Battle of the Civilizations: A game-theoretic approach to modeling globalization

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Abstract. Humans have developed a wide variety of civilizations that often rose in relative isolation and later were confronted with other civilizations. The outcome of these encounters themselves is complex and can vary greatly. Here, we use agent-based modeling and game theory to study a world populated by citizens belonging to four civilizations represented by four different games. We use a simple learning algorithm and investigate three parameters: 'ε', 'explorers' and 'patriotism', which respectively stand for the degree to which a random strategy is chosen, the number of citizens allowed to explore other parts of the worlds than that of their civilization, and the chance of keeping one's game/civilization even if other games/civilizations seem more lucrative. We explore the dynamics of the four games by repetitively simulating our system with varying parameters.

1 Introduction

It has long been assumed that human civilizations are in competition with one another. Often this competition presents itself in the negative face, giving rise to wars, invasions and massacres. However, there may also be a beneficial side to competition, with claims that competition is an acute driving force in the development of social organizational systems and culture [1]. One example of competition can be seen in the rise and fall of cultures themselves. Historically, we can think of examples of the highly organized (and aggressive) transmission of cultural ideals, such as that of the Roman Empire and British colonial rule.

More recently however, both scientists and the general public are more and more concerned with the rise of 'globalization', or the processes that give rise to increased integration of economic, social, cultural, and political systems across geographical boundaries. There is an underlying fear that the impact of increased globalization is an inevitable homogenization of cultures and identities; that globalization leads us deterministically toward a loss of cultural diversity under the weight of a new form of western cultural imperialism – that of consumerism [2]. However, it should not be forgotten that if some cultures are 'losing out' from this process, some cultures are clearly 'winning' in some respect.

This project aims to examine globalization and spread of cultural ideals by using an agent-based model. One of the problems with examining the rise and fall of cultures, historically or otherwise, is the sheer complexity of culture itself. As a complex system in its own right, human culture and social institutions are decidedly non-linear, and often highly influenced by initial contingencies or 'historical accidents' [3]. By using a computational model, we aim to investigate the general elements that contribute to one culture coming to dominate over another.

In our model we represent rival cultures by using game theory. This is a tool that has been used to tackle a variety of different problems, from representing co-ordination among individuals [4] and tumor cells [5], to the study psychology [6], alcohol treatment [7], hospital management [8], climate change [9], biology and evolution [10, 11] and much more besides. Essentially our model is comprised of four different 'civilizations', each of which plays a different kind of game, representing their different cultural ideals.

Civilizations are comprised of a finite number of citizens ('agents') who can interact with one another, and also with agents from other civilizations. During interaction periods, an agent could be persuaded to either change their personal strategy when playing games ('adaptive conformist'), or switch to a different civilization that may suit them better ('rebellious convert'). The likelihood of an agent conforming or converting is controlled by various parameters within the model, which shall be explained in more detail later. In general terms however, three main parameters were included in the model:

– Patriotism – the degree to which an agent is willing to switch from the civilization it was born in to a new civilization.
– Willingness to explore – the degree to which members of a certain civilization explore new geographical areas and mingle with agents of different cultures.
– Learning – ε value for ε-greedy action-value selection, where agents choose a random action with a probability of $\varepsilon * 100$, otherwise they choose the action which is optimal based on their current experience (greedy).

The main question that the research wants to address is what will the effect of these key parameters have on globalization? Will insular civilizations, characterized by high patriotism, few explorers, and few learning opportunities, be more resistant to invasion by another civilization. What is the ideal 'make-up' (in terms of the three parameters) for successfully globalizing civilizations? Is there a net benefit to being part of a global culture, or are some cultures 'better-off' alone?

2 Background

In many social, economic and political systems the attainment of globally optimal outcomes is hindered by the difficulty of co-ordinating individual actions [12]. This may occur purely because of a lack of information flow, but in many cases the fundamental problem is an apparent conflict between collective interests and an individual's selfish interests. An example is nuclear weapons: although nuclear disarmament and non-proliferation would be optimal for society as a whole, in practice it is very difficult to achieve. Game theory is a way of formalising these and other situations that involve choices and pay-offs [13]. The solution of global problems such as nuclear proliferation and environmental protection requires mechanisms that reconcile collective and selfish interests [12]. Game theory can provide insights into these problems and identify potential mechanisms that will encourage co-operation and trust.

