# CRITICAL BEHAVIOR IN A SMALL-SCALE, HETEROGENEOUS, SOCIAL SYSTEM

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Over the last decade new technologies for making measurements coupled to large data sets have led to the discovery that many biological systems sit near a critical point [1]. In these systems small perturbations can induce large-scale change that may allow access to alternative functional states. On the other hand, sensitivity to perturbations means a lack of robustness, and change induced by perturbation may not be adaptive. Here we develop a framework to quantify critical behavior in a heterogeneous social system, demonstrating its use on data on conflict dynamics and fight sizes from an animal society model system (*Macaca nemestrina*, $n = 48$). Because we have data from every individual in this social system, we are not interested in its properties as it scales to larger sizes. Instead, viewing a phase transition as a point of increased sensitivity caused by a collective instability, we operationalize criticality in information theoretic terms using generalized measures of sensitivity and stability. First, the Fisher information is a generalized susceptibility that diverges at true phase transitions [2]. Second, instabilities are measured with respect to perturbations in individual activity levels. In a branching process model, this corresponds to the basic reproductive ratio $R_0$, with a phase transition in an infinite system at $R_0 = 1$. In an equilibrium model, an analogous quantity measures the stability of the high-temperature mean field solution, with connections to the spin glass transition [3,4]. In this specific system, using equilibrium (Ising) and dynamic (branching process) models we find peak sensitivity and instability is reached when on average 3-5 individuals are "forced" to join fights, suggesting that the system is near enough to an instability to make use of its properties of information amplification, but far enough that stable social structure can persist.

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