PHYSICS of LIFE reviews

ELSEVIER

Reply to comment

Physics for better human societies
Reply to comments on "Statistical physics of crime: A review"

Maria R. D'Orsogna [a,b], Matjaž Perc [c,d,e,*]

[a] Department of Mathematics, California State University at Northridge, Los Angeles, CA 91330, USA
[b] Department of Biomathematics, UCLA, Los Angeles, CA 90095, USA
[c] Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška cesta 160, SI-2000 Maribor, Slovenia
[d] Department of Physics, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia
[e] CAMTP – Center for Applied Mathematics and Theoretical Physics, University of Maribor, Krekova 2, SI-2000 Maribor, Slovenia

We would like to thank all the experts for their insightful and very interesting comments that have been submitted in response to our review "Statistical physics of crime" [1]. We are delighted with the large number of comments that have been written, and even more so with the overwhelmingly positive opinions that these comments communicate to the wider audience [2–10]. Although methods of statistical physics have long proven their value in relevantly addressing challenges in the social sciences and the humanities [11–31], such interdisciplinary research often still struggles for funding and recognition at many academic levels.

In this reply, we would like to highlight the coming of age of complex systems research, network science, as well as advanced data analysis as applied to socio-technical systems in the broadest possible sense. We would also like to emphasize that the theoretical and modeling tools that have been developed by physicists, mathematicians, and computer scientists have reached the maturity to effectively address the many challenges of our time, not least aiding the surveillance, analysis, and ultimately also the prediction and prevention of crime. In what follows, we briefly discuss the comments on our review in the light of this fact, and we also point out the many outstanding challenges as well as opportunities for future research.

* Corresponding author.

E-mail addresses: dorsogna@csun.edu (M.R. D'Orsogna), matjaz.perc@um.si (M. Perc).

The comment by Kenett [6] brings the coming together of physics and social sciences beautifully to the point, and we could not agree more that combining the tools and theories of statistical physics with the ever growing data available in the social sciences will yield a deeper and better understanding of social life and its dynamics. This "marriage" will indeed be most mutually rewarding if experts from both disciplines could work side-by-side to develop optimal resilient infrastructure for sustaining our social wellbeing. Along the same lines, Pacheco [7] emphasizes that, crime as a complex system may benefit significantly from a statistical mechanics approach by drawing on important clues from the impact of simple, yet general concepts that together lead to the emergence of the complex dynamics associated with criminal behavior. For the same reason, and despite their simplicity, evolutionary games [32–35] are emerging as a very promising theoretical framework to study the socio-economic aspects of crime, in particular related to reward, punishment and fear of collective failure as means to further prosocial behavior [36–43]. Abou Chakra and Hilbe [2] also attest usefulness and merit to such modeling approaches, and they constructively conclude that such models are built on simple and intuitive principles that allow us to gain analytical insights into the dynamics of crime and punishment. Similarly, Barbaro [3] advocates a place for agent-based models in crime-related research for their usefulness in the study of intervention strategies or helping to assess the plausibility of behavior hypotheses. We fully agree, and we believe this is an excellent position that will promote such interdisciplinary research long into the 21st century.

In terms of outstanding challenges, a recent Editorial in Nature [44] makes an important point. Namely, while physics, chemistry, biology and the environmental sciences can deliver wonderful solutions to some of the challenges facing individuals and societies, if social, economic and/or cultural factors are not included in the framing of the questions, a great deal of creativity can be wasted. As aptly concluded by Donnay [4], this is especially relevant for studies that seek to provide insights that ought to be directly relevant to policy makers. Ultimately, social scientists will be most interested in new methodological approaches and would most easily recognize the full merit of the innovative research reviewed in [1] if studies were to actively address longstanding and central questions that are of broad interest in the field, in some cases with a specific eye to the particular. We fully agree that one of the next steps is to include more local "ingredients" to focus on specific urban layouts, crime types, or societal attitudes, in order to be more to the point and concrete, especially for the benefit of policy makers and stakeholders. To this end, interdisciplinary collaborations matter decisively: inputs from different perspectives will lead to more complete studies, approaches, questions, and possibly answers. The closer the collaboration between experts from the social and physical/mathematical sciences, the better.

