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A Spinglass Model of Video Recorded Street Violence

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1 Introduction

When groups encounter challenges in uncertain situations, collective action—in our case attack of or defense against opponents—has been explained by models of thresholds [1], cascades [2], and critical mass [3]. These models draw on initiative takers or leaders to initiate cooperation. We use an Ising spinglass model with asymmetric spin values, which is more parsimonious because it has no assumptions on initiative takers or leaders. It shows that cooperation can start by accidental cooperators rather than exceptionally zealous ones. More importantly, our model makes a novel prediction about the temporal unfolding of collective action. When a proportion of group members, p, does not cooperate, versus $1-p$ conditional cooperators who may cooperate if enough others do, a mean field analysis predicts that collective action breaks out in a burst if p is below a critical value, p_c [4]. Above the critical value there is no burst but a fizzle of one individual or few group members who start cooperating asynchronously. Furthermore, small groups and small clusters in large groups are more easily agitated to cooperate than large groups. The predicted critical value, the two temporal patterns, and the size effect are strongly supported by video data of street fights between a focal group against one or more opponents [4].

2 Results

Member i of a (fledgling) group can contribute, with behavioral variable $S_i = C$, or defect, with $S_i = -D$, and $0 < D < C$. Initially, everyone defects. Network tie $A_{ij} > 0$ means that i is in close proximity of and pays attention to group member j, else $A_{ij} = 0$. We assume that attention is reciprocal but not necessarily equal. Because people tend to respond to proportions of their social environment rather than absolute numbers [2], ties are row-normalized, with $w_{ij} = A_{ij}/\sum_{j=1}^{n} A_{ij}$. The Ising spinglass model [5] boils down to minimizing the following Hamiltonian equation

$$H = -\sum_{i \neq j}^{n} w_{ij} S_i S_j. \quad (1)$$

One can relate D and C to the symmetric spinglass model [5] through a mapping $\{-D, C\} \rightarrow \{S_0 - \Delta, S_0 + \Delta\}$ with a bias $S_0 = (C-D)/2$ with respect to 0. Then the two behavioral options are symmetrical at each side of S_0 at an offset $\pm\Delta$. It can be shown that the asymmetry in S is equivalent to the symmetric model (where $S_0 = 0$) with an external field, $2S_0$ [6].

Payoffs are defined to facilitate interpretation, but they play no role in the spinglass computations by the Metropolis algorithm or mean field approach [5]. The payoff for a cooperator is the same as in evolutionary game theory [7]; when an actor cooperates among N_C other cooperators, $P_C = \theta(N_C + 1)/n - 1$, with an enhancement factor $\theta \geq 1$. A defector's payoff is almost the same as in game theory, $P_D = \theta N_C/n + Q$, except for a factor Q, which establishes that P_D approximates P_C when D approximates C; $Q = (\theta/n - 1)(1 - R); R = (C - D)/(C + D)$; and $\theta = \theta_0 + R$ with a base rate $\theta_0 \geq 1$.

The dynamics of a group are driven by turmoil, T, analogous to temperature in the original model. Turmoil consists of opponents' provocations (see Methods). If turmoil increases, the chance that one or few individuals accidentally cooperate increases, although this hardly affects the level of cooperation of te group. At a critical level T_c, however, there is a burst of cooperation wherein many group members participate, depending on p (Fig. 1). If p increases, the proportion of participants in the burst obviously decreases, but if $p \geq p_c = S_0/\Delta = R$, the bursty pattern does not appear [4].

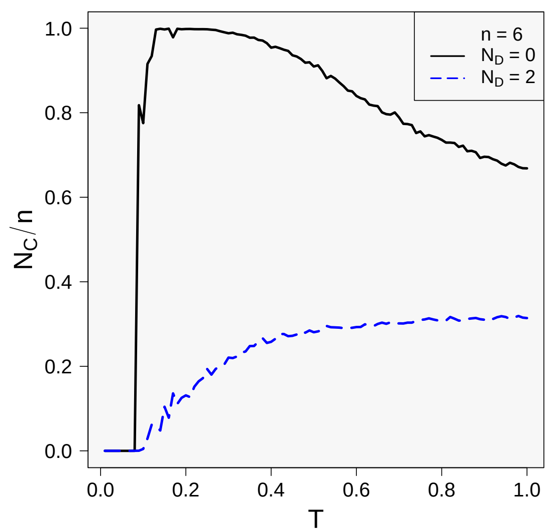

Fig. 1. Level of cooperation (N_C/n) with increasing turmoil (T) in a clique of $n = 6$ individuals, simulated by the Metropolis algorithm [5]. The continuous line depicts a burst at T_c without defectors ($p = 0$) and the dashed line a fizzle with two defectors ($p = p_c$).

