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Physics of Life Reviews 12 (2015) 1–21

PHYSICS of LIFE reviews

www.elsevier.com/locate/plrev

Review

Statistical physics of crime: A review

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Received 5 August 2014; received in revised form 20 October 2014; accepted 3 November 2014

Available online 6 November 2014

Communicated by L. Peliti

Abstract

Containing the spread of crime in urban societies remains a major challenge. Empirical evidence suggests that, if left unchecked, crimes may be recurrent and proliferate. On the other hand, eradicating a culture of crime may be difficult, especially under extreme social circumstances that impair the creation of a shared sense of social responsibility. Although our understanding of the mechanisms that drive the emergence and diffusion of crime is still incomplete, recent research highlights applied mathematics and methods of statistical physics as valuable theoretical resources that may help us better understand criminal activity. We review different approaches aimed at modeling and improving our understanding of crime, focusing on the nucleation of crime hotspots using partial differential equations, self-exciting point process and agent-based modeling, adversarial evolutionary games, and the network science behind the formation of gangs and large-scale organized crime. We emphasize that statistical physics of crime can relevantly inform the design of successful crime prevention strategies, as well as improve the accuracy of expectations about how different policing interventions should impact malicious human activity that deviates from social norms. We also outline possible directions for future research, related to the effects of social and coevolving networks and to the hierarchical growth of criminal structures due to self-organization.

Keywords: Punishment; Rehabilitation; Recidivism; Pattern formation; Evolution; Self-organization

1. Introduction

An unattended broken window invites bypassers to behave mischievously or even disorderly. Soon, one broken window may become many, and the inception of urban decay is in place. Similarly, a subway graffiti, however beautiful and harmless in appearance, points to an unkept environment that anyone can desecrate, signaling that more egregious

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http://dx.doi.org/10.1016/j.plrev.2014.11.001
1571-0645/

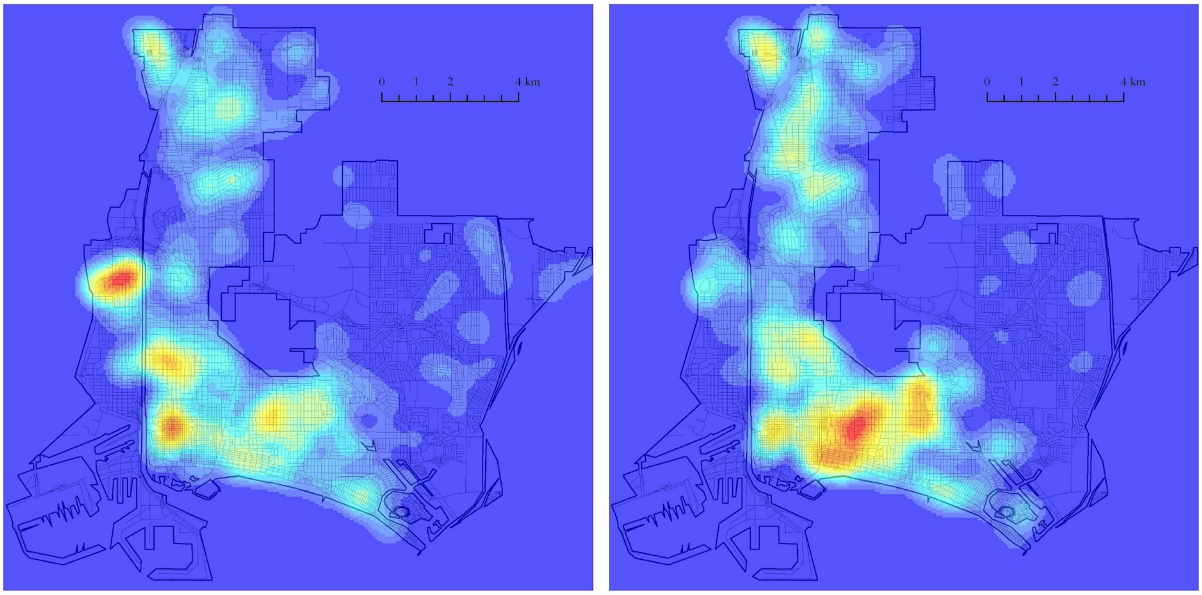

Fig. 1. Dynamic changes in residential burglary hotspots for two consecutive three-month periods, starting June 2011, in Long Beach, California. The emergence of different burglary patterns is related to how offenders move within their environments and how they respond to the successes and failures of their illicit activities. Residential burglars tend to return to previously victimized locations, or to their close vicinities, after having acquired information on the properties, the schedules of inhabitants, possible surveillance systems – a reasoning that is closely aligned with "routine activity theory" [2]. The figure is reproduced from [3].

damage will be tolerated. Panhandlers, drunks, addicts, prostitutes, and loiterers are more likely to frequent neglected subway stations than orderly and carefully patrolled ones. The 1982 seminal paper by Wilson and Kelling [1] contains many more lucid examples and anecdotes to introduce the "broken windows theory", articulating how seemingly unimportant and petty signals of urban disorder may elicit antisocial behavior and serious crime. Although not immune from criticism, this work has since become a widely adopted criminological theory.

To mathematicians and physicists, the broken windows theory may be reminiscent of complexity science and self-organized criticality [4], where seemingly small and irrelevant changes at the local level frequently have unexpected consequences at the global level later in time. Feedback loops, bifurcations and catastrophes [5], as well as phase transitions [6], are commonly associated with emergent phenomena stemming from the nonlinearities inherent to complex social systems [7]. Crime is ubiquitous, yet far from being uniformly distributed across space or time [8–13]. This is evidenced also by the dynamic nucleation and dissipation of crime hotspots shown in Fig. 1 [3,14], as well as by the emergence of complex geographical gang and organized crime networks. Such intriguing pattern formation naturally invites quantitative mathematical analyses, to which we attend in this review.

We consider crime as a complex phenomenon, where nonlinear feedback loops and self-organization give rise to system-wide unexpected behaviors that are difficult to understand and control [15]. Data provided by the Federal Bureau of Investigation shown in Fig. 2 suggest that crime deterrence policies are struggling to have the desired impact. Indeed, if viewed over a time scale of decades, the relative frequency of offenses, regardless of crime type, is heavily undulating and lacks persistent downward momentum.

Outside the realm of mathematical modeling, there exist well-known and widely accepted theories of criminal behavior. According to "routine activity theory" [2], most criminal acts are born out of the convergence of three factors: the presence of likely offenders and of suitable targets and the absence of guardians to protect against the attempted crime. Residential burglary, grand theft auto, armed robberies, pickpocketing and rape are examples of such criminal acts. Other crimes may imply a precise target focus, such as in murder for revenge or other clan-type retaliation offenses.

If viewed upon sociologically, these "ingredients" of routine activity theory are relatively straightforward conditions that obviously favor criminal activity. Mathematically, however, routine activity theory allows us to model criminal offender dynamics as deviations from simple random walks. This is due to built-in heterogeneities in target