



To vaccinate or not to vaccinate? A coevolutionary dilemma

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Volume 351, No. 9103, p637-641, 28 February 1998

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Early Report

RETRACTED: Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children

Dr AJ Wakefield, FRCP^{1,2}, SH Murch, MB, A Anthony, MB, J Linnell, PhD, DM Casson, MRCP, M Malik, MRCP, M Berelowitz, FRCPsych, AP Dhillon, MRCPath, MA Thomson, FRCP, P Harvey, FRCP, A Valentine, FRCR, SE Davies, MRCPath, JA Walker-Smith, FRCP

Altmetric 1,475

RETRACTED



DOI: [http://dx.doi.org/10.1016/S0140-6736\(97\)11096-0](http://dx.doi.org/10.1016/S0140-6736(97)11096-0)

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July 4, 2016

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Early Report

RETRACTED: Illnesses from the MMR vaccine, not autism, say scientistsDr AJ Wakefield, FRCP^{1,2}, FRCPsych³, FRCPsych, AP Dhillon, MRCGP⁴, Smith, FRCP 1,475
DOI: <http://dx.doi.org/10.1016/j.jch.2016.06.001> Article Info[Summary](#) | [Full Text](#)

Anti Vaccine Movement

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Here's The Truth About Vaccines And Herd Immunity

Natalia Reagan | Posted 04.26.2016 | Science

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This week is World Immunization Week and what better way to commemorate it than by discussing the facts about vaccines and the importance of herd immunity.

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How Anti-Vaccination Misinformation Could Exacerbate An International Health Emergency

Deena Zemelowitz | Posted 02.29.2016 | [Healthy Living](#)

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RETRA
colitis,Dr AJ Wakef
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Smith, FRCP

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DOI: <http://doi.org/10.1200/JCO.2013.56.10>

Article Info

Wales politics

Swansea measles epidemic: Worries over MMR uptake after outbreak

① 10 July 2013 | [Wales politics](#)

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Some parents are still ignoring the message to immunise their children against measles, an inquiry into the Swansea outbreak has heard.



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Review

Coupled disease–behavior dynamics on complex networks: A review

Zhen Wang^{a, b}, , Michael A. Andrews^c, , Zhi-Xi Wu^d, , Lin Wang^e, , Chris T. Bauch^f,
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Statistical physics of vaccination

Zhen Wang^{a, b}, , Chris T. Bauch^c, , Samit Bhattacharyya^d, Alberto d'Onofrio^e, Piero Manfredi^f, Matjaž Perc^{g, h}, Nicola Perraⁱ, Marcel Salathé^{j, k}, Dawei Zhao^l
 Show more

Wang, Z., et al. (2015). "Coupled disease-behavior dynamics on complex networks: A review". *Phys. of Life Rev.*, **15**, 1–29.

Wang, Z., et al. (2016). "Statistical physics of vaccination". In press in *Physics Reports*.

Vaccination dilemma

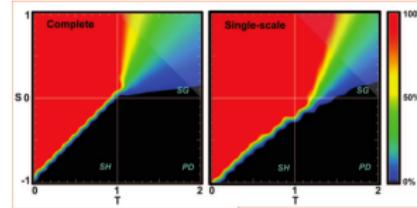


Erdős
Rényi

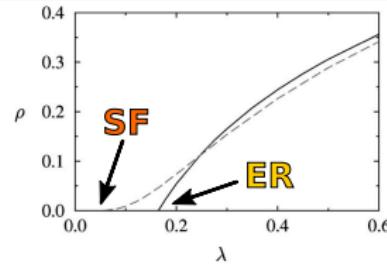
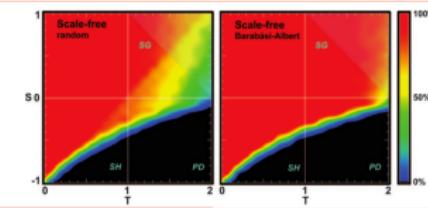


Scale
Free

ER



SF



Santos, F., et al. (2006). "Evolutionary dynamics of social dilemmas in structured heterogeneous populations." PNAS, **103**, 3490.

Pastor-Satorras, R., et al. (2001). "Epidemic Spreading in Scale-Free Networks." PRL, **86**, 3200.



**Cooperation VS Spreading
who will prevail?**

Can we trace some guidelines to bolster the adoption of pro-vaccine behaviours?



1. Motivation
2. (A very short) Introduction on epidemic spreading,
evolutionary game theory and multiplex networks
3. Evolutionary vaccination dilemma
4. Results
5. Take home messages



Epidemic Spreading

Compartmental Models

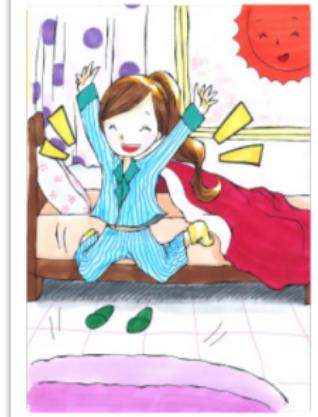


S - Susceptible (Healthy)



I - Infected (and infectious)

(From Petter Holme's blog)

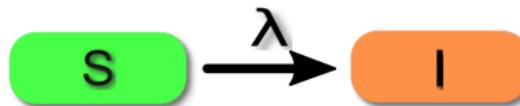


R - Recovered (immune/dead)

Pastor-Satorras, R., Castellano, C., Van Mieghem, P., & Vespignani, A. (2015). "Epidemic processes in complex networks".

