Computational Social Sciences II

BIFI Institute
UNIZAR



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1542

Nectunt
MORES HOMINUM
Social Dilemmas & Human Behavior

ISI
Institute for Scientific Interchange Foundation

Report on our most recent activity in the study of Social Systems & Computational Social Sciences (Cosnet lab, BIFI Institute)

Our activity in the field began 10 years ago (in 2011). Since then, we have tried to answer some relevant questions:



- Can we anticipate social collective phenomena and human behavioral responses? If yes, under which scenarios and at which scales?
- Do we have reliable data to answer the previous challenge?
- Will Big Data be enough for that purpose or more controlled, on-demand experiments need to be carried out?
- Can we build realistic models of how individuals behave and use them to study societal and organizational dynamics?
- Is it our online behavior the same as our offline reactions or responses?

Cosnet bifi Universidad Zaragoza 1542 Nectunt MORES HOMINUM SOCIAL DILEMMAS & HUMAN BEHAVIOR

Scope: The study of social systems, large-scale social contagion phenomena, dissemination of information, viral campaings, emergence of online social movements, Evolutionary Game Theory, the evolution of cooperation in humans, etc.

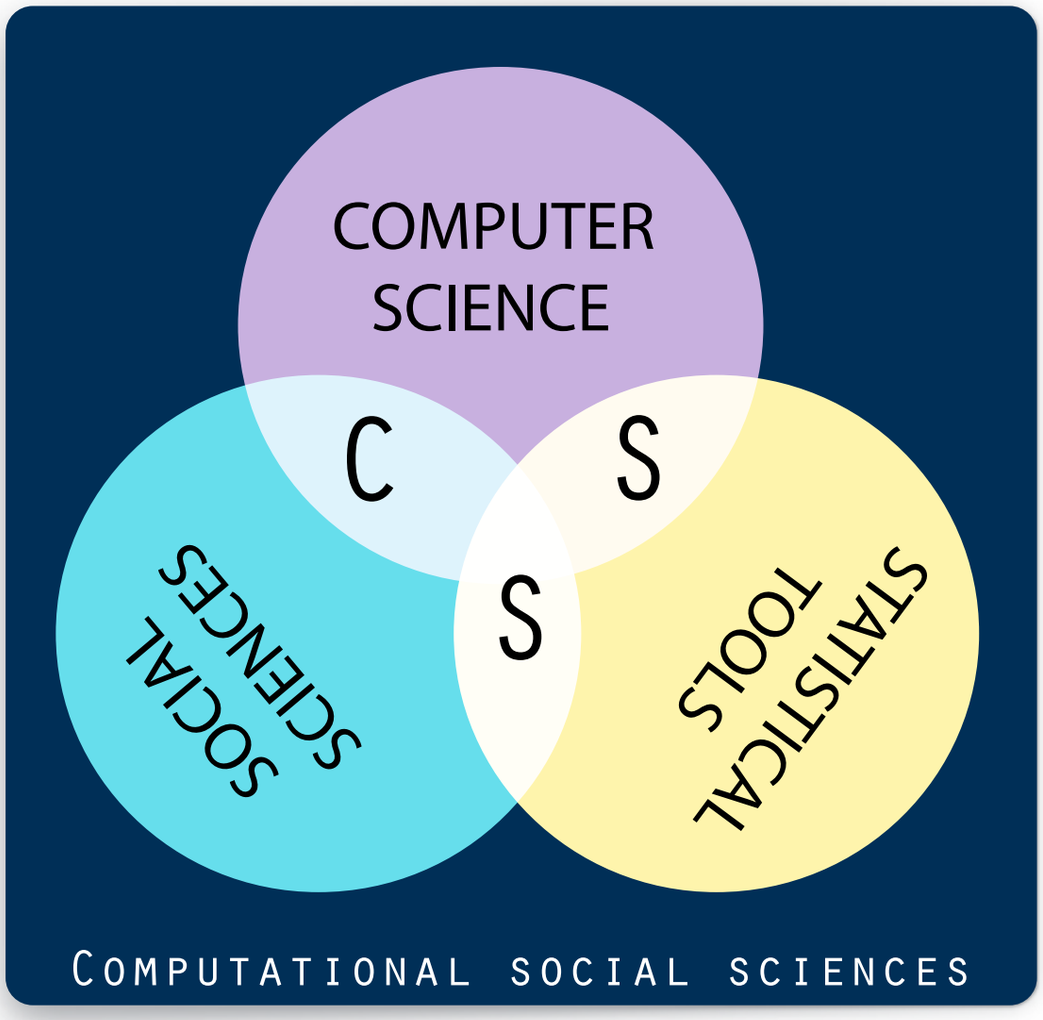
From an experimental point of view:

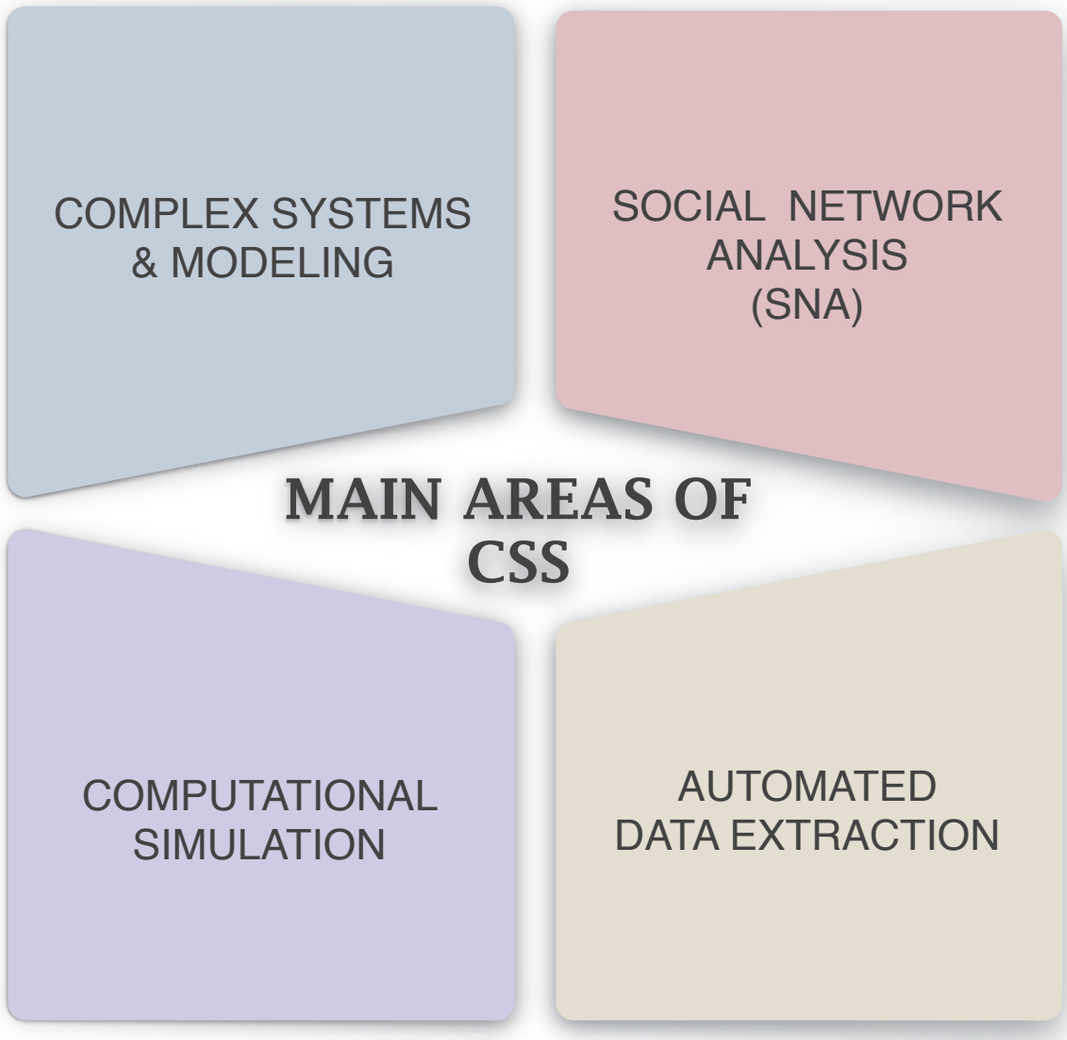
- To develop a *platform* (software and hardware) to carry out socio-economic or techno-social experiments with hundred of participants and build a *toolbox* (algorithms and hardware) for the analysis of the experimental data in an efficient and reliable way.
- It becomes mandatory to depart from theoretical assumptions and look at the system under study as we, physicists, are used to do. **This implies testing and validating theories and developing models that will be meaningfully informed with the findings found via experimentation.**





COMPUTATIONAL SOCIAL SCIENCES





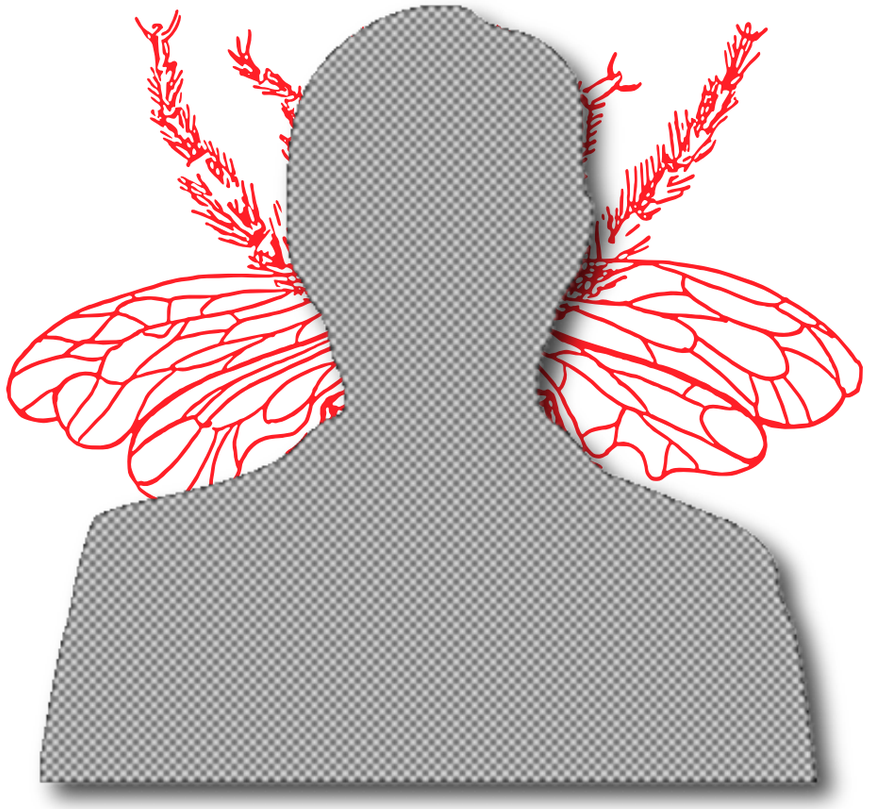
The study of social phenomena by means of computing and statistical data processing.

We are living the advent of the Big Data era. Hundreds of millions of connected people and billions of sensors yield previously unimaginable amounts of information.

- **ICT technologies invade our environment and are leading to profound changes in the way our society organizes and uses information.**
- These changes do not always lead to an evident and tangible social improvement, but rather generate a series of instabilities that make social and economic systems more vulnerable.
- The technological revolution is advancing at a rate never before seen, which makes it even more urgent to develop new tools and methodologies that allow us to better understand the emerging properties of these systems.







Scarce resources

Visibility & Attention

Competition

"Emergence of consensus as a modular-to-nested transition in communication dynamics"

J. Borge-Holthoefer, R. A. Baños, C. Gracia-Lazaro and Y. Moreno, ***"Emergence of consensus as a modular-to-nested transition in communication dynamics"****,* ***Scientific Reports 7****, 41673 (2017).*

- Online social networks have led to a new information ecosystem where people send and receive information through multiple channels.

- Nowadays, little is known about fundamental aspects such as **how collective attention arises** and **what determines the information life-cycle**.

- In information ecosystems, humans and memes are striving for scarce resources, visibility and attention, respectively.

- We develop a methodology that allows to cast all the previous aspects into a **compact framework and to characterize, using microblogging data, information-driven systems as mutualistic networks**.

- Our results show that collective attention around a topic is reached when the user-meme network self-adapts from a modular to a nested structure, which ultimately allows minimizing competition and attaining consensus.

Microblogging *is a combination of blogging and instant messaging that allows users to create short messages to be posted and shared with an audience online. A microblogging platform is the perfect test bed to answer questions such as:*

Are the similarities at the dynamical level (same type of interactions) **mirrored at the structural one?**

and (if so),

Why a nested architecture, in which specialists (interacting with only a few partners) **tend to be connected with generalists** (those interacting with many others), **emerge?**

In Microblogging Platforms:

a) Messages are limited to a small number of characters.
b) Competition is fierce.
c) The choice of memes critically determines the success of the message (outreach) and its lifetime on the system (persistence).

J. Borge-Holthoefer, R. A. Baños, C. Gracia-Lazaro and Y. Moreno, ***"Emergence of consensus as a modular-to-nested transition in communication dynamics"****,* ***Scientific Reports 7****, 41673 (2017).*

Considerations:

- **An information-driven system can be thought of as a bipartite network in which individuals and memes concurrently compete** (within their class) **and cooperate** (between classes).

- In our analysis, we represent a communication platform as a bipartite graph where connections exist only between agents (**users**) and the symbols (**memes**) they produce.

- **The user-meme network** self-organizes towards a nested structure minimizing competition and facilitating the coexistence of individual participants.

- **Collective attention around a topic is reached when the user-meme network self adapts from a modular to a nested structure**, which ultimately allows minimizing competition and attaining consensus. Even when the network is predominantly modular, nestedness appears to have significant values well beyond random counterparts, which already indicates the existence of an incipient consensus around sub-topics.

J. Borge-Holthoefer, R. A. Baños, C. Gracia-Lazaro and Y. Moreno, ***"Emergence of consensus as a modular-to-nested transition in communication dynamics"****,* ***Scientific Reports 7****, 41673 (2017).*

15M Movement **DATASET** (April- May, 2011)

Time-resolved Bipartite Networks:

WHO said **WHAT** & **WHEN**

WHO: ***n*** most active users

WHAT: ***m*** memes (*hashtags#*) that users produce within the time interval

WHEN: Time windows: $w=t_2-t_1$ (arbitrary width)

- **Bipartite Network is encoded in**:

n x m rectangular binary matrix M_t

- Sliding window scheme to evaluate the evolution of the System:

t: Origin of the time window *w*

$M_{u,h}=1$, if user *u* mentioned the *# h* within the period t_1 to t_2

Analyzing structure: 2 topological properties

1 MODULARITY

2 NESTEDNESS

1- How group of individuals using the same meme are build up...

(Community detection analysis, simulated annealing heuristics to maximize Barber´s Modularity Q)

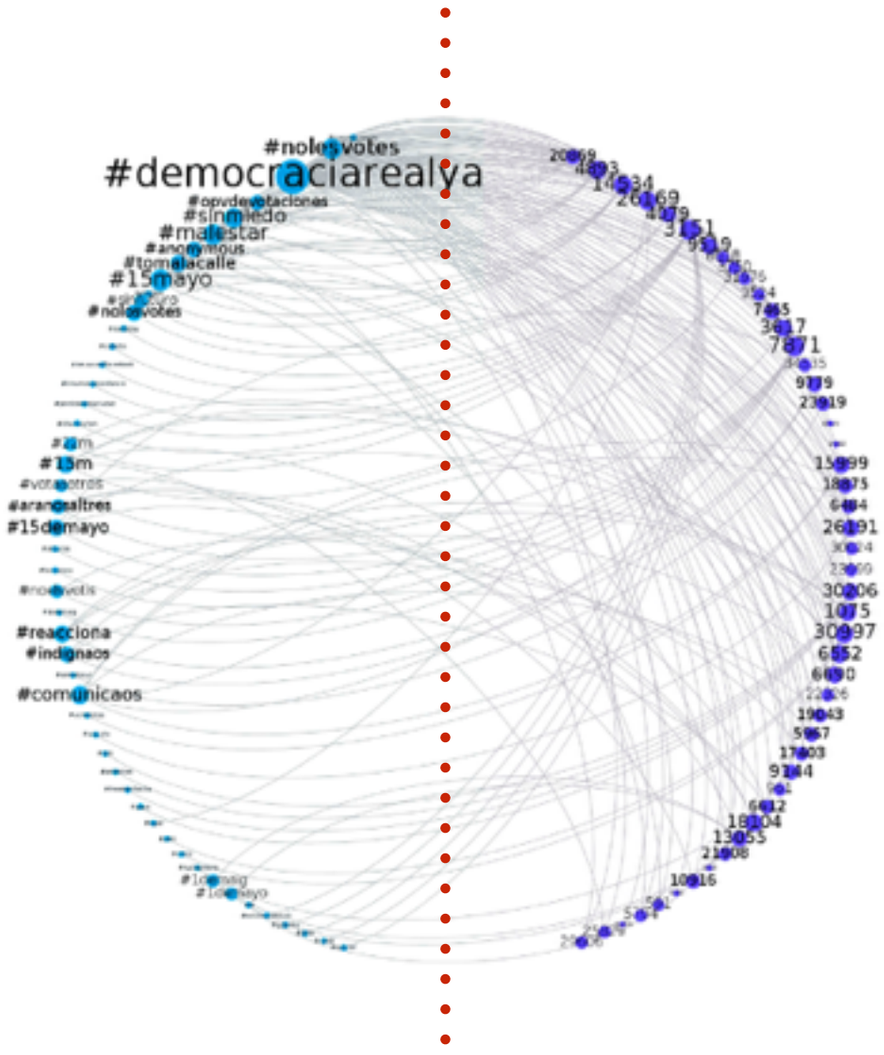
2- We analyze whether Nested patterns arise in the system:

Bell et al.

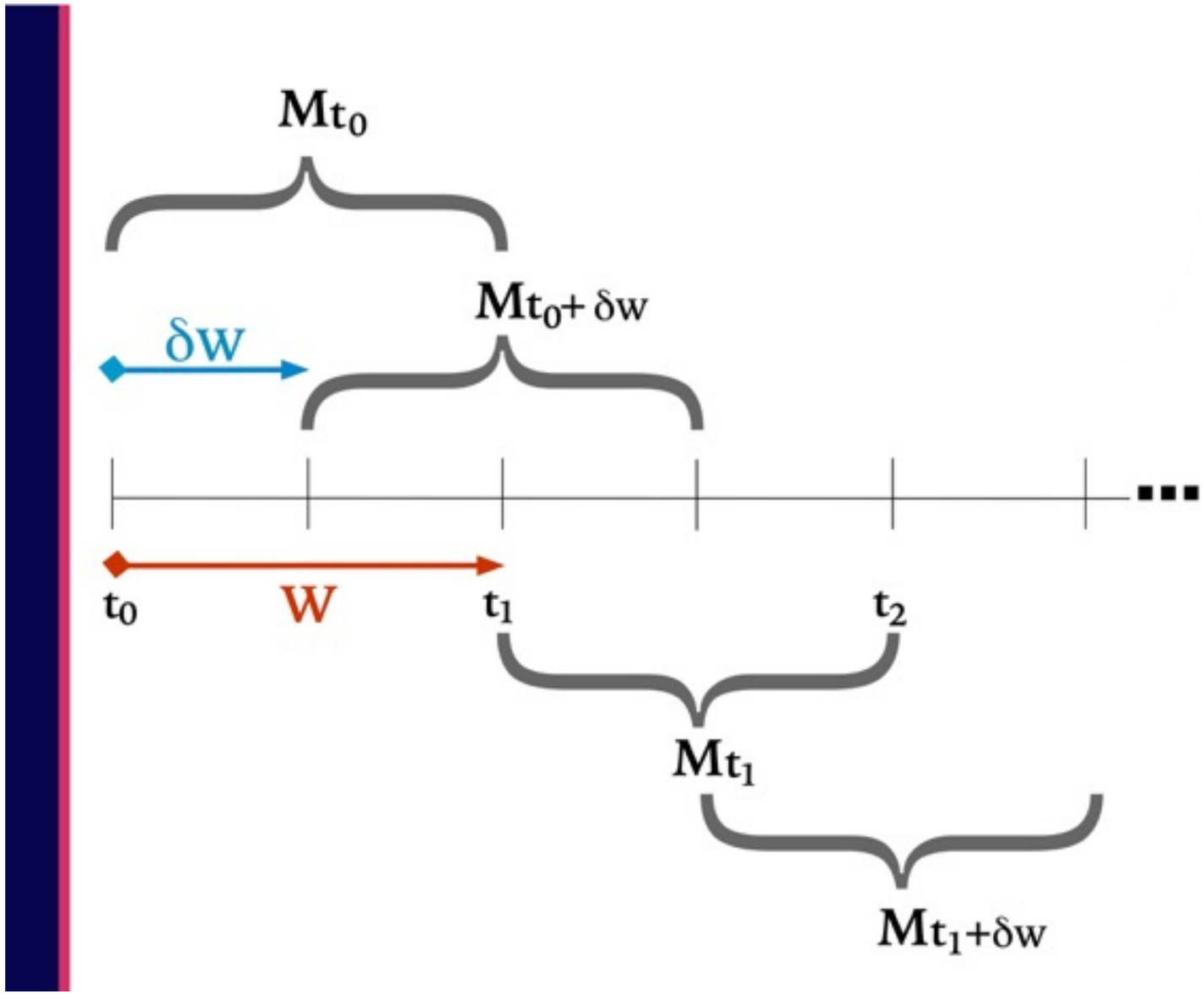
Staniczenko et al.

Nestedness is given by the maximum eigenvalue of the $(n+m)\times(n+m)$ adjacency matrix of the network, i.e. the square matrix counterpart of M_t

a)

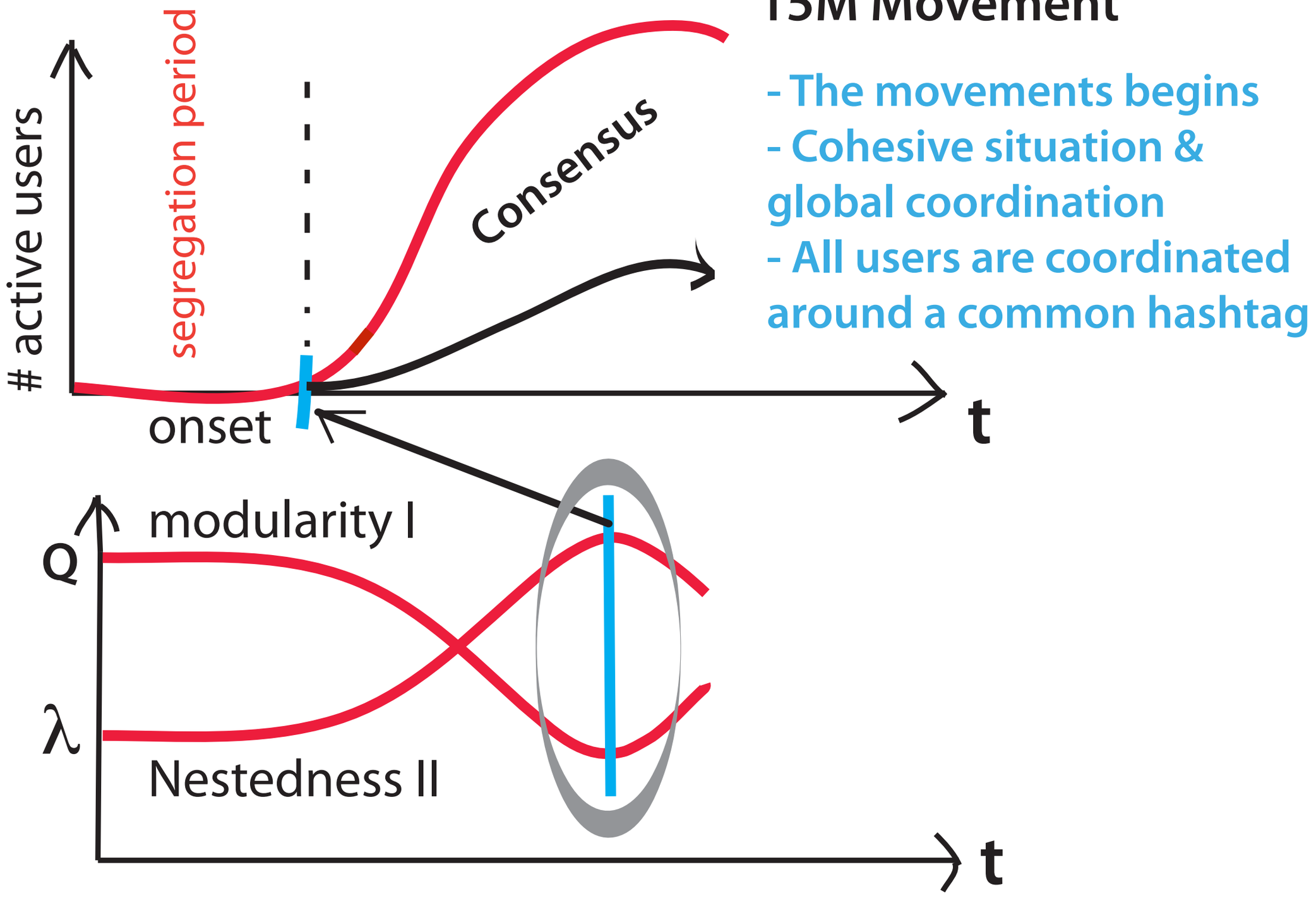


b)



