

Preferential Partner Selection in an Evolutionary Study of Prisoner's Dilemma

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Abstract

Partner selection is an important process in many social interactions, permitting individuals to decrease the risks associated with cooperation. In large populations, defectors may escape punishment by roving from partner to partner, but defectors in smaller populations risk social isolation. We investigate these possibilities for an evolutionary prisoner's dilemma in which agents use expected payoffs to choose and refuse partners. In comparison to random or round-robin partner matching, we find that the average payoffs attained with preferential partner selection tend to be more narrowly confined to a few isolated payoff regions. Most ecologies evolve to essentially full cooperative behavior, but when agents are intolerant of defections, or when the costs of refusal and social isolation are small, we also see the emergence of wallflower ecologies in which all agents are socially isolated. In between these two extremes, we see the emergence of ecologies whose agents tend to engage in a small number of defections followed by cooperation thereafter. The latter ecologies exhibit a plethora of interesting social interaction patterns.

Keywords: Evolutionary Game; Iterated Prisoner's Dilemma; Partner Choice and Refusal; Artificial Life; Genetic Algorithm; Finite Automata.

INTRODUCTION

Following the path-breaking work of Axelrod [1, 2, 3], the Iterated Prisoner's Dilemma (IPD) is now commonly used by researchers to explore the potential emergence of mutually cooperative behavior among non-altruistic agents. See, for example, Miller [13] and Lindgren and Nordahl [11]. These studies have shown that mutually cooperative behavior tends to emerge if the number of game iterations is either uncertain or infinite, the frequency of mutually cooperative play in initial game iterations is sufficiently high, and the perceived probability of future interactions with any given current opponent is sufficiently large.

Most studies of IPD assume that individual players have no control over which opponents they play. Players are matched as game partners either randomly or by means of a deterministic

mechanism such as round-robin or grid neighborhood play. In real-life situations, however, agents are not always prisoners who have no alternative but to play their assigned PD games. Instead, social interactions are often characterized by the preferential choice and refusal of partners. In what ways, then, might the introduction of preferential partner selection change the nature of the IPD?

Previous research suggests that, depending upon the precise population structure, the decision rules used for partner selection, and the penalties imposed for rejected offers and for deciding not to play, cooperators or defectors may benefit from preferential partner selection. For example, Kitcher [9] and Schuessler [15] show that the option of refusing to play previously defecting players can increase the fitness of cooperative players and allow them to invade defecting populations. Orbell and Dawes [14] argue that it is to the benefit of society as a whole to evolve social structures that allow individuals to opt out of games. Their experiments indicate that humans who are themselves cooperatively inclined tend to be more optimistic about the cooperative intentions of other players and hence to play more games. In Eshel and Cavalli-Sforza [5], beneficial assortative mixing may occur either because agents playing the same strategy are more likely to encounter each other, or because agents playing cooperative strategies actively select each other.

The ability to actively seek out known cooperators as partners also provides an incentive for agents to be reliably cooperative, so that they will be chosen as partners, and this potentially increases the incidence of cooperation in a society [20]. Hirshleifer and Rasmusen [7] find that group ostracism can permit cooperative agents to protect themselves from defectors. On the other hand, Dugatkin [4] shows that the ability to choose partners in large populations divided into isolated patches may permit roving defectors to move from one patch to the next, avoiding ostracism while taking advantage of each patch in turn.

Finally, the introduction of preferential partner selection results in social networks of interacting players. Who chooses whom, and why, affects who does well, and this in turn affects the outcomes of the overall game. Questions about social network formation are key to understanding societies. How do groups form? What roles do highly connected individuals play? Social networks are also interesting because they are pathways for the transmission of diseases, information, and cultural traits.

In a previous paper [17], we studied an IPD choice and refusal mechanism that combines active choice of potential game partners with the ability to refuse play with those judged to be intolerable. Players use continually updated expected payoffs to assess the relative desirability of potential partners. This use of expected payoffs is meant to capture the idea that players attempt to select partners rationally, using some degree of anticipation, even though they do not know their partners' strategies and payoffs. Our choice and refusal mechanism is thus more flexible and general than many of the mechanisms studied by previous researchers, although it does not currently allow for the information exchange between players assumed by Kitcher. Also, we considered a single small population, so that defectors cannot rove from one isolated population to the next, as in Dugatkin [4], but instead risk eventual ostracism.

In particular, we studied how the ability both to choose and to refuse potential game partners affects interactions among a small set of simple IPD strategies, and we used a five-player population to illustrate the formation of social networks. We also conducted a number of evolutionary simulations. The interaction dynamics in both our analytical and simulation studies were seen to be complex, even for small populations. Choice is used by all players to home in quickly on those who will cooperate with them. This permits nice players to interact with each other, but also allows predatory individuals to locate and form long term relationships with victims within the limit of occasional defection tolerated by the refusal mechanism. On the other hand, refusal ensures that very nasty players do poorly, since repeatedly defecting players are typically ostracized as other players increasingly refuse their offers. Indeed, wallflower populations sometimes emerged in which all players defected until they became solitary, neither making nor accepting game offers

from other players. Overall, however, we observed cooperation to emerge much more quickly and frequently with choice and refusal of partners than with round-robin matching.

In this paper we present a variety of new analytical and simulation findings on the evolutionary IPD with choice and refusal of partners, or evolutionary IPD/CR for short. We first review in Section 2 the basic structure and implementation of the evolutionary IPD/CR. In particular, we discuss the finite state machines used to represent players' IPD strategies as well as the genetic algorithm used to evolve the player population from an initial, randomly-chosen population.

Players in our co-evolutionary framework cannot necessarily jump from a defecting mode of behavior to a cooperative one. In particular, the genetic material available in our initial population constrains its future evolution. This path dependence turns out to be particularly important for the interpretation of the IPD/CR simulation studies reported in the present paper, since we work with relatively small populations of thirty players. Section 3 thus undertakes an analytical characterization of the distribution of behaviors in the initial player population. In particular, it is shown that a uniformly distributed selection of genetic structures for these players implies a nonuniform selection of their IPD strategies, one that is highly biased towards simple strategies.

In the final two sections we detail a series of simulation studies that have been conducted to explore the sensitivity of evolutionary IPD/CR outcomes to changes in key parameters. In particular, we first describe one-parameter and two-parameter sensitivity studies for the parameters characterizing the choice and refusal mechanism. We then report on experiments conducted to test the sensitivity of outcomes to changes in the potential complexity of players' IPD strategies, as measured by the number of states in their finite state machine representations. Also, we briefly summarize preliminary studies in which two key parameters characterizing the choice and refusal mechanism are incorporated into the genetic structure of each player and allowed to evolve over time. Finally, we discuss the sensitivity of the behavioral diversity of our populations to changes in the implementation of the genetic algorithm used to evolve our player populations.

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