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Research Article

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Implications of Reciprocity in the Evolution of Ethnocentrism and Cooperation

Keywords

Ethnocentrism, evolution, computer simulation, cooperation, reciprocity

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Abstract

Background: Ethnocentrism is defined as an individual's tendency to favor in-group members at the expense of out-group members. Recent computer simulations have studied its evolution by modelling cooperative and defective behaviours in a Prisoner's Dilemma framework.

Methods: This paper introduces reciprocity to the study of ethnocentrism and extends Hammond and Axelrod's agent-based model by simulating the effects of five new genotypic strategies. (1)

Results: In stable-state outcomes, although ethnocentrism still dominates, moderate ethnocentrism (in-group cooperation and out-group reciprocity) is more frequent than humanitarianism and is by far the most adaptive out of all reciprocal strategies. Because it is the only reciprocal strategy that cooperates with in-group members, we conclude that it is thanks to in-group cooperation that moderate ethnocentrism is successful, which confirms previous research findings. Additionally, throughout early and late evolutionary patterns, we see that moderate ethnocentrism benefits and suffers from the characteristics of both ethnocentrism and humanitarianism, which may explain why ethnocentrism still emerges as the dominant strategy overall.

Conclusion: The strengths of the present model lie in its ability to abstractly model reciprocal behaviours in the study of ethnocentrism and may be more externally valid than Hammond and Axelrod's original agent-based model. (1) However, this model does not take in account other factors that play a role in human decision-making, such as social context, learning, or development, which could be topics of future computational simulations on ethnocentrism.

Introduction

Although biological evolution is based on the competition for resources between individuals, cooperative behaviours are prevalent in human societies. From hunter-gatherer societies to modern civilizations, cooperation is the decisive organizing principle for our survival. (2) However, this cooperation is not universal. Ethnocentrism, which is defined by the tendency to favor in-group members at the expense of out-group members, is an illustration of this selective cooperation. (3) Several studies have shown that humans have a strong predisposition towards ethnocentric behaviours. For instance, individuals favor in-group members even when group definitions are trivial and arbitrary (e.g. color preference, shirt type), as shown by research done with the minimal group paradigm. (4, 5, 6) Moreover, this in-group bias has been largely identified as a universal and implicit phenomenon, as effects have been found cross-culturally (7) and preconsciously. (8, 9, 10)

In research fields such as evolutionary biology (11) and experimental social psychology, (12) many issues may be difficult or even impossible (e.g. evolutionary patterns of different species) to investigate experimentally. As such, computer simulations have been used to understand their theoretical underpinnings and to predict the outcomes of complex processes, while abstracting away irrelevant details and focusing on essential principles. Similarly, recent studies have applied this methodology to model the evolution of ethnocentrism. (1, 3, 13) In these simulations, the Prisoner's Dilemma game is often used to embody cooperative and defective behaviours between individuals abstractly. Before presenting our simulation and that of Hammond and Axelrod, (1) in addition to Schultz et al.'s simulations (13) upon which we will be extending, we will briefly review the Prisoner's Dilemma framework.

Middle phalanx ossification morphology

Widely considered as a classic framework to study mutual cooperation, (13) The Prisoner's Dilemma was originally designed in the 1950s by nuclear strategists. In that context, researchers were interested in how humans make decisions of cooperation, which involved not sending a missile, or defection (i.e., not cooperating), which involved launching a missile, when they did not know how the opposing party would respond. When experimental psychologists became interested in this paradigm, it was reframed to be about two prisoners who have been arrested for a crime. Defection involves confessing and cooperation involves keeping silent. If they confess while their partner does not, they are freed from all charges. However, the dilemma that the prisoners face is that while each of them is better off if they confess, the outcome of both confessing is worse than if they both kept silent. (14)

In the classic version of the game, two autonomous agents A and B each make a decision to cooperate or defect against one another. The cost to cooperate is c=0.01 while the benefit of receiving cooperation is b=0.03. As such, the outcome of an interaction for an agent is defined as $O=b-c$. If both agents cooperate, they will each receive an outcome of O=0.02. If only agent A cooperates but agent B defects, agent A will receive a negative outcome of O=-0.01, while agent B will receive a large positive outcome of O=0.03. If both agents defect, there is neither cost nor benefit and the outcome will be null. A summary of the basic outcomes for agent A can be found in Table 1.