The Prisoner's Dilemma [14] is a game theory model that exemplifies the problem of achieving mutual co-operation in social and economic systems. The basic version of the Prisoner's Dilemma is a two-player game in which each player has the choice either to co-operate or defect. The evolutionary stable strategy is for both players to defect, even though the pay-offs to each player are higher if both co-operate. This is because the pay-offs are structured such that, for the individual, defection is preferable to co-operation in any given situation.

The Battle of the Sexes [15] is a game theory problem in which each of two people, Amelie and Alex, has to choose whether to go to the ballet or the football. The pay-off to Amelie is higher if they both go to the ballet and the pay-off to Alex is higher if they both go to the football. However, the pay-off to both players is zero if they choose to go to different locations. As such, the Battle of the Sexes is a game of co-ordination. Another example of this game is the choice of which side of the road to drive on.

3 Model Description

We used NetLogo version 4-0 beta3 (http://ccl.northwestern.edu/netlogo/) to implement our model. Each citizen is an agent in the sense of agent-based modelling that is allowed to move on a two-dimensional grid.

Citizens belong to a single civilization at any given time (initially, 200 citizens are equally spread over the 4 civilizations), as identified by the game that they play upon interacting with others. Graphically, this is represented by four different colors. When two citizens or more land on the same cell of the grid, they play one game as identified by the citizens' civilization (i.e. civilization A plays game A). Depending on their strategy their currency is incremented by the value of the payoffs.

The payoffs of the four games are given in figure 1. Game A is the Prisoners Dilemma, and game B is what we called the 'Inverse Prisoners Dilemma'. Game C is a variant of the battle of the sexes where the person whose prefered strategy (S1 for player 1, S2 for player 2) is chosen gains more than the other. Game D is the inverse of this variant of the battle of sexes.

The payoffs were adjusted so that when the games are played independently of each other, they all bring a very similar amount of utility by the end of the simulations (see part 4.1). Because there is no negative payoff or any loss of currency in the current implementation of our model, the global utility keeps increasing throughout the simulation, and none of the agents die by lack of currency. Accordingly, the global population remains constant at 200.

When the (initially closed) borders between the civilizations are opened, a subset of the citizens are allowed to venture out of the limits of their civilizations. The parameter 'explorers' represents the willingness of the citizens to discover new parts of the world. When two citizens of different civilizations meet and play, they play the game of the first person to offer to play.

After the game is played, if the second player was playing a game that wasn't their own and if they were paid-off more than usual, they have the possibility to switch game and thus converting to the culture of player 1. The chance of converting is ruled by the parameter 'patriotism'. A high patriotism will push the agent to refuse to abandon his culture even though others seem more lucrative.

Agents have a capacity to learn which strategy is optimal in terms of the payoff they receive. This is based on an incremental implementation of calculating the expected reward per strategy. An ε-greedy action-value selection method is then used to select which strategy to use [16]. The parameter ε is a measure of randomness such that the agents choose a strategy at random with probability $\varepsilon * 100$, otherwise choosing the strategy with maximum expected reward.

Payoff Game A

	S1	S2
S1	3 , 3	0 , 5
S2	5 , 0	1 , 1

Payoff Game B

	S1	S2
S1	1 , 1	6 , 0
S2	0 , 6	3 , 3

Payoff Game C

	S1	S2
S1	4.5 , 2	0 , 0
S2	0 , 0	2 , 4.5

Payoff Game D

	S1	S2
S1	0 , 0	7 , 5
S2	5 , 7	0 , 0

Fig. 1. Payoff Tables.

