# Ethnocentrism Maintains Cooperation, but Keeping One's Children Close Fuels It

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## Abstract

Ethnocentrism, commonly thought to rely on complex social cognition, can arise through biological evolution in populations with minimal cognitive abilities. In fact, ethnocentrism is considered to be one of the simplest mechanisms for establishing cooperation in the competitive environment of natural selection. Here we study a recent agent-based model. Through our simulations and analysis, we establish that the mechanism responsible for the emergence of cooperation is children residing close to their parents. Our results suggest that group tags maintain cooperation, but do not create it. We formalize this observation as the dual direct hypothesis: ethnocentric agents dominate humanitarian agents by exploiting the unconditional cooperation of humanitarians of different tags to maintain the number of ethnocentric agents after world saturation. We affirm previous observations on the importance of world saturation, finding its drastic effect on dynamics in both spatial tag-based and tag-less models.

**Keywords:** cooperation; evolution; agent-based modeling; ethnocentrism; viscosity; minimal cognition.

## Introduction

Cooperation is essential for complex biological systems, including human society, but its evolution is puzzling because of the competitiveness of natural selection. The green-beard effect, or ethnocentrism in humans, is thought to be one of the simplest mechanisms for enabling cooperation (Hamilton, 1964). Here, we study a recent tag-based model of evolution of cooperation (Hammond & Axelrod, 2006a, 2006b). With the aid of simulations, we show that the factor responsible for inter-agent cooperation is not the visible group tags of agents, but rather children residing close to their parents. Our results suggest that tags can maintain cooperation, but do not actually create cooperation.

Altruistic cooperation, benefiting another at a cost to oneself, is essential to establishing more sophisticated levels of organization in biological systems. However, evolution — the main driving force for biological change — is based on competition between individuals. Consequently, one would expect natural selection to promote selfishness and design creatures for their own success at the expense of competitors. Yet the world abounds with cooperation: from single cells coming together in multi-cellular organisms to social insects and human society (Hamilton, 1964; Trivers, 1971; Axelrod & Hamilton, 1981; Fehr & Fischbacher, 2003).

Game theory can address the relation between evolution and cooperation (Maynard Smith, 1974). One approach is to allow randomly paired agents to play the prisoners dilemma (PD) game, a paradigmatic example of the problems in achieving mutual cooperation (Trivers, 1971; Axelrod & Hamilton, 1981). Here a cooperator pays some cost $c$ to provide a larger benefit $b$ to another agent, whereas a defector pays no cost and provides no benefit. If the agents are chosen randomly from a well-mixed population and interactions modify individuals' reproductive potential, then defectors will evolve to dominate the population. To establish large-scale cooperation, this random-interactions model must be modified.

The addition of identifiable tags to agents is one of the simplest ways to promote cooperation. Tag-based models rely on the so-called green-beard effect: the idea that agents can use an arbitrary tag to guide cooperation without any further information about other agents' strategies (Hamilton, 1964; Riolo, Cohen, & Axelrod, 2001; Traulsen & Schuster, 2003; Jansen & van Baalen, 2006; Hammond & Axelrod, 2006a, 2006b; Antal, Ohtsuki, Wakeley, Taylor, & Nowak, 2009). The effect has been observed in human placenta (Haig, 1996), ants (Keller & Ross, 1998), and microbes (Lenski & Velicer, 2000; Queller, Ponte, Bozzaro, & Strassmann, 2003; West, Griffin, Gardner, & Diggle, 2006). More abstractly, the beards can be any perceivable quality that distinguishes individuals: chemical signals, physical shapes, or cultural distinctions such as language, religion or ethnic characteristics.

In such multi-tag environments, humans exhibit a pervasive syndrome of discriminatory behaviors, including ethnocentrism (Hewstone, Rubin, & Willis, 2002; Brown, 2004) — the human social equivalent of the green-beard effect — which has been implicated in phenomena ranging from consumer choice (Klein & Ettenson, 1999) and voting (Kinder, 1998), to democratic instability (Rabushka & Shepsle, 1972) and war (van der Dennen, 1995). Thus tags are interesting for studying both human cognition and social behavior and the behavior of simple cognitive agents.