Given the choice of $C = 1$, as in game theory [7], we choose $D = 1/2$ as a first approximation halfway in between the trivial values of $D = 1$ and $D = 0$ [6]. Whatever value one chooses, for cooperation to pose a nontrivial dilemma, H (Eq. 1) must have a global minimum at $N_c = n$ and a single maximum somewhere in between 0 and n. Using $D = 1/2$ in a mean field approach implies that $p_c = 1/3$ [4]. Simulations show that when $p \geq p_c$ and $T > T_c$ there is no burst but a fizzle (Fig. 1). How about actual street fights?

Bystanders often film street violence with their phones, and upload their videos to websites such as YouTube, LiveLeak, and WorldStarHipHop, where we collected our data. Our sample is not random with respect to violence, but in all likelihood it is random with respect to the temporal patterns thereof. We analyzed 59 groups in the size range $2 \leq n < 10$; see Methods and [4] for details. After coding, distinguishing bursts from nonbursts was straightforward.

With only one exception, turmoil preceded collective violence. The critical level of turmoil (T_c) for bursts is case-specific and depends on group size, both in absolute number and relative to the size of the opponent group, and on p. The proportions of defectors in groups with bursts (mean = 0.19; s.d. = 0.21) and groups without (mean = 0.49; s.d. = 0.27) are box-plotted in Fig. 2 (Welch test $t = 4.796$; $p = 6.411 \times 10^{-6}$; df = 54.76). Despite the simplicity of the model, the critical level of $p_c = 1/3$, drawn as vertical line in Fig. 2, separates most of the bursts from the nonbursts in the data.

Consistent with simulations [8], we found that cooperation in small groups tends to start at lower turmoil than in larger groups (cor. = 0.53) and in the latter, it tends to start in small clusters. Because turmoil starts small, cooperation starts earlier in small groups. This bottom up mounting of cooperation is similar to bottom up synchronization in the Kuramoto model [9]. In simulations, decreasing clustering of a network of given size and density increases T_c [8]. Increasing p also increases T_c, whereas the degree distribution has no effect on T_c.

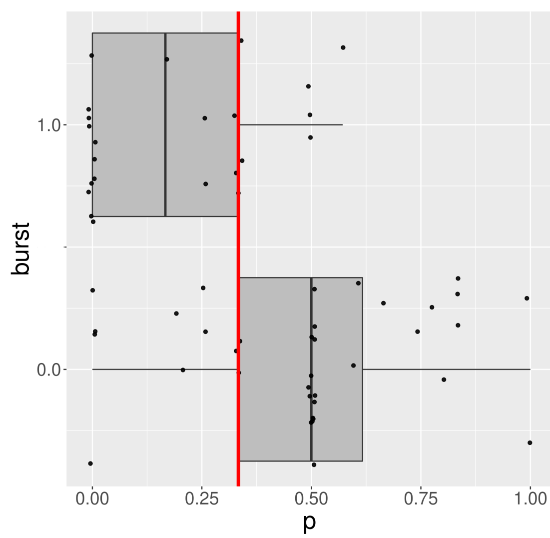

Fig. 2. The proportion of defectors, p, and the predicted critical level p_c as vertical line, with boxplots of bursts (1) and fizzles (0). The data points are scattered around the pertaining boxplot.

The simple Ising model is now a century old and has been applied to a wide range of problems [10, 11], to which we add the dilemma of collective action where it provides a new insight into its temporal unfolding. It explains cooperation parsimoniously without recourse to rationality, initiative takers, reputations, norms, or feedback through selective incentives, which one finds in numerous alternative models across the literature. In this first empirical application, we showed that it can explain the dynamics of street violence, and in all likelihood, more discoveries lay ahead.

3 Methods

The videos were coded using Noldus Observer XT 14 software. Videos were played at half speed many times over, and one of us discussed the coding of each with one or two assistants. Each of 406 individuals was coded for belonging to a focal, opponent, or third-party group. Their behavior was interpreted and represented on the timeline.

We coded *violence* when force was used against another's body (punching, slapping, kicking, hitting, stomping) and/or when another person's body was forcefully moved. For a *burst* of violence, we required that at least half of a group participated, or both individuals did in a dyad, and they started fighting less than 2 seconds after the first, with a 5% margin. We subsumed the following behaviors of members of the opponent group under *turmoil* for the focal group: aggressing, including fighting gestures; pulling off clothing (jackets or vests); pulling up pants; pointing toward opponents; provocative gesturing with fingers or hands (as an invitation to engage); bending forward toward an opponent; encroaching (invading opponents' personal space through using or damaging objects belonging to them); teasing, such as lightly hitting or ridiculing; and violence. Because turmoil accumulates in participants' minds, we calculated the level of turmoil from the beginning of the video until a focal group's (first) maximum participation in violence, by multiplying the duration of each instance of turmoil by the number of individuals involved, and adding up all weighted instances.

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