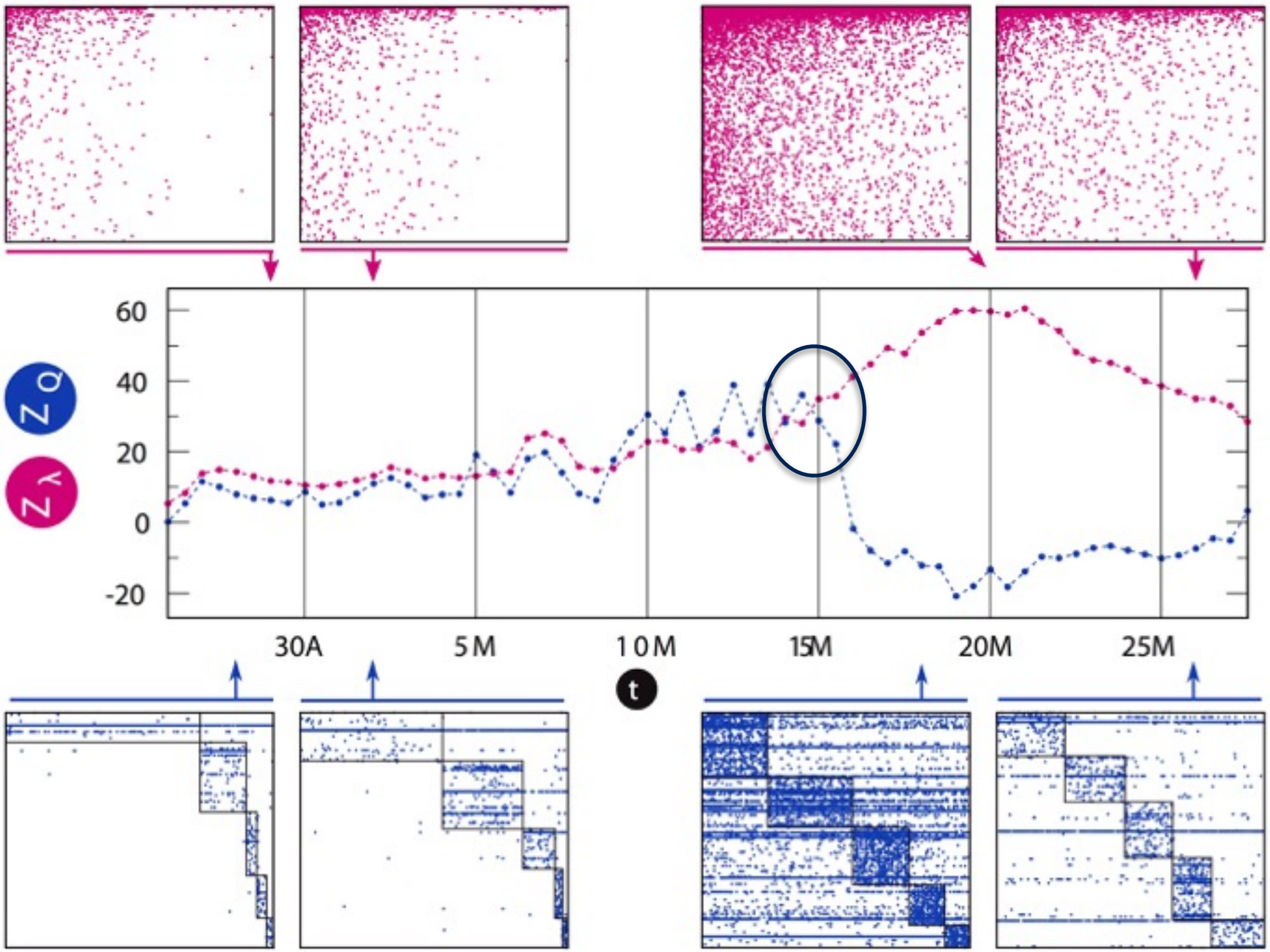
Time-dependent Mutualistic Networks. Bipartite representation of the user-hashtag interaction network at the beginning of the observation period **(a)**. An undirected link is shown whenever a user (represented here by an integer number) authors a tweet containing the corresponding hashtag. The size of hashtags and users is proportional to their frequency/activity. **Panel (b)** sketches the sliding-window scheme, which produces the matrices M_t that contain the interactions between users and hashtags starting at time t_0 and lasting till time t, with $w = t - t_0$.

In human communication scene, **<u>modularity</u> (I) and <u>nestedness</u> (II) can coexist in a single topology at its early stages**, but abruptly bifurcate as the system reaches maturity.



15M Movement

- The movements begins
- Cohesive situation & global coordination
- All users are coordinated around a common hashtag

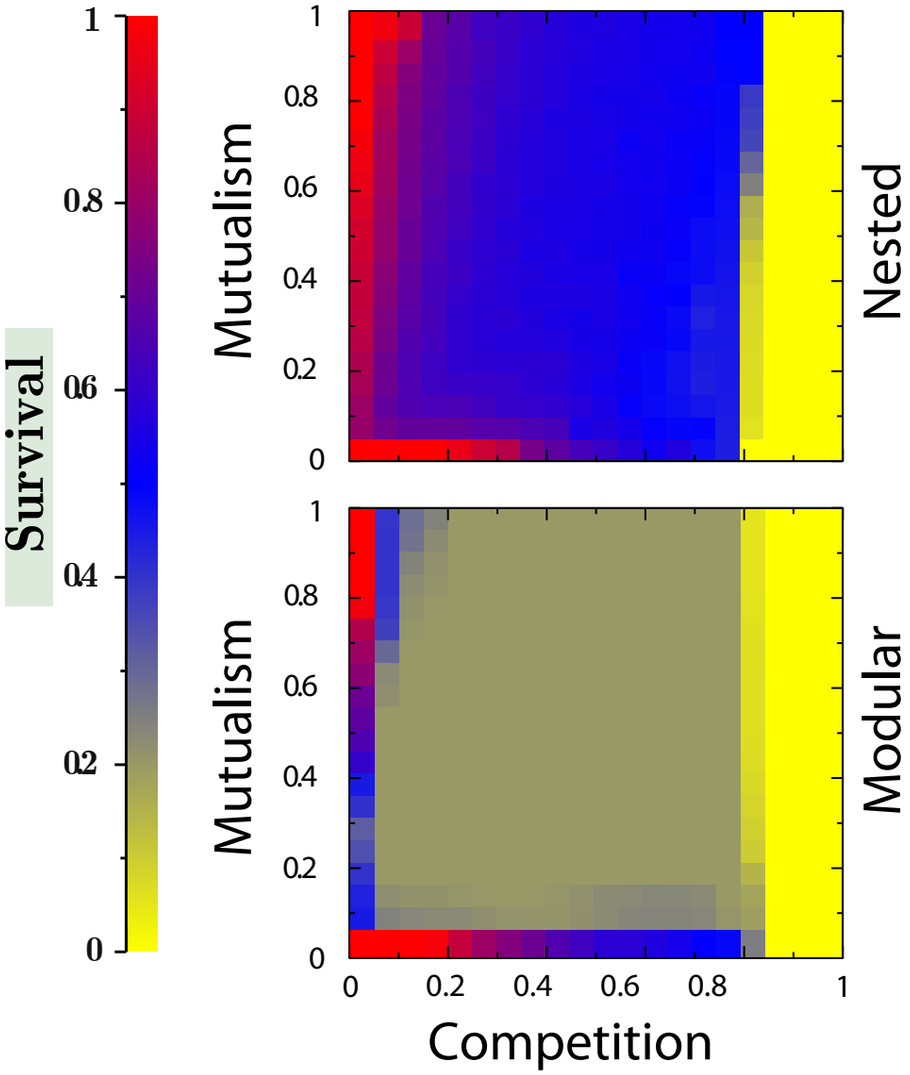


Modularity and nestedness bifurcate at the onset of system-wide attention. The central panel shows the evolution of modularity and nestedness, as standardised z-values. Remarkably, both metrics evolve in a coupled way up to the onset of the main protests (around May 15). **At this point, modularity collapses, whereas nestedness continues growing towards its peak value coinciding with the political movement's central dates** – that of the largest demonstrations across the country (May 17–20th).

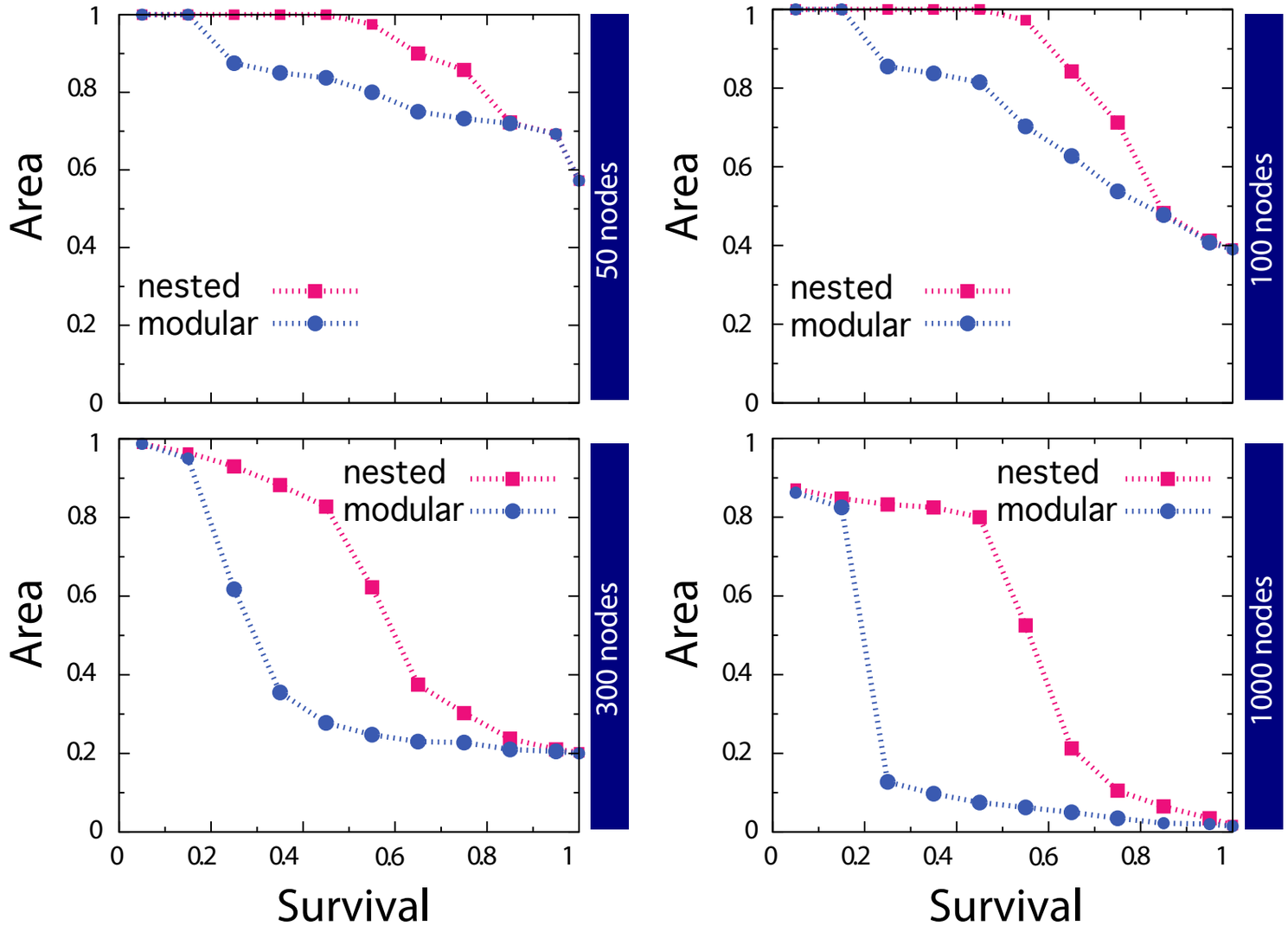
J. Borge-Holthoefer, R. A. Baños, C. Gracia-Lazaro and Y. Moreno, ***"Emergence of consensus as a modular-to-nested transition in communication dynamics"***, *Scientific Reports 7, 41673 (2017).*

“Modular and nested architectures under mutualistic dynamics"

3a



3b



Two synthetic networks with the same size (*N=1000)* and density (*ρ=0.25*), but different architecture (modular, nested), exhibit radically different outcomes when the mutualistic dynamical framework is applied on them via extensive numerical simulations.

Modular Architecture vs Nested Structure when Equilibrium is Reached

Fig. 3a:

The nested architecture presents large areas in the parameter space for which the system largely survives, whereas the modular structure does not.

The persistence is defined as the survival of a hashtag or user once the system has become stable, while the survival rate represents the final diversity

Fig. 3b:

1- **Nested architectures consistently out-survive modular ones.**

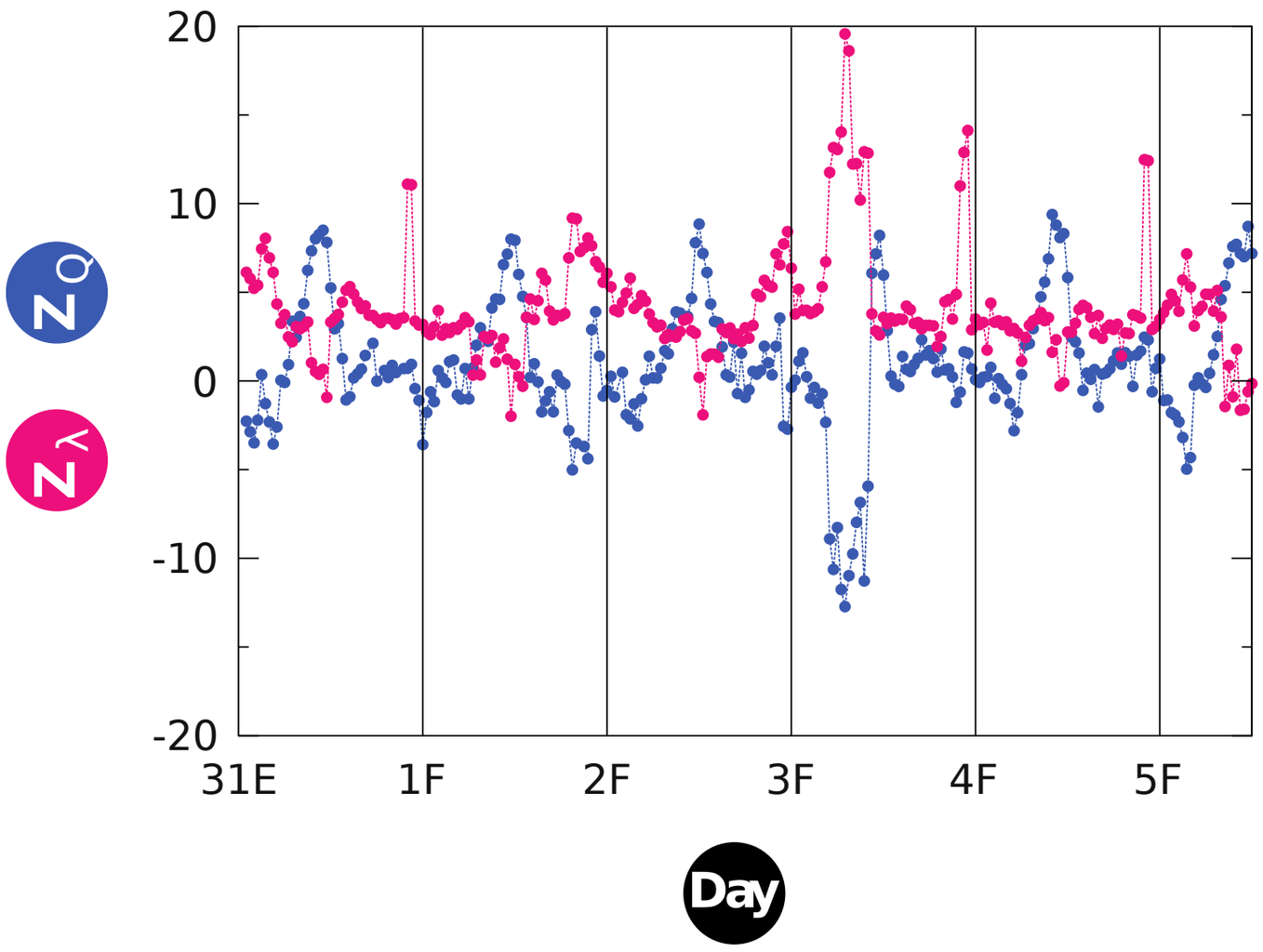
2- **The difference in survival areas increases with network size, being narrower for small system sizes.**

This latter finding suggests the reason why topic-centered bipartite networks in information systems exhibit a modular structure while they remain small-sized: the pressure for an architecture shift remains low, as the transition towards a nested topology does not yet present a critical advantage in terms of the survival of the topic.

We have analyzed an unfiltered dataset of Twitter traffic corresponding to tweets in United Kingdom and built bipartite user-hashtag networks -the subset comprising the top 1,024 most-active users and, independently, the subset of 1,024 most-used hashtags-.

This dataset shows **strongly fluctuating patterns for both modularity and nestedness, when measured at large window widths** (w> 3 h)

Results reveal that **collective attention around certain topics is reached when the network is maximally nested and minimally modular** (with overall r= –0.7126).



Nestedness and modularity show strongly anti-correlated behavior (*r= –0.7126*), with Z_λ peaking when a collective attention gathers around an outstanding topic (the Superbowl event, between February 3 and 4, 2013)

Main Conclusions:

- The unraveled structural change to a highly nested-only architecture allows interpreting **the evolution of the Spanish mobilization episodes as a build-up effort from segregation to coordination**.

- Our analyses have unveiled the mechanisms underlying the evolution of an information ecosystem, revealing that there is a traceable pattern for an emerging collective attention event to culminate. Such pattern implies **a sudden transition from an initially disperse scenario** (***modular architecture***) **to a cohesive situation** (***nested architecture***).

- Extensive numerical simulations reveal **that user-meme mutualistic interactions drive the networked structure towards that nested-only stage.**

- **Nestedness is a dominant pattern in complex networked systems**, but it has, paradoxically, received much less attention than modularity.

- The concepts of competition, cooperation and facilitation can now be put on firm theoretical standpoints.

- The phenomenology of the transition suggests that this methodological approach could be applied to other datasets, provided that **there is a brewing period in which consensus is built up as time progresses**.

The Contagion Effects of Repeated Activation in Social Networks

MODEL, MECHANISMS, DIFFERENCES, FACTORS…



P. Piedrahita, J. Borge-Holthoefer, Y. Moreno, and S. González-Bailón, **“The Contagion Effects of Repeated Activation in Social Networks”**, **Social Networks 54,** 326-335 (2018).



MAIN OBJECTIVES OF OUR MODEL:

1. To analyze the contagion dynamics that emerges in networks when repeated activation is allowed.
2. To disentangle the mechanisms that drive the emergence of decentralized, large-scale coordination.
3. To allow actors to repeatedly activate as a function of the dynamics unfolding in the rest of the network.
4. To answer how does **1.-**the structure of interdependence, **2.-**the variance in individual propensities to activate, and **3.-**the strength of social influence affect contagion and coordination.
5. To capture dynamics of activation within adoption.
6. To relax the assumption that actors can only transition from an inactive to an active state (classical models).



Basic Models:

The group of reference is the same for all actors.

- Granovetter, 1978
- Granovetter and Soong, 1983
- Schelling, 1978

Later Developments: - Networks were introduced…

The group of reference is now determined by connectivity in the network and it changes from actor to actor.

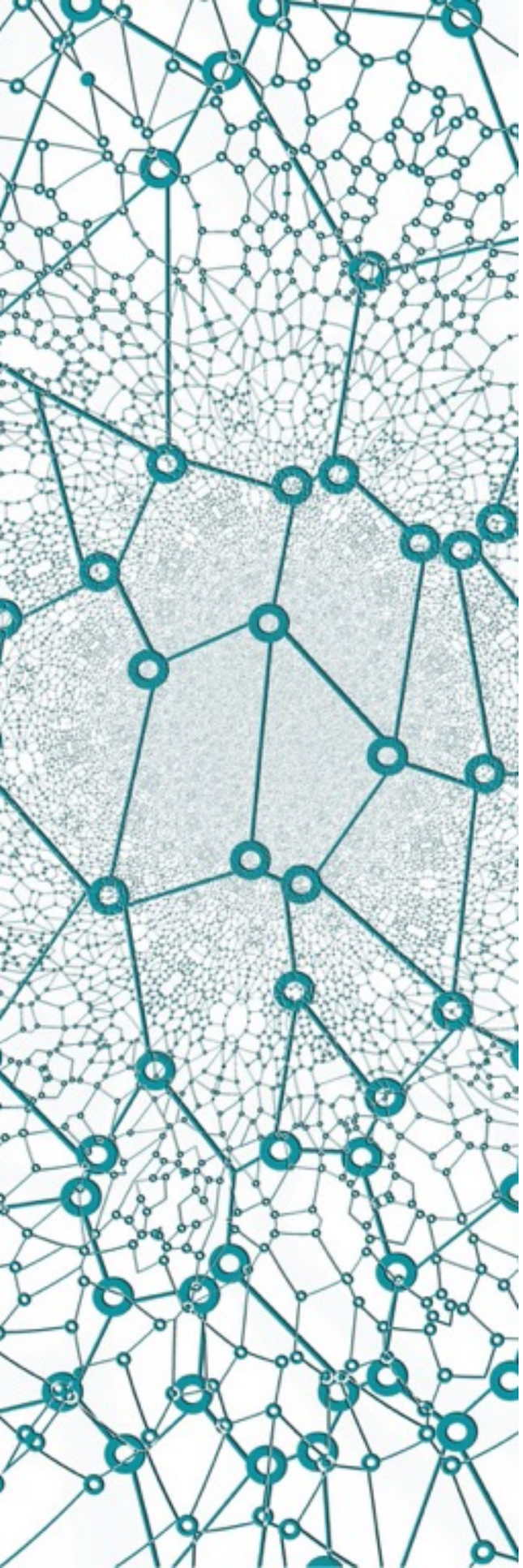
- Valente, 1996
- Watts, 2002

BASIC THRESHOLDS MODELS

- Activation happens only once (**one-off event**).
- The change of state (from inactive to active) is permanent.
- Activation is modeled as a step function that goes from **0** (inactivate) to **1**(activate).

OUR MODEL

- The effects of each activation vary over time (*temporal dimension)*.
- Activation can happen more than once, and consequently the change of state **is NOT permanent.**
- The model captures the dynamics of activation with adoption.
- The period of information exchange that follows the act of joining a collective effort is taking into account.



What are the differences in relation to other models?

- Our model points out that, once in the second stage, **individual propensities to activate will be influenced by the network and the signals it transmits**, which in turn, results from how other actors are influenced and react to that influence over time.

- Failure to trigger a chain reaction depends not only on the distribution of thresholds or the impact of network structure on activation dynamics, but also on whether the network facilitates coordination.

- Theoretical & empirical reasons to allow **repeated activation** to be the driving force of contagion dynamics.

P. Piedrahita, J. Borge-Holthoefer, Y. Moreno, and S. González-Bailón, **"The Contagion Effects of Repeated Activation in Social Networks"**, **Social Networks 54,** 326-335 (2018).

Classsic Models of
Synchronized Coordination

now, applied to

The study of social
mobilization (Dynamics)

To answer many
sociological questions

Identify the conditions under which coordination is more likely to arise from networks that are constantly pulsating with information.

They focus on the cascading effects of one-off activations (**first stage**)

Coordination dynamics is a two-step selection process:

1- In the 1st. stage, actors decide if they want to join a movement.

2- In the 2nd. stage, they coordinate their actions with those who also opted in.

Repeated Activation Model

We focus mainly on the Second Stage...

- *Actors repeatedly activate as a function of the dynamics unfolding in the rest of the network.*
- *Individual propensities to activate will be influence by the network and the signal it transmits.*
- *The activation signals sent by neighbors are more consequential if they are concurrent than if they are not.*
- *Large-scale coordination becomes visible only when the timings of individual activations become highly correlated.*

Activation can be classified into 2 components

Social Component

It depends on what other actors are doing

Every time a neighbor activates, they send a pulse that shifts the state of the focal actor closer towards the threshold zone.

Individual Component

Intrinsic propensity of actors to activate regardless of what others are doing

It is modeled as a function that increases monotonically over time within the range [0,1] until the upper bound (threshold) is reached.

- Most threshold models assume that activation happens only once and that, once activated, the change of state (*from inactive to active*) is permanent.

    - The dynamics of coordination, and how they lead to collective outcomes (trending topics, viral hashtags, etc.) **are overseen if activation is modelled as a permanent change of state** – that is, if we only focus on the first stage of what is, in fact, a two-step process.

The model we propose aims to capture dynamics of activation within adoption, that is, coordination amongst actors who already opted in and therefore have an interest in facilitating organizational efforts.

Motivational structure of actors can be defined by a limit that, when reached, triggers activation...