	B Cooperation	B Defection	Mean Outcome
A Cooperation	b-c	-c	0.005
	0.02	-0.01	
A Defection	b	Null	0.015
	0.03	0.00	

Table 1. Basic outcomes of the Prisoner's Dilemma Game for agent A.

Simulating ethnocentrism

As we observe from Table 1, the mean outcome of defecting, *O*=0.015, is higher than the mean outcome of cooperating, *O*=0.005. Therefore, the most adaptive behavior for rational agents should be to always defect and the outcome of two defecting agents will be null. This mutual defection is called the *Nash equilibrium*. When running the Prisoner's Dilemma game with species ranging from bacteria to humans, however, participants largely choose to cooperate. (15) From this intriguing observation, Hammond and Axelrod ran their first agent-based computer simulation. (1)

Although the *Nash equilibrium* predicts that rational agents should always choose defection, the original simulation found cooperation to dominate defection in 74% of interactions. The prevalence of ethnocentric strategies explains this finding, meaning in-group cooperation and out-group defection, which appears in 76% of agents. (1) Additionally, in Schultz et al.'s study, we see an early stage of humanitarianism dominance, in which an agent always cooperates. (13) Recent studies have also simulated reciprocity in an iterated Prisoner's Dilemma Game with tit-for-tat agents, who replicate the previous response of an opposing agent. (16, 17) In Baek et al.'s study, proportions of cooperation and defection were found to remain invariant despite changing proportions of agents in the population. (16) That said, reciprocity has not yet been studied in the context of in-group and out-group cooperation and defection.

Accordingly, we will be modelling reciprocity in simple abstract agents with a Prisoner's Dilemma game. Following Hammond and Axelrod's agent-based model, group membership is defined by a single arbitrary color and agents will have one of nine types of strategies. These strategies include the four original ones from Hammond and Axelrod's study, (1) as well as five new ones that will simulate reciprocal behaviours towards in-group and/or out-group members. I will be observing the impact of these new reciprocal strategies on stable-state evolutionary outcomes of cooperative and defective behaviours. Additionally, similar to Schultz et al., I will be examining the effects of reciprocal behaviour in earlier stages of ethnocentrism. (13)

Materials and Methods

The Hammond and Axelrod Model

The model used for this paper largely follows Hammond and Axelrod's original simulation. (1) In their simulation, each agent possesses four traits: a tag representing one of four abstract groups, a strategy towards agents with the same group tag (in-group members), a strategy towards agents with a different group tag (out-group members), and a reproductive rate of 0.12. These agents live in a world represented by a two-dimensional 50 by 50 lattice, in which every position in the lattice can be occupied by one agent. When an agent encounters other agents directly adjacent to it in any of four cardinal positions (i.e., north, south, east or west), an interaction occurs in the form of the Prisoner's Dilemma. The outcome *O* of these interactions (up to four, one with each potential neighbor) has a direct effect on the agent's reproductive potential. For example, if agent A decides to cooperate with its neighbor agent B while agent B defects, agent A's reproductive potential will be reduced by 0.01, leaving agent A with a reproductive potential of 0.12-0.01=0.11. Moreover, the 50 by 50 world is folded from north to south and from east to west to ensure that all agents have an equal number of potential neighbors.

As mentioned earlier, each agent possesses a strategy (cooperate or defect) toward other agents with the same group tag (in-group members) and another strategy toward agents with a different group tag (out-group members). As such, four genotypic strategies emerge: selfish, traitorous, ethnocentric and humanitarian. A summary of these four strategies can be found in Table 2.

Strategy	In-group	Out-group
Selfish	Defect	Defect
Traitorous	Defect	Cooperate
Ethnocentric	Cooperate	Defect
Humanitarian	Cooperate	Cooperate

Table 2. Four genotypic strategies in Hammond and Axelrod's simulation.

To assess which strategy dominated at stable-state outcomes, Hammond and Axelrod simulated 2000 evolutionary cycles. At each cycle, four stages occur:

1. Immigration: new agents are created according to the immigration rate of 1 (one new agent per cycle). All agent characteristics are randomized, including group tag, genotypic strategy and lattice placement. Reproductive rate is set to 0.12.

