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# Rise of an alternative majority against opinion leaders

K. Tucci [a], J.C. González-Avella [b], M.G. Cosenza [a,*]

[a] Grupo de Caos y Sistemas Complejos, Centro de Física Fundamental, Universidad de Los Andes, Mérida, Venezuela

[b] Departamento de Física, Pontificia Universidade Católica do Rio de Janeiro, Caixa Postal 38071, 22452-970 RJ, Brazil

## HIGHLIGHTS

- We investigate the role of opinion leaders in the collective behavior of a society.
- We challenge the idea that opinion leaders are essential for propagating behaviors.
- A majority group emerges having a state non-interacting to that of opinion leaders.
- We study the role of the network connectivity for the occurrence of this phenomenon.

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## ABSTRACT

We investigate the role of opinion leaders or influentials in the collective behavior of a social system. Opinion leaders are characterized by their unidirectional influence on other agents. We employ a model based on Axelrod's dynamics for cultural interaction among social agents that allows for non-interacting states. We find three collective phases in the space of parameters of the system, given by the fraction of opinion leaders and a quantity representing the number of available states: one ordered phase having the state imposed by the leaders; another nontrivial ordered phase consisting of a majority group in a state orthogonal or alternative to that of the opinion leaders, and a disordered phase, where many small groups coexist. We show that the spontaneous rise of an alternative group in the presence of opinion leaders depends on the existence of a minimum number of long-range connections in the underlying network. This phenomenon challenges the common idea that influentials are fundamental to propagation processes in society, such as the formation of public opinion.



## 1. Introduction

Propagation processes describe many important activities in societies, such as opinion formation, epidemic propagation, culture dissemination, viral marketing, and innovation diffusion, and their study is of much interest in social, biological and political sciences [1–5]. A central argument in the research of these processes has been that the most influential agents – a minority of individuals who influence an exceptional number of their peers – are fundamental to the propagation of behaviors in a society [6–8]. These agents are called opinion leaders, influentials, or spreaders [9–12]; in opinion dynamics models they are also named zealots, inflexibles, or committed agents [13–16]. Experimental investigation on a social network (Facebook) revealed that influential individuals are actually less susceptible to influence than noninfluential individuals [17]. The activity of opinion leaders has been considered an important resource in the diffusion of information

* Corresponding author.
*E-mail address:* mcosenza@ula.ve (M.G. Cosenza).

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and marketing strategies in society [18]. On the other hand, a common idea in social networks has been that the most connected people are responsible for the largest scale of spreading processes [19–21].

Recently, some works have questioned this so-called 'influentials hypothesis' [22]; for example, it has been argued that social contagion is driven by a critical mass of individuals susceptible to influence rather than by influentials [22]; and that there are circumstances under which the most highly connected or the most central people have little effect on a spreading process [23].

Although the notion of opinion leadership seems clear, precisely how and when the influence of opinion leaders over their environment shapes opinions and trends across entire societies remains an open problem. In this paper we present a dynamical agent-based model to investigate the collective behavior of a social system under the influence of opinion leaders. We define opinion leaders as agents that can affect the state of other agents, but their state remains unchanged; i.e., we assume that the interaction leader–agent is unidirectional. This simplifying assumption expresses the basic nature of the interaction with opinion leaders as described in the literature [6–18]. This also corresponds to the notion of cultural status proposed by Axelrod [5]. The unidirectional interaction dynamics of opinion leaders is similar to that of an external field, or mass media, acting on a social system [24,25]. Then, opinion leaders can be regarded as distributed mediators or originators of mass media messages in a society [6–8].

As interaction dynamics, we employ Axelrod's rules for the dissemination of culture among social agents [5], a non-equilibrium model that has attracted much attention from physicists [26,27,24,25,28–32]. In this model, the interaction rule between agents is such that no interaction takes place for some relative values characterizing the states of the agents. This type of interaction is common in social and biological systems where there is often some bound for the occurrence of interaction between agents, such as a similarity condition for the state variable [33–36].

