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Interconnected evolution of epidemic and public vaccination opinion

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During the COVID-19 pandemic, humanity faced not only a problem of a spread of the pandemic itself, but also an unexpected phenomenon of formation of negative attitude towards vaccination in the society. Since this latter process does significantly affect development and resulting consequences of the pandemic, it is very important to build qualitative understanding of factors influencing formation of public opinion in the particular context of epidemic dynamics.

To develop a quantitative model describing interrelated evolution of epidemics and epidemics-related attitude it is natural to use a two-layered network with interconnected strata containing networks on which there takes place formation of epidemics and epidemics-related attitude/opinion respectively. The particular model we build combines an Ising-type mechanism of formation of binary yes/no-type opinion operating on the social contact network coupled to the SIRS (Susceptible–Infected–Recovered–Susceptible) epidemic mechanism (see [1, 2] and references therein) operating on the network of physical contacts in real space. The model does thus describe two interrelated spreading phenomena taking place in the two-layer network in which two networks are glued at nodes representing agents.

Behavioural motives behind epidemics were previously analysed in game-theoretic setting in the literature on vaccination decision formation (for detailed review see [3] and references therein). However, to the best of authors' knowledge, these models mostly analyse the vaccination-related free-rider type problems. The COVID 19 pandemic showed that at the early stages of viral spreading vaccination decisions are to a large extent based not on a proper factual analysis of contagion probability with or without vaccination, but mostly on subjective analysis of opinion of acquaintances, information from media, etc., as factual data on vaccination efficiency, virus spreading and its danger are not yet available or seem to be not enough reliable. One of possible ways of describing public opinion formation in the binary choice setting is to use an Ising-type model [4–11]. The present paper introduces an Ising-type model describing vaccination-related decisions.

The main results of the paper are the following.

First, we uncover a nontrivial dependence between the noise amplitude influencing the vaccination opinion formation and the fraction of recovered agents (i.e. people who caught the virus and later recovered from it). It turns out that an increase of the noise amplitude triggers two oppositely directed effects. On the one hand, public opinion formation on vaccination takes more time and, therefore, epidemics spreading is faster. On the other hand, the probability of reaching an equilibrium where almost all individuals are vaccinated and, therefore, epidemics terminates, is higher. A superposition of these oppositely directed trends leads, in principle, to an existence of some "optimal" noise amplitude. The position of this optimum is, however, strongly dependent on the values of model parameters.

Second, we uncover a new effect related to the external field influence. In the model under consideration the external field represents an intensity of the official information delivery. We show that if initial beliefs on vaccination and agents' attitude to official information sources are highly correlated and clusterized, growing intensity of the official information delivery intensity can lead to a decrease of probability of reaching a preferable equilibrium with respect to vaccination attitude and, consequently, to potential growth of epidemics – related risks.

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