2. Interaction: each agent has a chance to play a game of Prisoner's Dilemma with its four possible neighbors, and the outcome affects its reproductive potential. As noted previously, cooperating with an agent will reduce reproductive potential by 0.01, while receiving cooperation increases reproductive potential by 0.03. If all agents decide to defect, reproductive potential will remain unchanged.

3. Reproduction: after being placed in a random order, each agent has a chance to reproduce according to its reproductive potential. This entails creating an offspring in an adjacent empty position in the lattice who will inherit all traits of the parent, with a mutation rate of 0.005 for each trait (i.e. group tag, in-group strategy and out-group strategy).

4. Death: each agent has a death rate of 0.1, which would lead to its removal from the lattice.

The Reciprocal Model

For the purposes of the present study, all parameters (lattice size, number of group tags, cost and benefit of cooperation, reproduction rate, mutation rate and death rate) are kept the same except for the addition of reciprocal behavior, which increases the total number of genotypic strategies (code is available in Appendix B). In the context of our model, reciprocity is defined as an agent replicating the opposing agent's behaviour. Specifically, if the opposing agent cooperates, the reciprocal agent will also cooperate. Similarly, if the opposing agent defects, the reciprocal agent will also defect. If two reciprocal agents interact, the interaction ends early and results in no outcome. As such, agents will have one of three behaviours against in-group or out-group members: defect, cooperate or reciprocate. Thus, nine genotypic strategies are formed. The first four are repeated from Hammond and Axelrod's simulation: selfish (always defect), traitorous (in-group defection and out-group cooperation), ethnocentric (in-group cooperation and out-group defection) and humanitarian (always cooperate). (1) With the addition of reciprocity, five new strategies emerge: moderate selfish I (in-group defection and out-group reciprocity), moderate selfish II (in-group reciprocity and out-group defection), moderate traitorous (in-group reciprocity and out-group cooperation), moderate ethnocentric (in-group cooperation and out-group reciprocity), and universal reciprocal (reciprocating regardless of group). The term "moderate" for these new strategies reflects that reciprocity can be seen as a milder way to defect opposing agents. The behavioral outcomes of all nine strategies are detailed in Table 3.

To study the effects of reciprocity on both stable-state outcomes and earlier stages of evolution, we ran 23 simulations of different worlds with 2000 evolutionary cycles each. We first analyzed the stable-state results of mean strategy frequencies averaged across the 23 worlds after the 2000th cycle. Then, similar to Shultz et al.'s method, (13) which also extends to Hammond and Axelrod's original study, the number of agents in each of the nine strategies were tabulated after each cycle, and two separate chi-square tests were performed with critical values at the p=0.01 level. The first chi-square test assessed whether one strategy dominated over the others overall. If the result was significant, a second chi-square test was performed on the two most frequent strategies to assess which one of them was dominant.

Strategy	In-group	Out-group
Selfish	Defect	Defect
Traitorous	Defect	Cooperate
Ethnocentric	Cooperate	Defect
Humanitarian	Cooperate	Cooperate
Moderate selfish I	Defect	Reciprocate
Moderate selfish II	Reciprocate	Defect
Moderate traitorous	Reciprocate	Cooperate
Moderate ethnocentric	Cooperate	Reciprocate
Universal reciprocal	Reciprocate	Reciprocate

Table 3. Nine genotypic strategies in the Reciprocal Model.

	Mean frequency	SD
Selfish	44.56522	21.090338
Traitorous	22.73913	13.705398
Ethnocentric	781.34783	139.478121
Humanitarian	261.60870	79.285869
Moderate selfish I	21.00000	12.336200
Moderate selfish II	26.21739	8.284468
Moderate traitorous	18.69565	13.596239
Moderate ethnocentric	402.26087	122.326767
Universal reciprocal	19.13043	11.442760
	Df	8
	F-value	347
	p-value	<0.001

Table 4. Mean genotypic strategy frequencies and standard deviation after 2000th cycle.