Reviews of Modern Physics, 87, 925-979.

SI



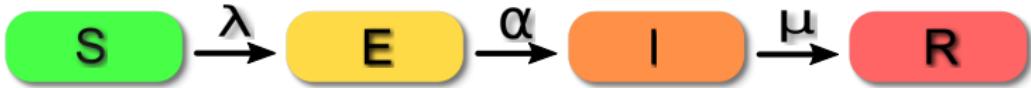
SIS



SIR



SEIR



Pastor-Satorras, R., Castellano, C., Van Mieghem, P., & Vespignani, A. (2015). "Epidemic processes in complex networks".
Reviews of Modern Physics, **87**, 925-979.

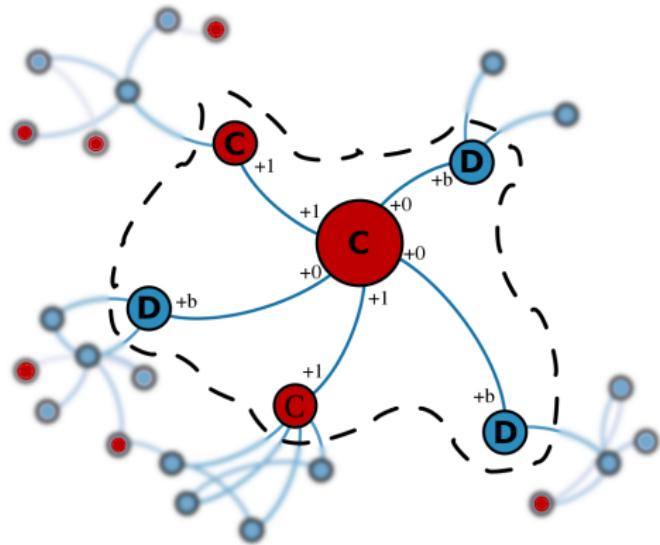
Evolutionary Games



Intro on evolutionary games

- Agents **states** are equal to **strategies** of a game;
- Consider the following **payoff matrix**:

$$\begin{array}{cc}
 C & D \\
 C & \begin{pmatrix} 1 & 0 \\ b & 0 \end{pmatrix} \text{ with } b > 1;
 \end{array}$$



Roca, C. P., et al. (2009). "Evolutionary game theory: Temporal and spatial effects beyond replicator dynamics."

Phys. of Life Rev., 6, 208.

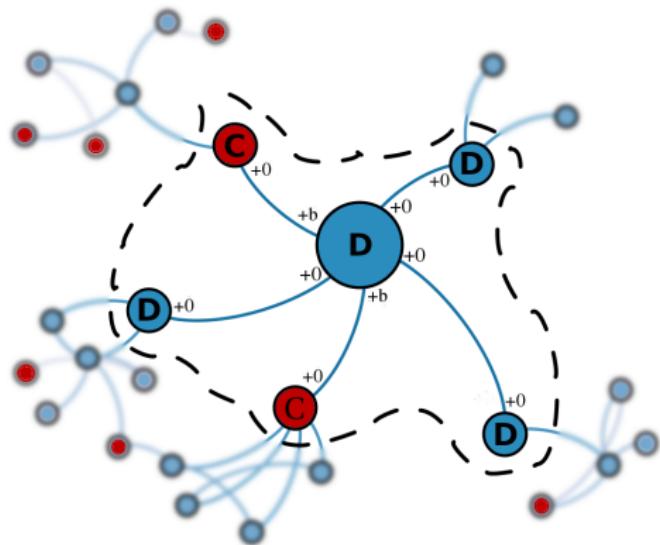
A. Gárdián, & Szolnoki, A. (2010). "Coevolutionary games—A mini review." Biosystems, 99, 109–125.

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Roca, C. P., et al. (2009). "Evolutionary game theory: Temporal and spatial effects beyond replicator dynamics."

Phys. of Life Rev., 6, 208.

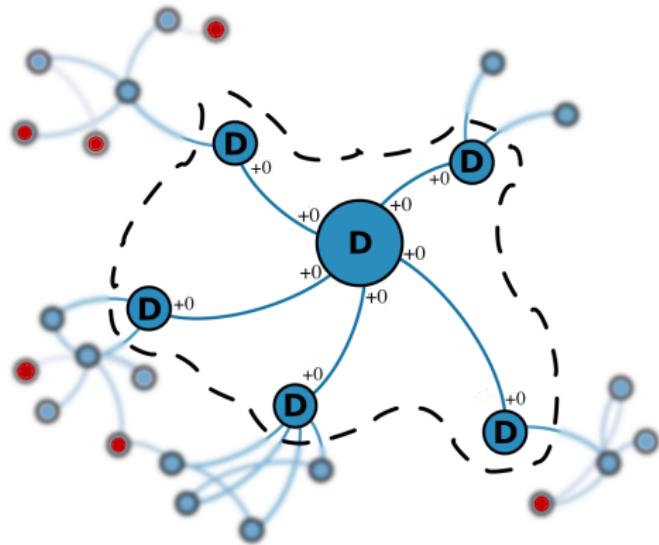
A. Gárdián, & Szolnoki, A. (2010). "Coevolutionary games—A mini review." Biosystems, 99, 109–125.

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$$\begin{array}{cc}
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 \end{array}$$

- Agents **update** their strategy;
- Repeat until stationary state.