↓

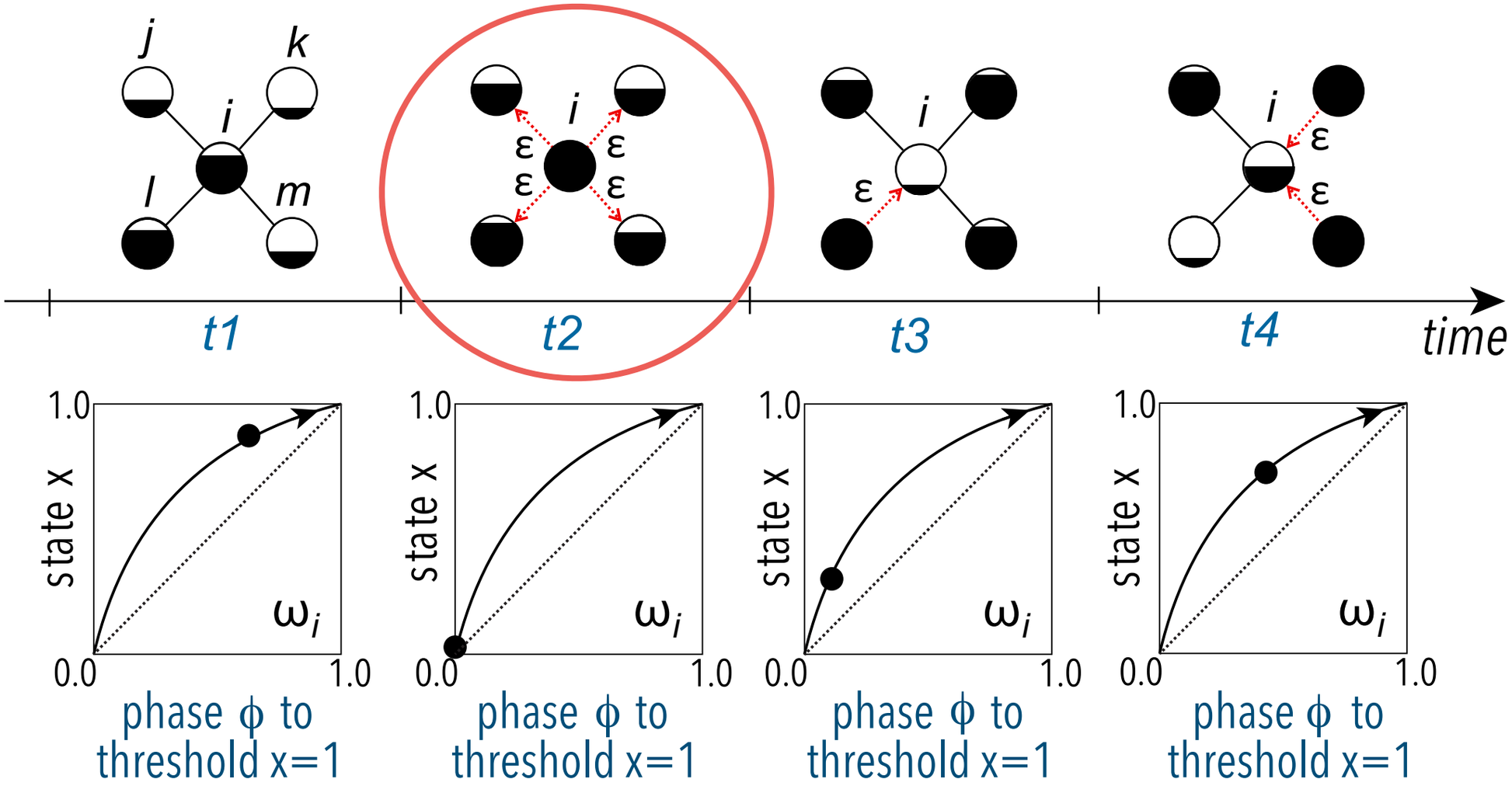
It is determined by:

- The parameter ω, which defines how quickly they reach the activation zone.

- The parameter ε, which determines the strength of social influence.

→

The combination of values of the two parameters ω and ε, (when $\varepsilon > 0$), determines the speed at which coordination emerges: - how long it takes for all nodes to start pulsating, or activating concurrently.



Our model, adapted from (*Mirollo and Strogatz 1990*), **assumes that actors** (i.e. the nodes in the network) **reach their activation threshold at different speeds.**

- The figure shows how actor ***i*** advances towards activation as a function of both parameters: ***ω & ε***.

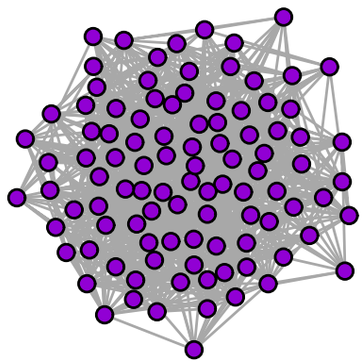
- When a node activates (**as node *i* does in *t2)***, she shifts the state of her neighbors with the *ε* signal and resets her state back to the beginning of her phase.

- The activation signals sent by neighbors are more consequential if they are concurrent (***t4***).

NETWORKS TOPOLOGY MATTERS…

- **Networks determine how actors influence each other via the ε signal.**

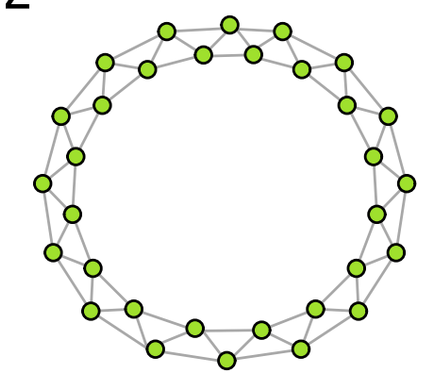
1



Erdős-Rényi

$N = 10^4$
$\langle k \rangle = 4$
$k_{min} = 2$

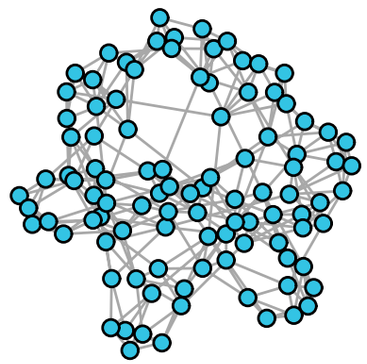
2



Regular

$N = 10^4$
$k = 4$

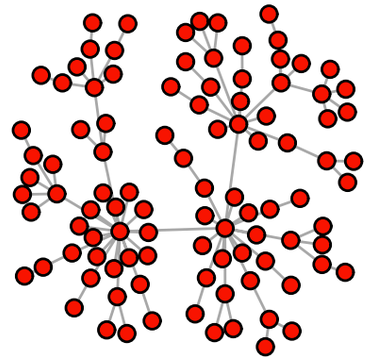
3



Small world

$N = 10^4$
$k = 4$
$p = 0.1, 0.2$

4

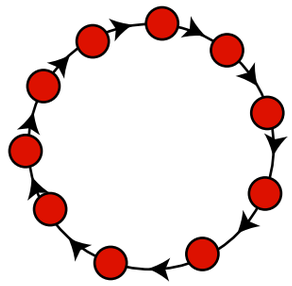


Scale free

$N = 10^4$
$\langle k \rangle = 4$
$k_{min} = 2$
$\gamma = 3$

- **ER** topology could account for a scenario where actors are connected through their online search patterns.
- **Regular network** allows mapping interdependence when it is highly structured by logistical or space constraints (does not rely on online servers and are more difficult to monitor).
- **The Small World and Scale Free Networks** are the topologies we use to approximate most observed networks.

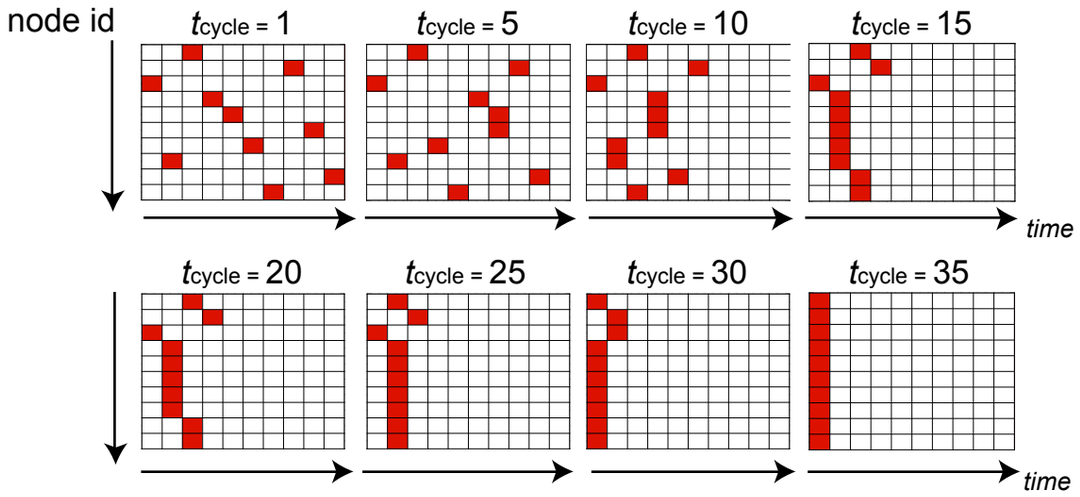
1a



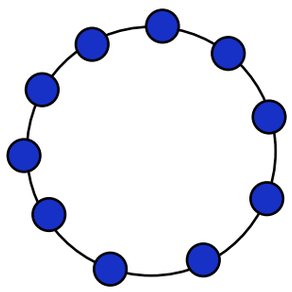
Directed cycle

k_{out} = 1

1b



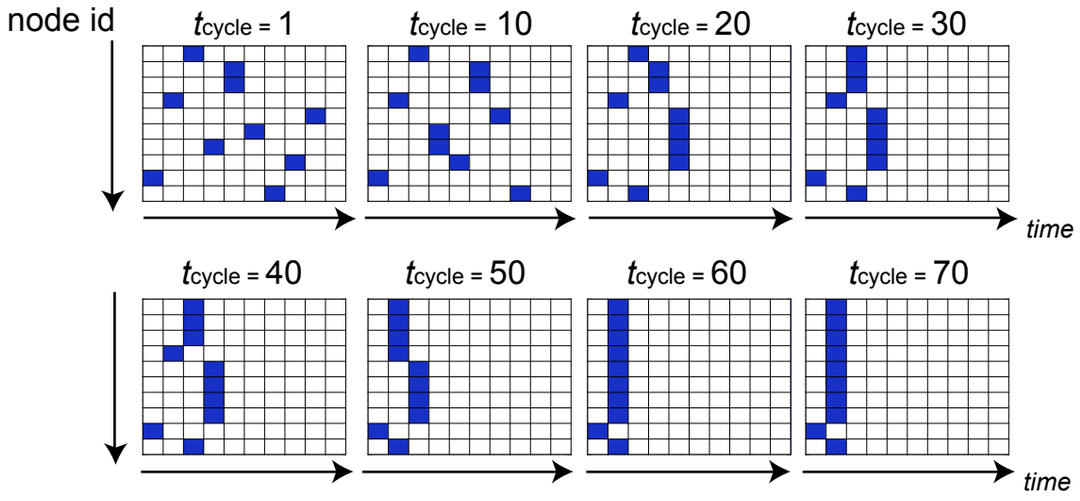
2a



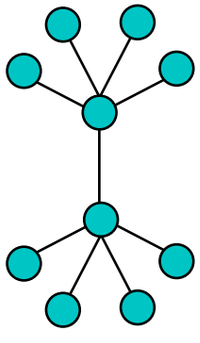
Undirected cycle

k = 2

2b

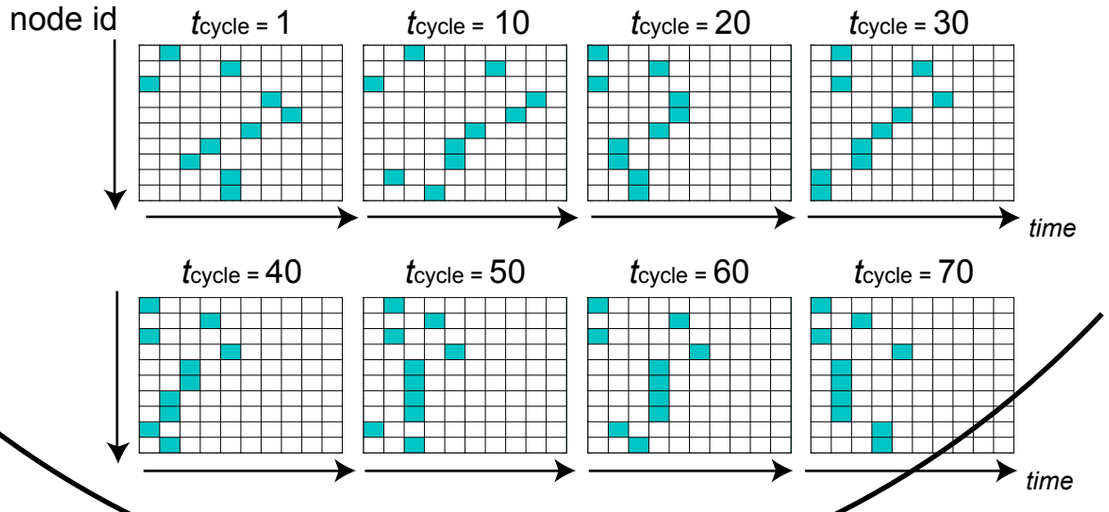


3a



Tree

3b

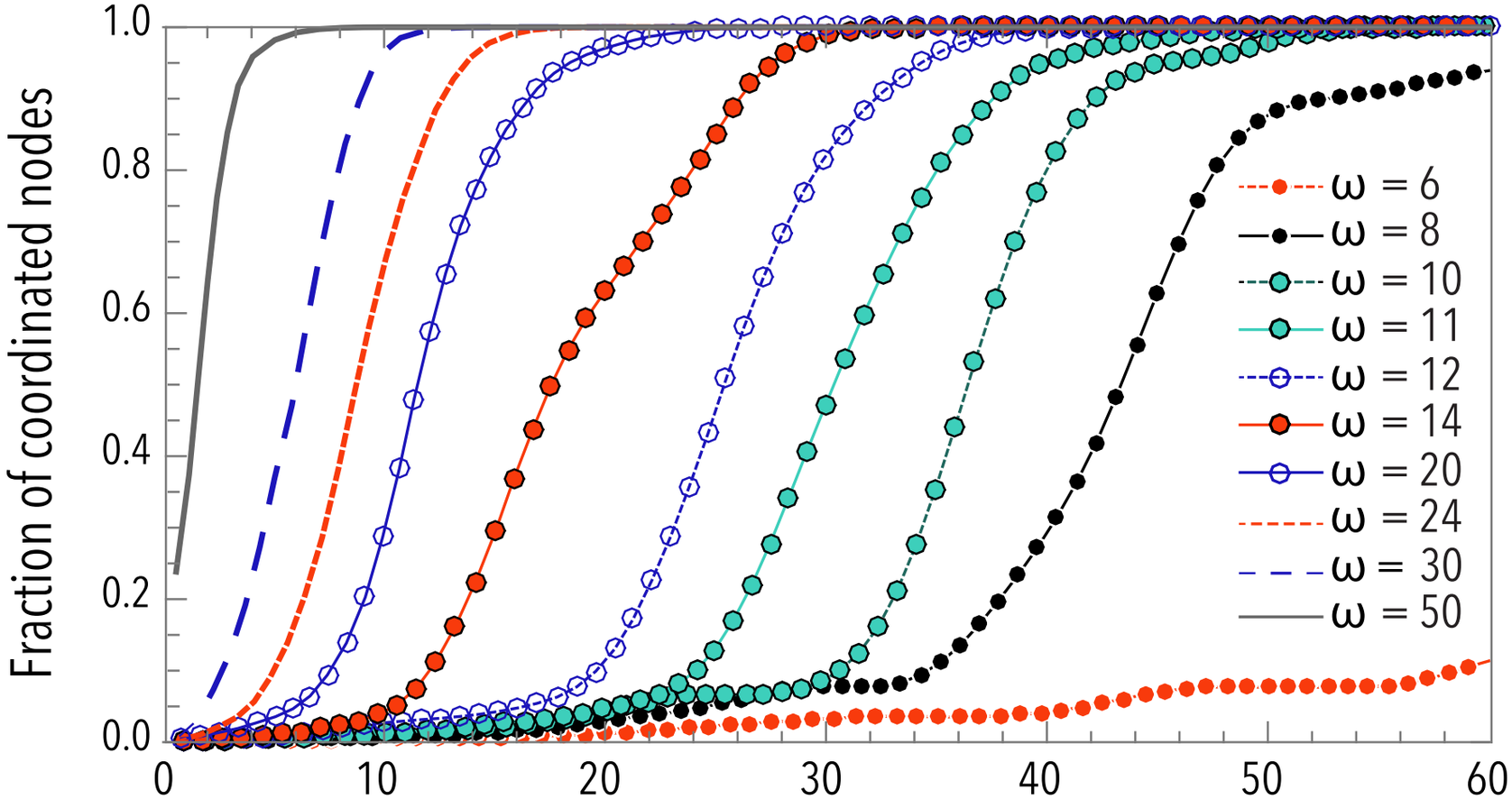


This figure summarizes contagion dynamics in toy networks with size ***N = 10,*** and values ***ω = 3*** and ***ε = 0.008***.

The initial state randomly allocates actors to different points in their progression towards activation.

As time passes, the impact of social influence (***via ε***) starts aligning nodes to the same timing (a *tcycle* is complete when every actor in the network has activated at least once).

The tree structure is the least conducive to coordination: the presence of hubs, and their greater influence over the peripheral nodes that are only connected through them, hampers the spontaneous emergence of coordination.



- Our model allows large-scale coordination to arise when small local islands of coordinated nodes start merging together through the cascading effects of social influence.

- The curves track the fraction of actors in the network that activate simultaneously.

- **Simulations here run on a Small-World Network** with rewiring probability ***p = 0.1*** and a fixed ***ε = 0.01***. As expected, high ***ω*** values (which are here the same for all actors) lead to faster large-scale coordination.

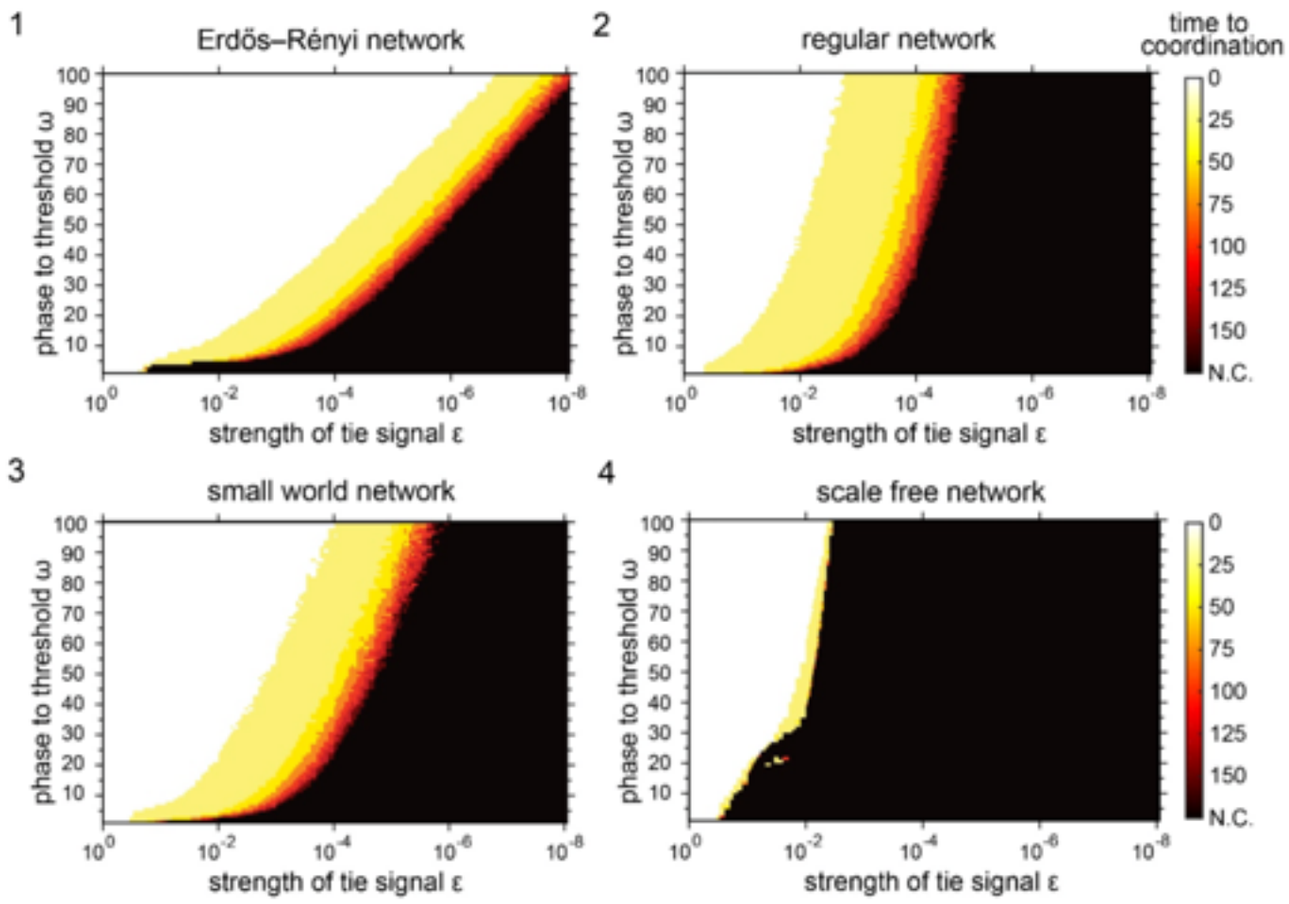
- As ***ω*** decreases, the time to full coordination increases. At low values (i.e. ***ω = 6***), system-level coordination is unattainable.

How do contagion dynamics differ when ω and ε are held constant but the underlying networks change?

The panels summarize coordination dynamics for different values of ω (the intrinsic motivation parameter) and ε (social influence strength) across the four network topologies.

Lighter colors indicate earlier coordination, **darker colors** later coordination and **black signals** that no large-scale coordination was possible.

- **In a random Erdös–Rényi network (1)**, large-scale coordination emerges for most social influence conditions when ω is high, even when the impact of each neighbor activation is really low.
- **Regular & Small-World Networks (2 & 3)** are more restrictive in their support to spontaneous coordination.
- **SF Networks (4)** either allow coordination to emerge fast (white region) or it prevents it very abruptly (black region).



Important considerations:

- All networks are capable of generating coordination in scenarios with strong to moderate social influence (**$0.5 < \varepsilon < 1$**), regardless of the ω value.

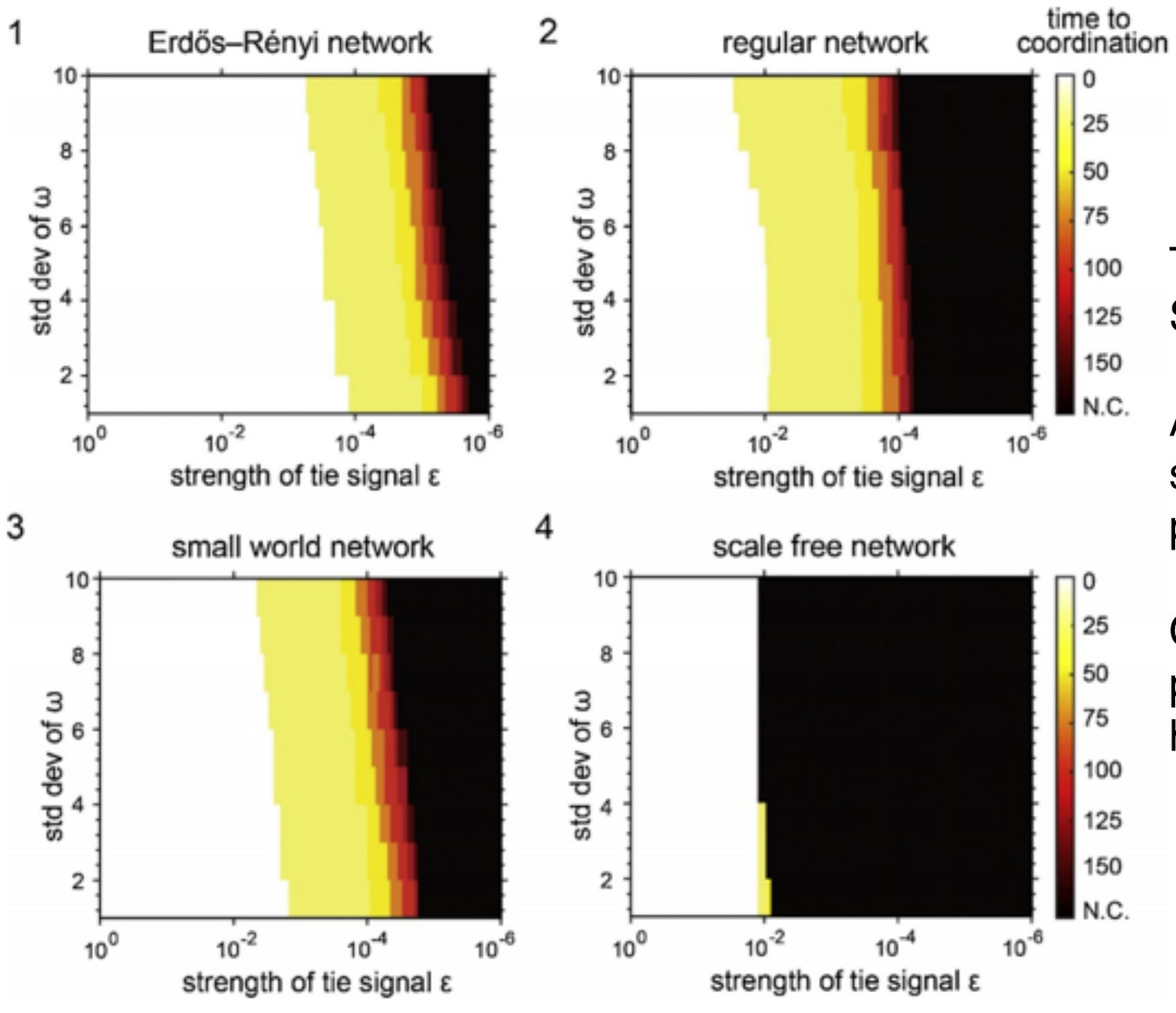
- **Random, homogenous networks** are more conducive to large-scale coordination.

- **Heterogeneous networks characterized by the presence of hubs** (i.e. scale free networks) do not allow large-scale coordination soon after the social influence signal weakens.

- **Small-world networks** are also more restrictive in the emergence of coordination than regular networks, in spite of the global shortcuts created by random rewiring (or because of them).

Not all actors have the same propensity to reach the activation zone.

We introduce heterogeneity in the distribution of the ω parameter, simulations show that **heterogeneity reduces opportunities for large-scale coordination across all networks.** This supports the idea that, for a cause to grow large, actors need to be as similar as possible in their willingness to act.