Results

Stable-state outcomes

Mean genotype strategy frequencies across the 23 simulated worlds after the 2000th evolutionary cycle are presented in Figure 1, with error bars indicating plus or minus 1 standard deviation of the mean. Table 4 reports these means and standard deviations in more detail, as well as the results of a simple linear regression summarized with an ANOVA. A large main effect of strategy was revealed, F(8)=347, p<0.001. Then, to distinguish which genotypic strategies were significantly more frequent than others at stable-state outcomes, Tukey Honest Significant Differences were computed between each pair-wise comparison of strategy. The results of these tests can be seen in Appendix A. Similar to Hammond and Axelrod's findings, (1) ethnocentrism (in-group cooperation and out-group defection) emerged as the dominant strategy and was significantly more frequent than all other strategies (Mean=781.35, SD=139.48). The second significantly most frequent strategy was moderate reciprocity (in-group cooperation and out-group reciprocity) with a mean of 402.26 and standard deviation of 122.33. No other reciprocal strategies were significant. Lastly, humanitarian strategy was the third significantly more frequent strategy (Mean=261.61, SD=79.29), while selfish and traitorous strategies were both not significant.

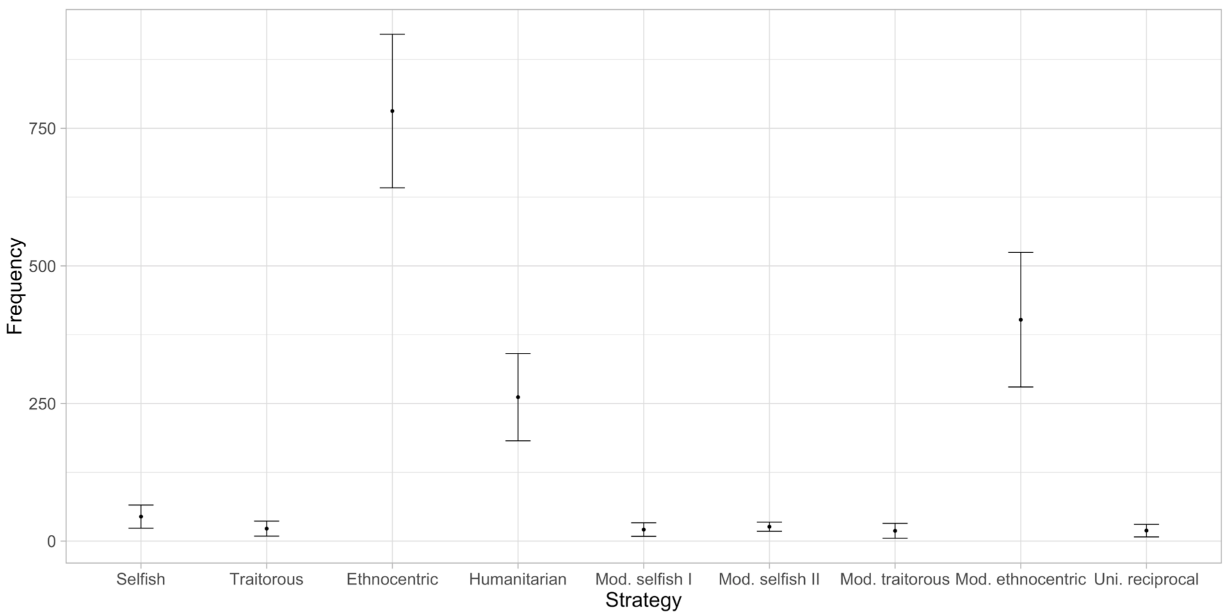

Figure 1. Mean genotypic strategy frequencies after 2000th cycle.