By considering an abstract biologically motivated model, we take a biogenic approach to cognition (Lyon, 2006). During an interaction the agent observes its partner's tag and then makes a decision to cooperate or defect. To accomplish this, the agent must be capable of active categorical perception, a standard problem of study in minimal cognition (Beer, 2003). Note that the agent does not receive any direct information on its partner's strategy, and instead relies on potential correlations of a partner from the same group having the same strategy. This prototypic decision making is in the scope of minimal cognition (van Duijn, Keijzer, & Franken, 2006). Our approach of studying the explicit dynamics and visualizing trends over evolutionary cycles places our work within dynamic modeling of cognition (Beer, 2000). We believe it is important to look at simple agents in such a full view, incorporating their evolutionary history and social setting.

We adopt this full view to answer a number of questions relevant to the evolution of cooperation, ethnocentrism, and cognition. Most generally, we clarify the minimal modifications of the inviscid model needed to foster cooperation. In particular, we examine the role ethnocentrism plays in creating and sustaining cooperation. Our technical contribution is to clarify the mechanism that allows cooperation to emerge and sustain itself in a simple spatial model. We show that the minimal cognition we demand of our agents can help maintain cooperation, but not create it.

## The Model

Hammond and Axelrod (2006a, 2006b) extended beyond random interactions and proposed an agent-based simulation (hereafter, the standard model) for studying the green-beard effect. Instead of randomly choosing interaction pairs, agents populate a toroidal lattice and interact with their four adjacent neighbors. Each individual is simple, only perceiving whether it shares a common tag with neighbors, allowing for two interaction strategies, an in-group (IGS) and an out-group (OGS) strategy. The outcome of PD interactions is added to the agent's potential to reproduce (PTR): the agent's chance of cloning itself into one of the four neighboring cells if one is empty. Each evolutionary cycle, an agent has a constant probability of dying and vacating its location until habitation by a new agent. To start the world, introduce the randomness necessary for evolution, and avoid the population dying out, a randomly generated individual (with random tag, IGS, and OGS) is placed in a randomly selected empty cell at the start of each cycle.

### Previous Results

Hammond and Axelrod (2006b) showed that, after a transient period, ethnocentric agents dominate the population. Shultz, Hartshorn, and Hammond (2008) examined the transient period to uncover evidence for early competition between ethnocentric and humanitarian strategies. More recently, Shultz, Hartshorn, and Kaznatcheev (2009) focused on explaining the mechanism behind ethnocentric dominance over humanitarians. In particular, they introduced the direct and free-rider-suppression hypotheses and showed evidence for the former. The direct hypothesis states that ethnocentric clusters of agents directly suppress contacted clusters of humanitarian agents. The contrasting free-rider-suppression hypothesis is that ethnocentrics are more effective than humanitarians at suppressing free riders: selfish and traitorous agents. Kaznatcheev (2010a) showed that ethnocentrism is not robust to increases in the cost of cognition and studied the proportion of cooperative interactions to show that ethnocentrics can maintain higher levels of cooperation than humanitarians. Most recently, Kaznatcheev (2010b) demonstrated that ethnocentric behavior is robust across a variety of games, even when out-group hostility is classically irrational. However, questions remain about how and why such ethnocentric cooperation emerges.

### Restricted models

In a set of restricted simulations, we identify which aspects of the standard model are critical for ethnocentric dominance, what roles they play, and suggest an intuition for understanding why ethnocentric cooperation emerges. We extend previous work by explicitly examining the dynamics of each model over time. We show that cooperation is created by population viscosity, and tags help to maintain cooperation. We also reinforce the importance of world saturation that Shultz et al. (2009) first observed: world saturation produces a drastic change in the dynamics of cooperation in spatial models.

We removed key characteristics of the standard model — arbitrary tags and local child-placement — in order to assess their effects on cooperation. Without tags, agents cannot distinguish between in-group and out-group agents. Without local child-placement, a randomized procedure was used: a parent cloned an identical copy of itself into a randomly selected cell. If no empty cell was found in four tries, no child was created, analogous to having no empty neighbors in the standard model. Removing one or both of these features (tags or local child-placement) provided three restricted simulations with which to study the evolution of cooperation.