The Impact of Actor Heterogeneity on Large-Scale Coordination across ε Values.

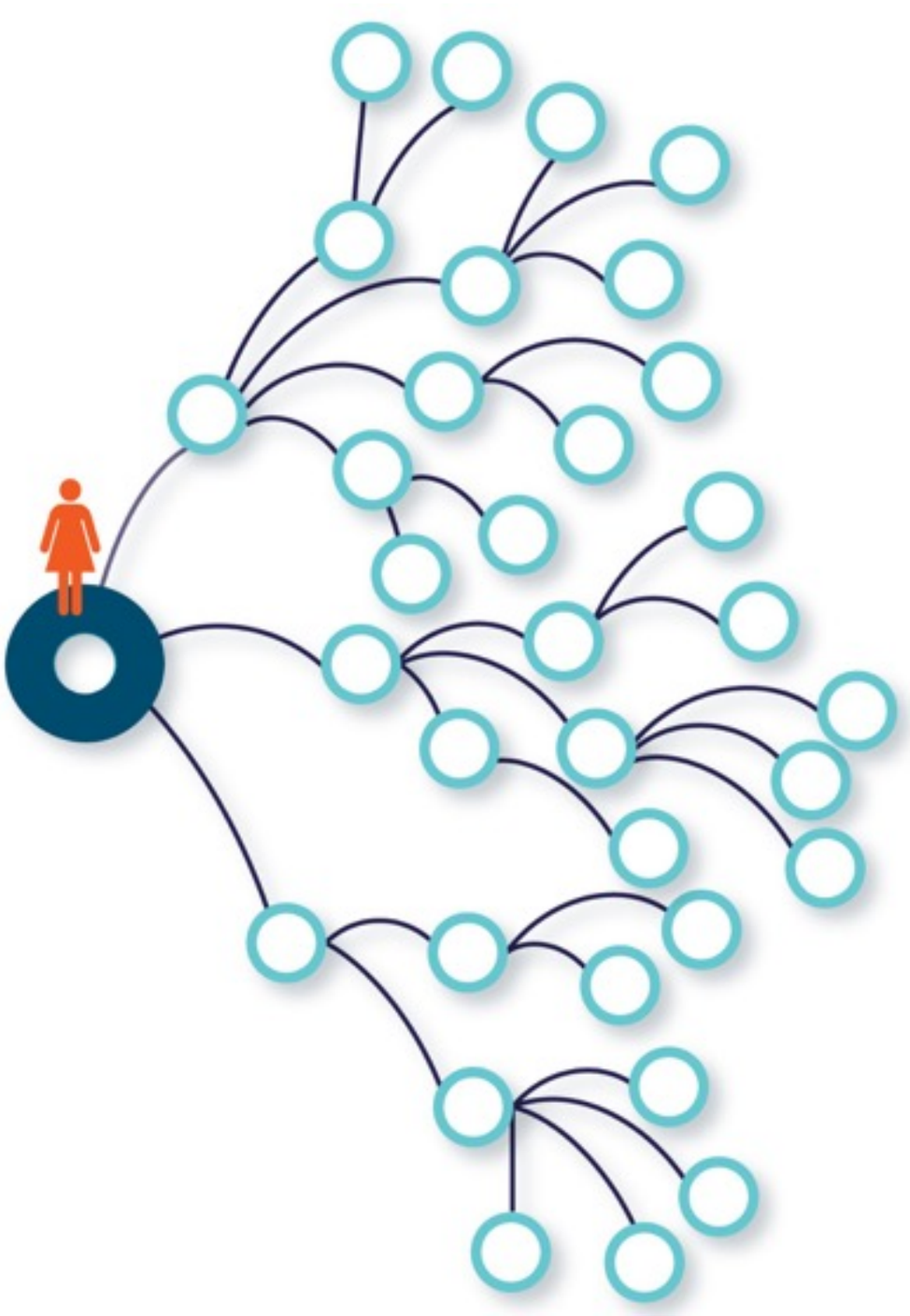
All networks are less efficient in allowing large-scale coordination than the random benchmark provided by the Erdös–Rényi topology.

Overall, low to mild heterogeneity increases the probability of global coordination, whereas high heterogeneity hinders it.

“Effects of network structure, competition and memory time on social spreading phenomena”

“Men acquire a particular quality by constantly acting a particular way…” Aristotle

J. P. Gleeson, K. P. O’Sullivan, R. A. Baños, Y. Moreno, **“Effects of network structure, competition and memory time on social spreading phenomena”**, **Physical Review X 6**, 021019 (2016).



A person adopts
a new behavior

↓

A new app, item or rumor is sent
to his/her friends

↓

The avalanche spreads if the friends
decide to adopt the new behavior
and in turn, pass on
the social influence effect
to their own friends

↓

SOCIAL SPREADING PHENOMENA
(“Viral propagation”)

↓

but, what happens when the dissemination
of information occurs in a **COMPETITIVE CONTEXT**?

**Why some items become extremely popular while
others go unnoticed?, what mechanisms influence this drift?**

A- Cascade Size S=N / Activation of the cascade

Threshold=1
First adopter

0 S=1

1 S=2

2 S=3

3 S=4

N-1 S=N

B- Cascade Size S=1/ **NO** collective behavior

First adopter

0

2

3

N-1

Granovetter Model

- Spread of rumors
- Disease spreading
- Political mobilizations
- Strikes
- Dissemination of information

Design Cosnet

SOCIAL SPREADING PHENOMENA

Competition between
a large number of different items
(**URLs Twitter, apps on Facebook, videos on YouTube, etc.)**

Definition of "memes":

“Elements of a culture or system of behavior passed from one individual to another by imitation...” **Dawkins's term**

The definition of memes is very wide ranging from the study of cascades on Facebook to the spreading of news through blogs, popularity of hashtags on Twitter, popularity distributions of offline items, etc.

- Many meme popularity distributions are **very fat-tailed**.

- Humans absorb and transmit information on a **wide variety of time scales**.

- We are not particles or magnetic spins. Then, **models of social interaction must therefore include “memory” effects** (non-Markovian aspects).

- We investigate the effects of memory on popularity avalanches caused by users choosing between multiple items that they have seen in the past.

We develop a probabilistic model (**"Null model"**) that use computational simulations to fit to data in order to:

a)- get analytical insights into the respective **roles of the network degree distribution**,
b)- **the memory-time distribution** of users,
c)- **the competition between memes for the limited resource** of user attention.

THE MODEL

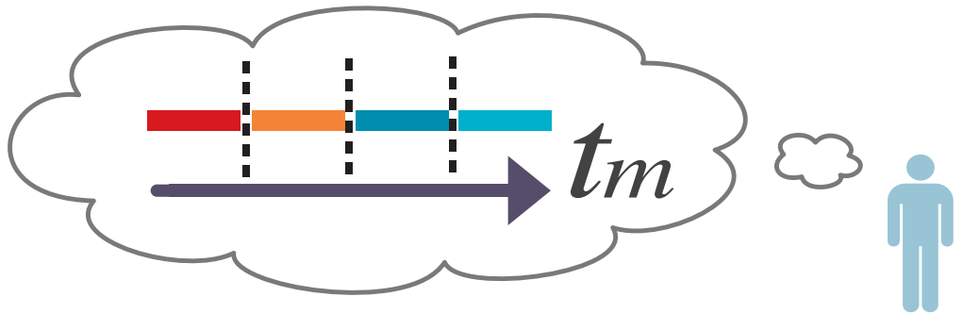
- Analytically tractable.

- Realistic enough (fitted to empirical data & able to reproduce several features of them).

- The phenomenon of “competition induced criticality” is robust to:

a) the inclusion of memory times
b) heterogeneous user activity rates
c) complex network structures

- Mathematical analysis to deal with the long memory of users.



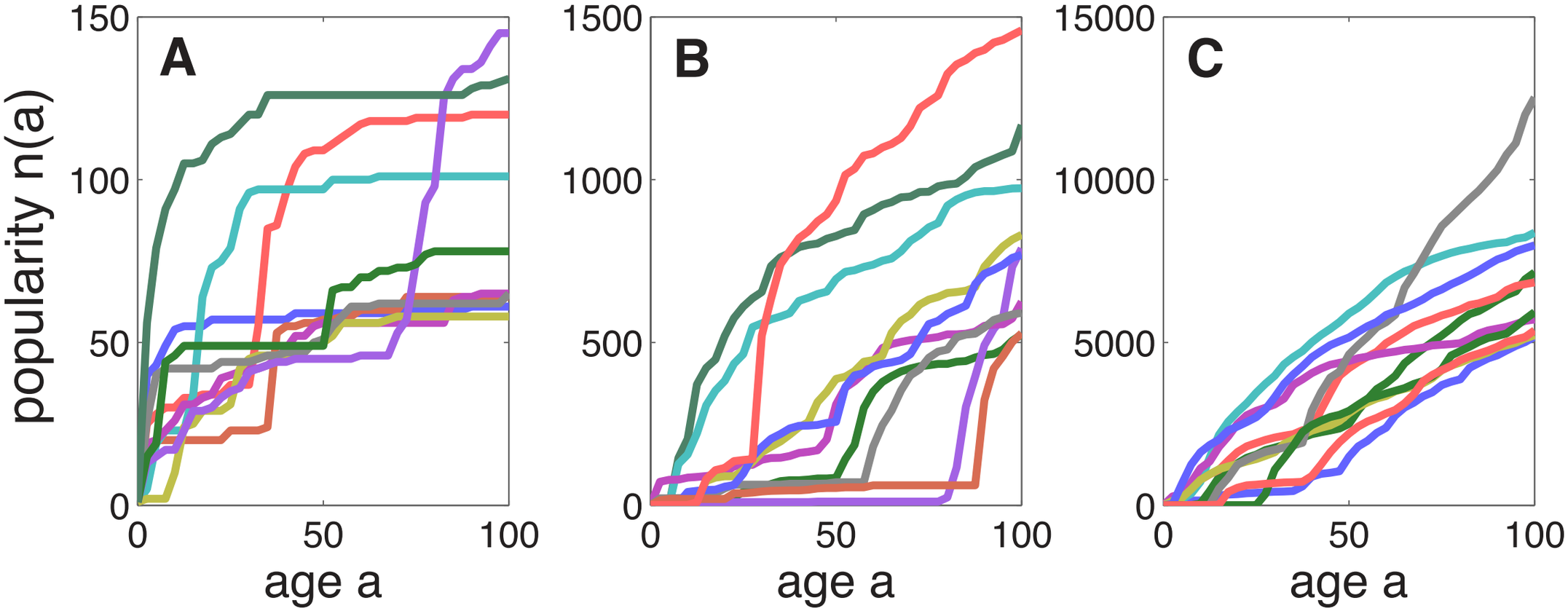
- It allows us to understand how heavy-tailed distributions of meme popularity evolve over a range of time scale.

- Model can be extrapolated to other examples of viral phenomena.

- There is a strong competitive pressure for user attention.

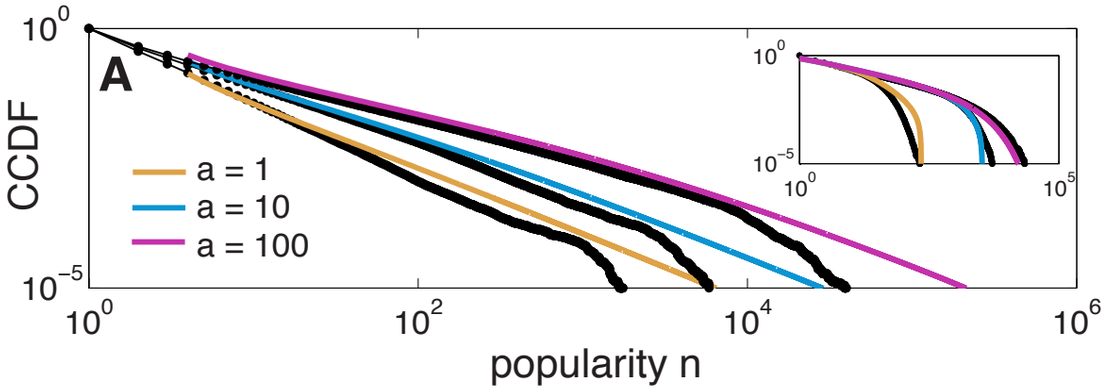
- All memes has the same fitness (NO advantage in terms of attractiveness to users).

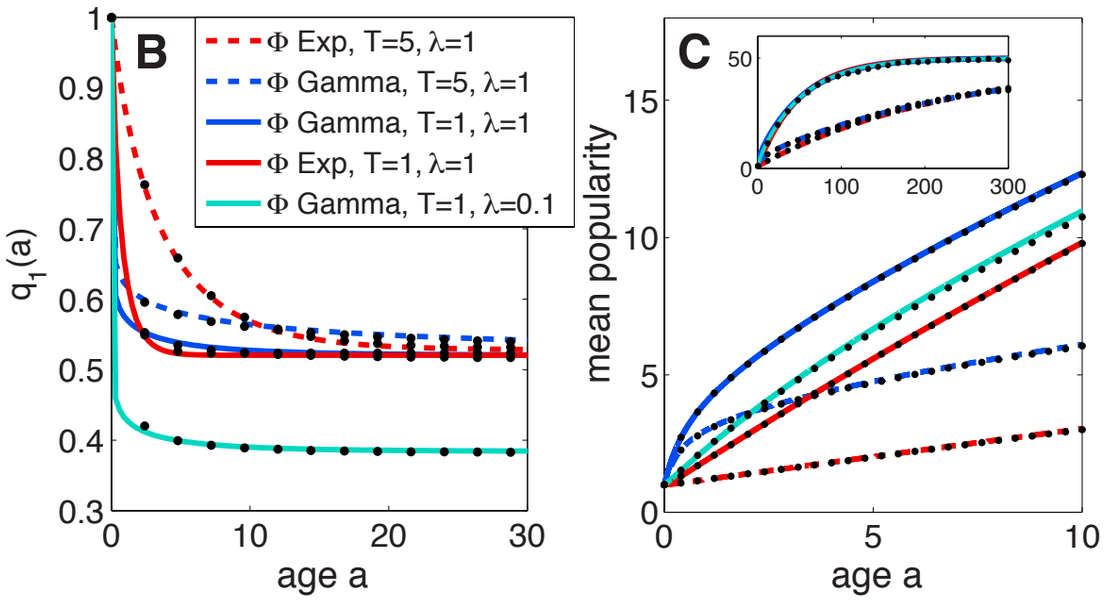
J. P. Gleeson, K. P. O’Sullivan, R. A. Baños, Y. Moreno, **“Effects of network structure, competition and memory time on social spreading phenomena”**, **Physical Review X 6**, 021019 (2016).

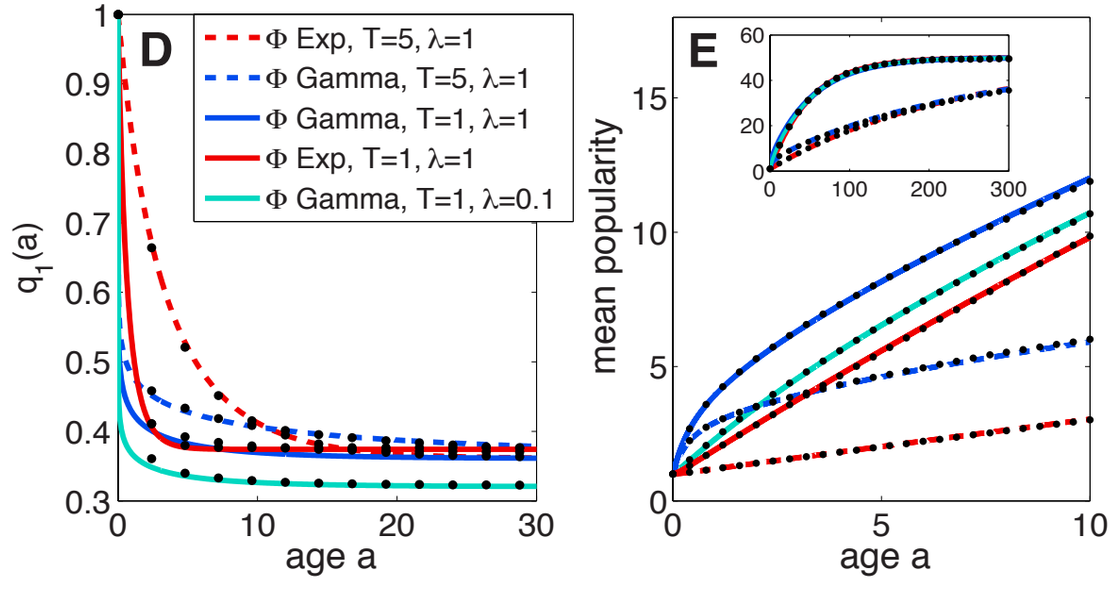


Examples of the age dependence of meme popularity from numerical simulations of the model. Each panel shows the popularity of 10 different memes.

The competition between memes for the limited resource of user attention causes **initial random fluctuations in popularities of memes to be amplified and leads to the variability across memes and to popularity distributions with very heavy tails**: heavier, for example, than what can be generated by models of preferential attachment or cumulative advantage type.







Panel(A) shows results for networks with the scale-free out-degree distribution $p_k \sim Dk^{-\gamma}$ for $k \geq 4$ and exponent $\gamma = 2.5$ (with $p_k = 0$ for $k<4$).

The mean popularity $m(a)$ of age-a memes is shown in panels (**C**) and (**E**) for the Scale-free and Poisson networks, respectively, and for the same memory-time distributions as used in panels (**B**) and (**D**).

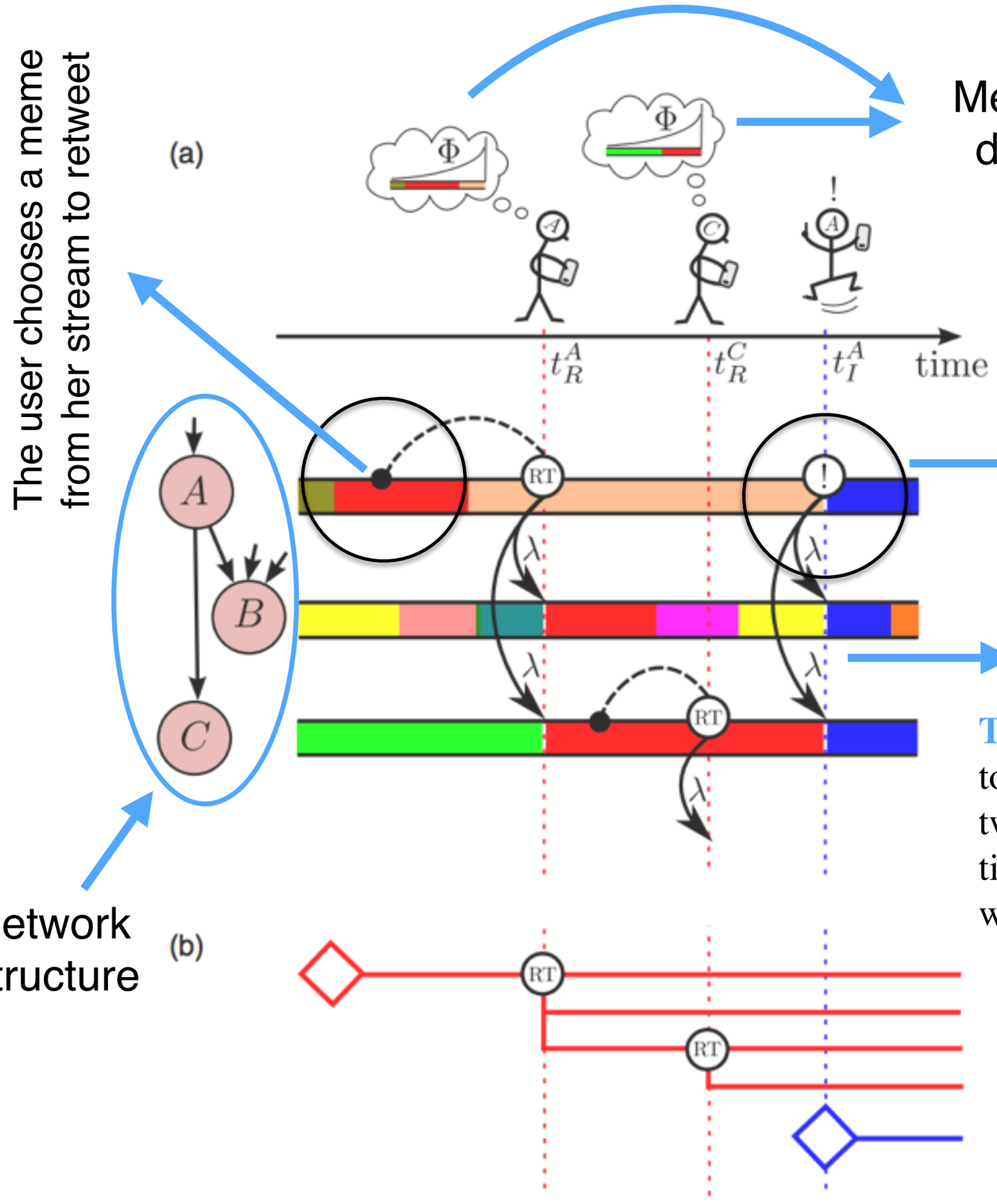
The mean memory time T determines the rate of linear growth of $m(a)$ at intermediate ages, while early memory times are exponentially distributed.

The $m(a)$ **curves can be fitted to empirical data on the popularity of Twitter hashtags**.

The qualitative features identified here (***nonlinear early growth, linear intermediate-time growth, saturation at later times***) have also been observed in several other measures of information spread on social networks: YouTube Videos, Facebook Apps.

The short-term behavior of the model [such as the small-a behavior in panels (**B**)–(**E**)] would be affected by introducing burstiness; incorporating such realistic features into the model is left as a challenge for further work.

The user chooses a meme from her stream to retweet



Memory-time distribution

The user invents a new meme

Is it really interesting?

Network Structure

The popularity $n(a)$ of a meme is the total number of times it has been tweeted or retweeted by age a, *i.e.*, by a time a after its first appearance (when it was tweeted as an innovation)

“Physics of Humans, Physics for Society”



What do we have?

Large amount of Data

Computational Social Sciences (CSS)
- Interdisciplinarity
- Tools from Statistical Physics, Network Theory & Complexity Science, Computacional Methods...

- New ways to analyze data
- Simulation Models
- Conduct Lab experiments in controlled environments.
- Validate theoretical predictions
- Analyze strategic interactions among subjects and the real clues of human behavior.
- Humans are heterogeneous and often unpredictable.

- New emergent behaviors
- A better understanding of the functioning of different systems

- Hints to Policy Makers
-Sustainable Society
- Future for Society

New concepts such as:
Big Data, Programmatic Advertising or Machine Learning are present in our environment

- Data must be transformed into VALUABLE INFORMATION
- Data per se do not constitute KNOWLEDGE
- Remove noise from Data

More Efficient Algorithms

Data demand:
- Large Storage
- High computacional power

- Security protocolos
- Privacy issues
- Protection against threats and attacks
- Confidentiality

Internet of Things



Artificial Intelligence



IoT, AI
Need to storage & process data in real time (*high speed transportation*)
HPC (High performance computing)

ADVANCES IN SCIENCE & INDUSTRY

Cosnet

New Era, New Approaches, New Paradigm

Inclusive & innovative
Society
(Data for Social Good)

Quality of the
Data
(not only the quantity
matters, but the quality)

Tools from
Statistical Physics &
Complex Systems Science,
Interdisciplinarity



New Theoretical Models,
Validation through Large-scale
data-driven simulations

Lack of Protocolos,
Ethical issues,
Privacy

Categorization/characterization
of human-generated datasets

New emergent patterns/ collective behavior

- Is the Online World representative of the population at large?

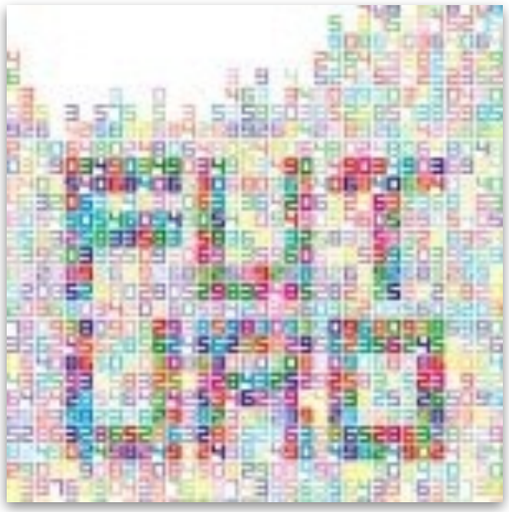
Standardized Data Collection
(measuring & accurate acquisition of data)
and Data Mining Processes

Reproducibility
of Experiments
(reinforce findings)

Cosnet

A new book: *“L’algoritmo e l’oracolo” is* based on how science predicts the future and helps us change it. In the book, personal stories merge with enriching scientific experiences drawn from several contexts. I could certainly stay with many passages of this book, but one in particular caught my eye. It is a succinct, but powerful approach.

“È invece importante essere consapevoli che stiamo entrando in una nuova era, dove riuscire a guardare il futuro sarà una pratica costante a partire dai fenomeni sociali per arrivare ai bisogni di ogni singolo individuo. Una pratica che definirà nuovi equilibri e poteri, ma che non dobbiamo considerare infallibile: può inciampare, ed è soggetta a pregiudizi che possono essere pericolosi. Ma proprio per questi motivi dobbiamo prenderla sul serio”.



L’ algoritmo e l’oracolo

…”Instead, it is important to be aware that we are entering a new era, where to look at the future will be a constant practice, starting from social phenomena until reaching the real needs of each individual. A practice that will define new balances and powers, but that we should not consider infallible: it can stumble, and it is subject to prejudices that could be dangerous. It is precisely for all these reasons that we must take it seriously”.