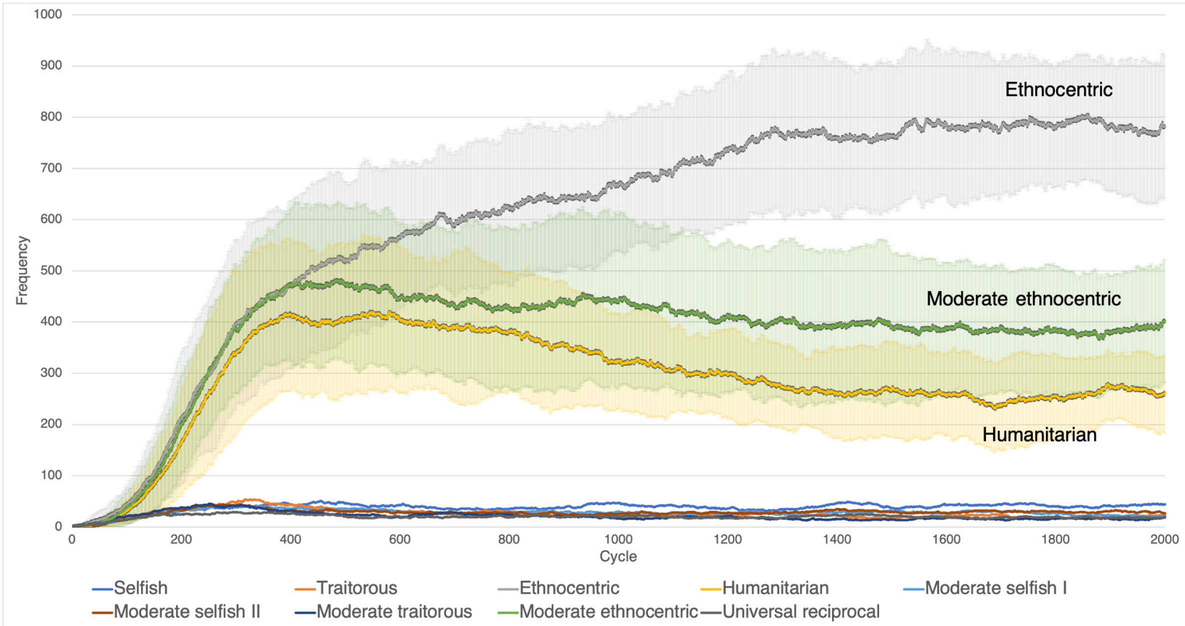

Figure 2. Mean genotypic strategy frequencies throughout 2000 cycles.

Stages of evolution

In Figure 2, mean strategy frequencies across the 23 simulated worlds are plotted for each evolutionary cycle, with error bars indicating plus or minus 1 standard deviation of the mean. As mentioned earlier, strategy frequencies were tabulated after each cycle and two separate chi-square tests were performed with critical values at the p=0.01 level. The critical values for the overall dominance between the top two strategies were $\chi^2_{crit}(8)=20.09$ and $\chi^2_{crit}(1)=6.64$ respectively. Many strategies' evolutionary patterns resemble the findings of Schultz et al. (13) However, the inclusion of reciprocal behaviors adds interesting findings to these patterns. Indeed, there is early competition between ethnocentric, humanitarian and moderate ethnocentric (in-group cooperation with out-group reciprocity) strategies. Although overall chi-square tests reach significance from cycle 85 ($\chi^2(8)=20.25$, $p<0.01$) until the end of the simulations, ethnocentric strategy only statistically dominates over the second most frequent strategy (moderate ethnocentrism) from cycle 573 ($\chi^2(1)=7.11$, $p<0.01$). Moderate ethnocentrism and humanitarianism continue to compete until the latter half of the simulations, when moderate ethnocentrism eventually significantly dominates over the latter from cycle 865, ($\chi^2(1)=6.64$, $p<0.01$). Moreover, moderate ethnocentrism even statistically dominated ethnocentrism over multiple cycles in 13 out of the 23 simulated worlds. Lastly, similar to the previous results of stable-state outcomes, no other reciprocal strategies were notable.