Roca, C. P., et al. (2009). "Evolutionary game theory: Temporal and spatial effects beyond replicator dynamics."

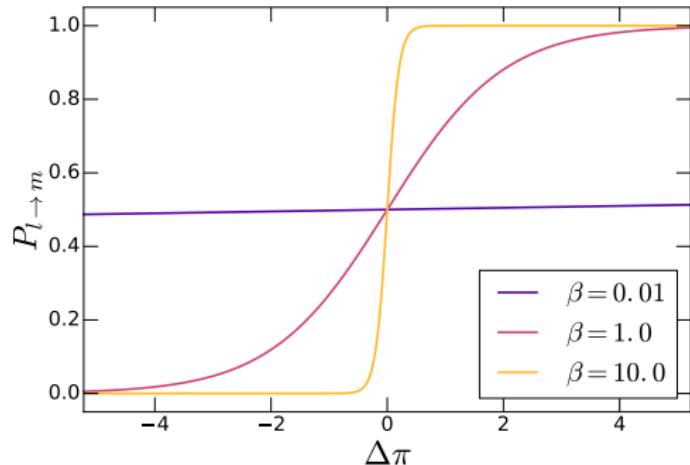
Phys. of Life Rev., 6, 208.

A. Gárdián, & Szolnoki, A. (2010). "Coevolutionary games—A mini review." Biosystems, 99, 109–125.

Intro on evolutionary games

Fermi's Rule

$$P_{I \rightarrow m} = \frac{1}{1 + e^{-\beta(\pi_m - \pi_I)}}.$$

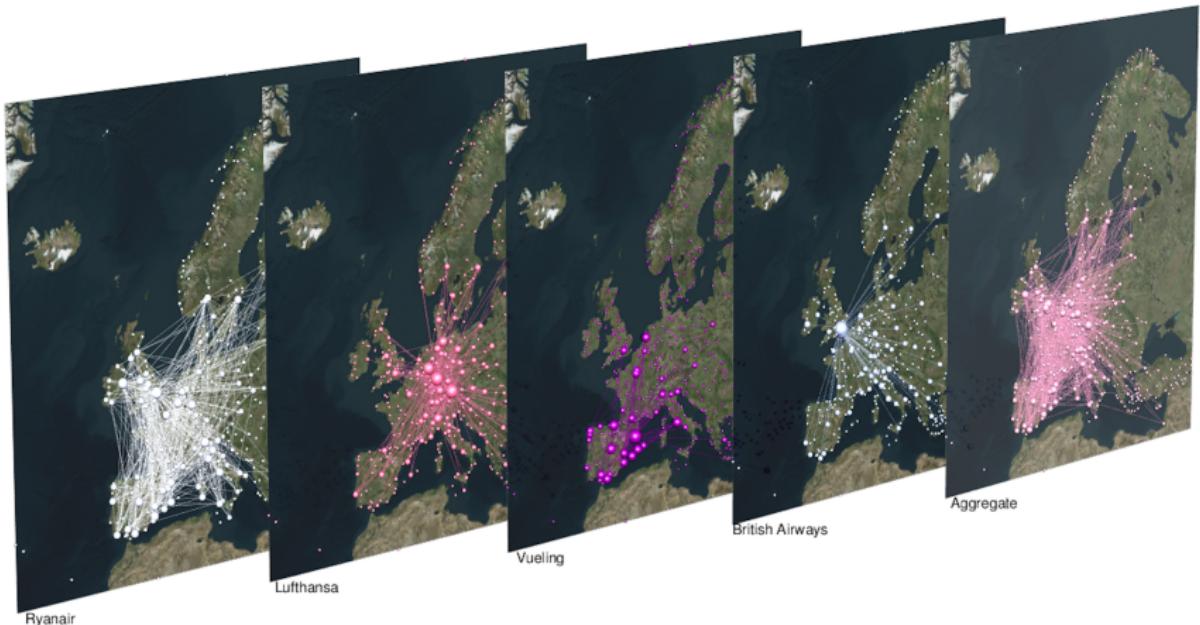


Roca, C. P., et al. (2009). "Evolutionary game theory: Temporal and spatial effects beyond replicator dynamics."

Phys. of Life Rev., 6, 208.

Perc, M., & Szolnoki, A. (2010). "Coevolutionary games—A mini review." Biosystems, 99, 109–125.