- How can Physics benefit from the enormous amount of data generated by the massive use of ICT? How important are behavioral data? What role does Physics, as a discipline, play in this context?

- We need to build what we call: “**Physics of Society**”. A society composed of many interacting heterogeneous entities (people, businesses, institutions) as a physical system. This will allow us:

  - To anticipate and forecast future societal trends and human behavioral responses.

- People are extremely difficult to study. Humans are not molecules of an ideal gas nor do they follow a well-behaved Maxwell–Boltzmann distribution function.

- People have the capacity to adapt (degree of uncertainty) and the concept of ‘*representative agent*’ as a typical, perfectly rational and omniscient entity is unrealistic.

- Even if a suitable description of individual behavior were available, scaling it up to groups of individuals wouldn’t be straightforward because the fluctuations with respect to the average can be large.

Guido Caldarelli, Sarah Wolf, and Yamir Moreno, **“Physics of humans, physics for society”,** Nature Physics 14, 870 (2018).

- It is esential to make sense of the data.

- While different methods for data analysis can efficiently extract information from the data, they lack explanatory power.

- **“What if” scenarios.** The art of modeling (**definition, calibration and validation**) could be used in collaboration with the social sciences, for the development of mechanistic and theoretical models that could contribute to a better understanding of (technology-mediated) human interactions and societal dynamics.

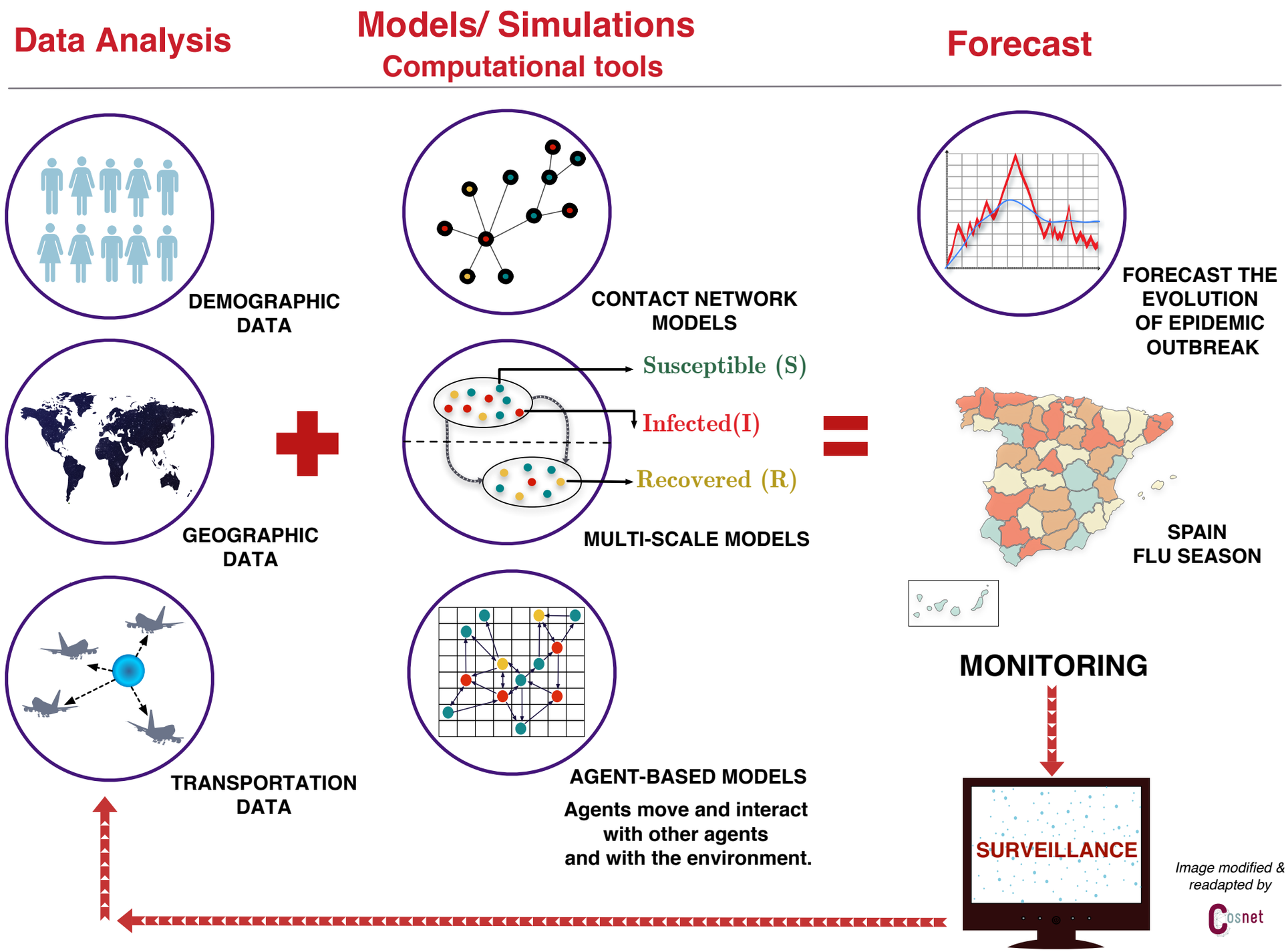
- **Testing theoretical predictions**. Large-scale Experiments (Observation under controlled conditions).

- **Interdisciplinary/multidisciplinary effort**. Physicists have to leave their traditional comfort zone and establish unconventional collaborations with researchers of other disciplines.

- **More initiatives & support of international organizations.**

Guido Caldarelli, Sarah Wolf, and Yamir Moreno, **“Physics of humans, physics for society”,** Nature Physics 14, 870 (2018).

Modern Epidemiology, for example, has demostrated a great success in predicting the large-scale spreading of infectious diseases.



InfluenzaNet is a system to monitor the activity of influenza-like-illness (ILI) with the aid of volunteers via the internet. InfluenzaNet obtains its data directly from the population. This creates a fast and flexible monitoring system whose uniformity allows for direct comparison of ILI rates between countries. **There are several European countries involved in this project.**



Nectunt
MORES HOMINUM
Social Dilemmas & Human Behavior

+ 10 Experiments
+ 6.000 volunteers

Fundación ibercivis

+ 50 Experiments
+ 10.000 volunteers

Dissemination projects

FECYT FUNDACIÓN ESPAÑOLA PARA LA CIENCIA Y LA TECNOLOGÍA

+ 10 Projects

www.ciencia-ciudadana.es

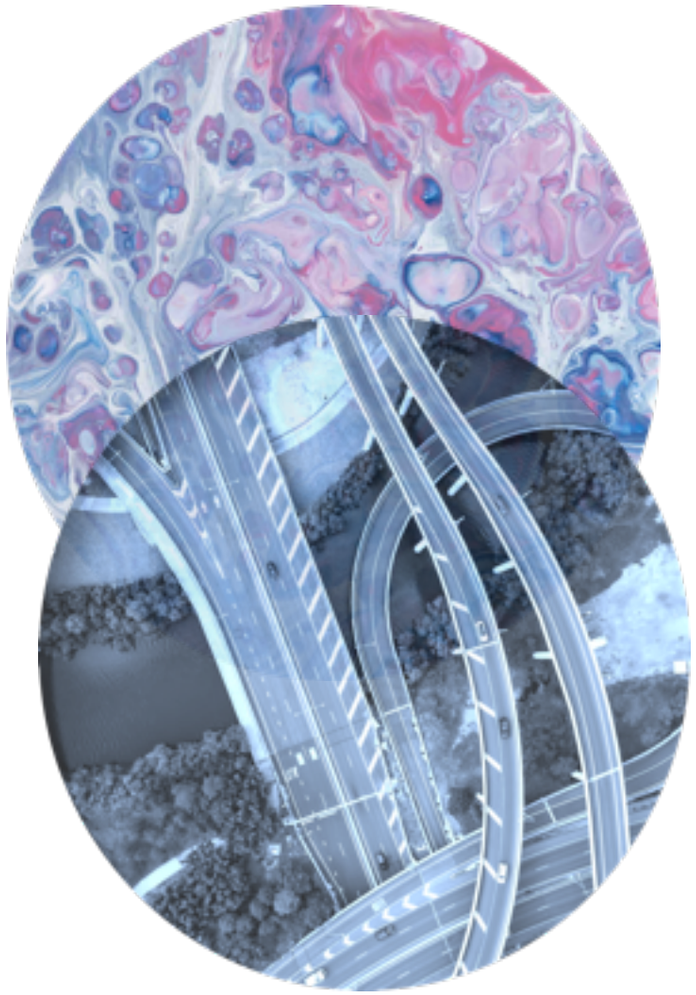
1 White paper on Citizen Science

precipita

3 Crowfunded Projects

WHY COMPLEXITY?

Agent interactions



COM

PLEX

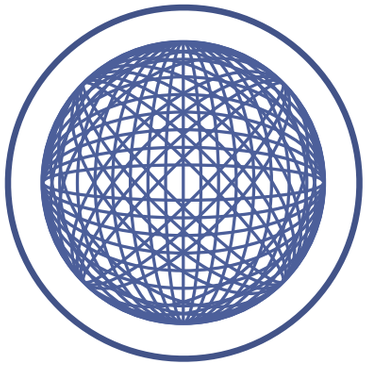
ITY

- New Paradigm
- Integrative, multidisciplinary vision
- Collective behavior
- Interaction with the environment
- Adaptability
- Emergent properties
- Out of equilibrium dynamics
- Analysis of the different scales

Emergent behaviors
macroscopic phenomena

How individual components give rise to emergent & global properties?

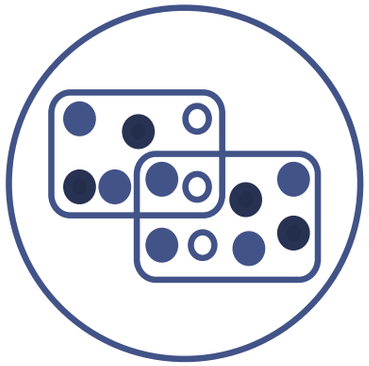
Complexity & Interdisciplinarity



COMPLEX SYSTEMS
FOUNDATIONS



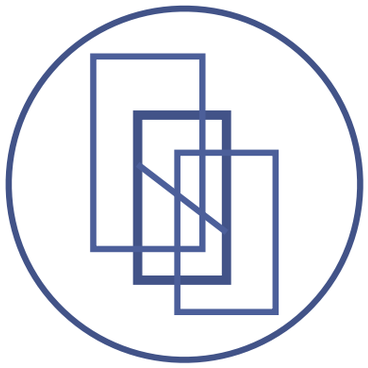
BIOLOGICAL SYSTEMS



CONTAGION &
EPIDEMICS



ECOLOGY



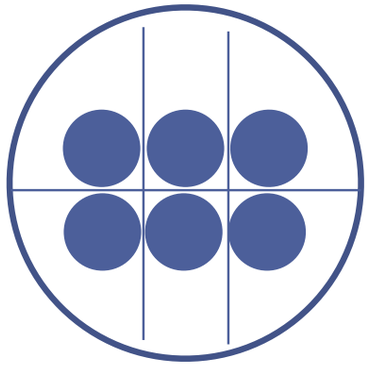
MULTIPLEX NETWORKS



SOCIAL & TECH.
SYSTEMS



HUMAN SYSTEMS



COLLECTIVE
BEHAVIOR



EVOLUTIONARY
GAME THEORY



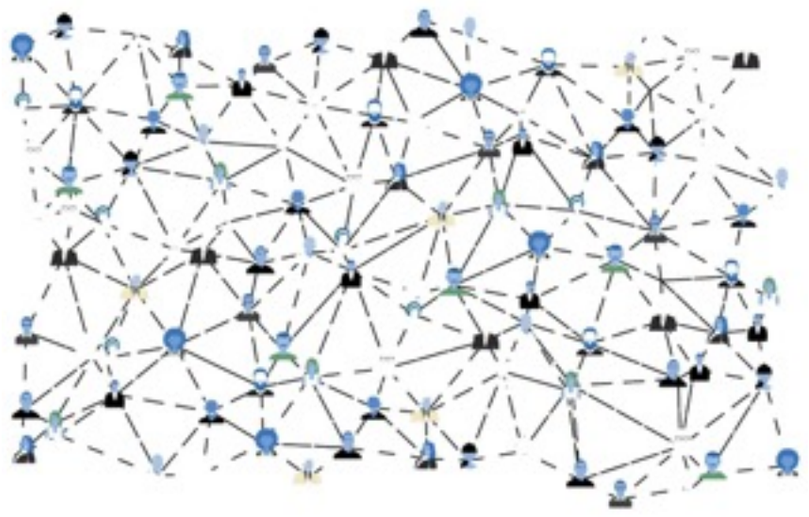
URBAN PLANNING
& INFRASTRUCTURE



ECONOMICS
& FINANCE

Social Networks

The study of social networks & their influence on society.



Social network analysis (SNA) is the process of investigating social structures through the use of networks and graph theory.

- **Social Network** is a social structure consisting of nodes represented by individuals (friends, colleagues, etc.) or organizations and a set of links that represent the interactions between them.

- The study of social networks is very useful to understand how people interact with each other and how networks influence human behavior.

- The new concepts derived from this study have markedly influenced different disciplines ranging from Physics to Psychology or Anthropology.

- The analysis **is focused on the interactions among the elements of a social entity and not on individual behavior**.

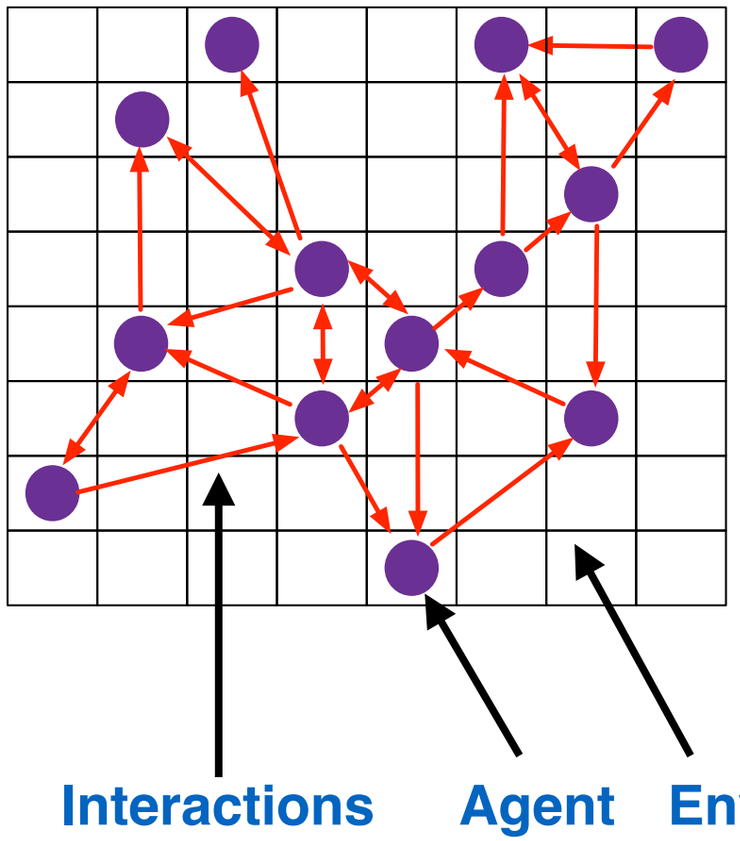
- **Some applications**: predicting a financial crisis, dissemination of information, determine the impact of a disease in a community, etc.

Social Networks

The advent of Social Networks has been a turning point in the way we relate to each other.

There are many examples of studies that use the information contained in Social Networks to unravel the real functioning of Society:

- Studies on public opinion using Twitter information
- The position on climate change (a moral dilemma)
- The analysis of homophobia and racism
- The level of happiness in the world
- The impact of networks on major social protests such as: the Arab Spring, 15M Movement or the Occupy Wall Street.
- The fluctuations in the stock market (*economic context*)
- Sistemic risk and financial stability
- The spread of Influenza (*epidemics*)
- The possibility of predicting a depression by analyzing Twitter messages, for example.



Some advantages:

- Heterogeneous, autonomous & adaptive agents
- Process oriented
- Flexibility
- Agent-based simulation is generally used to study how individual behavior at the micro-level can produce macro-level structures and regularities.

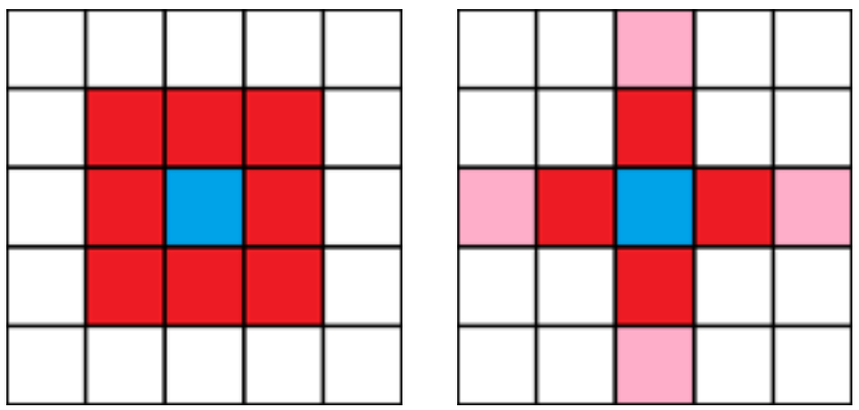
Agent-Based Models (ABM)

- Simulation modeling tecnique to build models of real-world systems.
- Agents are autonomous entities.
- **Agents interact among them and with the environment**.
- **Agents are able to perceive** (*perception*) **and respond to the changes in the environment.** More environmental complexity.
- **Set of behaviors**: Agents can move & communicate with other agents.
- We are able to modeling both individuality and heterogeneity.
- The whole system exhibits an emergent behavior as the result of interactions among the components (agents).

Cellular Automata (CA):

A discrete model of a spatially distributed process that can be used to simulate various real-world processes.

- Usufeul to simulate complex systems and self-organizing processes over space and time.
- A cell is assigned to each element in the system.
- **All interactions are local.**
- State of a cell is determined by the previous states of the surrounding neighbourhood of cells.
- Transition function/rule: the state of a cell at a given time depends exclusively on its own state one time step before and the states of its nearby neighbours at the previous time step.
- Time, space and states of the system are discrete.
- It allows to study the emergent patterns that born from local interactions between neighboring cells of a grid (physical environment).



Images: wikipedia.org

Human Social Systems

When we analyze human social systems, there is not a universal law, theory or rule that can be used to accurately anticipate their behavior and evolution.



Behavioral, personal, environmental factors, etc.

New Technologies & Social media:
Internet, Twitter, Facebook, Youtube...

↓

New way of analyzing human behavior

A bit of History…



Lambert Adolphe Jacques Quetelet (1796-1874) was a Belgian astronomer, mathematician and statistician. He was considered one of the most prominent and influential statisticians of XIX Century and the first scientist to apply statistical methods to humans. Quetelet also introduced the famous concept of: ***L' Homme Moyen*** (the 'average man') who would exhibit the average features of all individuals. According to Quetelet, social phenomena were extremely regular and those regularities could be predicted by applying statistical techniques ("social physics"). He tried to unveil and understand the statistical laws that were behind different social phenomena (suicide rate, crime rate, etc.)



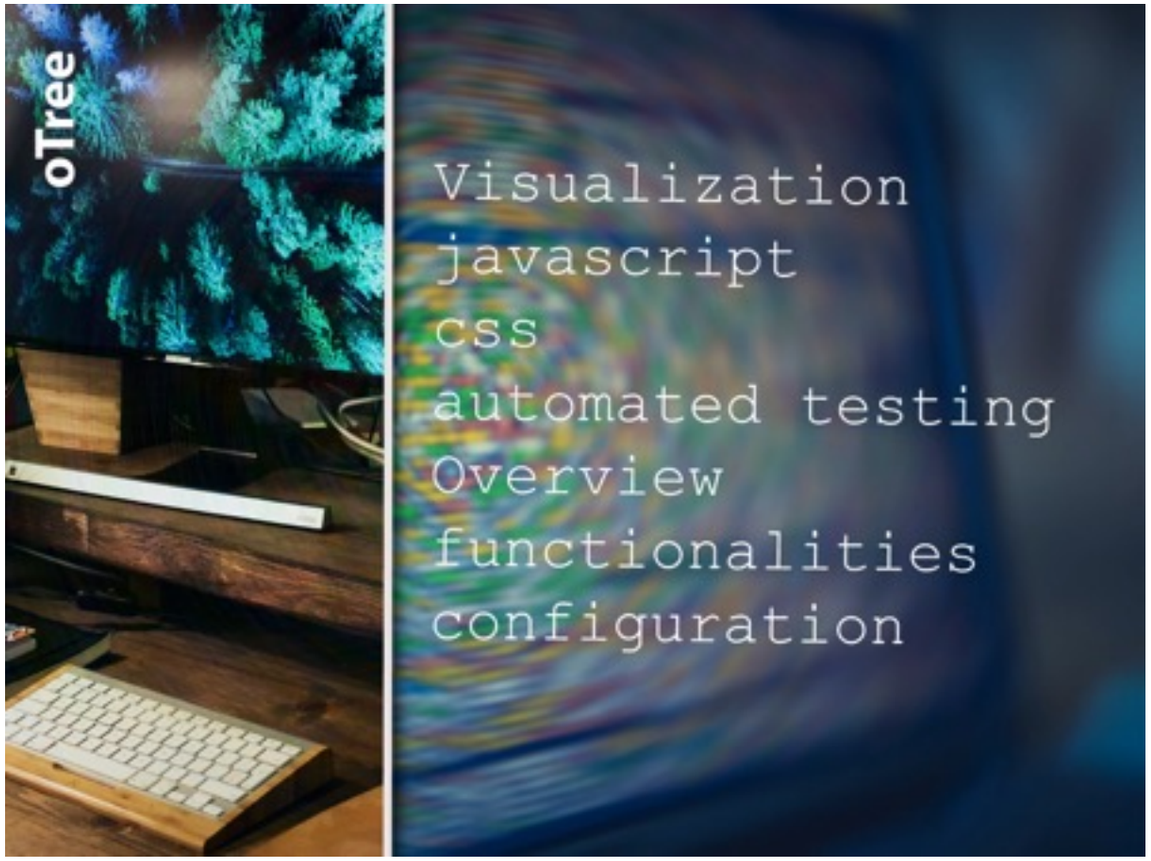
Isidore Marie Auguste François Xavier Comte (1798-1857) was an influential French philosopher, the founder of Positivism and the first to coin the term **Sociology** in 1838 **as a new way to looking at society**. This term had already been introduced in the year 1780, albeit with a different meaning, by the French essayist Emmanuel Joseph Sieyès (1748–1836). Comte's view, there was a need of a new science capable of discovering laws for society in the same way that other laws had been discovered progressively for natural phenomena (using scientific evidence to find out causes for human behavior).

Note that there is a vast and specialized literature on this subject. These are just examples of the dawn of a new science capable of studying society and human behavior.