Discussion

The dominance of in-group cooperation

These simulations confirm many findings from previous ethnocentrism studies and strengthen Hammond and Axelrod's original finding that evolution favors in-group cooperation due to its positive effect on reproductive potential. (1) As seen in stable-state mean strategy frequencies in Fig. 1 and Table 4, the three most frequent genotypic strategies are ethnocentrism, moderate ethnocentrism and humanitarianism. Interestingly, they are the only three strategies that involve in-group cooperation, as seen in Table 3. Similarly, moderate ethnocentrism (in-group cooperation and out-group reciprocity) is the only strategy that achieves notable evolutionary outcomes, while also being the only reciprocal strategy that involves cooperation with in-group members. As such, this indicates that the reason for its dominance over other reciprocal strategies is not due to its reciprocal behaviour towards out-group members, but its cooperative behaviour towards in-group members, which has positive effects on reproductive potential. Much like ethnocentrism, this strategy allows for selective cooperation, which increases in-group members' fitness without extending it to free riders who only defect. As such, with mechanisms such as in-group favoritism, keeping offspring close, and environmental viscosity, strategies that involve in-group cooperation dominate. (13)

The poor outcomes of other reciprocal strategies further confirm that in-group cooperation is by far the most adaptive evolutionary behaviour. As explained by Schultz et al., selfish and traitorous strategies do poorly due to their inability to cooperate with each other, resulting in lower chances of reproduction. (13) Similarly, all other reciprocal strategies either defect in-group members or reciprocate, except for moderate ethnocentrism. We could also hypothesize that strategies involving in-group reciprocity do better than in-group defection, but there were no significant results found. Therefore, this strengthens the finding that agents need to always cooperate with in-group members to thrive evolutionarily.

Hammond and Axelrod have also argued that ethnocentric agents were vulnerable to in-group selfish agents, or "free riders", who benefit from in-group cooperation without contributing. (1) These free riders are controlled by nearby ethnocentric agents from other groups. By introducing reciprocal behaviors, agents who reciprocate with in-group members like moderate selfish II (in-group reciprocity and out-group defection), moderate traitorous (in-group reciprocity and out-group cooperation) and universal reciprocal agents might have an advantage over ethnocentric or moderate ethnocentrics, because they can suppress their own free riders without reliance on other group members. However, no advantages of in-group reciprocity were found in stable-state outcomes, nor in earlier stages of evolution. This is most likely due to the same reasons why selfish and traitorous strategies fail to dominate: the absence of in-group cooperation. Indeed, even if free riders are suppressed, the lack of cooperation between in-group members results in lower reproductive potential than ethnocentric, moderate ethnocentric or humanitarian strategies. As such, we can infer that in-group cooperation is a more adaptive factor for evolutionary success. Another question we might ask, then, is what distinguishes ethnocentrism from moderate ethnocentrism and humanitarianism, and why does it dominate in stable-state outcomes?

The dominance of ethnocentrism

In Fig. 2, mean frequencies of genotypic strategies throughout all 2000 cycles are represented. From these evolutionary outcomes, two patterns of competition for dominance emerge: ethnocentrism versus moderate ethnocentrism (with ethnocentrism achieving dominance at cycle 573) and moderate ethnocentrism versus humanitarianism (with moderate ethnocentrism achieving dominance at cycle 865). Starting with the second pattern of competition, the reason why moderate ethnocentrism is able to surpass humanitarianism in later stages may be due to its greater resistance to ethnocentrism. As stated by the direct hypothesis, humanitarians lose to ethnocentrics in later stages of evolution because they cooperate, while ethnocentrics do not. (3) Thus, since moderate ethnocentrics only cooperate with ethnocentrics when reciprocity is present, they are less affected by ethnocentrics in the long run.

As for the competition between ethnocentrism and moderate ethnocentrism, an interesting question is why the latter statistically dominated over ethnocentrism itself in certain cycles in half of the simulated worlds (13 out of 23). An explanation may be that like humanitarianism, moderate ethnocentrism benefits from cooperation early on and is not hurt by encounters with defectors. However, in the same realm of thought, this strategy doesn't benefit from cooperation as much as humanitarianism does due to its reciprocal nature towards out-group members, which might explain why ethnocentrism still dominates in stable-state outcomes. Moreover, the difference in interactions of ethnocentric versus moderate ethnocentric agents with humanitarian agents may also explain this dominance. Indeed, moderate ethnocentric agents always cooperate with both in-group and out-group humanitarians, because it replicates the humanitarians' universally cooperative behavior. On the other hand, ethnocentric agents always defect with out-group members, thus taking advantage of these out-group humanitarians and increasing their reproductive potential at a faster rate than moderate ethnocentric agents. All in all, by analyzing evolutionary patterns, we see that moderate ethnocentrism benefits from the advantages of both ethnocentrism and humanitarianism. Consequently, it also suffers from the disadvantages of both strategies, which might explain why it is not the dominant strategy in stable-state simulations. As such, ethnocentrism still prevails as the most adaptive evolutionary strategy, replicating the findings of Hammond and Axelrod, and Schultz et al. (1, 13)

