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On social sensitivity to either zealot or independent minorities

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ABSTRACT

Individuals act in their own self-interest, but in so doing contribute to the observed wellbeing of society, as determined using the self-organized temporal criticality (SOTC) model. This model identifies the timing of crucial events as a new mechanism with which to generate criticality, thereby establishing a way for the internal dynamics of the decision making process to suppress the sensitivity of social opinion to either zealot or independent minorities. We find that the sensitivity to the influence of zealots is much smaller than in the case of criticality with a fine tuning control parameter and the action of independent minorities may affect temporal complexity so as to realize the condition of ideal $1/f$ noise.

1. Introduction

The role played by committed minorities, *zealots* or *fanatics*, in the behavior adopted by large groups, whether it is in the apparently frivolous taking on of a fad or fashion, or the more serious adoption of new social conventions, has attracted the attention of a significant number of sociologists [1–3], physicists [4,5], network scientists [6–10], and engineers [11], in addition to scientists working in many other disciplines. These investigators explore, using a variety of models from multiple vantage points, how in times of crisis, committed activists may produce political, or other, changes of significant importance to society, in spite of their relatively small number. A common feature of these models is criticality, at which point the aggregate of individuals becomes a collective with a single purpose, and under the right conditions the zealots can leverage the organized behavior to redirect the collective. We observe that in a system of finite size the global consensus state is not permanent and times of crisis occur when there is an ambiguity concerning a given social issue. The correlation function within the cooperative system becomes similarly extended as it is observed at criticality. This combination of independence (free will) and long-range correlation makes it possible for very small, but committed minorities to produce substantial changes in social consensus, see *e.g.* [10].

On the other hand, fluctuations are assumed to be generated by the same form of self-organization that brought the system to criticality in the first place. This assumption is frequently made by researchers studying the dynamics of the human brain [12–15] leaving open, however, the origin of criticality in this context. Allegrini et al. [16] emphasized that the intermittent nature of these fluctuations, according to the prediction that the inverse power-law (IPL) spectrum:

$$S(f) \propto 1/f^{\beta}, \tag{1}$$

with the IPL index,

$$\beta = 3 - \mu, \tag{2}$$

should lead to the ideal $1/f$ - noise condition $\beta = 1$ for $\mu = 2$. The IPL index μ labels the time intervals between crucial events [10] at the tipping point (critical point of a phase transition); the three dimensional Ising model [17] generates $\mu = 1.55$, whereas the decision making model (DMM) [4] yields $\mu = 1.5$ at criticality.

Xie et al. [18] studied the influence of inflexible individuals on social behavior, using the Naming Game to model the social interaction, and found that when the committed minority reaches a threshold of 10% of the population the opinion of the entire social network can be reversed to conform to that of the minority. The theoretical results were shown to be supported by laboratory experiment [1]. The theoretical influence of the minority was also shown to be largely independent of the structure of the interactions within the social model, but can be determined by as much as 10% to as little as 4% for a sparse network [19]. The percentage at which the tipping point occurs is clearly model dependent and can vary from 4% to 15% [20,21].

In this paper we consider also another kind of minority, the minority of *independents*. An independent is an individual who makes

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her choices with no influence from her nearest neighbor. In the long-time scale the behavior of the independent looks erratic and she exerts an influence on society, because their nearest neighbors make their choice taking into account also the erratic choices of the independent.

The analysis herein is based on the form of self-organization, called Self-Organized Temporal Criticality (SOTC) recently proposed in [22]. The individuals of this society have to make a choice between cooperation and defection. This paper shows that the bottom-up form of spontaneous organization described by SOTC strongly reduces the efficiency of the committed minority in redirecting the behavior of society. We show that the SOTC model also disrupts the action of independents, paying however the price of changing the IPL index μ that provides a measure of the system's complexity. This is an important finite size effect and its discussion makes this paper meet the request of the call for papers [23].

In Section 2 we adapt the linked concepts of intuition and deliberation by constructing a dynamic two-level network model, where single individuals are located at the two-dimensional lattice nodes of a composite network. The composite network consists of two interacting subnetworks. One subnetwork is based on the decision making model (DMM) [10] and leads to strategy choices made by the individuals under the influence of the choices of their nearest neighbors. The other subnetwork measures the Prisoner's Dilemma Game (PDG) payoffs of these choices [24]. The interaction between the two subnetworks is carried out by increasing or decreasing the individual imitation strength K_r according to the history of payoffs to that individual. This is a generalization of the self-organized criticality (SOC) model [25], called the self-organized temporal criticality (SOTC) model [22,26].