Multiplex Networks



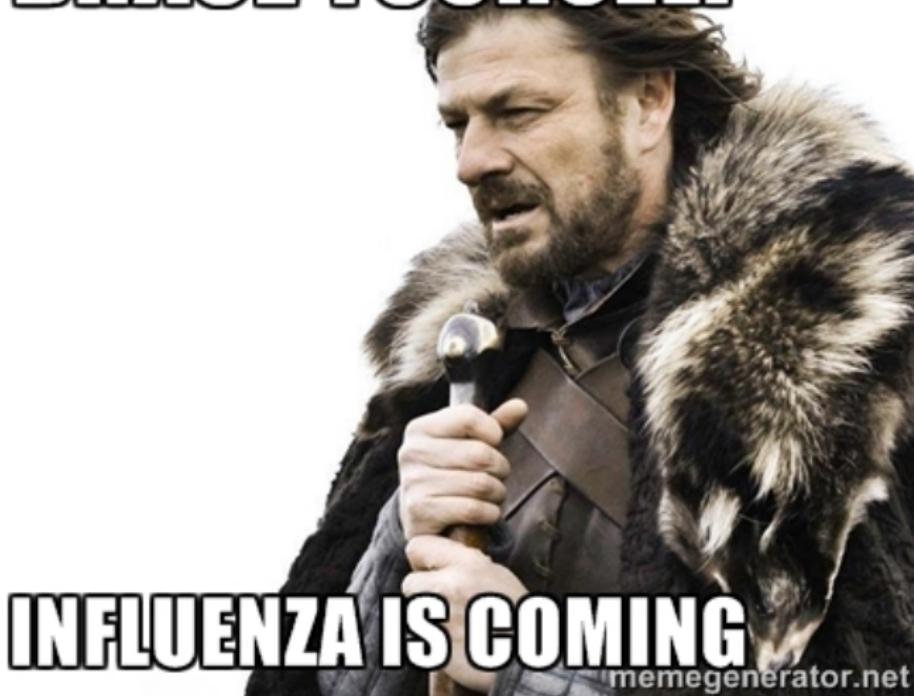
Boccaletti, S., et al. (2014). The structure and dynamics of multilayer networks. *Physics Reports*, **544**, 1–122.

Cardillo, A., et al. (2013). Emergence of network features from multiplexity. *Scientific Reports*, **3**, 1344.

Section 3

The coevolutionary model

BRACE YOURSELF



PHYSICAL REVIEW E

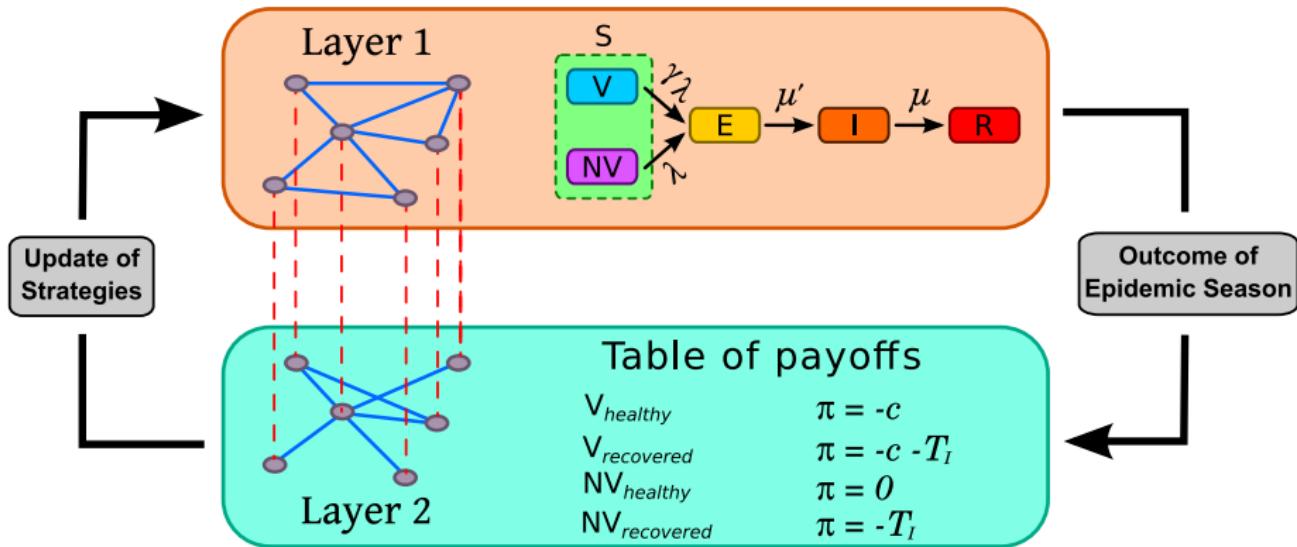
covering statistical, nonlinear, biological, and soft matter physics

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Evolutionary vaccination dilemma in complex networks

Alessio Cardillo, Catalina Reyes-Suárez, Fernando Naranjo, and Jesús Gómez-Gardeñes
Phys. Rev. E **88**, 032803 – Published 5 September 2013