## Simulation Results

For all four cases: standard, no child-proximity, no tags, and neither tags nor child-proximity, we studied 6 parameter variations. In all simulations, we kept the world size (50 by 50), default PTR (0.12), death rate (0.10), and number of tags (4 — for the cases that had tags) constant. Small variations in these parameters preserve the qualitative nature of the results.

The important parameter of the simulation is the underlying interaction between agents. Large variations in the game were considered earlier by Kaznatcheev (2010b), but we consider only the prisoner's dilemma and the natural variable is the ratio between $b$ — the benefit of receiving, and $c$ — the cost of giving. We kept the cost of giving constant at $c = 0.01$ and varied the benefit of receiving through 6 settings for each case study: 0.0015, 0.0020, 0.025, 0.030, 0.035, and 0.040. Thus, we looked at 6 different $^{b}/_{c}$ ratios with 4 different types of simulations (standard model, no child-proximity, no tags, and neither tags nor child-proximity). For each of the 24 case-parameter combinations, we conducted 30 simulations for 1000 cycles each and considered mean results. We present results for 3 of the six $^{b}/_{c}$ ratios in Figure 1. The remaining 3 cases are qualitatively similar and omitted for brevity.

Cooperation emerged in only one of the restricted models, but did not persist there as well as in the standard model. Figure 1 shows the proportion of cooperative behavior for each condition at each evolutionary cycle for 3 different values of $^{b}/_{c}$; each line's thickness quantifies the standard error from averaging across 30 simulations.

The red (without tags) and yellow (with tags) lines show the two models without random child-placement, neither of which led to cooperation. On the other hand, both of the models with local child-placement caused cooperation to emerge; the green (without tags) and blue (with tags, standard model) lines show these results. It is clear that the standard model and the no-tag model show similar levels of cooperation in the early stages, and peak at approximately the same maximum level of cooperation. However, the standard model is able to maintain the achieved level of cooperation, while in the no tag model cooperation decays.

As the environment becomes more benign (higher $^{b}/_{c}$) the decay in the no tag model is less pronounced until for $^{b}/_{c} = 4$ there is no decay. Figure 1 shows that local child-placement drives the early emergence of cooperation, whether tags are present or not, while the addition of tags maintains this cooperation in more competitive environments, allowing it to dominate in the long term.

## Discussion and Future Directions

Examining the simplified conditions shows how cooperation emerges in the standard model. Cooperation emerged without tags if children were placed near their parents, but not when tags were present without local child-placement. These results suggest that child proximity is the driving force behind the emergence of cooperation and that tags help maintain cooperators by providing a way to resist invading defectors. To under-

