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Explosive Contagion in Networks

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The spread of social phenomena such as behaviors, ideas or products is an ubiquitous but remarkably complex phenomenon. A successful avenue to study the spread of social phenomena relies on epidemic models by establishing analogies between the transmission of social phenomena and infectious diseases. Such models typically assume simple social interactions restricted to pairs of individuals; effects of the context are often neglected. Here we show that local synergistic effects associated with acquaintances of pairs of individuals can have striking consequences on the spread of social phenomena at large scales. The most interesting predictions are found for a scenario in which the contagion ability of a spreader decreases with the number of ignorant individuals surrounding the target ignorant. This mechanism mimics ubiquitous situations in which the willingness of individuals to adopt a new product depends not only on the intrinsic value of the product but also on whether his acquaintances will adopt this product or not. In these situations, we show that the typically smooth (second order) transitions towards large social contagion become explosive (first order). The proposed synergistic mechanisms therefore explain why ideas, rumours or products can suddenly and sometimes unexpectedly catch on.

Communication between pairs of individuals constitutes the basic building block of macroscopic contagion and dissemination of social phenomena such as behaviors, ideas or products. The mathematical formulation for social diffusion is reminiscent of the spread of infectious diseases and it is indeed common to use the term *viral* to refer to the rapid advent of a product or an idea. Following this analogy, compartmental epidemic models such as the Suceptible-Infected-Susceptible (SIS) or the Susceptible-Infected-Recovered (SIR) are often used to describe the dynamics of the transmission of social phenomena[1–3].

Epidemic models assume that the transition to macroscopic epidemic invasions in a population can be fully explained in terms of microscopic contagions between pairs of individuals. However, the dynamics of social transmission do not only depend on the characteristics of the transmitting and receiving individuals (*e.g.* on attitude or persuasiveness) but also depend on the context of the transmission event. In particular, individuals connected in some way to transmitter-receiver pairs of individuals might have important and unexpected effects on the spread of social phenomena at the global population level[4,5].

The first attempt to include the influence of the context within an epidemiological modelling framework was made by Daley and Kendal (DK)[6]. In the DK model, an individual spreading a rumor or idea may stop spreading it and become a stifler after realizing that the rumor is already known by some of its contacts. The importance of accounting for this effect was highlighted in their work by showing that a rumor can reach a large fraction of a population even if it is transmitted at an infinitesimally small rate α. This finding was in sharp contrast with prototype SIR epidemics which ignore the effects of individuals surrounding infected-susceptible pairs and only predict large invasions if the rate of transmission of infection is larger than a certain critical value, *i.e.* if $\alpha > \alpha_c$[7]. Despite the different location of the invasion threshold given by the DK and SIR models, both models and their variants[8] predict that the number of individuals affected by the spreading phenomenon increases smoothly with increase of the pair transmission rate, α. This corresponds to a *second-order phase transition* from non-invasive to invasive regime at the critical value, α_c. Continuous transitions were also obtained with an extended SIR model involving context-dependent transmission mechanisms assuming that each pairwise contagion can be enhanced or diminished depending on the number of infected/spreader individuals surrounding the transmitter-receiver pair[9,10].

A continuous transition between the non-invasive and invasive regimes is not able to explain the fact that social phenomena often become accepted by many people overnight. Examples include the sudden unfolding

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J.G.G. and F.J.P.R. designed the research. J.G.G., L.L., S.N.T. and F.J.P.R. performed the research. J.G.G., S.N.T. and F.J.P.R. wrote the paper.

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