A. Cardillo, et al. "Evolutionary vaccination dilemma in complex networks." Phys. Rev. E, **88**, 032803. (2013).

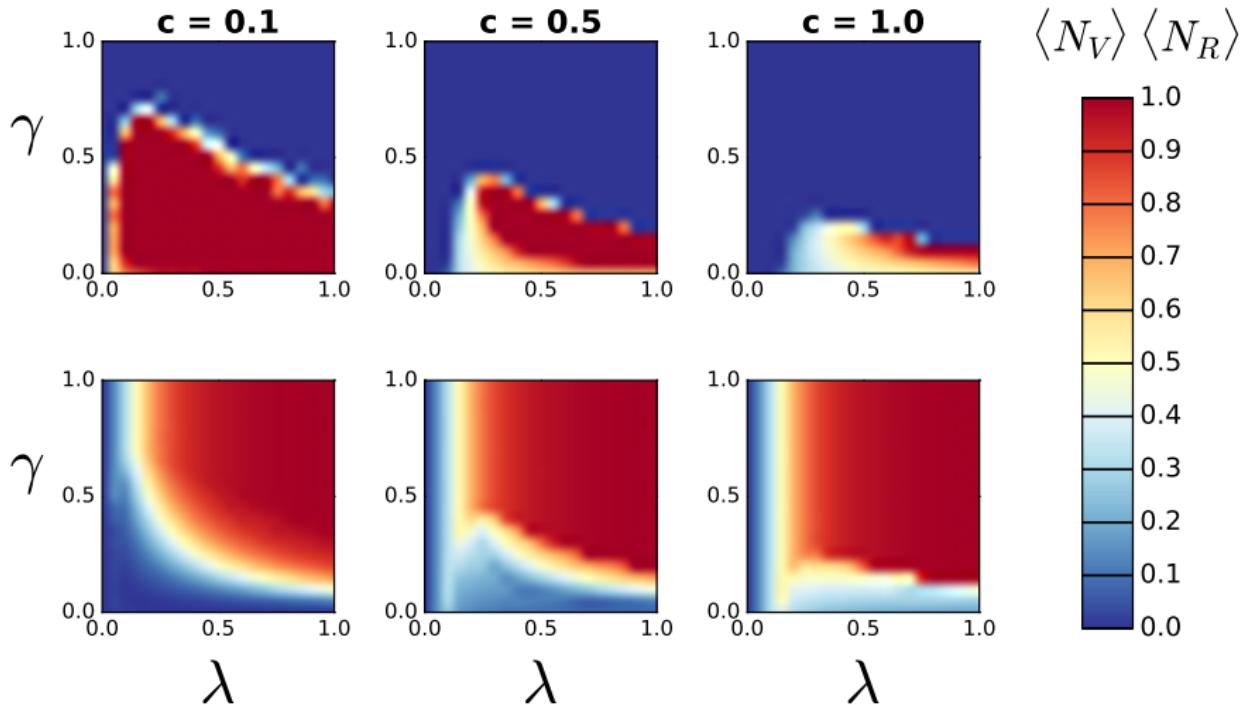


A. Cardillo, et al. "Evolutionary vaccination dilemma in complex networks." Phys. Rev. E, **88**, 032803. (2013).

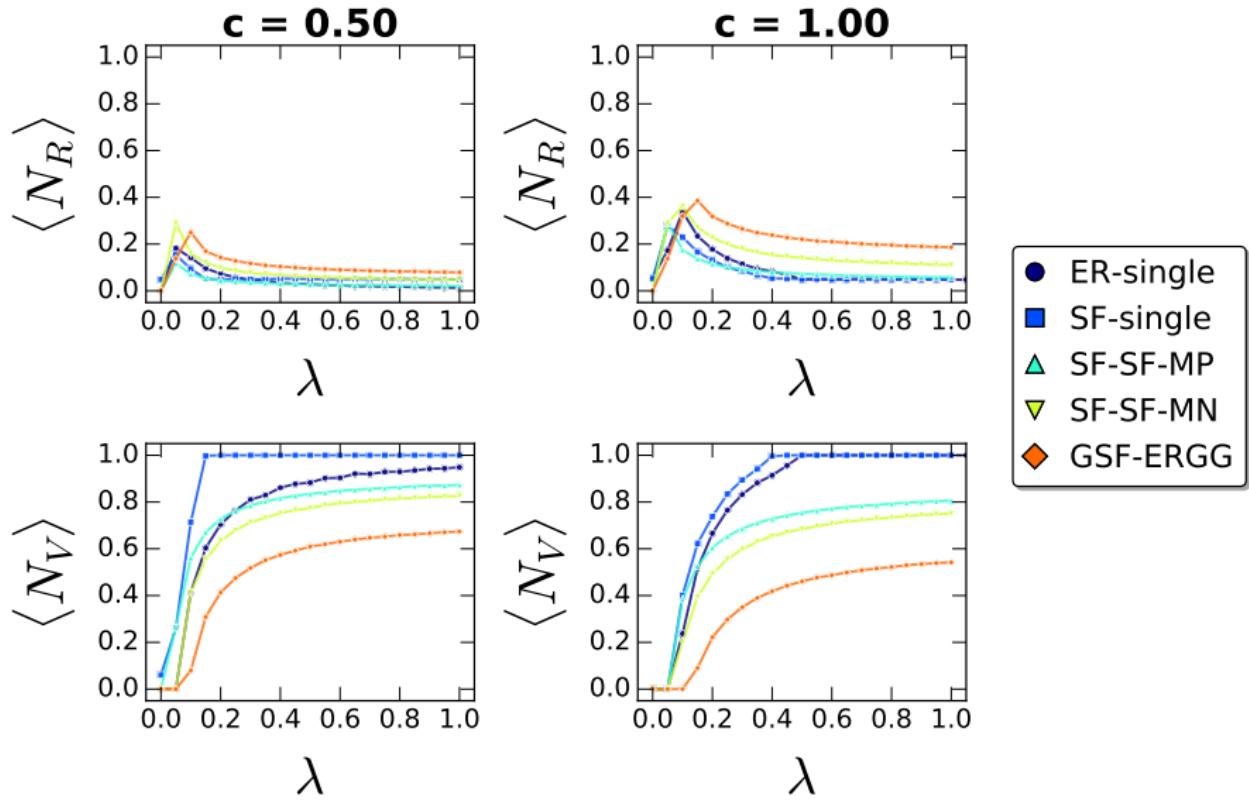
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Results