4 Numerical Simulations

4.1 Model Parameters

All simulations were done using the code we implemented in the NetLogo software. For all simulations, the initial setup was: initial utility equal to 50; 10000 steps; 50 randomly distributed individuals separated by borders in each of the four parts of grids. The payoffs matrixes shown in figure 1 were chosen after a normalization process. To do that we first ran simulations with closed borders, so as to study the dynamics of each game independently. We calibrated the payoffs so that when using 90% learning ($\varepsilon = 0.1$), the final utility of each civilization would be approximately the same. By having the capacity to accumulate equal utility, all games were considered to have an equal chance of dominating the simulations.

Once the payoffs were normalised, they were kept constant for all simulations.

Using these payoffs, we explored how many time steps were necessary for the best strategy of each game to be learnt strategies under a high level of learning ($\varepsilon = 0.1$). This high level of learning reflects the fact that agents are usually considered rational and self-regarding, but can still occasionally have unpredictable behaviour [17].

In the situation where $\varepsilon = 0.1$, around 90% of the individuals in population A and C on average learn to play with strategy 1, with a very fast adaptation period. On the contrary, the individuals belonging to the population B adapt slower. Although they initially favour strategy 1, they reverse to strategy 2 after some time. In population D, which plays a game that favours disagreement, strategies 1 and 2 tend to be equally played. This allows for the highest chance of meeting a player with the opposite strategy.

It is clear from the simulations that after 2000 time steps the individuals belonging to populations A, C and D have decide which strategy they want to play (see figure 2). In case of population B we see that the learning process is quite slow however after 2000 steps the individuals are orientated i.e., around 55% of individuals prefer strategy S2. Thus, in all presented simulations the borders will be opened after 2000 time steps.

As a general rule, the equilibrium reached during our simulations was completely different from the Nash equilibrium [18]. Indeed, the Nash equilibrium predicts that the equilibrium of the Prisoner's Dilemna is defect. However, we find that it is nearly always cooperation. The difference is due to the fact that our implementation allows for learning and evolution.

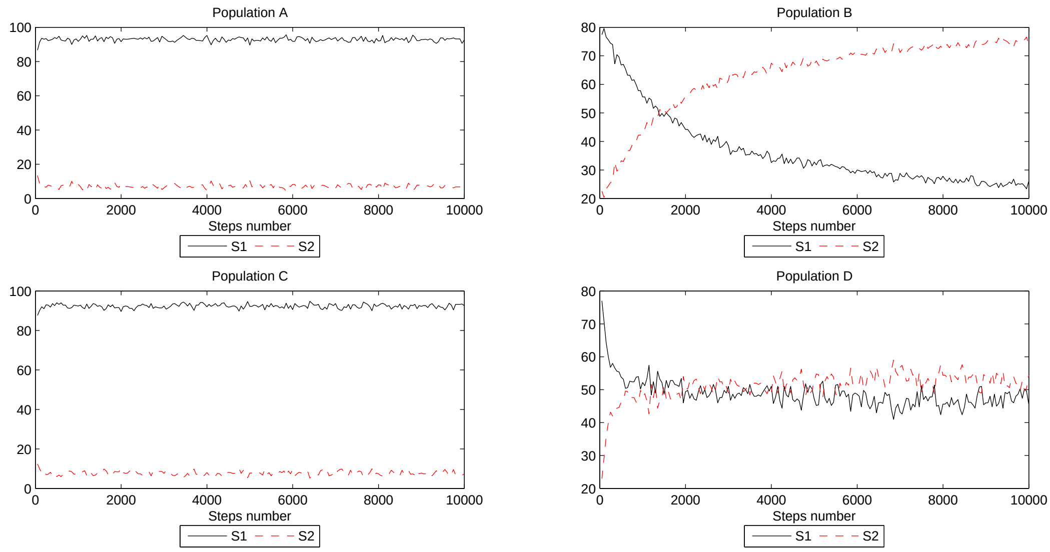

Fig. 2. Strategy choice at Epsilon 0.1, with the borders always closed.

4.2 Learning Process

We studied the effect of variable learning capacities when the borders are constantly closed (no interaction between the games). We observed that the strategy as well as the final utility are influenced in a game-specific way by the level of learning (see figure 2).