Conclusion

By adding reciprocal behaviours to Hammond and Axelrod's agent-based model of cooperation and defection, (1) we were able to study the implications of reciprocity in evolutionary patterns of ethnocentrism and humanitarianism. By observing both stable-state outcomes and earlier evolutionary patterns, the finding that in-group cooperation is the most adaptive strategy is strengthened by the prevalence of moderate ethnocentrism (in-group cooperation and out-group reciprocity) in overall strategies. As such, the strengths of this model lie in its ability to abstractly model reciprocal behaviours in the study of ethnocentrism. While Hammond and Axelrod's original model did not include reciprocity in order to maximize abstraction, the present model may be more externally valid. In face of a decision of cooperation or defection, humans are not black or white; multiple factors including reciprocity, context, and learning all play in role in our behaviour. Similarly, this model does not consider other factors like context or development, which could be topics of future computational simulations. Future research could also simulate a world in which only reciprocal behaviours exist, which may resemble the world we live in today. Additionally, the implications of reciprocity could be studied in other decisional games such as the iterated Prisoner's Dilemma game, the Closed-bag exchange, or the Friend or Foe game.

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Appendix A

	Tukey HSD	Adjusted *p*-value
Humanitarian-Ethnocentric	-519.73913	0.00000
Mod. ethnocentric-Ethnocentric	-379.08696	0.00000
Mod. Selfish I-Ethnocentric	-760.34783	0.00000
Mod. selfish II-Ethnocentric	-755.13043	0.00000
Mod. traitorous-Ethnocentric	-762.65217	0.00000
Selfish-Ethnocentric	-736.78261	0.00000
Traitorous-Ethnocentric	-758.60870	0.00000
Uni. reciprocal-Ethnocentric	-762.21739	0.00000
Mod. ethnocentric-Humanitarian	140.65217	0.00000
Mod. selfish I-Humanitarian	-240.60870	0.00000
Mod. selfish II-Humanitarian	-235.39130	0.00000
Mod. traitorous-Humanitarian	-242.91304	0.00000
Selfish-Humanitarian	-217.04348	0.00000
Traitorous-Humanitarian	-238.86957	0.00000
Uni. reciprocal-Humanitarian	-242.47826	0.00000
Mod. selfish I-Mod. ethnocentric	-381.26087	0.00000
Mod. selfish II-Mod. ethnocentric	-376.04348	0.00000
Mod. traitorous-Mod. ethnocentric	-383.56522	0.00000
Selfish-Mod. ethnocentric	-357.69565	0.00000
Traitorous-Mod. ethnocentric	-379.52174	0.00000
Uni. reciprocal-Mod. ethnocentric	-383.13043	0.00000
Mod. selfish II-Mod. selfish I	5.21739	0.99999
Mod. traitorous-Mod. selfish I	-2.30435	1.00000
Selfish-Mod. selfish I	23.56522	0.96153
Traitorous-Mod. selfish I	1.73913	1.00000
Uni. reciprocal-Mod. selfish I	-1.86957	1.00000
Mod. traitorous-Mod. selfish II	-7.52174	0.99999
Selfish-Mod. selfish II	18.34783	0.99208
Traitorous-Mod. selfish II	-3.47826	1.00000
Uni. reciprocal-Mod. selfish II	-7.08696	0.99999
Selfish-Mod. traitorous	25.86957	0.93438
Traitorous-Mod. traitorous	4.04348	0.99999
Uni. reciprocal-Mod. traitorous	0.43478	1.00000
Traitorous-Selfish	-21.82609	0.97580
Uni. reciprocal-Selfish	-25.43478	0.94029
Uni. reciprocal-Traitorous	-3.60870	1.00000

Table 5. Tukey HSD pair-wise comparisons of strategies.

Appendix B

The full code is available at https://osf.io/ah5gm/.

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