Exploring Multiplexity with Evolutionary Game Theory and Complex Networks

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Abstract

In recent years, there has been growing interest in studying linked social contexts through the lens of evolutionary games on complex networks. Despite much progress, accounting for this multiplexity is still a challenging task, and many questions remain open.

In this thesis, we address the aforementioned issue with a model in which individuals are engaged in two domains of interactions: close proximity neighbors on a spatially embedded lattice network, and distant contacts with random individuals. We then incorporate multiplexity from two different perspectives.

We start by distinguishing the modifiability of links: ties with close neighbors are fixed, while long-range ties to random individuals are rewirable. Using a coevolutionary model of cooperation and partner rewiring range preference, we find resultant partner networks that are highly degree heterogeneous, with low average shortest path lengths, while retaining high clustering, and thus possess small-world properties. We also discover an optimal availability of reputation information for the emergence of cooperators who form distant partnerships at a cost to themselves.

We then derive analytical solutions for a simpler model, and find a threshold frequency of partner switching that triggers a phase transition from full defection to cooperation. We also demonstrate how heterogenous social popularity can emerge in this simplified model.

Next, we disallow partner rewiring, and instead explore multiplexity from the perspective of cross-context interference, or spillover, of strategic behaviors between two distinct games. Individuals play the iterated Prisoner's Dilemma with neighbors on the lattice, and the one-shot Prisoner's Dilemma with random partners. We derive analytical results using extended pair approximation, which shows good agreement with extensive simulations.

Our investigation indicates that increasing the magnitude of spillover can encourage cooperation, provided cooperation is favored in one of the games, but too much spillover is deleterious. We also observe a bistability phenomenon: whether spillover benefits cooperation depends on initial propor-

tions of cooperation in each game. Furthermore, comparing strategy combinations arising from each spillover mode effectively indicates the outcome of their coevolutionary dynamics with cooperation.

Our results are experimentally testable, inspire future research, and shed light on the evolution of cooperation across social realms.