If the borders are closed and individuals belonging to each civilization are not able to learn ($\varepsilon = 1$), then half of all individuals play strategy S1, as individuals randomly choose between the two strategies every time they are about to play a game (see figure 3:I).

A decrease in ε of 50% causes the adaptation process in all populations. Namely, the members of populations A and C prefer (60% up to 80%) to play strategy S1, while situation in population D chooses as in the case where $\varepsilon = 1$: as close to random as possible. After around 2000 time steps the $70 - 80\%$ of individuals in population B chooses strategy S2 (data not shown).

For the populations A and C, an increase in learning capacity ($\varepsilon \to 0$) increases the final utility (see figure 3:II). B is relatively resistant to variations in the learning capacity, while for population D, which thrives on disagreement, learning (at least as we implemented it) reduces the payoffs since both players always get 0 when they both play S1.

4.3 Explorers Effect

To study the effect of the percentage of explorers on the outcome of the simulations, we used the calibrated parameters: $\varepsilon = 0.1$, opening of the borders after 2000 time steps, and the patriotism was set to 70 for each civilization.

We then varied the percentage of explorers in all civilizations and observed the effect on the final population count (see figure 4).

Population A, which implements the Prisoners Dilemma game, is always more efficient at 'winning' the simulations since it is the one that has overall the highest population count, independently of the percentage of explorers. In addition, it is the only game to fully benefit from more interactions.

It therefore appears that calibrating the payoffs in order to obtain the same utility when the games were played independently doesn't assure equality of chances for each game to win the simulations. Indeed, the combination of payoffs and strategies induces certain migrations to be more probable than others, independently of the average scoring of a given game.

