Complexity emerges in measures of the marking dynamics in football games

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In this work, we aim to study the marking dynamics using network science. To do so, we survey a database containing the coordinates of the players in the field at each second of three professional games. With this information, we define a bipartite graph where the nodes are the players of both teams, but the connections can be only between opponents.

To establish the connections in our networks, we will use the euclidean distance of the players in the field since the opponents' closeness is strictly related to the marking. This particular type of graph is known as proximity network and has been widely used to study multiple phenomena in complexity science.

Summarising, we observed that the proximity network evolves following the marking dynamics, exhibiting oscillating periods of high defragmentation and high clusterization.
To characterise this phenomenon, we calculated the heterogeneity parameter (κ) and found that the system evolves in a regime similar to a transition in percolation theory.
Since the system is far from the thermodynamic limit, we cannot frame our results in the theory of phase transitions. Our observations, however, evidence the emergence of complexity in the marking dynamics.

We were able to study this complex behaviour by analysing the temporal structure of the time series of κ. We found the presence of anti-persistency and self-similarity, which we characterised by uncovering a scaling law in the average shape of the fluctuations, see Fig. 1.

Lastly, we proposed a model to simulate the players' motion on the field. From simulations, we obtained the evolution of a synthetic proximity network that we analysed with the same methodology we used in our analysis of the empirical data. Remarkably, the model showed a good performance in recovering the statistics of the empirical trajectories; and, consequently, the statistics of the temporal structure of the parameter κ.

In conclusion, we can state that the correlations observed in the proximity network associated with the marking dynamics could be related to the high level of coordination required to keep running the tactical system. In this sense, our framework based on proximity networks allows us to observe that at each game challenge, the entire team will proceed in coordination to give a response. They will tend to react optimally, according to the training precepts received. Therefore, it is expected that, in similar situations, they will produce equivalent responses. In our framework, these responses are encoded in the proximity networks as recurrent configurations and yield the memory effects we observe in the evolution of the heterogeneity parameter.

Moreover, the presence of correlations reveals the players are strongly connected. These connections drive the team to behave flexible and adaptable to stimuli, something crucial for the development of the game. We can compare this "state of alert" of the teams with what occurs with bird flocks or fish shoals, in which connections among the individual make the group stronger to avoid predators. The difference between these cases and the dynamics of a football team relies on the cognition capabilities required to achieve this level of organisation among the group's individuals.

The emergence of complexity in the game of football is somewhat similar to that observed in a living system. In these systems, when the delicate equilibrium between inhibition and promotion, cooperation and competition, is unbalanced, something abnormal occurs. This effect is observed, for example, in the appearance of cancer cells, in diseases of the nervous system, in diseased mitochondria, etc. When the complexity of the system is lacking, its functioning is severely damaged. Analogously, in the case of football dynamics, the lack of complexity would be related to low level played games. Therefore, our framework provides a tool that can help to detect a lack of performance in the teams.

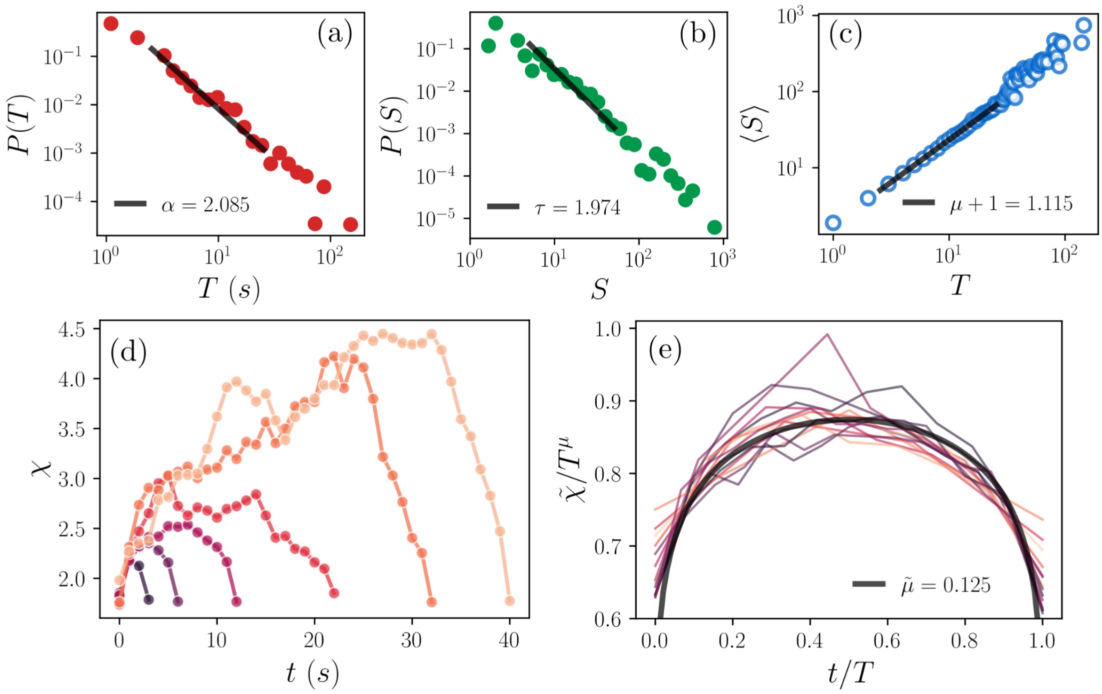

Fig. 1 Self-similarity in the series of κ. (a and b) Probability distributions of avalanche lifetime P(T) and avalanche size P(S). (c) Relation between avalanches lifetime T and the mean value of the size of the avalanches S. (d) Several examples of avalanches with a different lifetime. (e) Collapse of the avalanches produced by rescaling. Black solid lines in (a)–(c) and (e) show the result of nonlinear fit in the drawn regions.