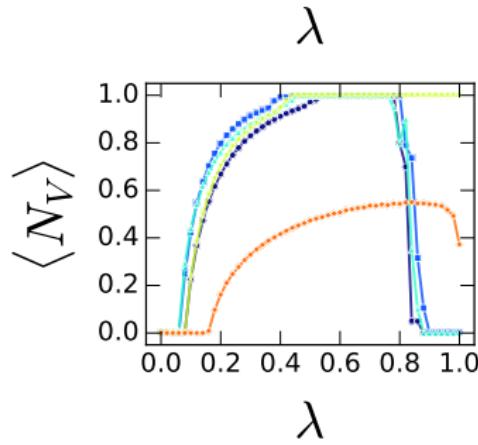
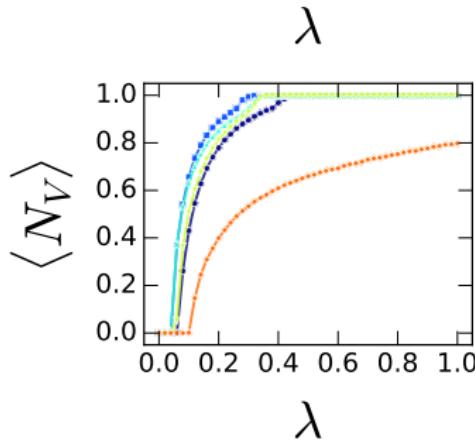
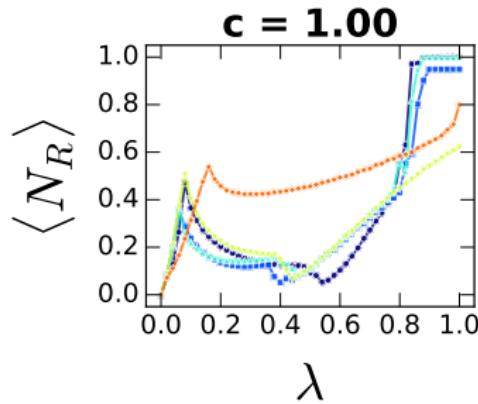
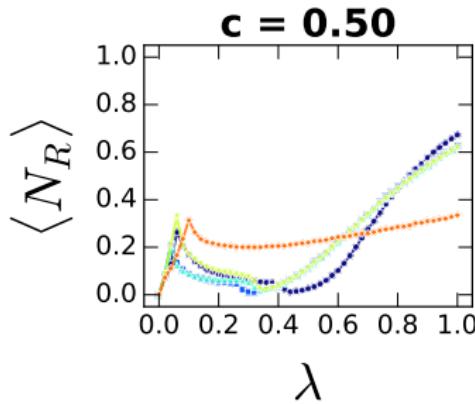
Global Behaviour (RGG - SF)



Effect of multiplexity



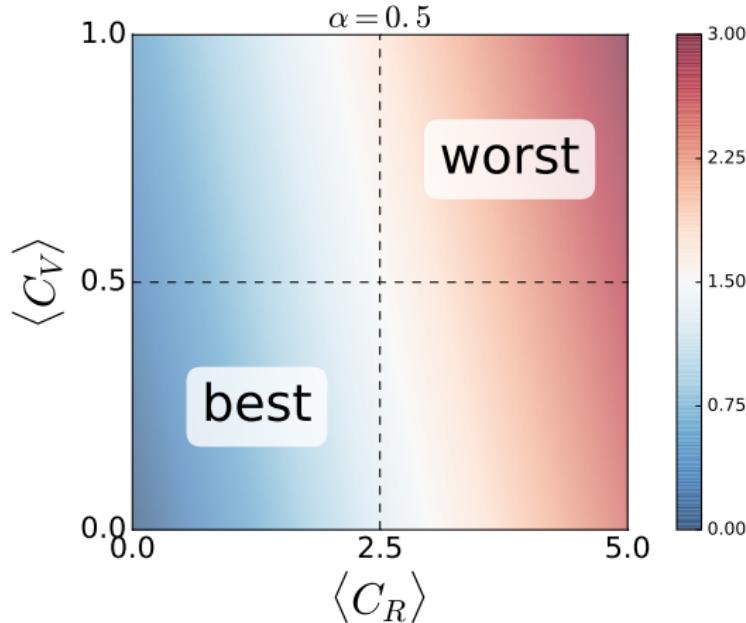
Effect of multiplexity



- ER-single
- SF-single
- ▲ SF-SF-MP
- ▽ SF-SF-MN
- ◆ GSF-ERGG

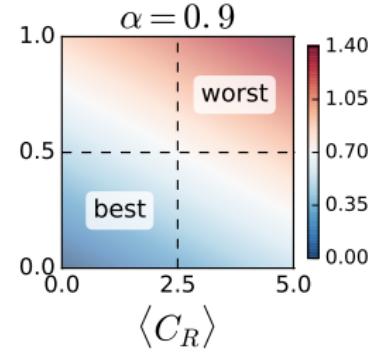
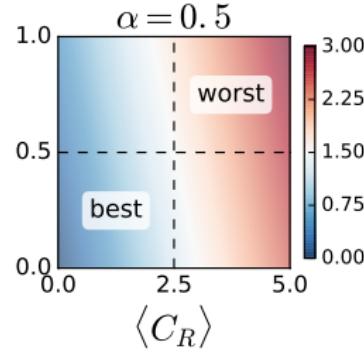
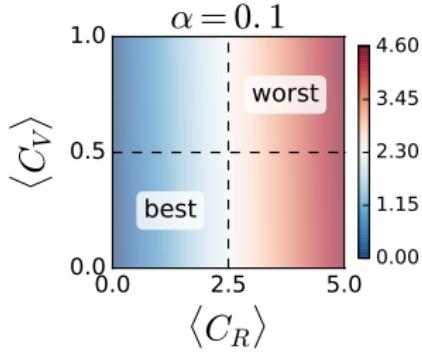