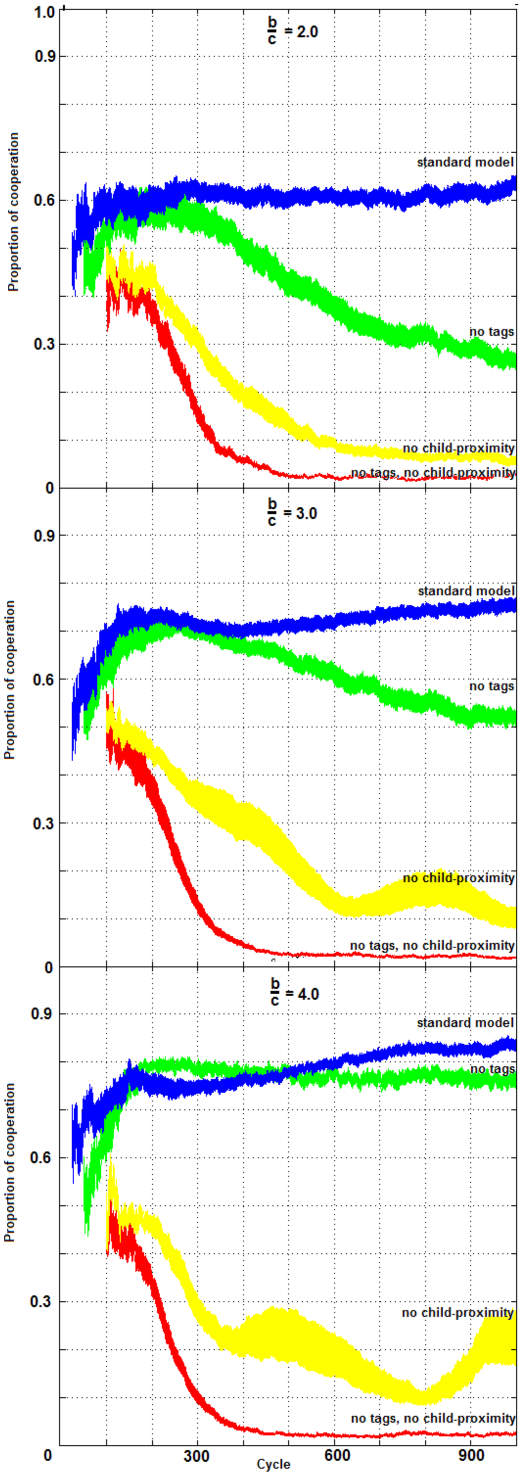

Figure 1: Proportion of cooperative interactions averaged over 30 simulations vs. cycle for the standard model and three simplified conditions with 3 different $^{b}/_{c}$ ratios. Line thickness indicates 1 SE around the mean. The data start at cycle 25 for the standard model (blue), cycle 50 for no tags (green) and cycle 100 for no child proximity (yellow) and no tags or child proximity (red). Data before the start cycle were omitted for clarity because their SEs were too high to be meaningful.

stand why child proximity is the key factor, we examine the differences between placing children locally and randomly.

When children are placed randomly, we can use standard tools of evolutionary game theory (Hofbauer & Sigmund, 2003) to analyze the dynamics. For PD interactions, the population converges toward total defection. To bolster cooperation, it is important to increase the probability of self-interaction: interaction with agents of the same strain (genetically identical) as oneself. If agents interacted only with same strain partners, then a simple group selection argument shows that cooperators (humanitarians or ethnocentrics in the tag models) would dominate: cooperative self-interaction would increase their fitness past the base PTR, while defectors would remain at base PTR. On the other hand, in the inviscid model, the probability of interacting with a strain is the proportion of that strain in the population. Thus, a defector has the same probability as a cooperator of interacting with a cooperator. Since defectors benefit more from the interaction, the defectors will have a higher fitness.

Without a mechanism to increase the probability of self-interaction, cooperation cannot emerge in the PD. This mechanism can be a preset bias toward similar agents (Riolo et al., 2001; Traulsen & Claussen, 2004), a much higher level of mutation for tags than for strategies (Antal et al., 2009), or in the case of Hammond and Axelrod (2006a, 2006b): spatial viscosity.

Because spatial structure affects humanitarian and ethnocentric agents in the same way, this analysis also casts doubt on earlier expectations that a simple variation of the Hammond and Axelrod model could favour humanitarian cooperation (Shultz et al., 2008, 2009). This agrees with evidence that natural selection favours strategies that are increasingly accurate in targeting altruism to only the same strain (Clune, Goldsby, Ofria, & Pennock, 2011). To curb ethnocentrism more drastic variations, like cost of cognition (Kaznatcheev, 2010a), have to be introduced. Future research can look at specific cognitive mechanisms and constraints that are needed to favour humanitarian cooperation.

Ohtsuki and Nowak (2006) showed that the increase in self-interaction can be analyzed mathematically in simple structures such as regular random graphs. Unfortunately, their methods are not applicable to highly structured graphs such as the toroidal grid in our study, nor to models with free space and world saturation. For our model, careful study of simulation results is the best approach to understanding the dynamics. An important future question is to understand if there are simple analytic approximations to our model.

Visualizing trends over cycles, as in Figure 1, allows us to see that local child-placement (without tags) does about as well as the standard simulation (both local child-placement and tags) up to around 300 cycles. Shultz et al. (2009) have previously found that world population saturates at about 300 cycles, on average, and that is where ethnocentrics start to pull ahead of humanitarians (who cooperate with everyone). As the world fills up and clusters of cooperators collide with egoists, the presence of group tags become critically important. The partial information about their parents allows ethnocentric agents to avoid exploitation by egoists, and lets them maintain their levels, unlike the cooperators in no-tag simulations, or humanitarians in tag simulations. Tags provide cooperators with information with which to avoid potential exploiters.