On a similar note, Ribeiro [9] rightfully emphasizes that, although statistical physicists may represent the ideal professional to take on such an interdisciplinary challenge, physicists nevertheless need to invest even more into moving further away from their "comfort zone" and to really make their research count in terms of actual applicability. Of course, dialogue with different disciplines is challenging and requires flexibility, openness and humility. We hope the examples provided in our review are an attempt in this direction, as we have made a sincere effort to showcase research involving criminologists, anthropologists, economists and urban planners working together with physicists and mathematical modelers.

As pointed out by Ferrara [5], however, to a considerable degree the actual applicability of the theory and models reviewed is already at hand, for example in the form of computational prediction of crime from mobile phone data [45,46]. Methods of statistical physics, applied mathematics and computational models informed by big data might provide just that crucial edge in the never-ending arms race between law enforcement agencies, policy makers, and researchers, who oppose criminal and terrorist organizations that operate to dismantle modern societies.

We would also like to thank Primicerio [8] for pointing out the important role of mathematical modeling in modern criminology, and to emphasize how rich the panorama of the methods that can help us to better understand and prevent crime truly is.

We conclude by citing from the comment by Rodríguez [10], who notes that "the most important reason why this is such a compelling avenue of research is its untapped potential". Indeed, current research has only scratched the surface of what can be done, and we gladly join the hope that, as the gap between the modeling and real-life is reduced, this research will hopefully be able to move more and more from having an exploratory nature towards having predictive and truly applicable value.

Acknowledgements

References

[1] D'Orsogna MR, Perc M. Statistical physics of crime: a review. Phys Life Rev 2015;12:1–21 [in this issue].

[2] Abou Chakra M, Hilbe C. Modelling the dynamics of crime and punishment: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:22–3 [in this issue].

[3] Barbaro A. A place for agent-based models: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:24–5 [in this issue].

[4] Donnay K. Why interdisciplinary research enriches the study of crime: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:26–7. [in this issue].

[5] Ferrara E. Toward computational crime prediction: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:28–9 [in this issue].

[6] Kenett DY. Bridging the gap between physics and the social sciences: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:30–1 [in this issue].

[7] Pacheco JM. Crime as a complex system: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:32–3 [in this issue].

[8] Primicerio M. The role of mathematical modelling in modern criminology: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:34–5 [in this issue].

[9] Ribeiro HV. We need more empirical investigations and model validation for a better understanding of crime: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:36–7 [in this issue].

[10] Rodríguez N. Recent advances in mathematical criminology: comment on "Statistical physics of crime: a review" by D'Orsogna and Perc. Phys Life Rev 2015;12:38–9 [in this issue].

[11] Gell-Mann M. Simplicity and complexity in the description of nature. Eng Sci 1988;57:2–9.

[12] Bak P. How nature works: the science of self-organised criticality. New York: Copernicus Press; 1996.

[13] Mantegna RN, Stanley HE. An introduction to econophysics: correlations and complexity in finance. Cambridge: Cambridge University Press; 2000.

[14] Albert R, Barabási AL. Statistical mechanics of complex networks. Rev Mod Phys 2002;74:47–97.

[15] Helbing D. Traffic and related self-driven many-particle systems. Rev Mod Phys 2001;73:1067.

[16] Marro J, Dickman R. Nonequilibrium phase transitions in lattice models. Cambridge: Cambridge University Press; 2005.

[17] Boccaletti S, Latora V, Moreno Y, Chavez M, Hwang D-U. Complex networks: structure and dynamics. Phys Rep 2006;424:175–308.

[18] Szabó G, Fáth G. Evolutionary games on graphs. Phys Rep 2007;446:97–216.

[19] Lazer D, Pentland A, Adamic LA, Aral S, Barabási AL, Brewer D, et al. Life in the network: the coming age of computational social science. Science 2009;323:721–3.

