) | 4.1 (1.3) | 1.0 (0.0) | 7.6 (0.9) | 3.6 (1.5) | 1.0 (0.0) |
| 9 | 9.3 (1.0) | 4.8 (0.5) | 0.9 (0.8) | 9.9 (0.1) | 4.3 (0.8) | 0.5 (0.0) |
| 10 | 7.8 (1.1) | | 3.0 (0.1) | 8.8 (0.3) | | 3.0 (0.0) |
| 11 | | | 1.9 (0.9) | | | 1.5 (0.0) |
| Mean | 7.9 (1.4) | 4.8 (0.9) | 2.9 (1.9) | 8.8 (1.0) | 4.6 (1.0) | 2.6 (2.0) |

Table 1: SI. Mean accepted offers for each condition and group of subjects, with standard deviations in parentheses. The last line gives means across all groups. CA = Competitive Altruism, EO = Equal Options, RS = Runaway Selfishness.

## 3.2 Exploratory variables in the behavioral experiment

We recorded the following variables for each subject at the end of session questionnaire, but had no a priori hypotheses on them and did not use them in our analysis. These variables were thus only exploratory.

- guessed number of people in the group
- guessed number of proposers in the group (for the CA and RS treatments)

- thought process during the experiment
- change of thought process during the experiment
- guess the behavior of other subjects
- rate how fair or selfish they think their behavior was
- idea of a selfish offer
- idea of a fair offer
- whether or not they made fair offer
- general comment
- sex

## 3.3 Instructions

### 3.3.1 RS and CA conditions

Thank you for your participation! Please take your time to read the following instructions carefully.

**Overview:**

You will be doing multiple rounds of an experiment with a group of people. Before you begin, you will be randomly assigned to one of two roles ("proposer" or "responder"), and will be informed of your role. In each round of this experiment, proposers and responders may form partnerships to split a pool of money.

Each round proceeds in the following order:

(1) Each person with the role of proposer will decide how £10 would be divided in a potential partnership with a responder.

(2) A single responder is chosen at random to choose from among the proposers' offers.

(3) Step 2 is repeated with a new randomly selected responder who hasn't been selected before. However, the list of proposers' offers only includes offers from proposers who have not yet been selected this round. Thus, each proposer can only be selected by one responder per round. Step 2 repeats until there are no responders left who have not chosen, or until there are no proposers left to be chosen. If there is only one offer left, the responder has no choice but to accept it.

(4) Each person's earnings for the round are reported to that person. For each proposer and responder who ended up as part of a partnership, their earnings are dictated by the proposer's offer. Any proposer or responder who did not end up as part of a partnership earns £0. (A proposer will not end up in a partnership if no responder chooses an offer from that proposer. A responder will not end up in a partnership if all of the proposers have already been chosen by responders randomly selected to choose earlier in the round.)

**Important Notes:**

- One practice round will take place at the beginning of the experiment to help you understand the instructions.
- You have already earned a show-up fee of £4 in this experiment, and at the end of the experiment your AVERAGE payoff earned across all rounds will be computed and paid to you, on top of the show-up fee.
- Note that you DO NOT know the number of people in your group, nor the number of proposers and responders at each round. The only information you have is whether or not one of your offer was accepted (if you are a proposer) or what offers remain available to you in the current round (if you are a responder).
- We ensure that this experiment is 100% anonymous. Nobody, including the experimenter,

will be able to know what decisions you have made personally. Groups are formed randomly from all the people who entered the lab at the same time as you. Your data will remain confidential at all times.

### 3.3.2 EO condition

Thank you for your participation! Please take your time to read the following instructions carefully.

**Overview:**

You will be doing multiple rounds of an experiment with a group of people. Before you begin, you will be randomly assigned to one of two roles ("proposer" or "responder"), and will be informed of your role. In each round of this experiment, proposers and responders may form partnerships to split a pool of money.

Each round proceeds in the following order:

(1) Each person with the role of proposer will decide how £10 would be divided in a potential partnership with a responder.

(2) A single responder is chosen at random to choose from among the proposers' offers.

(3) Step 2 is repeated with a new randomly selected responder who hasn't been selected before. However, the list of proposers' offers only includes offers from proposers who have not yet been selected this round. Thus, each proposer can only be selected by one responder per round. Step 2 repeats until there are no responders left who have not chosen, or until there are no proposers left to be chosen. If there is only one offer left, the responder has no choice but to accept it.

(4) Each person's earnings for the round are reported to that person. For each proposer and responder who ended up as part of a partnership, their earnings are dictated by the proposer's offer. Any proposer or responder who did not end up as part of a partnership earns £0. (A

proposer will not end up in a partnership if no responder chooses an offer from that proposer. A responder will not end up in a partnership if all of the proposers have already been chosen by responders randomly selected to choose earlier in the round.)

(5) Each person decides whether to continue in the same role (proposer or responder) in the next round, or whether to switch roles and become the opposite role in the next round.

**Important Notes:**

- One practice round will take place at the beginning of the experiment to help you understand the instructions.
- You have already earned a show-up fee of £4 in this experiment, and at the end of the experiment your AVERAGE payoff earned across all rounds will be computed and paid to you, on top of the show-up fee.
- Note that you DO NOT know the number of people in your group, nor the number of proposers and responders at each round. The only information you have is whether or not one of your offer was accepted (if you are a proposer) or what offers remain available to you in the current round (if you are a responder).
- We ensure that this experiment is 100% anonymous. Nobody, including the experimenter, will be able to know what decisions you have made personally. Groups are formed randomly from all the people who entered the lab at the same time as you. Your data will remain confidential at all times.

### 3.4 Novelty of the experimental work

Our experiment goes beyond the one by Fischbacher et al. (2009) in at least three aspects:

- First, we use dictator games, whereas Fischbacher et al. (2009) use ultimatum games.

- Second, we observe behaviors over 30 rounds and not only 20, which helps to see the time dynamics of the offers, and we increase the sample size in each condition.
- Finally, and more importantly, we have a condition (EO) in which partner competition leads to fair offers, whereas the "fair" offers observed in the UG condition of Fischbacher et al. (2009) come from only one proposer interacting with one responder.

# References


Jean-Baptiste André and Nicolas Baumard. The evolution of fairness in a biological market. *Evolution*, 65(5):1447–56, May 2011a. ISSN 1558-5646. doi: 10.1111/j.1558-5646.2011.01232.x. URL `http://www.ncbi.nlm.nih.gov/pubmed/21521194`.

Jean-Baptiste André and Nicolas Baumard. Social opportunities and the evolution of fairness. *Journal of theoretical biology*, 289:128–35, November 2011b. ISSN 1095-8541. doi: 10.1016/j.jtbi.2011.07.031. URL `http://www.ncbi.nlm.nih.gov/pubmed/21907216`.

Urs Fischbacher, Christina M. Fong, and Ernst Fehr. Fairness, errors and the power of competition. *Journal of Economic Behavior & Organization*, 72(1):527–545, October 2009. ISSN 01672681. doi: 10.1016/j.jebo.2009.05.021. URL `http://linkinghub.elsevier.com/retrieve/pii/S0167268109001589`.

University of Wisconsin–Madison. HTCondor, 2013.

U. Wilensky. NetLogo, 1999. URL `http://ccl.northwestern.edu/netlogo/`.

Inc. Wolfram Research. Mathematica Edition: Version 9.0, 2012.