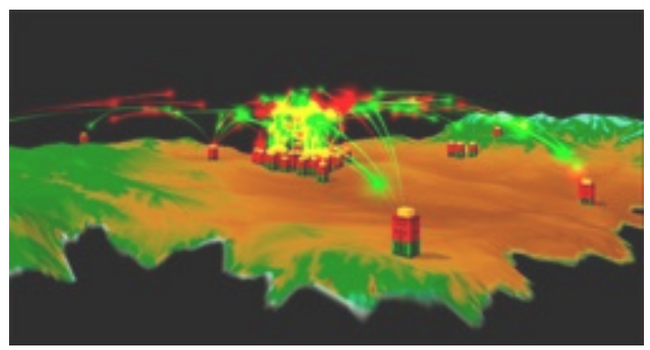
Conduct Experiments

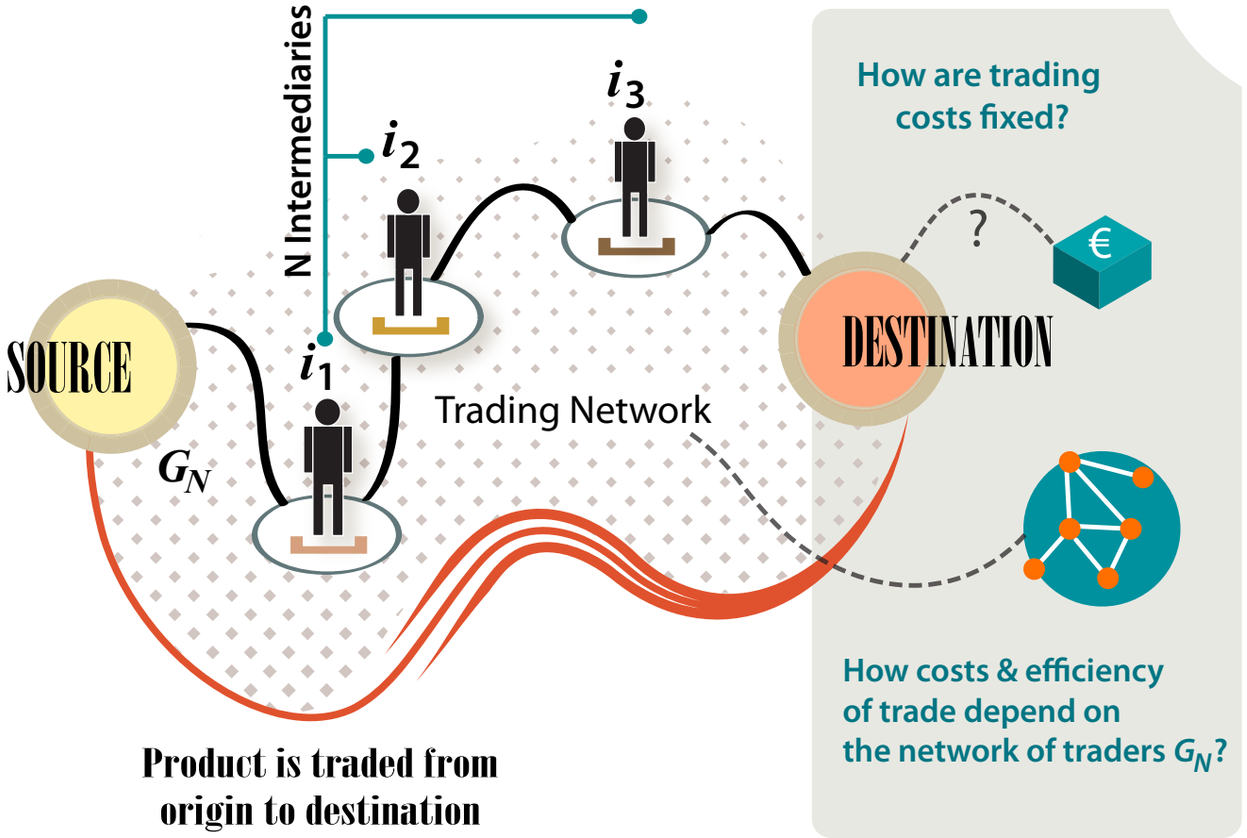
LARGE-SCALE EXPERIMENTS:

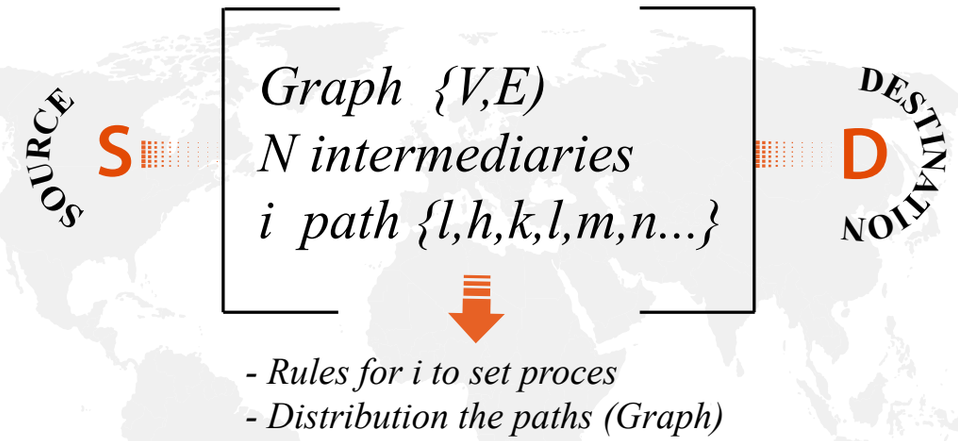
- What's the problem? **Identify the problem and make a prediction**
- Define real objectives
- Experimental design (simple & clear). **Select input variables**
- HPC infrastructures
- Establish user rules
- Ethical considerations (user's consent, privacy…)
- Collect & analyze data
- Interpret the results
- Conclusions, validation & applicability of the results



- Test the prediction, analyze the results and determine if the theory is true or false.







RULES OF TRADE

Users have to set a price: $C_{SD} = \sum_j C_{i_j}$

If $C <$ threshold, trade occurs through the path that satisfied main $\{C_{SD}\}$

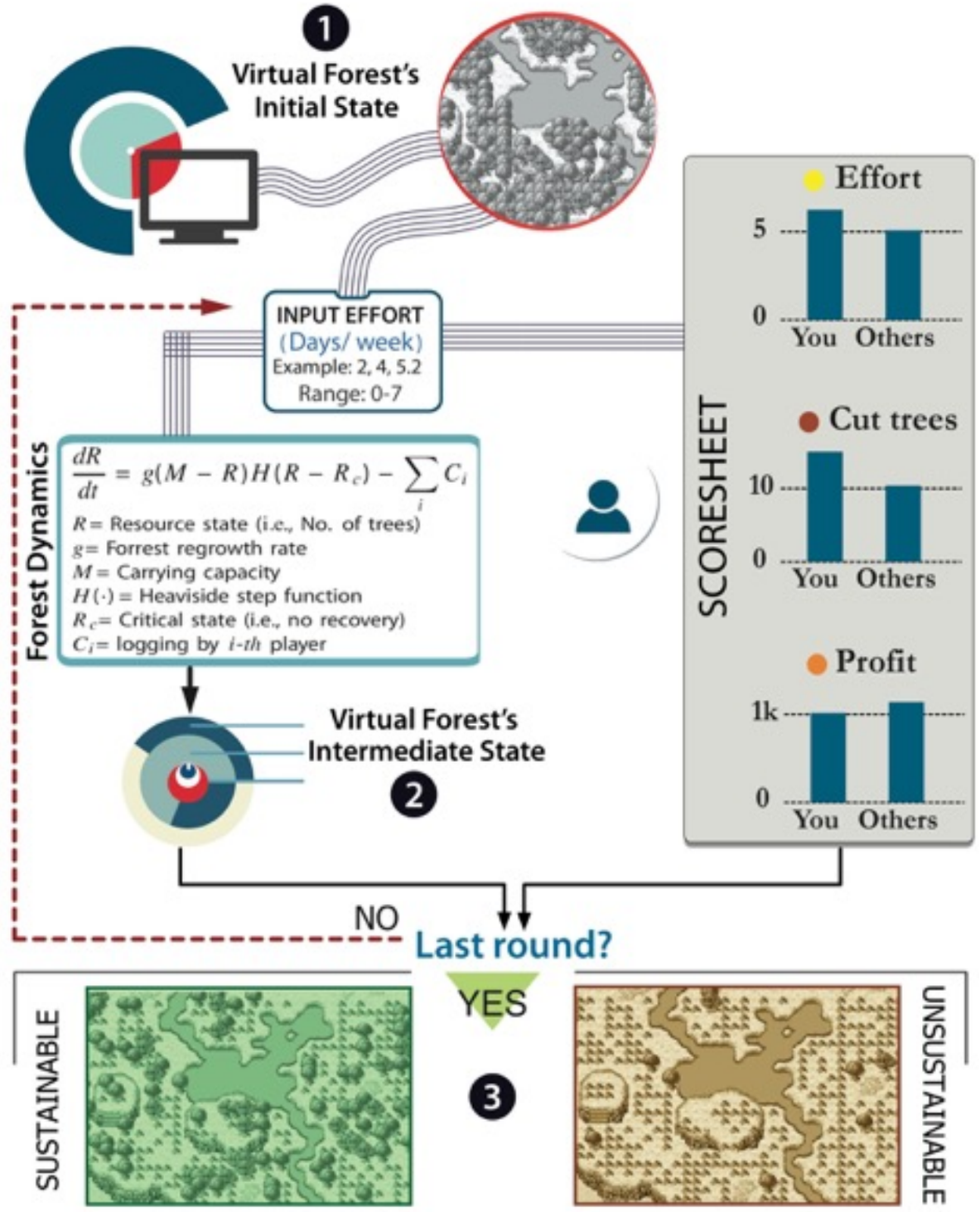
QUESTIONS

How cost and efficiency of trade depend on the network of traders G_N?

How traders set their prices, *ie*, behavioral rules?

Cosnet

Experimental set up



Cosnet

Game Theory

Evolutionary Game Theory is based on a mathematical application that is able to analyze the strategic interaction between rational or irrational agents that can be individuals, groups, companies, large corporations, etc.

The game consists of a set of players and strategies. Each player wins a reward that depends not only on his own strategy, but also on the strategy carried out by his competitors.

This theory is very useful for revealing and predicting human behavior and provides a framework and essential analytical tools for understanding a wide range of phenomena that occur in real life and are linked to decision making by individuals or groups of individuals that interact with each other *(see contributions by John von Neumann, Oskar Morgenstern and John Nash*).

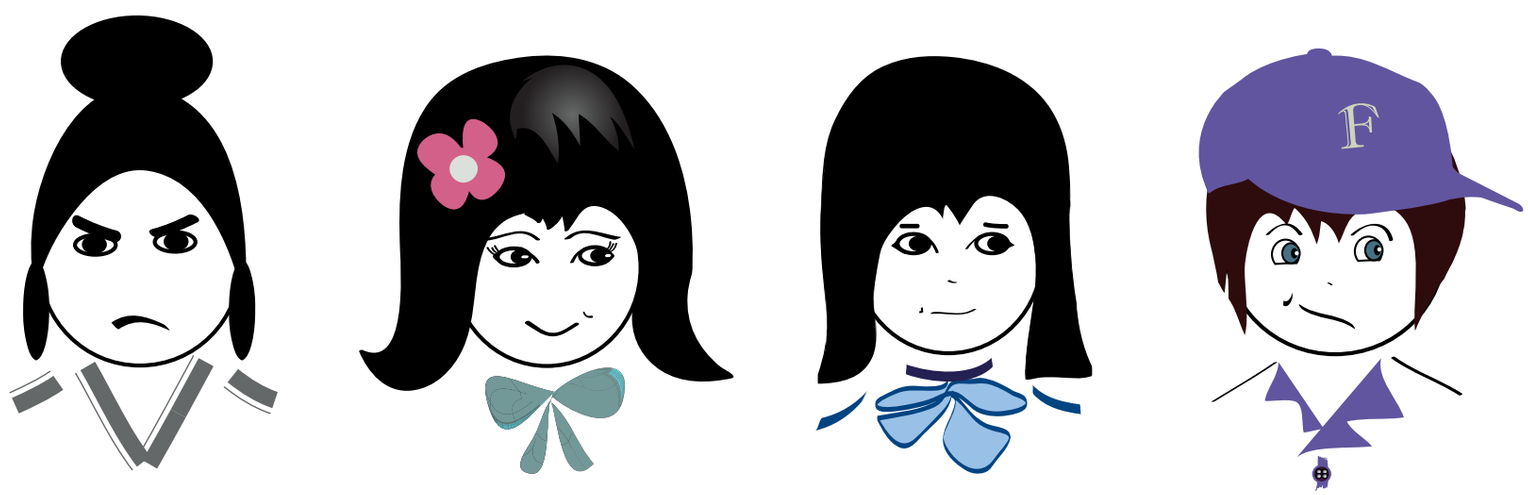


Image: Cosnet

GAMES	Payoff Matrixes
HARMONY GAME	**T:** Temptation to defect
SNOW DRIFT GAME	**R:** Reward for mutual cooperation
STAG HUNT GAME	**P:** Punishment for mutual defection
PRISONER'S DILEMMA GAME	**S:** Sucker's payoff

Nash equilibrium is a term used to describe a scenario where no player can profitably deviate given the strategies of the other players.

A **pure strategy** is one strategy according to which a certain behavior (or "move") is chosen with certainty in a given context.

Game Theory

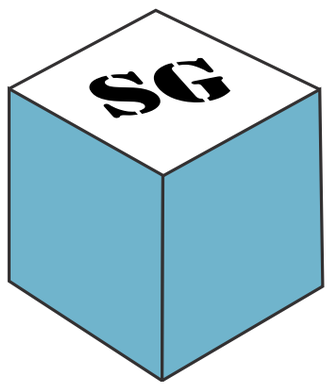
S > P, R > T



The expected payoff is higher for cooperation regardless other player's actions.
Cooperation is the only strict best response to itself and to defection.

Unique Nash Equilibrium
Non Dilemma Game
No collective action problem

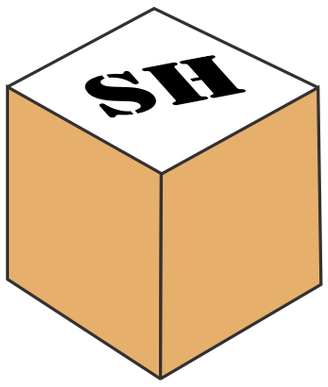
T > R > S > P



Defecting provides the higher benefits against a cooperator, but defection is risky since defectors are penalized.
The best strategy is to do the opposite of what your opponent does.

2 Nash Equilibria
Two pure strategies equilibria and a mixed strategy of cooperation and defection (Mixed equilibrium).
Mixed strategy is inefficient.

R > T > P > S



Conflict between safety & social cooperation
(cooperation is a risky choice)

2 Nash Equilibria
Both players cooperate/defect
Mutual cooperation/ mutual defection are Nash Equilibria

T > R > P > S

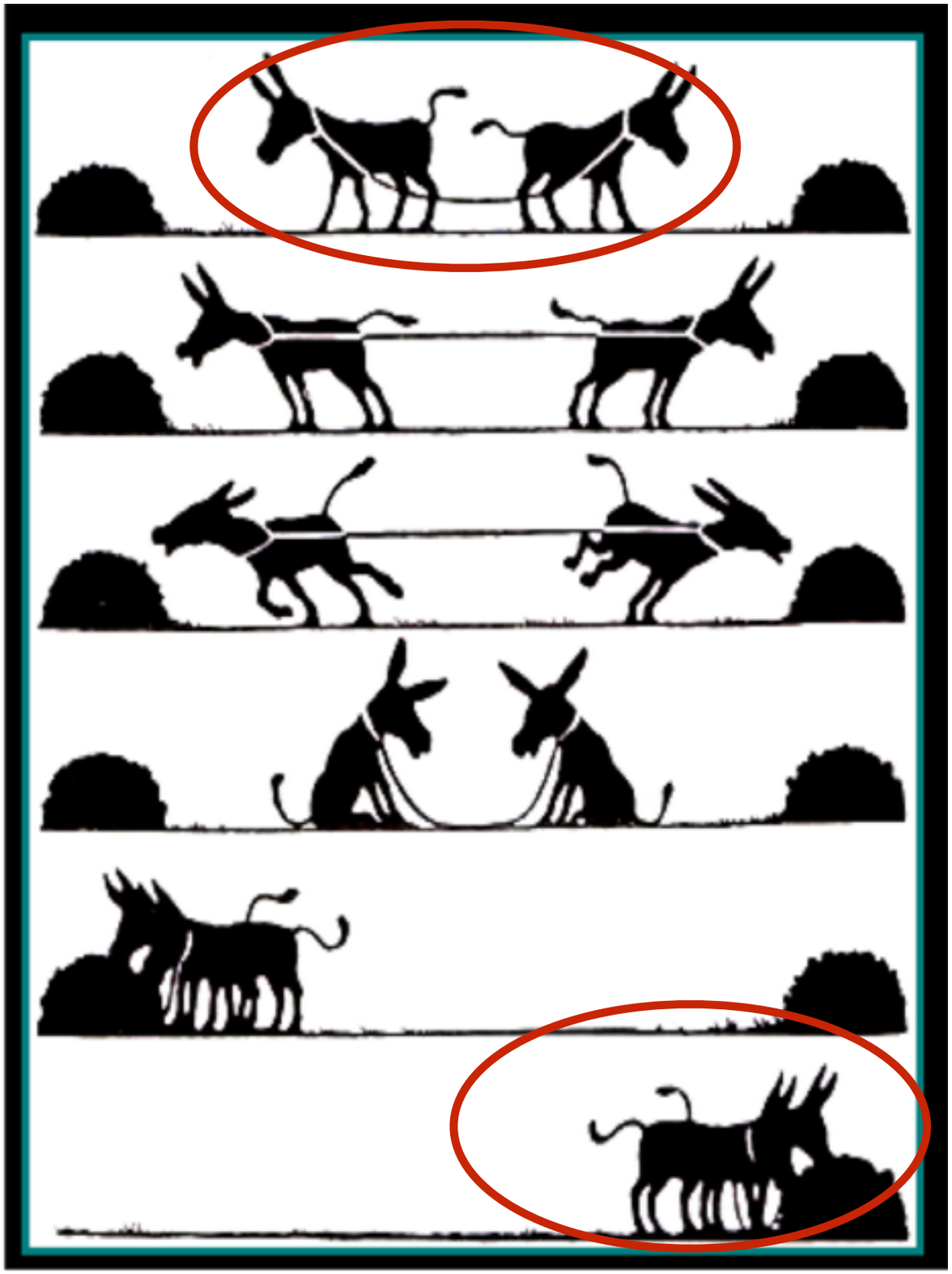


Conflict between individual rationality and mutual benefit.
In equilibrium, each prisoner chooses to defect even though both would gain more if they cooperate.

Nash Equilibrium
One dominan strategy equilibrium:
Both players defect

Cosnet

Game Theory

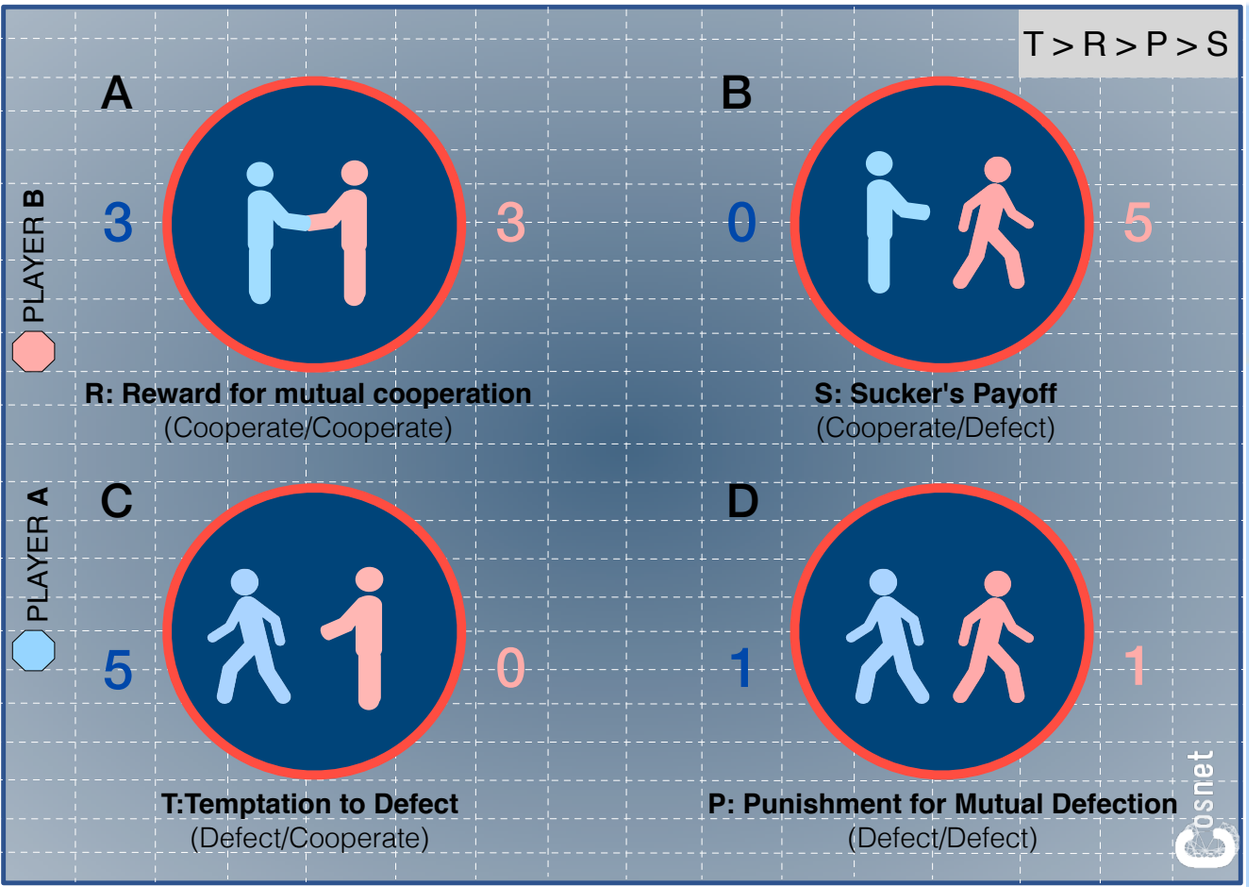


Snow drift game

The famous Prisoner's Dilemma is a formalized incentives game, which considers two types of players:

- **Cooperators**: who pay a cost to help other people.
- **Defectors**: who avoid paying this cost while reaping benefits from cooperators.

- From a selfish perspective, not cooperating is always the best option.
- However, mutual cooperation is much better than not cooperating individually. **This is the dilemma!!!**
- Sometimes, selfish behavior would not get anything in return, but by cooperating, we obtain mutual benefits.





Prisoner Dilemma **T>R>P>S**

Snow Drift Scenario **T>R>S>P**

Player A \ Player B	*C*	*D*
C	(3, 3)	(0, 5)
D	(5, 0)	(1, 1)

Player A \ Player B	*C*	*D*
C	(3, 3)	(1, 5)
D	(5, 1)	(0, 0)

duality, dilemma, social approach, global, change …





Thanks to M.C. from Cosnet Lab for the Posters design
2nd poster: Inspired by Banksy & Magda Drobczyk works.
E.L.M.P._250141



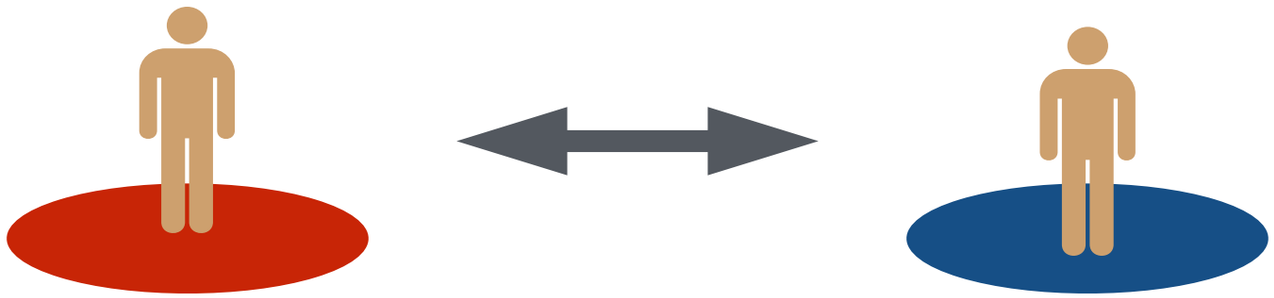
BEHAVIORAL ECONOMICS

The field of behavioral economics studies economic decision-making. According to its theories, human behavior is less rational, stable, and selfish than traditional theory suggests (*homo economicus*), due to bounded rationality, limited self-control, and social preferences.

Homo economicus, also known as economic human, denotes a view of humans in the social sciences (particularly Economics) as self-interested agents who seek optimal, utility-maximizing outcomes. In other words, a human being characterized by the infinite ability to make rational decisions.

Homo economicus

(Highly reductionist concept, Neoclassical Economics)



- Rational agent (perfect rationality)
- Self-interested
- Ideal decision-maker
- Stable preferences

unrealistic scenario

Humans

Accurate concept

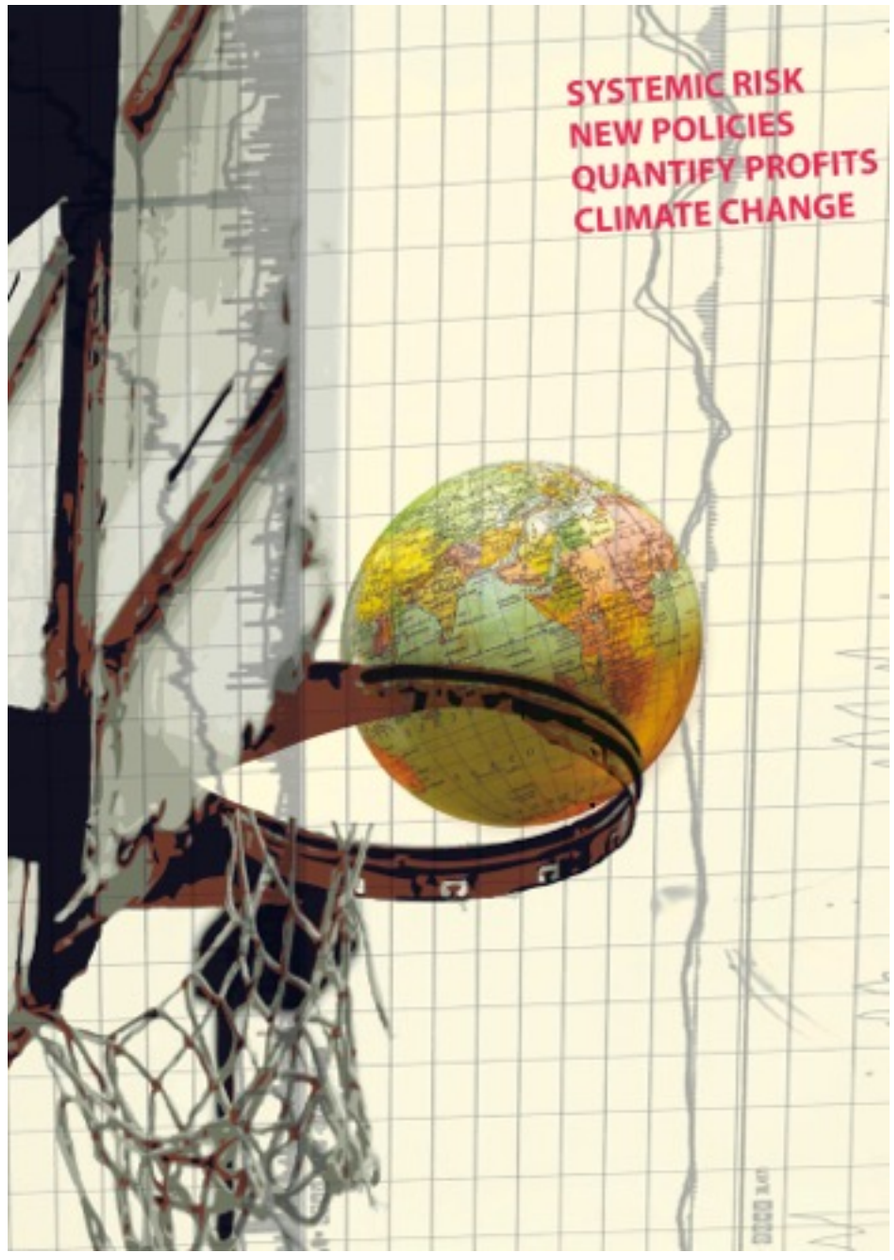
- Irrational agent
- Uncertainty/lack of information
- Decisions influenced by the context/environment
- Agent not only motivated by self-interest. Possibility to choose considering diverse factors: ethics, fairness, feelings, loyalty, social pressures, norms, etc.

realistic scenario

Experiment on impact investment
Experimental Economics

RESEARCH QUESTIONS:

- What is the effect of previous knowledge about impact investing?
- Do potential investors invest differently if they are already familiar with the "***impact investing"*** concept as opposed to those who have never heard of it?
- How do investors' preferences change depending on the way different investment instruments are proposed to them?
- How much financial return can investors sacrifice for social impact, considering different risk factors?
- Do external factors affect citizens' behavior (i.e. could incentives from the government change investors' behavior)?



