Coherent and incoherent strategists: Evolutionary dynamics on multiplex networks

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Cooperation is a very common, yet not fully-understood phenomenon in natural and human systems. The introduction of a network structure within the population is known to affect the outcome of cooperative dynamics, as described by the Game Theory paradigm, allowing for the survival of cooperation in adverse scenarios. Recently, the introduction of multiplex networks, where individuals can adopt different strategies in different layers, has yet again modified the expectations for the outcome of the Prisoner's Dilemma (PD) game, compared to the single-layer (monoplex) case: for example, it is known that the average level of cooperation is slightly lower in the multiplex scenario for very low values of temptation, but also, cooperation is able to resist until higher values of the temptation. These phenomena, however, are not well understood at a microscopic level, and much remains to be studied regarding the rest of the social dilemmas in the T-S plane (PD, Stag-Hunt, Snow Drift and Harmony) on multiplex.

We explore here the microscopic organization of the strategies across layers, and find some remarkable and previously unknown phenomena, that are at the root of the differences between monoplex and multiplex. Specifically, we find that in the stationary state and for any given time step, there are individuals that play the same strategy in all layers ("coherent"), and others that don't ("incoherent", Figure1). We find that this group of incoherent players is responsible for the surprising fact of a non full-cooperation in the Harmony Game on multiplex (values of around 90%), which has never been observed before, as well as a higher-than-expected survival of cooperation in some regions of the other three social dilemmas. Moreover, we are able to prove mathematically the existence of defectors in the case of the harmony game on multiplex networks, also calculating the probability of the necessary topological configuration happening for uncorrelated Erdős–Rényi layers.

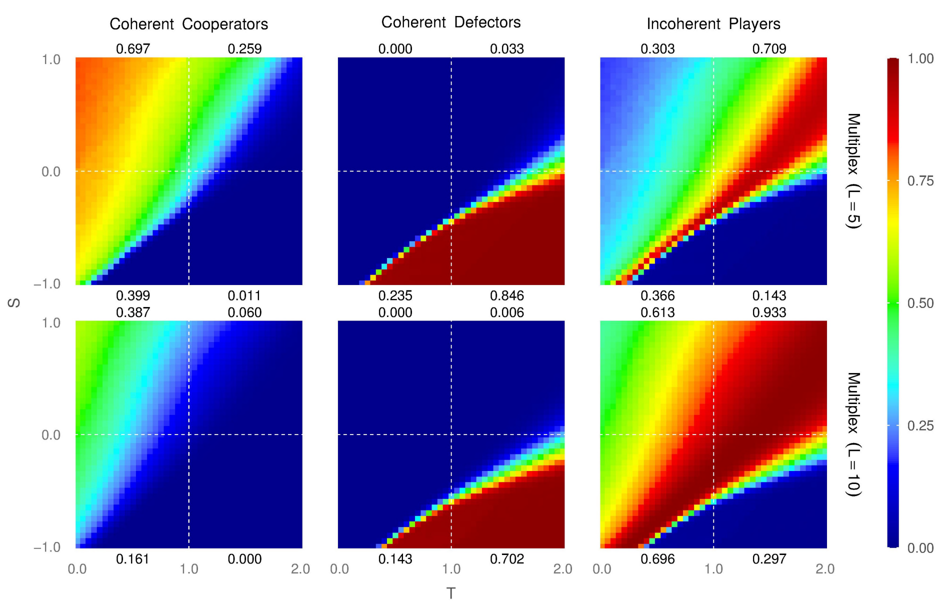

FIGURE 1. Average density of coherent cooperators (left column), coherent defectors (middle column) and incoherent individuals (right column) for networks with 5 layers (top row) and 10 layers (bottom row). The average density of the corresponding type of individuals is also provided for each one of the quadrants (upper-left is the Harmony Game, upper-right is the Snow Drift, Stag-Hunt is the lower-left, and the Prisoner's Dilemma in the lower-right). The average asymptotic density of coherent cooperators, coherent defectors and incoherent players for each one of the games is also indicated, as a numerical value, next to the corresponding quadrant.

To summarize, the introduction of a multiplex structure in the population not only allows for more sophisticated and realistic behaviors for the individuals (that can now display different strategies in different layers), but also helps promote cooperation in regions of the parameter space in which it can not survive in the monoplex scenario, at the expense of a moderate decrease of cooperation in those where traditionally it was very high. These phenomena can only be understood by the existence of incoherent players.