In particular, without tags, there are two strains to consider, cooperators and defectors; an agent has no way of telling them apart, and consequently is at the mercy of the distribution of agents. Adding, for example, four tags increases the strains to 16 — four strategies for each tag. If agents distinguish tags, they know that 12 of those 16 strains are not their own (different tag) and can be defected against, producing ethnocentric agents that cooperate with their in-group but not with out-groups. Our results suggest a new role for group tags, not as a mechanism to fuel cooperation, but as a method for sustaining it after world saturation.

Unfortunately, there are two distinct features of world saturation: (i) the total world population stabilizes and remains relatively constant, and (ii) clusters of cooperators and egoists start to collide. The first feature is the definition and method of detecting world saturation used by Shultz et al. (2009), but the second feature is the important feature for explaining the decline of cooperation after world saturation. Under the parameter ranges we study, both features occur together. However, in worlds with low default PTR and high death rate, the total population at world saturation is very low. In such cases, we cannot reasonably say that clusters of agents collide. A tempting future direction is to consider models or parameter settings where the two features of world saturation can be studied separately and their individual contributions to the emergence of cooperation better understood.

Analyzing trends over cycles allows us to notice qualitative similarity in the decline of humanitarians in tag simulations found in previous studies (Shultz et al., 2008, 2009) and the decline in cooperation in no tag cases. This observation suggests a refinement of the direct hypothesis. Proposed as a method of ethnocentric dominance over humanitarians, there was strong early support for the direct hypothesis that stated that ethnocentric agents suppressed humanitarians directly. However, it is clear in the no-tag simulations that there are no ethnocentric agents to suppress cooperators (who are functionally equivalent to humanitarians) and yet cooperation declines in the population. This suggests that a decline in cooperation is the default behavior after world saturation.

We should think of ethnocentric agents not as suppressing humanitarians but instead exploiting their unconditional cooperation in order to bolster ethnocentric fitness. We call this the dual direct hypothesis because it is an alternative view of the original direct hypothesis. While the original direct hypothesis stressed that humanitarians were exceptionally disadvantaged by their interaction with ethnocentrics, here we stress the dual notion that instead ethnocentrics were exceptionally advantaged by their interaction with humanitarians. Our hypothesis is that ethnocentric agents dominate humanitarian agents by exploiting the unconditional cooperation of humanitarians to maintain the number of ethnocentric agents after world saturation. Humanitarian numbers decrease not because of suppression by ethnocentrics, but because of a lack of mechanism for maintaining fitness in the highly competitive post-saturation environment.

Although the difference from the direct hypothesis is subtle it is an important conceptual clarification. Previous results that built support for the direct hypothesis carry over nicely to the dual direct hypothesis. However, the dual direct hypothesis is also consistent with the findings of this study, while the original is harder to justify. With the dual direct hypothesis, we can clearly say that ethnocentrism maintains but does not create cooperation among simple agents.

This interpretation is strengthened by the decline in the importance of tags as the environment becomes less competitive. In the prisoner's dilemma the competitiveness of the environment is captured by ratio between $b$ — the benefit of receiving, and $c$ — the cost of giving. As $^b/_c$ increases, the risk of being a cooperator decreases. If $^b/_c = k$ then as long as at least one out of every $k$ agents you cooperate with is of the same strain as you, you have produced a net benefit for your strain. Thus, low $^b/_c$ corresponds to a more competitive environment where agents have to take higher risks.

The results in Figure 1 show that as the environment becomes less competitive (compare the plots for $^b/_c = 2$ and 4), tags become less important. In a highly competitive environment ($^b/_c = 2$) the proportion of cooperation differs by over 40% between the tag and no tag conditions while for $^b/_c = 4$ the two conditions produce almost the same levels of cooperation (less than 10% difference). The cooperation maintaining mechanism of tags is only important in competitive environments of low $^b/_c$ ratio. A more thorough future direction is to quantify our observation by building on the ideas of Kaznatcheev (2010a) and studying the maximum cost of cognition ethnocentric agents are willing to sustain for various levels of environmental competitiveness.

