Evolutionary Dynamics of Human Cooperation Across Scales: Dyads, Networks, and Populations

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Abstract

The evolution of cooperation, particularly in human society, is one of the most challenging problems in the 21st century. In this thesis, we consider interactions between self-interested individuals at different levels: dyads (two players), networks (social networks and other spatial structures), and populations (compartmental models). Our work adopts a uniform approach grounded on complex systems and evolutionary game theory to improve our understanding of human cooperation problems across these scales.

We first study extortion and fairness in reciprocal actions. The iterated Prisoner's Dilemma serves as a theoretical paradigm for repeated encounters between the same two players. We unravel strategies that are *unbending* to extortion. Any greedy extortioner will ultimately concede in their own interest by offering a fair split in head-to-head matches. Our result has implications for promoting fairness and resisting extortion to uphold a just and altruistic society.

We then turn from reciprocity between dyads to that within populations and even social networks. In the so-called public goods games, we describe the interplay of infectious diseases and human behavior. The study on vaccine uptake shows that hysteresis can appear as an unprecedented roadblock for the recovery of inoculation rate. We, therefore, offer a possible explanation for the persistence of the vaccine compliance problem. Another study on antibiotic overuse indicates that social learning of prescription behavior can promote population optimum of antibiotic use. Prompt feedback to prescription behavior with the collective consequences of treatment decisions and costs related to resistance helps curb antibiotic overuse. Amid the ongoing pandemic of COVID-19, we also explore the coordination problem in transmission control via travel restrictions. We measure the effectiveness of massive travel bans on suppressing outbreaks. A data-driven approach shows that the synchrony of *inter*-province and *intra*-city mobility is critical in minimizing disease impact in China.

This thesis contributes to understanding the aforementioned aspects of the evolutionary dynamics of human cooperation. Further work extending

applications to make the world a better place is of broad interest and primary significance, especially in the wake of a pandemic that has ruthlessly shuttered the world.