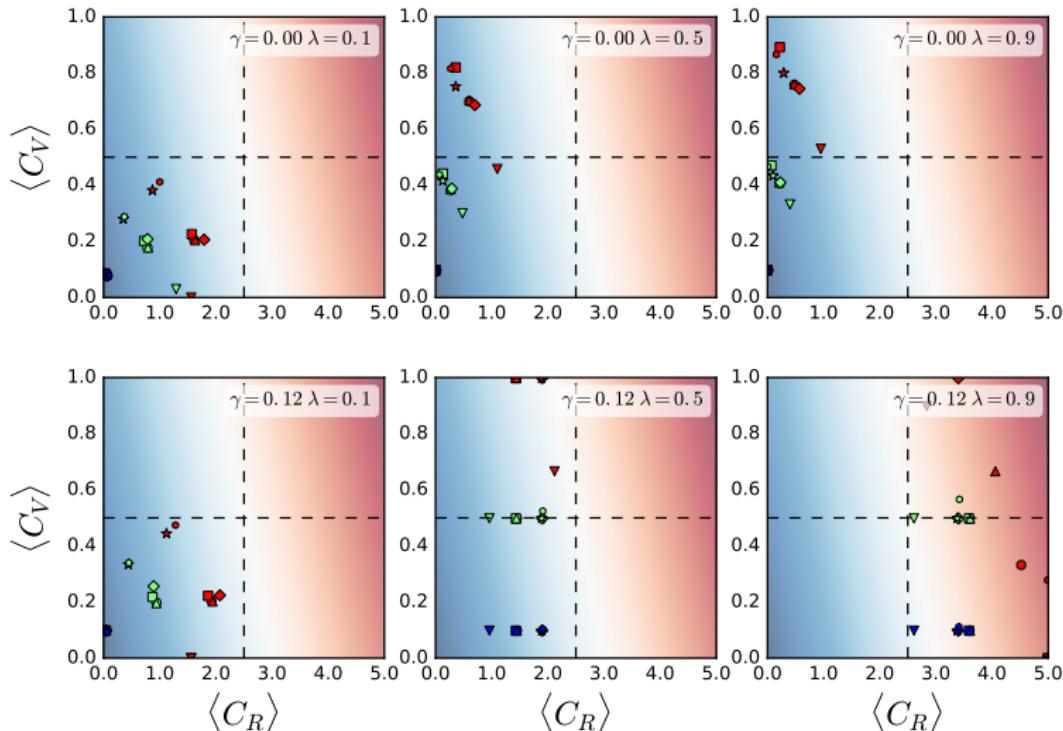
$$\rho = \alpha \langle C_V \rangle + (1 - \alpha) \langle C_R \rangle$$





Overall cost





● ER-single	■ SF-single	▲ SF-SF-MP	▼ SF-SF-MN	◆ ER-ER	★ GSF-EER	● GSF-ERGG
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“ Between 2005 and 2010, the proportion of French people in favour or very in favour of vaccination dropped from 90% to 60% (2013 INPES Peretti-Watel health barometer). The percentage of French people between the ages of 18 and 75 who are anti-vaccination increased from 8.5% in 2005 to 38.2% in 2010. In 2005, 58% of doctors questioned the usefulness of vaccines administered to children while 31% of doctors were expressing doubts about vaccine safety. These figures must surely have increased since then. (Michèle Rivasi) ”

“

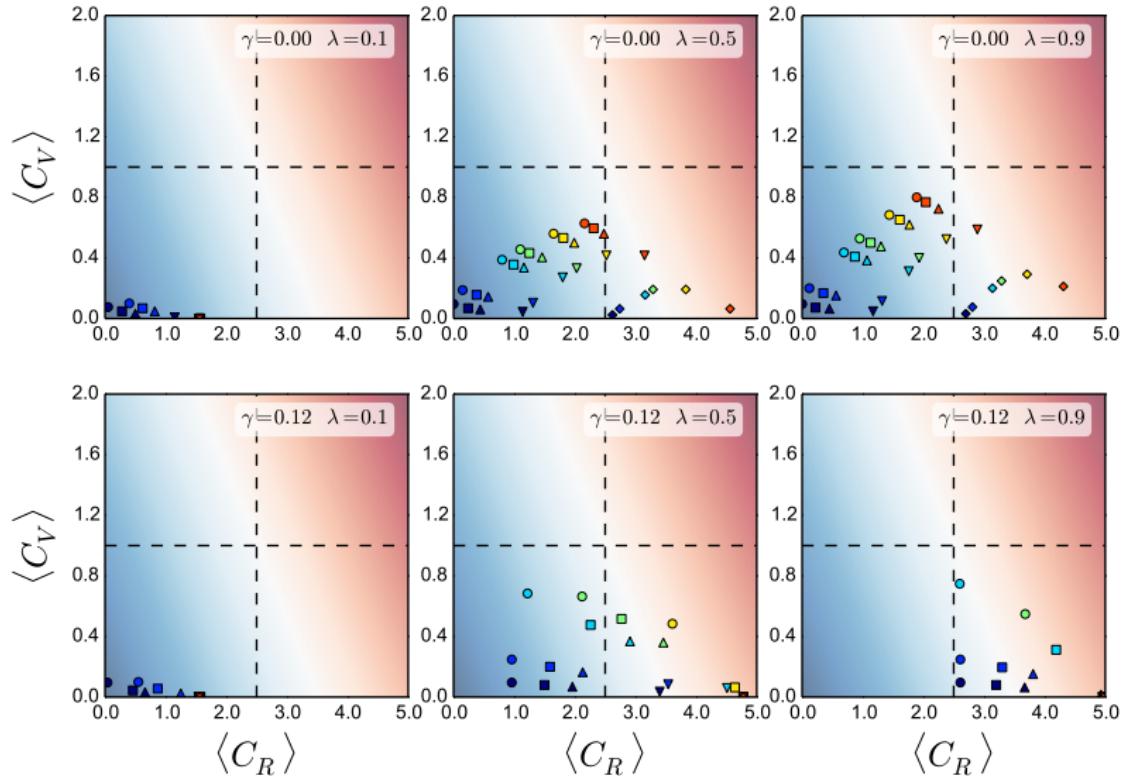
Between 2005 to 38.2% of French parents dropped their children from vaccination programs.



