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Modeling the dynamics of dissent

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HIGHLIGHTS

- A dissenting opinion can spread against authority from the systematic bias toward it.
- The heterogeneity in the authority and network is crucial for the opinion spreading.
- The detailed dynamics corresponds to percolation-like opinion group formation.

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ABSTRACT

We investigate the formation of opinion against authority in an authoritarian society composed of agents with different levels of authority. We explore a "dissenting" opinion, held by lower-ranking, obedient, or less authoritative people, spreading in an environment of an "affirmative" opinion held by authoritative leaders. A real-world example would be a corrupt society where people revolt against such leaders, but it can be applied to more general situations. In our model, agents can change their opinion depending on their authority relative to their neighbors and their own confidence level. In addition, with a certain probability, agents can override the affirmative opinion to take the dissenting opinion of a neighbor. Based on analytic derivation and numerical simulations, we observe that both the network structure and heterogeneity in authority, and their correlation, significantly affect the possibility of the dissenting opinion to spread through the population. In particular, the dissenting opinion is suppressed when the authority distribution is very heterogeneous and there exists a positive correlation between the authority and the number of neighbors of people (degree). Except for such an extreme case, though, spreading of the dissenting opinion takes place when people have the tendency to override the authority to hold the dissenting opinion, but the dissenting opinion can take a long time to spread to the entire society, depending on the model parameters. We argue that the internal social structure of agents sets the scale of the time to reach consensus, based on the analysis of the underlying structural properties of opinion spreading.

1. Introduction

How much an opinion against a firmly established authority can spread in a population is an important estimate of the population's adaptability [1], in particular when there exists a strong heterogeneity in the distribution of influential power regarding opinion formation. The topic of opinion formation has been studied widely to reveal the hidden mechanisms of a

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collective opinion dynamics on social networks [2–5]. There has been a wide variety of opinion formation models, such as the voter model [6,7], the majority rule model [8], the bounded confidence model [9], and the Sznajd model [10]. Many opinion formation models have focused on the effect of heterogeneity in a network structure for a global consensus [11] and considered heterogeneous distributions of personal characteristics—gender, age, job, economic level, personal interests [12,13], and so on, as those two areas of heterogeneity are important for opinion dynamics on networks [14,15].

However, most of those opinion formation models mix the concept of heterogeneity in the individual level with the heterogeneity in social structures, even though structural and individual heterogeneity can be independent of each other [16,17]. Previous studies derive the personal heterogeneity in influential power from the structural heterogeneity, such as the number of neighbors (or "degree", in the terminology of network science) [11] or PageRank (or "eigenvector centrality") [18,19]. There have been other attempts to highlight heterogeneity in individual attributes [20–23], as well as in authority dispersion and in asymmetric options. [24] and asymmetric opinions [25]. Nevertheless, all these are different from the genuine authority dispersion, so we are still lack understanding of the transmission of opinions held by non-influential agents, grounded in the heterogeneity of both network-structural properties and influential power or authority. To address this need, in this paper, we investigate the following questions: when a population is composed of different levels of authority of agents, how can an opinion held by obedient agents with less influential power be spread to the whole population? How do the structure and authority collectively contribute to the spreading process?

To answer these questions, we introduce a stylized opinion formation model in a population with the prescribed authority scores assigned to its agents, who are connected via networks [26]. We assume heterogeneously distributed authority scores assigned to the agents, and each agent additionally has two essential characteristics: the willingness to uphold a dissenting opinion against authority and the confidence level for their own opinion. The probability of dissent is characterized by the parameter hinted at in the experiment of Milgram [27], which exemplifies the obedient tendency to an authoritative person's injustice order for the individual level, along with the tendency to resist the authority when there exist companions who would do so together. The agents apply the social comparison process to judge the relative authority level [28]. An illustrative case is a corrupt society where authoritative agents have an agreement on a certain immoral decision, and a less influential population has a dissenting opinion against it. As the results of our analysis, we present the crucial role of the correlation between network structure and authority, via intrinsic social relations representing the authority comparison process.

2. Model

To model the society presented in Section 1, for each individual we take heterogeneous degree distributions representing heterogeneous networks structures where individuals reside, heterogeneous authority levels of the individuals, and the correlation between them. In addition, we also incorporate individuals' inner characteristics for the confidence to their own opinion and willingness to follow the dissenting opinion. For heterogeneous structures, we construct a network composed of N agents as nodes; thus, we use the terms "agent" and "node" interchangeably in this paper. The edges between the nodes represent the relationship between the nodes on which the authority comparison and the opinion spreading are based.

For network generation, we use an unweighted and undirected scale-free network (SFN) without self-loop and multiple edges, from the configuration model [29]. The degree distribution follows the power-law, $p(k) \sim k^{-\lambda}$, which yields a degree sequence $\{k_i\}$ for node $i \in \{0, 1, \ldots, N-1\}$ (thus there exist N nodes in total). We set the minimum degree $k_{\min} = 2$ for the initial network construction. To keep the overall connectivity, we use the largest connected component from the initially constructed network for the dynamics of our model. We verify that the change of network sizes in terms of the number of nodes and edges due to this selection process is negligible. Given the resultant connected network, we adjust the degree exponent λ to control the degree heterogeneity, where the smaller λ results in more heterogeneous degree distributions. When $\lambda = 2$, the average degree $\langle k \rangle \simeq 9$, and the maximum degree $k_{\max} \simeq 306$. For $\lambda = 3$, $\langle k \rangle \simeq 4$ and $k_{\max} \simeq 100$. As the control group compared to such heterogeneous structures, we also take the fully connected network to simulate the well-mixed population, which is expected to more accurately follow the result of the analytic derivation based on the mean-field approximation in Section 3.

For the authoritarian structure, we assign an intrinsic authority score $\{s_i\}$ to each node $i \in \{0, 1, \ldots, N-1\}$. To generate heterogeneous authority scores, we extract random numbers (real numbers, in contrast to the natural numbers for the degree sequence $\{k_i\}$ by definition) from the power-law distribution $p(s) \sim s^{-\gamma}$ with the minimum value of unity. The setup is inspired by the Pareto distribution [30] of wealth and income, which are indirect representatives of authority. Therefore, in general, we have two sets of power-law distributed values: λ for the degrees $\{k_i\}$ and γ for the authority scores $\{s_i\}$. For simplicity, however, we use the same power-law exponent for the authority score and degree, i.e., $\lambda = \gamma$ in our model, assuming that the same power-law exponent controls both structural and authoritarian heterogeneities. The set of authority scores $\{s_i\}$ for agents $i \in \{0, 1, \ldots, N-1\}$ will be correlated with the agents' degree with different types of correlations. In addition, we take the two representative cases for the degree exponent to see the effect of the heterogeneity of degree distribution: relatively heterogeneous $\gamma = 2$ and relative homogeneous $\gamma = 3$.

To investigate the effect of the correlation between authority and network structures [16,17], we take three types of correlations: positive, no (uncorrelated), and negative correlations. The positive correlation implies that agents with higher authority scores have larger degree values. To control the correlation in practice, we sort both $\{s_i\}$ and $\{k_i\}$ from the smallest to the largest and match the indices of the sorted $\{s_i\}$ with the sorted $\{k_i\}$ in their exact order (as a result, the rank-based correlations such as Spearman's r or Kendall's $\tau = 1$). The negative correlation is achieved by the opposite way of ordering,