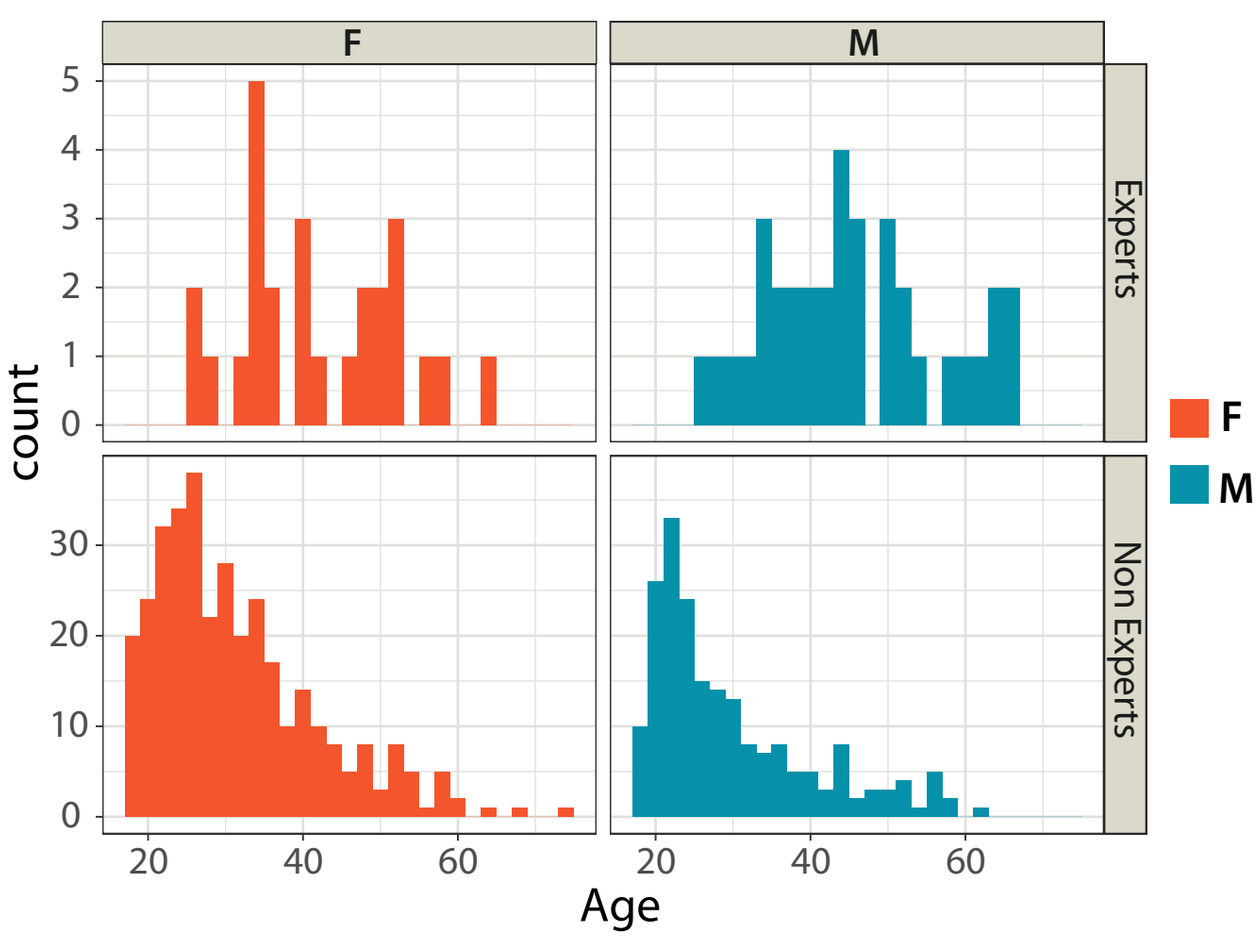
Felipe M. Cardoso, Luisa De Amicis, Silvia Binenti, Carlos Gracia-Lázaro, Ángel Sánchez & Yamir Moreno, **"Understanding Drivers when Investing for Impact: an Experimental Study"**, **Palgrave Commun 6, 86 (2020).** https://doi.org/10.1057/s41599-020-0447-y

SAMPLE DESCRIPTION:

Experts: A group consisted of 55 experts and practitioners in the field of impact investing, which were recruited through PlusValue's professional network and thanks to a referral sampling system.

Non experts: A non-probability sampling of 541 individuals, who are likely to have no previous knowledge on the concept of impact investing.

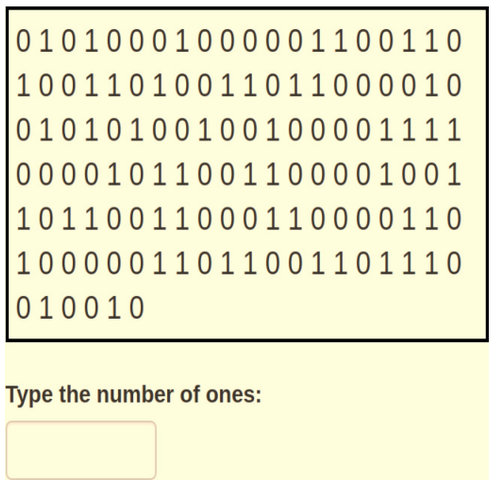
Out of 596 participants, our sample was composed by 366 female participants (341 non-experts and 25 experts) **and 230 male participants** (200 non-experts and 30 experts).



METHODOLOGY:

- Individuals made **scenario-sensitive investment decisions** generating different financial returns and impact outcomes, including no impact at all.

- **The game starts with a simple "effort task"**, in which the subject is asked to count the number of ‘ones’ they are displayed in a sequence of 1s and 0s.

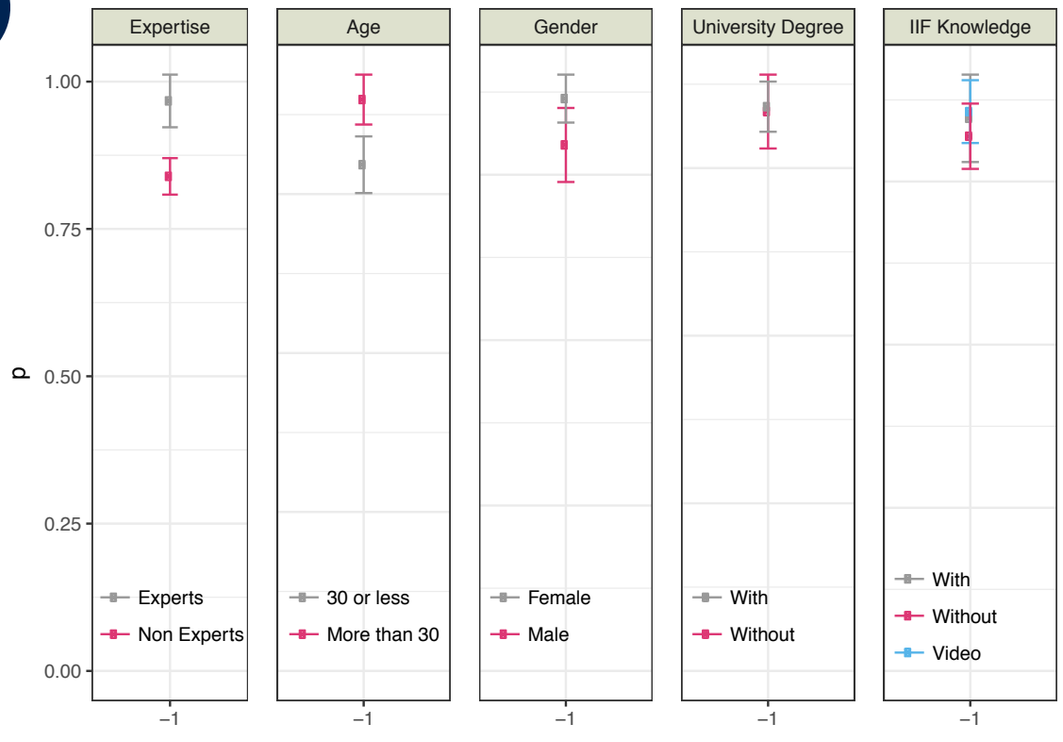


- **Participants were assigned a budget as a function of how well they performed in the effort task** - this budget represents the ‘**capital**’ they could invest in each of the scenarios proposed during the game.

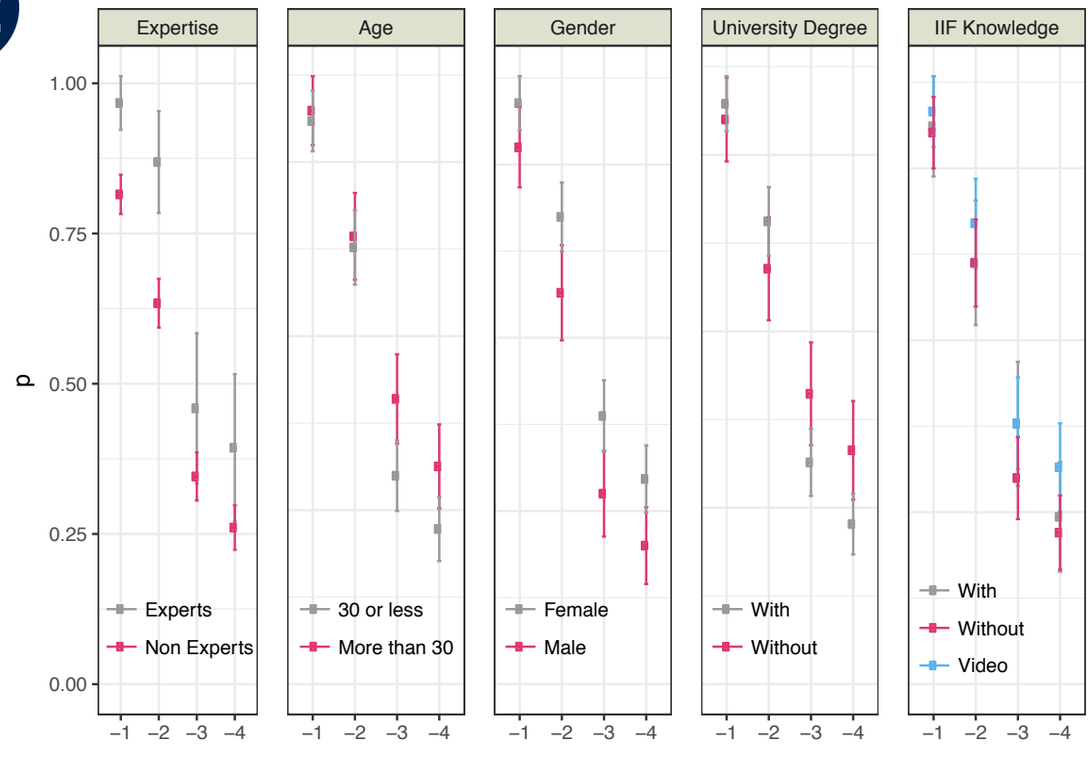
- Subjects were made aware that, thanks to a lucky draw selecting about 10% of the participants, their earnings for each investment decision could be turned into real money.

Simple traditional *versus* impact investment scenario.

Q1

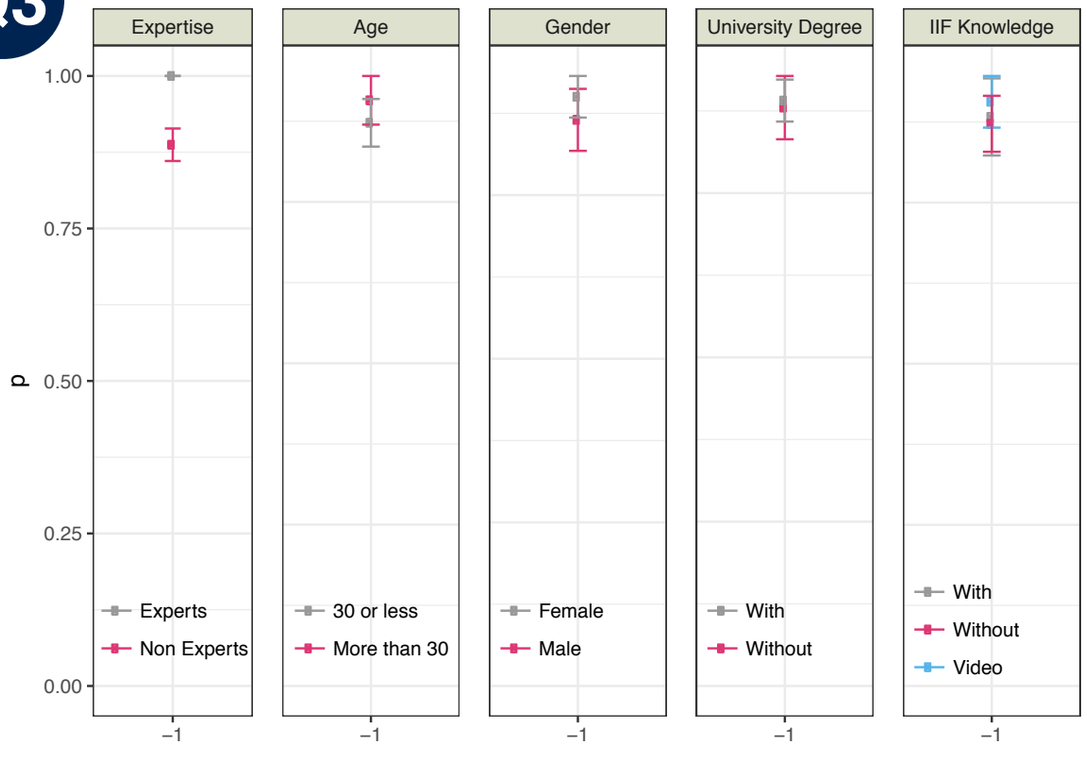


Q2

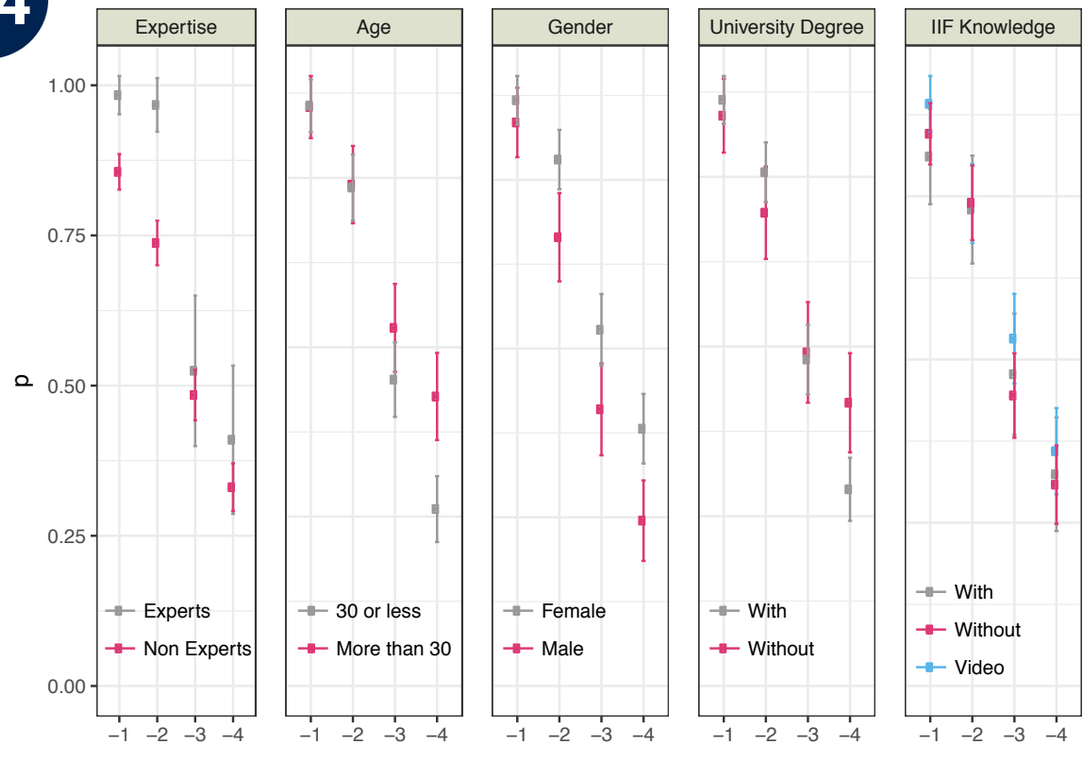


Traditional *versus* impact investment scenarios with additional details on social impact

Q3

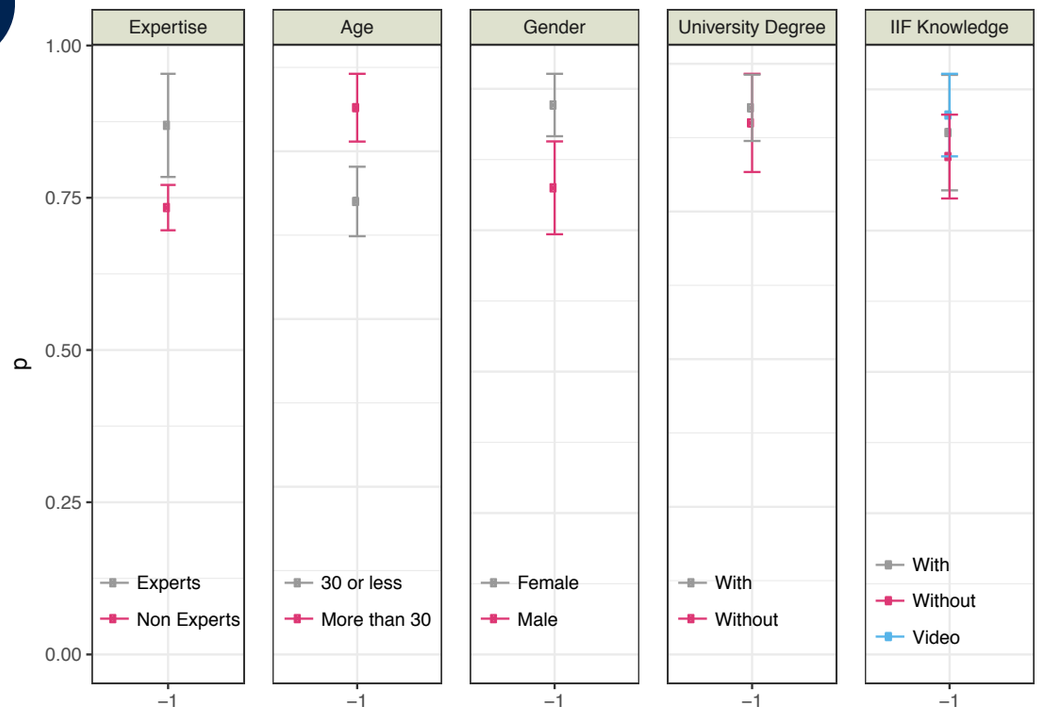


Q4

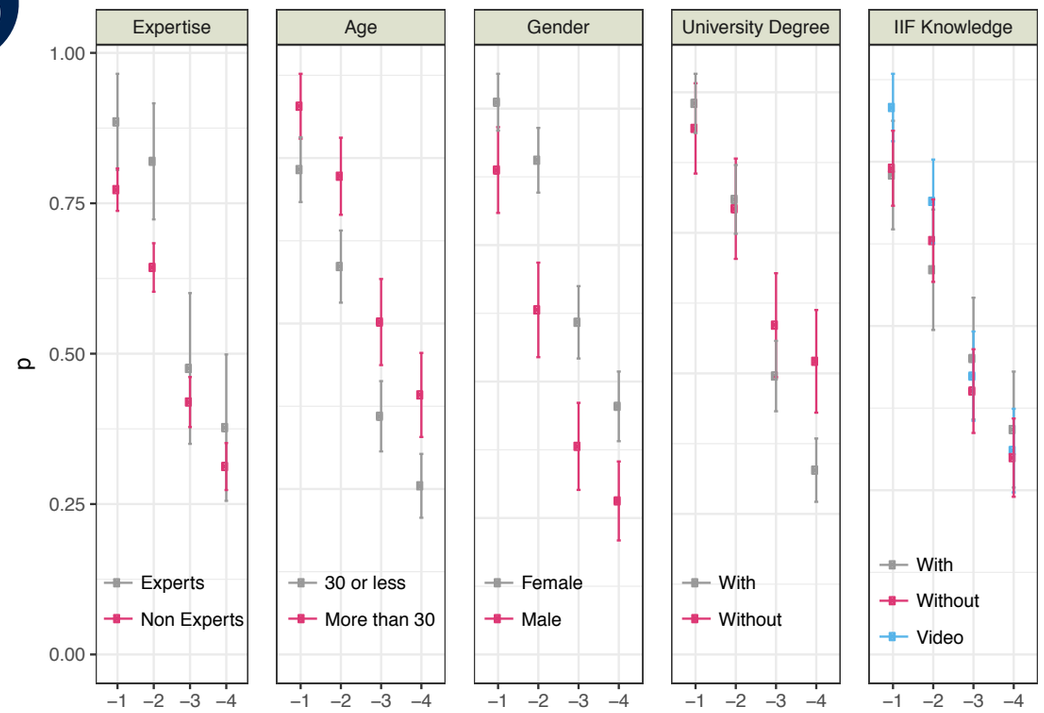


Traditional *versus* impact investment scenario with a risk factor

Q5

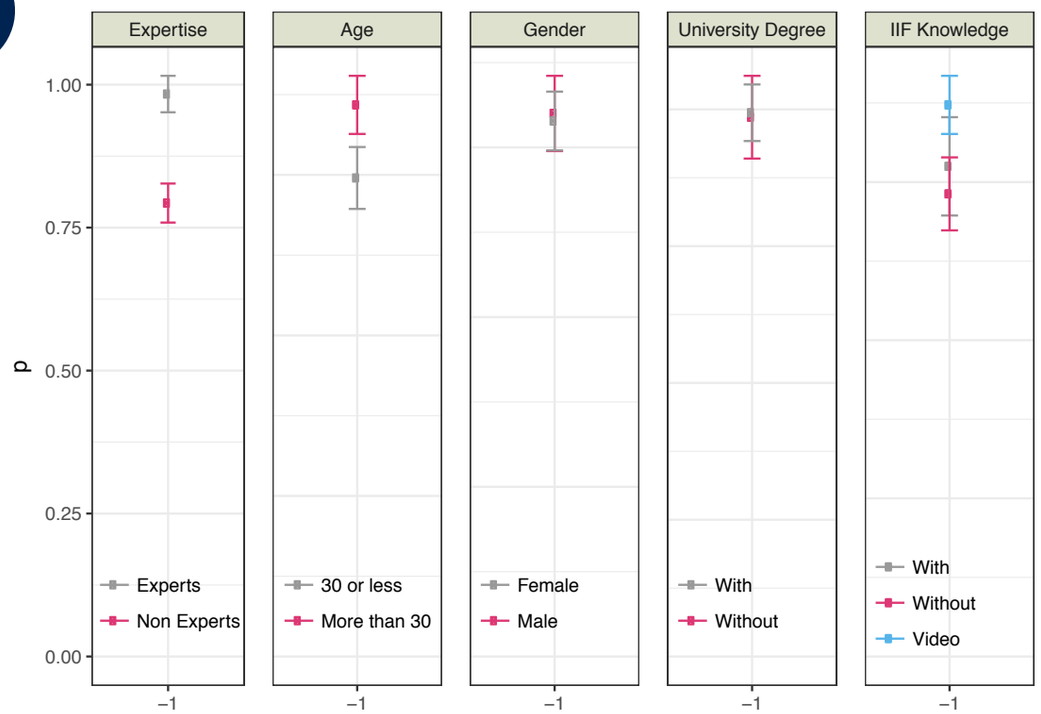


Q6



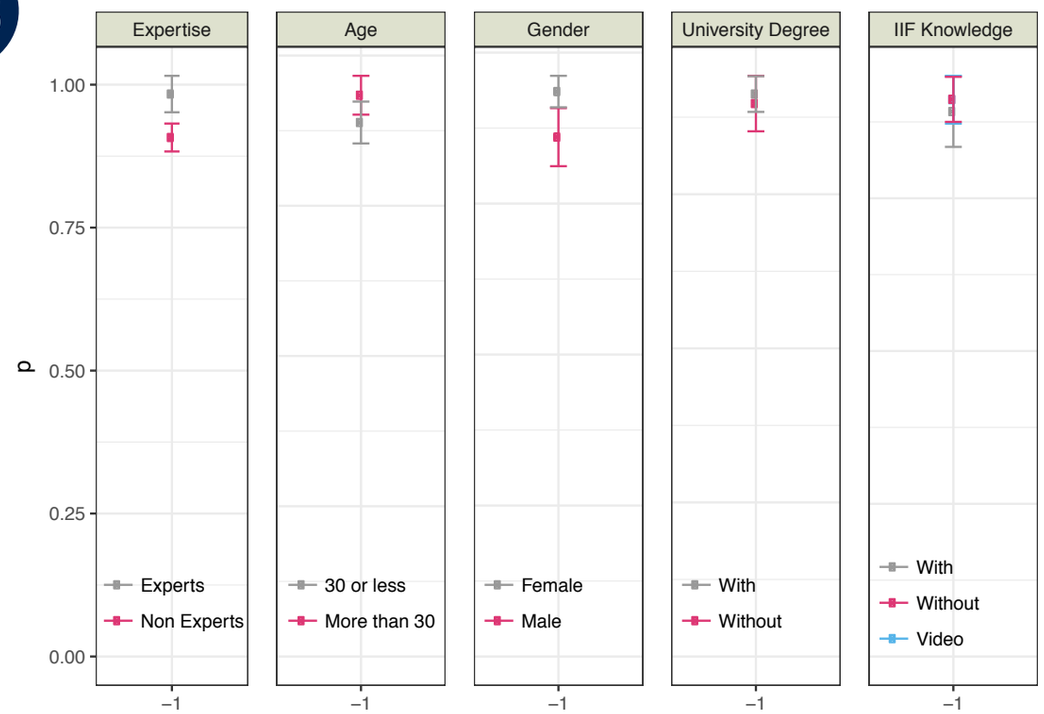
Traditional *versus* impact investment scenario with fiscal benefit.