The cognition employed by our simulated agents is fairly minimal, but not beyond the pale of what contemporary cognitive science regards as cognition (Beer, 2000, 2003; Lyon, 2006; van Duijn et al., 2006). Although humanitarian (cooperate with all) and selfish (cooperate with none) strategies are indeed simple, the conditional strategies of ethnocentrics and traitors (reverse of ethnocentrism) are more complicated and come with an extra cognitive cost that has evolutionary consequences (Kaznatcheev, 2010a). Indeed, just to condition, we have to assume that agents are capable of categorical perception; a task that already merits a rich analysis (Beer, 2003). A natural future direction is to replace our primitive agents by Beer's model agents and coevolve their neural structure and strategy.

Framing ethnocentrism as the green-beard effect in biology also opens up the potential for empirical studies on simple animals that have been proposed as model organisms for both minimal cognition and evolution, such as *E.coli* (van Duijn et al., 2006) and fruit flies (Greenspan & van Swinderen, 2004). In fact, the documentation of the green-beard effect in microbes (Lenski & Velicer, 2000; Queller et al., 2003; West et al., 2006) and the proposal of microbes as the simplest cognitive agents (di Primio, Muller, & Lengeler, 2000; van Duijn et al., 2006) could provide fertile ground for studying the coevolution of strategic behavior and cognition. We believe that it is important for cognitive science to occasionally stretch beyond its dominant anthropogenic focus on individual humans and consider the full range of cognition, whether supported by brains or metabolic processes, in its full social and evolutionary dimensions. When expanded completely, it seems important to strive for abstract explanations like those offered by our current results.

## Acknowledgments

The authors would like to thank Kyler Brown and Julian Z. Xue for helpful comments. This research began while AK was at the School of Computer Science and Department of Physics, McGill University. It was supported by a summer research fellowship to AK and an operating grant to TRS, both from the Natural Sciences and Engineering Research Council of Canada, and an operating grant to TRS from the Deans Excellence Fund, Faculty of Science, McGill University.

## References

Antal, T., Ohtsuki, H., Wakeley, J., Taylor, P. D., & Nowak, M. A. (2009). Evolution of cooperation by phenotypic similarity. *PNAS USA*, *106*, 8597-8600.

Axelrod, R., & Hamilton, W. (1981). The evolution of cooperation. *Science*, *211*, 1390-1396.

Beer, R. D. (2000). Dynamical approaches to cognitive science. *Trends in Cognitive Sciences*, *4*, 91-99.

Beer, R. D. (2003). The dynamics of active categorical perception in an evolved model agent. *Adaptive Behavior*, *11*, 209-243.

Brown, D. E. (2004). Human universals, human nature, and human culture. *Daedalus*, *133 (4)*, 47-54.

Clune, J., Goldsby, H. J., Ofria, C., & Pennock, R. T. (2011). Selective pressures for accurate altruism targeting: evidence from digital evolution for difficult-to-test aspects of inclusive fitness theory. *Proc. R. Soc. B*, *278*, 666-674.

di Primio, F., Muller, B., & Lengeler, J. (2000). Minimal cognition in unicellular organisms. In J.-A. Meyer (Ed.), *SAB2000 proceedings supplement: Sixth international conference on simulation of adaptive behavior. from animals to animats.* (p. 3-12). Honolulu: The International Society for Adaptive Behavior.

Fehr, E., & Fischbacher, U. (2003). The nature of altruism. *Nature*, *425*, 785-791.

Greenspan, R. J., & van Swinderen, B. (2004). Cognitive consonance: complex brain functions in the fruit fly and its relatives. *Trends in Neurosciences*, *27*, 707-711.

Haig, D. (1996). Gestational drive and the green-bearded placenta. *Proc. Natl. Acad. Sci. USA*, *93*, 6547-6551.

Hamilton, W. (1964). The genetical evolution of social behaviour. I and II. *Journal of Theoretical Biology*, *7*, 1-52.