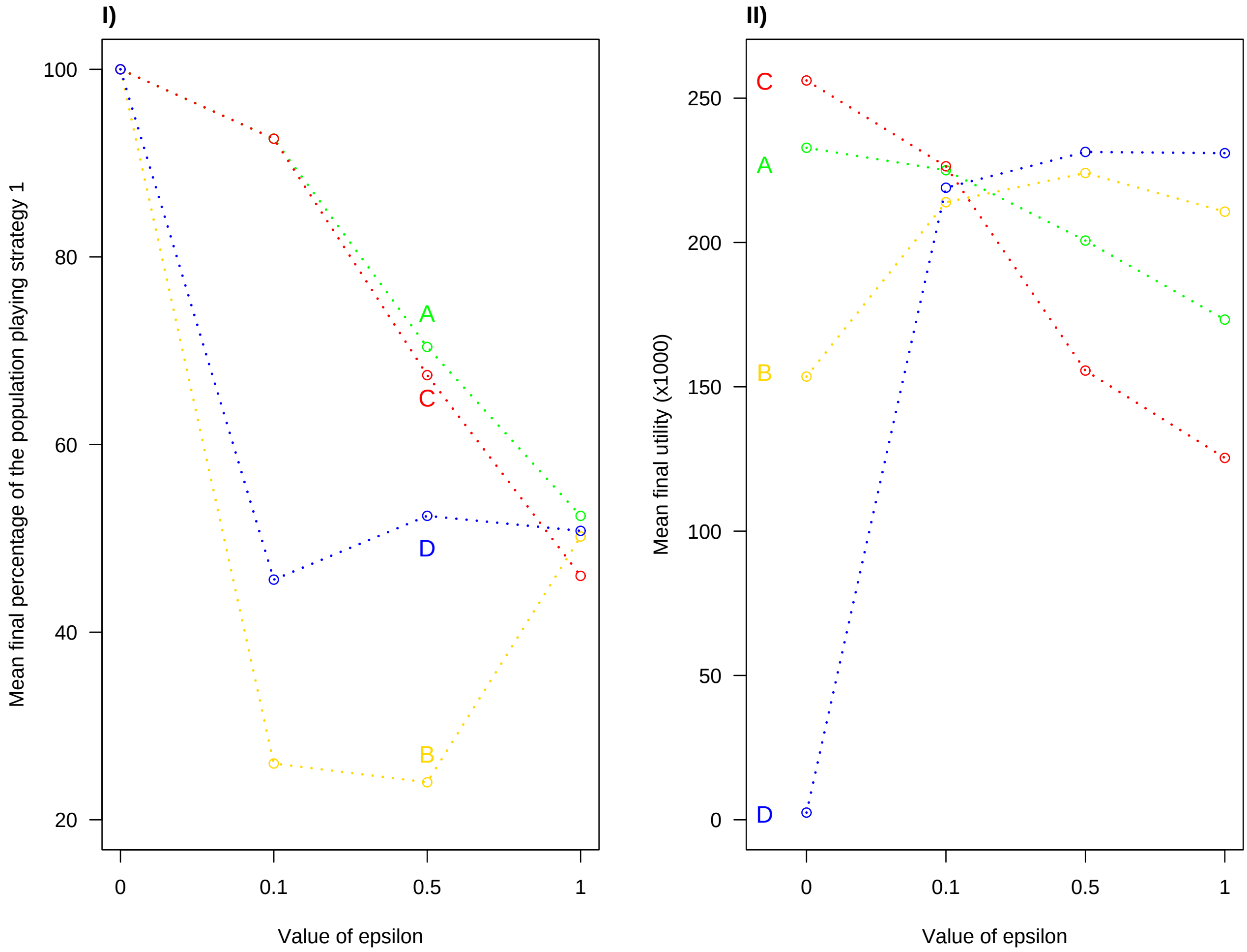

Fig. 3. Effect of learning on strategy choice (I) and utility (II).

4.4 Patriotism Effect

Setting other parameters to their default value, we studied the effect of varying the values of patriotism on the final population count (see figure 5).

Globally, all populations do better when their own patriotism increases. Indeed, in such a case, the individual will refuse to convert to a new civilization more often even if the alternative game offers better payoffs.

It is interesting that the 'radical' patriotism, i.e., equal to 100% only for one population causes the extinction of the others civilizations in finite time. In the real world we might expect that it can only influence the other populations in small range. Here however, the individual playing with another which has the highest possible patriotism, is forced to play his game, i.e., join his population. It is easy to notice this effect qualitatively observing the transitions of individuals from their populations to the new civilizations in time (data not shown).

The behavior of the model in the case when two civilizations have their patriotism set to 100% can be very interesting and will be investigated in the future.