We show that for low values of the fraction of opinion leaders present, the system is driven towards the opinion state of the leaders. However, above some critical value of the fraction of opinion leaders, we find the nontrivial result that a majority group emerges in the system possessing a state non-interacting – or alternative – with that of the leaders, challenging the influentials hypothesis. When the number of available states for the agents is large, the system reaches a disordered state where many small groups coexist. These three collective phases are characterized on the space of parameters of the system, given by the fraction of opinion leaders and a quantity representing the number of available states.

## 2. Social dynamics in the presence of opinion leaders

We consider a system of $N$ agents located at the nodes of a network. The agents are distributed into two populations: a population $\alpha$ representing opinion leaders having a fixed opinion or cultural state, with size $N_\alpha$; and a population $\beta$ of agents capable of changing their states, with size $N_\beta$, such that $N_\alpha + N_\beta = N$. The fraction of opinion leaders is $\rho = N_\alpha/N$. Both opinion leaders and agents in $\beta$ are randomly assigned to the nodes in the network. The set of neighbors of an agent $i \in \beta$ is denoted by $\nu_i$. The state of agent $i \in \beta$ is given by an $F$-component vector $x^f_\beta(i)$, $(f = 1, 2, \dots, F)$, where each component can take any of the $q$ different values $x^f_\beta(i) \in \{0, 1, \dots, q-1\}$. On the other hand, opinion leaders share the same state, i.e., if $i \in \alpha$, $x^f_\alpha(i) = y^f$, where each component $y^f$ is fixed and remains invariant during the evolution of the system. At any given time, a selected agent in population $\beta$ can interact with any agent in its neighborhood, which can be either another agent in $\beta$ or an opinion leader in population $\alpha$, in each case following the dynamics of Axelrod's model for cultural influence [5]. As initial condition, each state $x^f_\beta(i)$ is randomly assigned one of the $q^F$ possible vector states with a uniform probability. Then, the dynamics of the system is defined by the following iterative algorithm:

(1) Select at random an agent $i \in \beta$ and an agent $j \in \nu_i$ whose state we generically denote by $x^f(j)$.
(2) Calculate the overlap between the states of agents $i$ and $j$, defined as

$$d(i,j) = \begin{cases} \displaystyle\sum_{f=1}^{F} \delta_{x^f_\beta(i)\, y^f}, & \text{if } j \in \alpha, \\ \displaystyle\sum_{f=1}^{F} \delta_{x^f_\beta(i)\, x^f_\beta(j)}, & \text{if } j \in \beta. \end{cases} \tag{1}$$

(3) If $0 < d(i,j) < F$, with probability $d(i,j)/F$ choose $h$ randomly such that $x^h_\beta(i) \neq x^h(j)$ and set $x^h_\beta(i) = y^h$ if $j \in \alpha$, or $x^h_\beta(i) = x^h_\beta(j)$ if $j \in \beta$. If $d(i,j) = 0$ or $d(i,j) = 1$, the state $x_\beta(i)$ does not change.

In this model, opinion leaders can affect the states of other agents, but their state remains unchanged. Thus the dynamical changes of the system occur on the population $\beta$. We shall consider small values of $\rho$ to take into account the observation that opinion leaders constitute a minority in a social system [6–8,17].

When no opinion leaders are present ($\rho = 0$), a system subject to Axelrod's dynamics reaches a stationary configuration in any finite network, where the agents form domains of different sizes. A domain is a set of connected agents that share the same state. A homogeneous phase in a system is characterized by $d(i,j) = F$, $\forall i, j$. The coexistence of several domains corresponds to an inhomogeneous or disordered phase in a system. It is known that, on several networks, the system reaches a homogeneous phase for values $q < q_c$, and a disordered phase for $q > q_c$, where $q_c$ is a critical point [26,27].