percentage of children from 8.5% in 2005 to 38.2% administered these figures

”

Zealots \neq overall cost

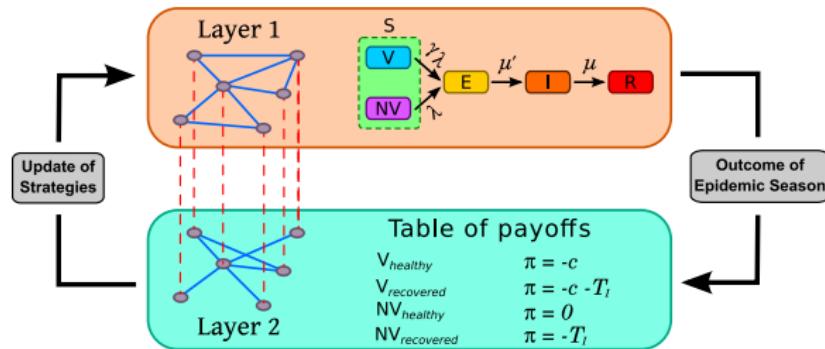


Section 5

Take home messages

Take home messages

- ▶ Coevolutionary model based on **epidemic spreading** and **evolutionary game theory** on multiplex networks.



Take home messages

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Take home messages

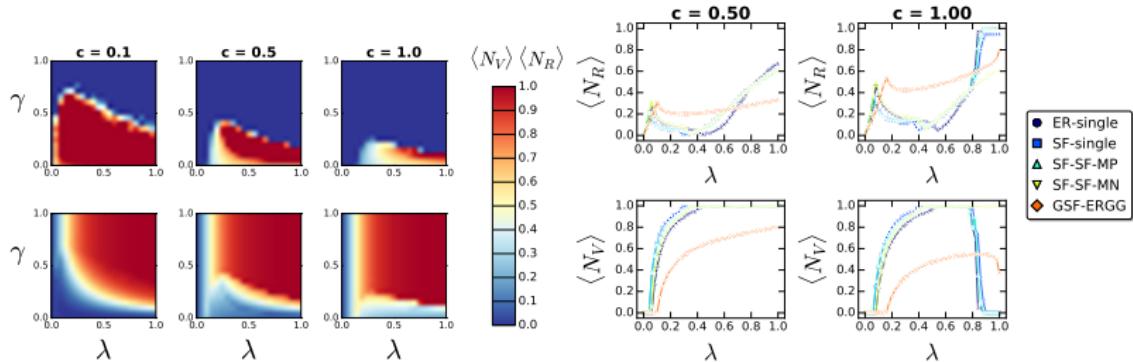
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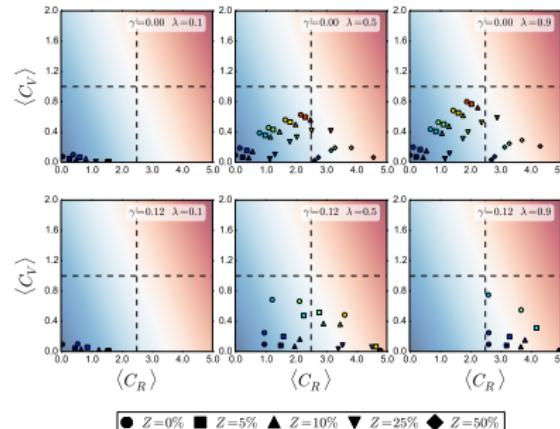
Take home messages

- ▶ Coevolutionary model based on **epidemic spreading** and **evolutionary game theory** on multiplex networks.
- ▶ Influence of topology/quality/cost on the overall performance.



Take home messages

- ▶ Coevolutionary model based on **epidemic spreading** and **evolutionary game theory** on multiplex networks.
- ▶ Influence of topology/quality/cost on the overall performance.
- ▶ Effects of zealotry and cost on the overall performances and possible solutions.



Acknowledgements

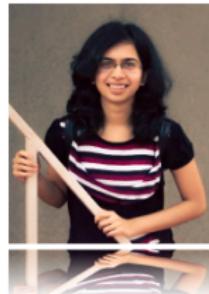


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(EPFL)



Jesús Gómez-Gardeñes
(UNIZAR)

***Kanchan
Mopari***
(EPFL)



Alex Arenas
(URV)



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