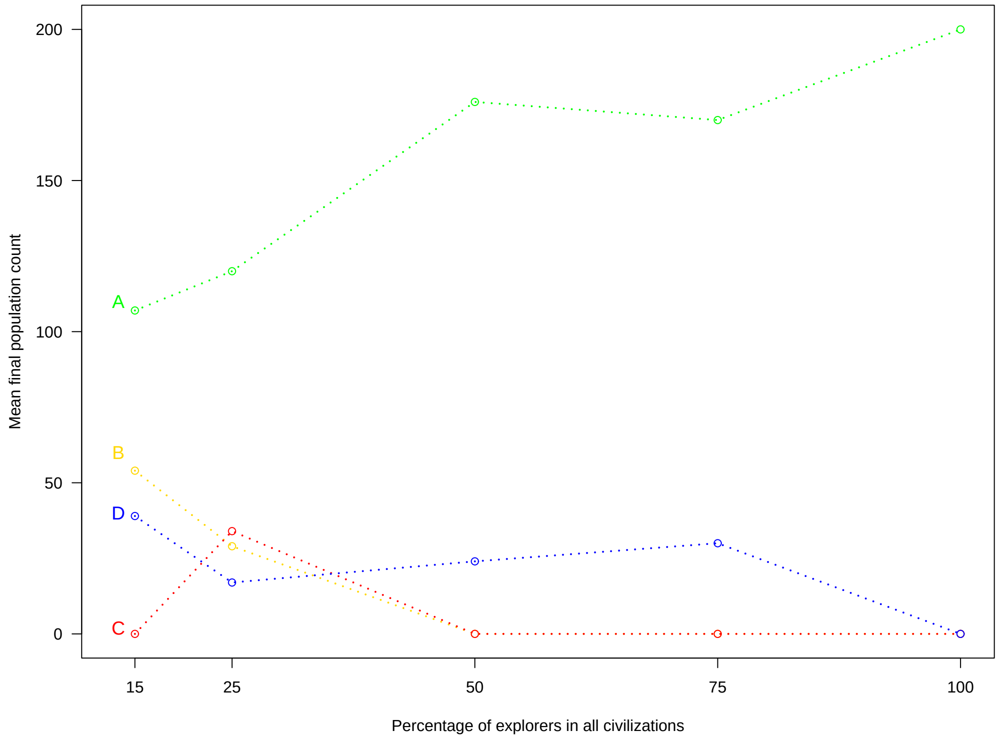

Fig. 4. Effect of percentage of explorers on the final population count

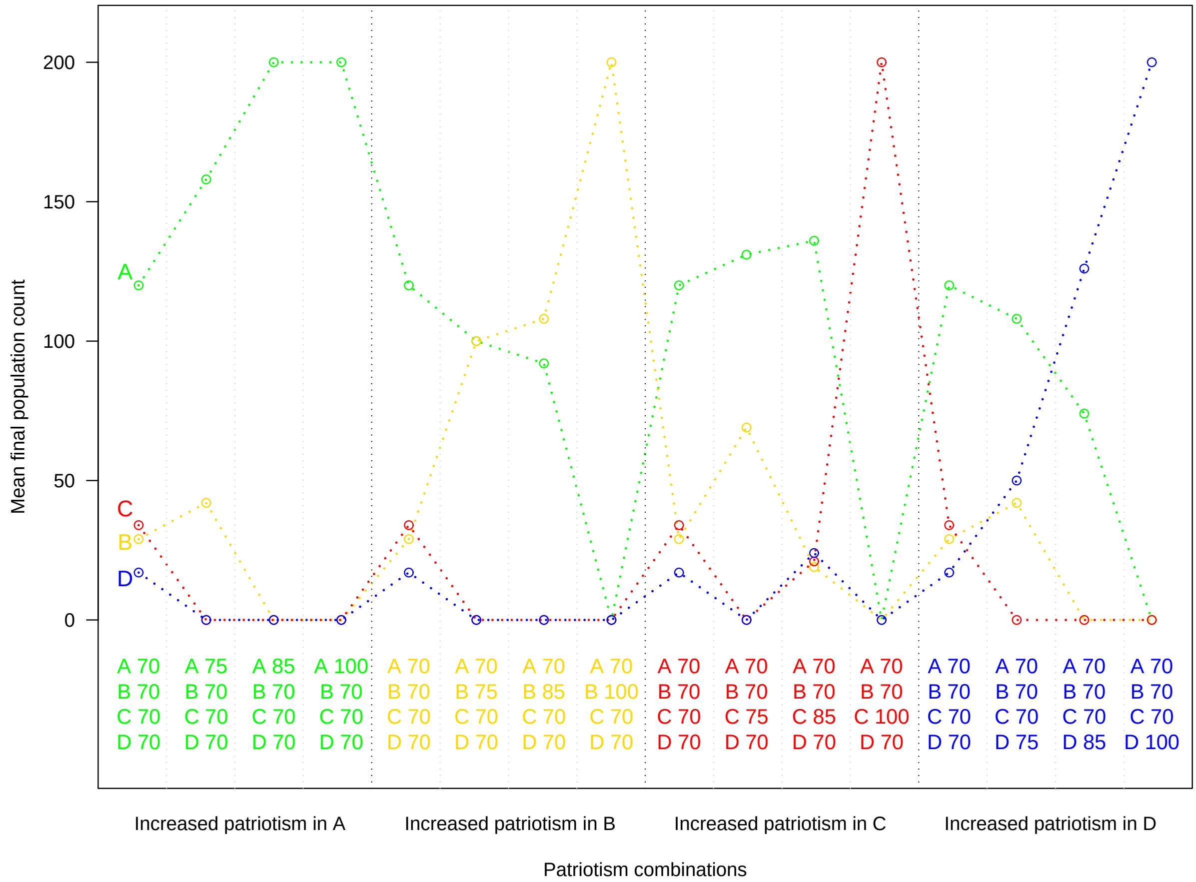

Fig. 5. Effect of patriotism on final population size. The level of patriotism was modified independently for each civilization. Each experiment was repeated 10 times.