In the SOTC model the decisions made by individuals are assumed to be consistent with the criterion of bounded rationality [27], which were expanded by Kahneman [28], and more recently discussed from the perspective of evolutionary game theory [29,30]. Rand and Nowak [29] acknowledge the tension between what is good for the individual, what is good for society and they discuss the tension between them in the language of evolutionary game theory. Without reviewing the long history of studies into the nature of cooperation, defection, and the theoretical strategies that people may adopt to overcome their selfish urges, we note the meta-analysis of 67 empirical studies of cognitive-manipulation of economic cooperation games by Rand [30]. He concluded from his meta-analysis that all the experimental data could be explained using a dual-purpose heuristic model of cooperation, a model consisting of a dynamic interaction between deliberation and intuition. Deliberation is considered to be a rational process that always favors non-cooperation, whereas intuition is treated as an irrational process that can favor cooperation or non-cooperation, depending on the individual.

In Section 3 we present numerical results built on those presented earlier [22] to determine the social sensitivity to the uncompromising behavior of a small number of individuals holding either inflexible opinions or changing their opinion with no influence from their nearest neighbors. The committed minority individuals are assigned the state D and do not change their opinion. The independent change their choices in random way. In both these cases the minorities are totally independent of their nearest neighbors but their nearest neighbors are influenced by them according to the DMM rules. The remarkable result is that the SOTC approach to criticality turns out to be much less sensitive to the influence of these minorities that in the case of criticality is obtained by a fine tuning of the control parameter K. It is also remarkable that the independent minority does succeed in affecting the temporal complexity making it possible to realize $\mu = 2$, the condition that generates $1/f$ noise, produced by the brain in the wakefulness state.

2. Two-level network model

The dynamics of the model of interest consists of the interaction between two distinct subnetworks. The behavior of one subnetwork consists of decisions made by individuals influenced by their nearest neighbors and realized by the DMM [10]. The second subnetwork assesses the choice made by the individual and assigns a payoff based on the PDG model. The interaction between the two subnetworks is established by making the individual's imitation strength K_r increase or decrease, according to whether the average difference of the last two payoffs increase or decrease, in accordance with the corresponding changes in K_r. Although each of these imitation strengths is selected selfishly, which is to say the individual choices of imitation strengths are made in the best interest of the individual making the decision at that time, the social system is driven by the resulting internal dynamics towards the state of cooperation, which has the greatest social benefit, which is a unique property of the SOTC. The individuals of the two-level network are located at the nodes of a regular two-dimensional network, denoted by the symbol r, which is equivalent to the double index (i, j).

2.1. The DMM subnetwork

The intuition mechanism proposed by Rand [30] is realized through the dynamics of one subnetwork through the DMM. The DMM on a two-dimensional lattice is based on individuals imperfectly imitating the majority opinion of their four nearest neighbors, thereby biasing the probability of deciding to transition from being a cooperator (C) to being a defector (D):

$$g_{CD}^{(r)} = g_0 \exp\left\{-K_r \frac{N_C^{(r)} - N_D^{(r)}}{N}\right\}, \qquad (3)$$

where $N_C^{(r)}$ is the number of nearest neighbors to individual r that are cooperators, $N_D^{(r)}$ the number of defectors, and each individual on the simple lattice has $N = 4$ nearest neighbors. In the same way the transition rate from defectors to cooperators $g_{DC}^{(r)}$ is obtained from Eq. (3) by interchanging indices. The unbiased transition rate is $g_0 = 0.01$ throughout the calculations, and $1/g_0$ defines the time scale for the process.

To realize SOTC, as we shall explain in Section (2.3), the imitation strength of the single individual changes in time, according to the interaction with the PDG subnetwork. The goal of this paper, as mentioned in Section 1, is to discuss the influence on the SOTC organization of a fraction ρ of individuals that do not fit the bottom-up approach to cooperation. These individuals are *zealots* (fanatics) or *independent* individuals. The zealots are individual who do not change their choice. In this paper they always select defection. The independent individuals exert a random perturbation on the SOTC organization. These individuals have an imitation strength $K_r = 0$, which does not change in time. Furthermore to enhance their random nature we assign to them $g_0 = 0.5$.

The DMM in isolation, with neither zealots nor independent individuals either, assigns to all the individual imitation strengths K_r the same value K, a control parameter that has been shown to make this theory undergo critical phase transitions and to be a member of the Ising universality class in which all the members of the network can act cooperatively, depending on the magnitude of K [10]. In the present two-level model the K_r can all be different. This decision making process is fast, emotional and in its original form does not involve any reasoning about payoff.

To denote the effect of imitation we assign to the units selecting the cooperation state the value $\xi_r = 1$ and to the units in the defection state the value $\xi_r = -1$. To establish whether cooperation or defection is selected by the social system we use the mean field