[20] Castellano C, Fortunato S, Loreto V. Statistical physics of social dynamics. Rev Mod Phys 2009;81:591–646.

[21] Fortunato S. Community detection in graphs. Phys Rep 2010;486:75–174.

[22] Galam S. Sociophysics: a physicist's modeling of psycho-political phenomena. Berlin: Springer; 2012.

[23] Conte R, Gilbert N, Bonelli G, Cioffi-Revilla C, Deffuant G, Kertesz J, et al. Manifesto of computational social science. Eur Phys J Spec Top 2012;214:325–46.

[24] Helbing D. Social self-organization. Berlin: Springer; 2012.

[25] Havlin S, Kenett DY, Ben-Jacob E, Bunde A, Hermann H, Kurths J, et al. Challenges of network science: applications to infrastructures, climate, social systems and economics. Eur Phys J Spec Top 2012;214:273–93.

[26] Barabási AL. The network takeover. Nat Phys 2012;8:14–6.

[27] Perc M. The Matthew effect in empirical data. J R Soc Interface 2014;11:20140378.

[28] Sornette D. Physics and financial economics (1776–2014): puzzles, Ising and agent-based models. Rep Prog Phys 2014;77:062001.

[29] Boccaletti S, Bianconi G, Criado R, del Genio C, Gómez-Gardeñes J, Romance M, et al. The structure and dynamics of multilayer networks. Phys Rep 2014;544:1–122.

[30] Kivelä M, Arenas A, Barthelemy M, Gleeson JP, Moreno Y, Porter MA. Multilayer networks. J Comput Netw 2014;2:203–71.

[31] Pacheco JM, Vasconcelos VV, Santos FC. Climate change governance, cooperation and self-organization. Phys Life Rev 2014;11:573–86.

[32] Maynard Smith J. Evolution and the theory of games. Cambridge, UK: Cambridge University Press; 1982.

[33] Hofbauer J, Sigmund K. Evolutionary games and population dynamics. Cambridge, UK: Cambridge University Press; 1998.

[34] Nowak MA. Evolutionary dynamics. Cambridge, MA: Harvard University Press; 2006.

[35] Sigmund K. The calculus of selfishness. Princeton, NJ: Princeton University Press; 2010.

[36] Dreber A, Rand DG, Fudenberg D, Nowak MA. Winners don't punish. Nature 2008;452:348–51.

[37] Rand DG, Dreber A, Ellingsen T, Fudenberg D, Nowak MA. Positive interactions promote public cooperation. Science 2009;325:1272–5.

[38] Hilbe C, Sigmund K. Incentives and opportunism: from the carrot to the stick. Proc R Soc B 2010;277:2427–33.

[39] Santos FC, Pacheco JM. Risk of collective failure provides an escape from the tragedy of the commons. Proc Natl Acad Sci USA 2011;108:10421–5.
[40] Van Segbroeck S, Pacheco JM, Lenaerts T, Santos FC. Emergence of fairness in repeated group interactions. Phys Rev Lett 2012;108:158104.
[41] Szolnoki A, Perc M. Evolutionary advantages of adaptive rewarding. New J Phys 2012;14:093016.
[42] Szolnoki A, Perc M. Correlation of positive and negative reciprocity fails to confer an evolutionary advantage: phase transitions to elementary strategies. Phys Rev X 2013;3:041021.
[43] Hilbe C, Traulsen A, Röhl T, Milinski M. Democratic decisions establish stable authorities that overcome the paradox of second-order punishment. Proc Natl Acad Sci USA 2014;111:752–6.
[44] Editorial. Time for the social sciences. Nature 2015;517:5.
[45] Catanese S, Ferrara E, Fiumara G. Forensic analysis of phone call networks. Soc Netw Anal Min 2013;3:15–33.
[46] Ferrara E, Meo PD, Catanese S, Fiumara G. Detecting criminal organizations in mobile phone networks. Expert Syst Appl 2014;41:5733–50.