Hammond, R., & Axelrod, R. (2006a). Evolution of contingent altruism when cooperation is expensive. *Theoretical Population Biology*, *69*, 333-338.

Hammond, R., & Axelrod, R. (2006b). The evolution of ethnocentrism. *Journal of Conflict Resolution*, *50*, 926-936.

Hewstone, M., Rubin, M., & Willis, H. (2002). Intergroup bias. *Annual Review of Psychology*, *53*, 575-604.

Hofbauer, J., & Sigmund, K. (2003). Evolutionary game dynamics. *Bull. Amer. Math. Soc.*, *40*, 479-519.

Jansen, V. A., & van Baalen, M. (2006). Altruism through beard chromodynamics. *Nature*, *440*, 663-666.

Kaznatcheev, A. (2010a). The cognitive cost of ethnocentrism. In S. Ohlsson & R. Catrambone (Eds.), *Proceedings of the 32nd annual conference of the cognitive science society.* Austin, TX: Cognitive Science Society.

Kaznatcheev, A. (2010b). Robustness of ethnocentrism to changes in inter-personal interactions. *Complex Adaptive Systems - AAAI Fall Symposium.*

Keller, L., & Ross, K. (1998). Selfish genes: a green beard in the red fire ant. *Nature*, *394*, 573-575.

Kinder, D. (1998). Opinion and action in the realm of politics. In D. Gilbert, S. Fiske, & G. Lindzey (Eds.), *Handbook of social psychology.* Boston: McGraw-Hill.

Klein, J., & Ettenson, R. (1999). Consumer animosity and consumer ethnocentrism: An analysis of unique antecedents. *Journal of International Consumer Marketing*, *11*, 5-24.

Lenski, R., & Velicer, G. (2000). Games microbes play. *Selection*, *1*, 51-57.

Lyon, P. (2006). The biogenic approach to cognition. *Cognitive Processing*, *7*, 11-29.

Maynard Smith, J. (1974). The theory of games and the evolution of animal conflict. *Journal of Theoretical Biology*, *47*, 209-221.

Ohtsuki, H., & Nowak, M. A. (2006). The replicator equation on graphs. *Journal of Theoretical Biology*, *243*, 86-97.

Queller, D., Ponte, E., Bozzaro, S., & Strassmann, J. (2003). Single-gene greenbeard effects in the social amoeba *Dictyostelium discoideum*. *Science*, *299*, 105-106.

Rabushka, A., & Shepsle, K. (1972). *Politics in plural societies: a theory of democratic instability.* Columbus, OH: Merrill.

Riolo, R., Cohen, M., & Axelrod, R. (2001). Evolution of cooperation without reciprocity. *Nature*, *414*, 441-443.

Shultz, T. R., Hartshorn, M., & Hammond, R. A. (2008). Stages in the evolution of ethnocentrism. In B. Love, K. McRae, & V. Sloutsky (Eds.), *Proceedings of the 30th annual conference of the cognitive science society* (p. 1244-1249). Austin, TX: Cognitive Science Society.

Shultz, T. R., Hartshorn, M., & Kaznatcheev, A. (2009). Why is ethnocentrism more common than humanitarianism? In N. Taatgen & H. van Rijn (Eds.), *Proceedings of the 31st annual conference of the cognitive science society* (p. 2100-2105). Austin, TX: Cognitive Science Society.

Traulsen, A., & Claussen, J. (2004). Similarity-based cooperation and spatial segregation. *Physical Review E*, *70*, 046128.

Traulsen, A., & Schuster, H. G. (2003). Minimal model for tag-based cooperation. *Physical Review E*, *68*, 046129.

Trivers, R. (1971). The evolution of reciprocal altruism. *The Quarterly Review of Biology*, *46*, 35-57.

van der Dennen, J. (1995). *The origin of war.* Groningen, Netherlands: Origin Press.

van Duijn, M., Keijzer, F., & Franken, D. (2006). Principles of minimal cognition: Casting cognition as sensorimotor coordination. *Adaptive Behavior*, *14*, 157-170.

West, S., Griffin, A., Gardner, A., & Diggle, S. (2006). Social evolution theory for microorganisms. *Nature Reviews Microbiology*, *4*, 597-607.