5 Conclusion and future work

With this project, we wanted to get a first understanding of the dynamics of game theory when several games are in competition. We implemented a world featuring four civilizations represented by a game each, where games were carried by citizens. Direct competition between the games happened when citizens were allowed to explore the world and to eventually convert to other games. We showed that learning, exploring and patriotism all had an important influence on the outcome of the simulations.

In the future, we intend to run more simulations varying the patriotism coefficient in a more diverse way. Including the standard deviation on all the plots will help understanding better the significance of our results.

We would also like to improve our model, so that each civilization could have a different learning rate (allow for a different ε for each civilization) and a different percentage of explorers. We will also introduce the chance to lose utility either by having to pay to play a game or by setting negative payoffs. This way, agents will be able to die and thus civilization be 'wiped out' rather than consisting of a population of 'converts'.

Generally, we intend to understand better each game and the dynamics of their interaction and increase our knowledge of the field by reading more articles about the work that has been done in the field of game theory.

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References

1. Y Bar-Yam. *Making things work: solving complex problems in a complex world.* Knowledge Press, 2005.
2. J. Tomlinson. Globalization and cultural identity. In D. Held & A.G. McGrew, editor, *The Global Transformations Reader*, pages 269–277. Cambridge: Polity, 2003.
3. Murray Gell-Mann. Complexity and complex adaptive systems. In John A. Hawkins and Murray Gell-Mann, editors, *The Evolution of Human Languages.* Addison-Wesley, Reading, MA, 1992.
4. Hisashi Ohtsuki, Christoph Hauert, Erez Lieberman, and Martin A Nowak. A simple rule for the evolution of cooperation on graphs and social networks. *Nature*, 441(7092):502–505, May 2006.
5. Robert Axelrod, David E Axelrod, and Kenneth J Pienta. Evolution of cooperation among tumor cells. *Proc Natl Acad Sci U S A*, 103(36):13474–13479, Sep 2006.
6. Jeffrey R Stevens and Marc D Hauser. Why be nice? psychological constraints on the evolution of cooperation. *Trends Cogn Sci*, 8(2):60–65, Feb 2004.
7. Mingshan Lu and Ching to Albert Ma. Financial incentives and gaming in alcohol treatment. *Inquiry*, 43(1):34–53, 2006.
8. Steven B Dowd. Applied game theory for the hospital manager. three case studies. *Health Care Manag (Frederick)*, 23(2):156–161, 2004.
9. Thomas Pfeiffer and Martin A Nowak. Climate change: all in the game. *Nature*, 441(7093):583–584, Jun 2006.
10. Peter Hammerstein. Strategic analysis in evolutionary genetics and the theory of games. *J Genet*, 84(1):7–12, Apr 2005.
11. Thomas Pfeiffer and Stefan Schuster. Game-theoretical approaches to studying the evolution of biochemical systems. *Trends Biochem Sci*, 30(1):20–25, Jan 2005.
12. S. A. Levin. Learning to live in a global commons: socioeconomic challenges for a sustainable environment. *Ecological Research*, 21:328–333, 2006.
13. O. Morgenstern and J. von Neumann. *Theory of Games and Economic Behavior.* Princeton University Press, Princeton, 1947.
14. A. Rapoport and A. M. Chammah. *Prisoner's Dilemma.* University of Michigan Press, Ann Arbor, 1965.
15. A Rapoport. *Two-Person Game Theory: The Essential Ideas.* University of Michigan Press, Ann Arbor, 1966.
16. R. S. Sutton and A. G. Bartow. *Reinforcement Learning.* MIT Press, Cambridge, MA, 1998.
17. Colin F Camerer and Ernst Fehr. When does "economic man" dominate social behavior? *Science*, 311(5757):47–52, Jan 2006.
18. Charles A Holt and Alvin E Roth. The nash equilibrium: a perspective. *Proc Natl Acad Sci U S A*, 101(12):3999–4002, Mar 2004.