Q7



Traditional *versus* impact investment scenario with additional details on social impact and visual aid.

Q8



CONCLUSIONS:

In all the scenarios, experts are more prone to choose the impact investment option than non-experts. With respect to the non-experts, we can also observe:

- Females are also more willing to choose an IIF, except on the tax reduction question.

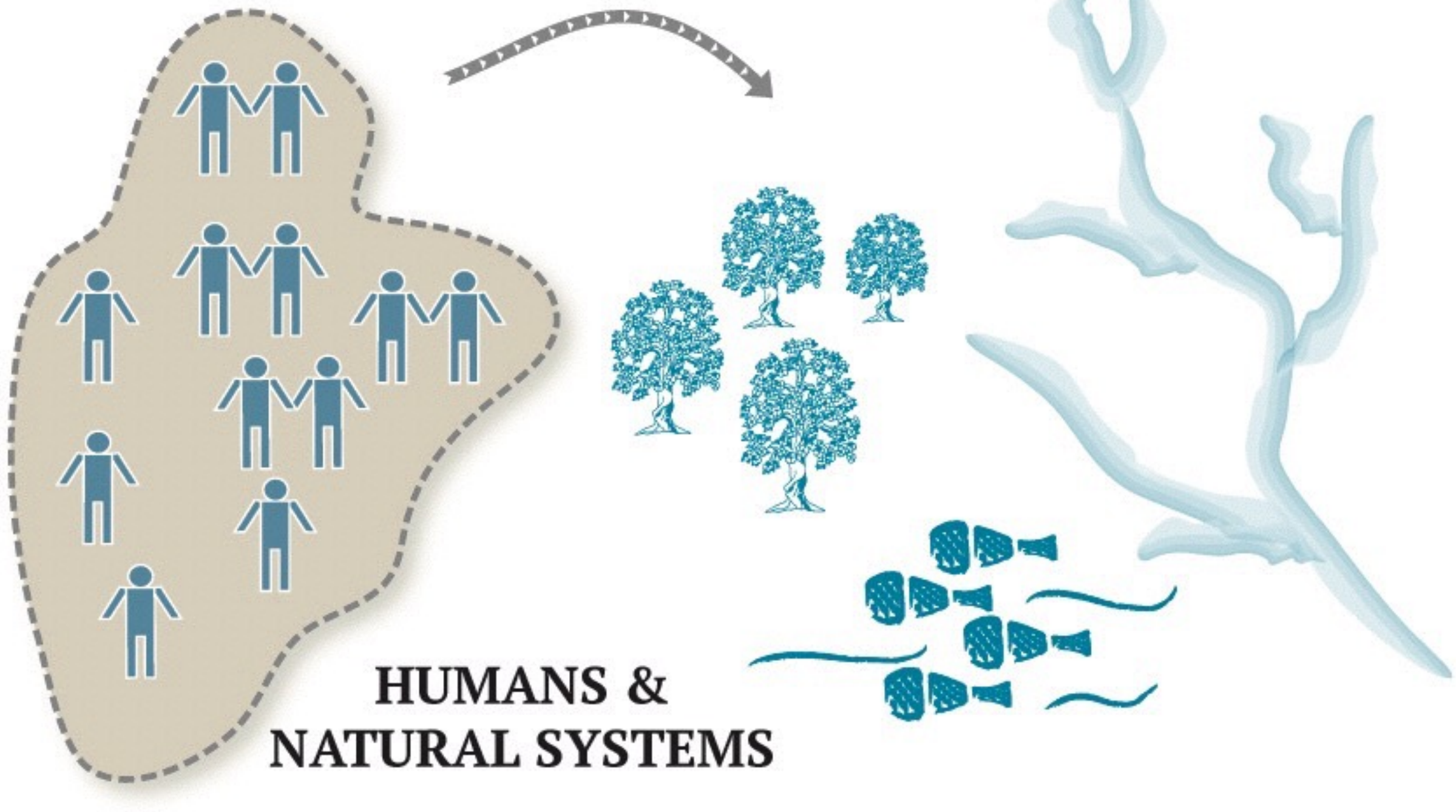
- Older people appear to have a slightly higher tendency for choosing impact investment than younger people. This difference increases for larger values of absolute returns and when there is a higher risk associated with the IIF option.

People with an academic degree are more favourable to impact investment for difference in returns smaller than 2%, with respect to the TIF.

However, **for a difference higher than 2%, we observe the contrary**, e.g., people without an academic degree are more likely to choose the IIF option.

When considering participants' prior knowledge on the topic, the difference between control groups is relatively small.

In some scenarios, showing the video had a positive impact with potential normative implications for current incentive structures, awareness campaigns and educational programmes about impact investing.



SOCIAL DILEMMAS

The tragedy of the commons *is a situation in a shared-resource system where individual users acting independently according to their own self-interest behave contrary to the common good of all users by depleting or spoiling that resource through their collective action.*

Essentially, the tragedy of the commons is an ethical dilemma between private interests and collective benefit. Everyday, we face situations like this in which the economic interests of a certain group, often without any associated cost or punishment, are detrimental to society. **The indiscriminate use of natural resources, over-logging in forest management, overuse of fish stocks, water pollution, biodiversity loss due to human activity, greenhouse gas emissions and climate change**, etc., are examples that proof the magnitude of the problem. In any case, the main question is:

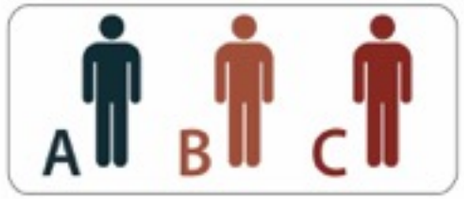


Is it possible a sustainable governance of Common-Pool Resources (CPR)?

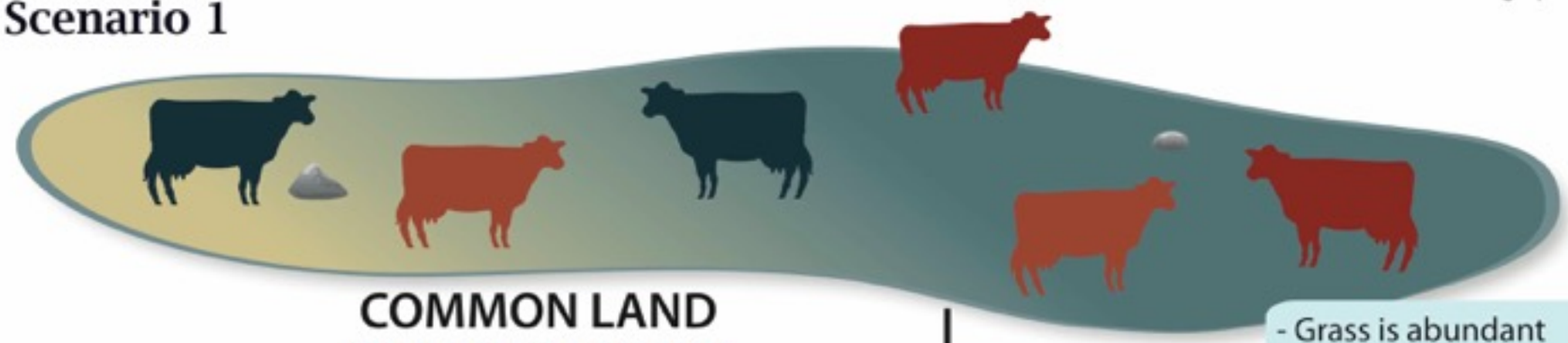
TRAGEDY OF THE COMMONS

Infographic design: Cosnet Lab

CATTLEMEN:
(Individual users)



Scenario 1



COMMON LAND
(Share-resource system)
Unowned resource with economic value for men

- Grass is abundant
- Land is fertile
- NO-Overuse of grazing land.
- The system is **sustainable**

Scenario 2



- At certain point, one of the cattlemen (A) decided to introduce another cow in the land at NO costs to him: **Selfish** attitude

Scenario 3



This trend continues by others & the results are:
- Less fertile soil
- Less grass
- Grass quality decreases
- Resources are depleted (overexpolitation) and cows cannot graze

Overexploitation of the common resources= **resource depletion**

Everyday we are exposed to situations like this, but it is there any effective solution?



Elinor Ostrom (Nobel Prize in Economic Sciences) **and her 8 principles for managing the commons:**

- Define clear group boundaries.
- Match rules governing use of common goods to local needs and conditions.
- Ensure that those affected by the rules can participate in modifying the rule.
- Make sure the rule-making rights of community members are respected by outside authorities.
- Develop a system, carried out by community members, for monitoring members' behavior.
- Use graduated sanctions for rule violators.
- Provide accessible, low-cost means for dispute resolution.
- Build responsibility for governing the common resource in nested tiers from the lowest level up to the entire interconnected system.

8 PRINCIPLES FOR SOLVING THE TRAGEGY OF THE COMMONS

by Elinor Ostrom

GRADUATED SANCTIONS (Punishment)

MONITORING BEHAVIOR

INTERCONNECTED SYSTEM

RESPECT BY OUTSIDE AUTHORITIES

EASY ACCESS TO DISPUTE RESOLUTION (Avoid conflicts)

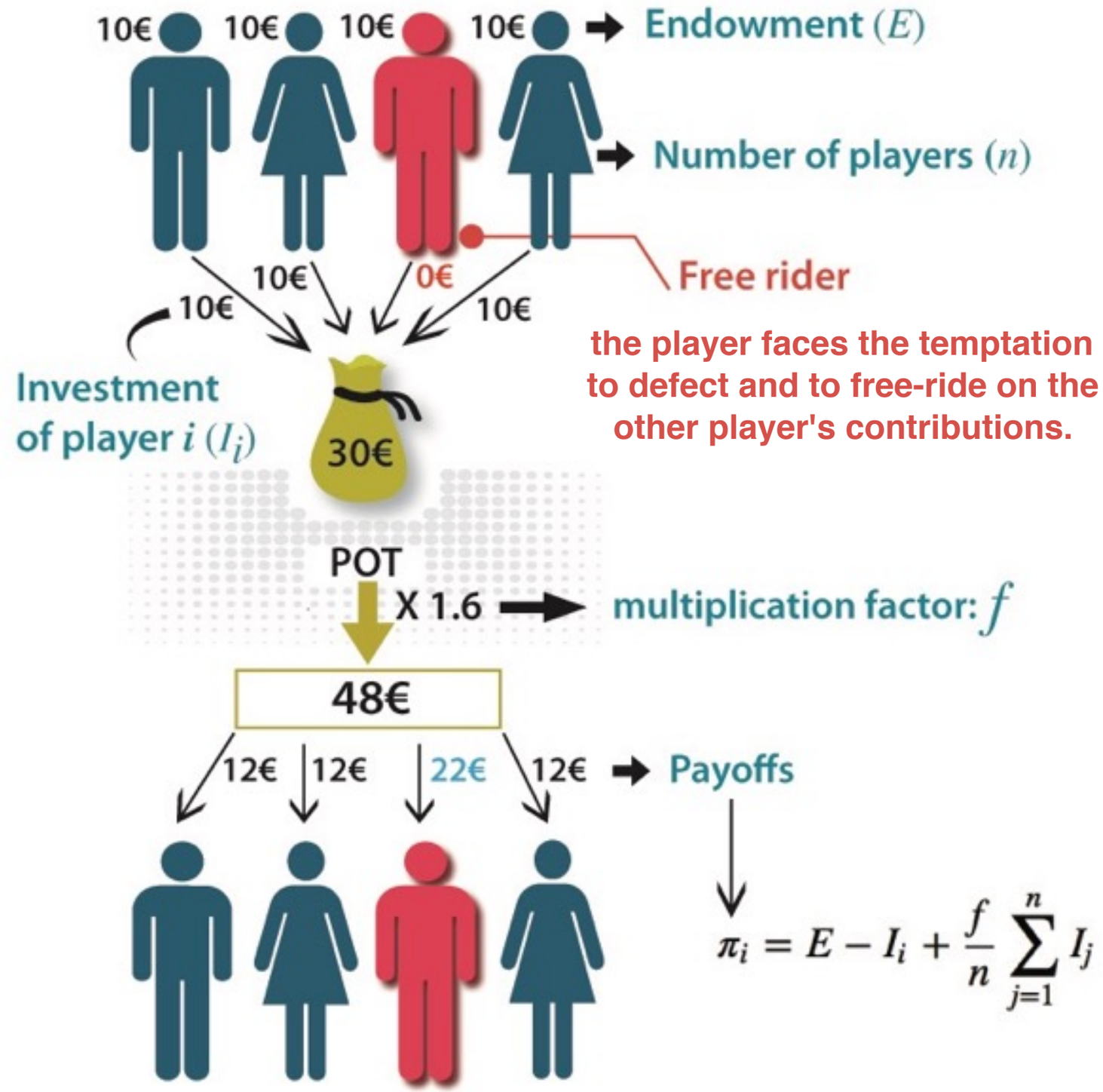
COHESION & RULES

REGULATIONS BASED ON THE COMMUNITY NEEDS

BOUNDARIES

INFOGRAPHIC DESIGN: COSNET LAB

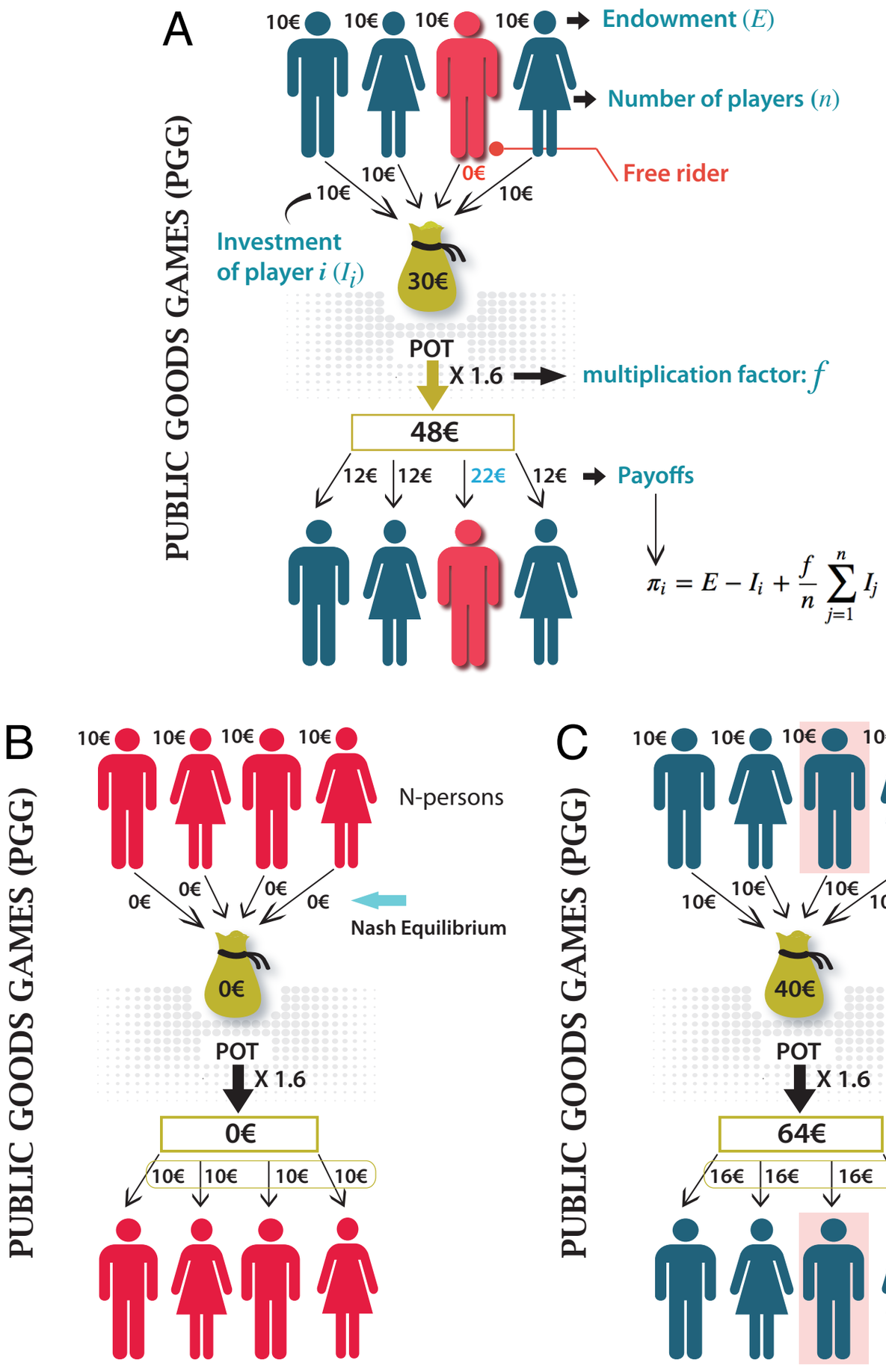
PUBLIC GOODS GAMES (PGG)



the player faces the temptation to defect and to free-ride on the other player's contributions.

PGG: A game in which all the players have an endowment of 10€, for example, and have to decide how much of it to contribute to a common pool (investment). Players can also keep the money and do not contribute to the fund. Then, the overall money is multiplied by f and split between the players.

Public good: In Economic terms, is a good that is both **non-excludable and non-rivalrous**. This implies that individuals cannot be effectively excluded from its use, and use by one individual does not reduce its availability to others.



Infographic design: Cosnet Lab

PANEL A: This is the scenario that produce the maximum *individual* payoff, which corresponds to every player donating everything, but one (the free rider) contributing nothing.

A Nash equilibrium is a situation in which no player can improve her payoff by unilaterally changing her strategy.

PANEL B: The Nash equilibrium in this game, for example, is zero contributions by all players (total defection).The rational strategy for a player would be to contribute nothing to the common pool regardless of the decision of the other players.

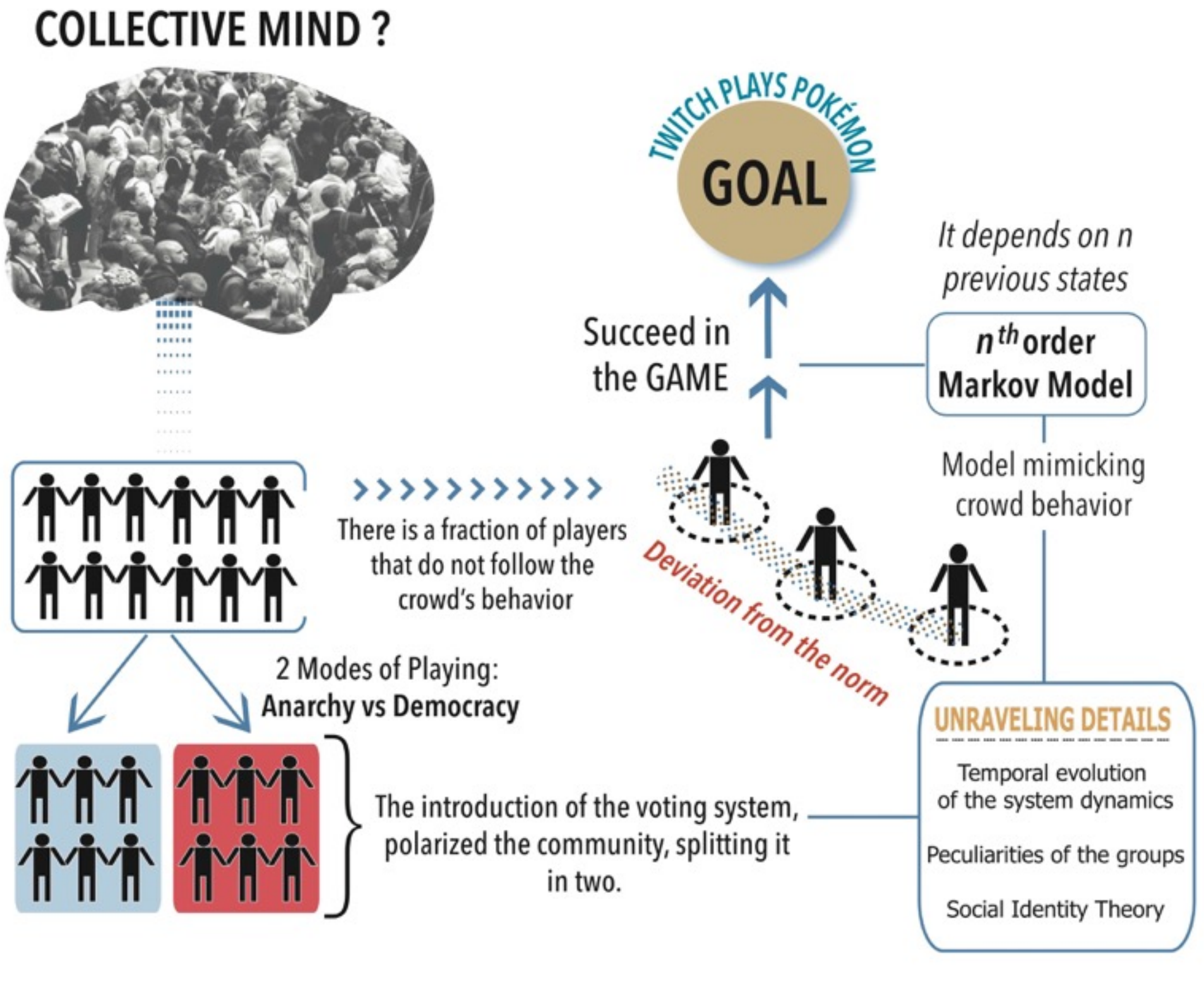
PANEL C: Represents the scenario that yields the maximum *collective* payoff which corresponds to every player donating everything to the common pool.



Collective social behavior

The power of collectivity

“Collective social behavior in a crowd controlled game”



Alberto Aleta and Yamir Moreno, **“Collective social behavior in a crowd controlled game”**, **EPJ Data Science** 8:22 (2019).

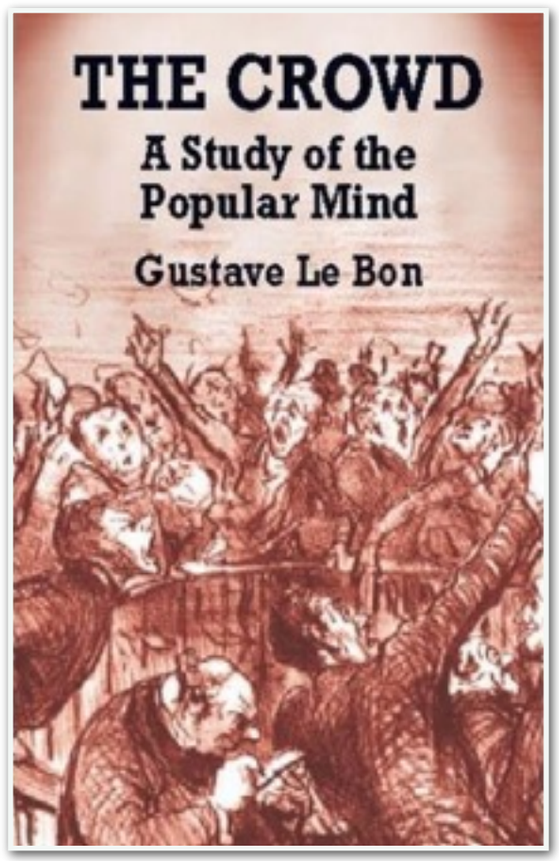
- Collective phenomena have been the subject of intense research in Psychology and Sociology since the XIX century.
- One of the first attempts to address this subject was Le Bon's Theory on the psychology of crowds (Contagion Theory) in which he argued that when people are part of a crowd they lose their individual consciousness and become more primitive and emotional thanks to the anonymity provided by the group. The crowd can cause a hypnotic impact on individuals.

  "He is no longer himself, but has become an automaton who has ceased to be guided by his will." The Crowd: A Study of the Popular Mind.

- On the contrary, another theory of collective behavior: Convergence Theory holds that crowd behavior is not a product of the crowd itself, but is carried into the crowd by particular individuals. The behavior of a crowd is just a result of like-minded individuals coming together.

Charles-Marie-Gustave Le Bon (1841-1931)





The information era has created a new kind of crowd, as it is no longer necessary to be in the same place to communicate and take part of collective actions.

Crowds collaborate online in different ways (crowdsourcing, crowdworking, etc)



WHAT DO WE NEED?

Understanding the mechanisms that drive and govern the dynamics of these complex systems.

- **Group decisions** (voting, consensus making or opinion averaging)
- **Strategies to motivate the crowd to perform some task**



Twitch Plays Pokémon (TPP) took place in February 12, 2014. It was a live-stream of a hacked version of Pokemon Red (1996).

The game was an unprecedented Social Experiment, a multiplayer cooperative game, an absolute mess, and a good chance to demonstrate the true potential of collective intelligence towards a common goal.

NOVELTY:

- The streamer did not play the game. He set up a bot in the chat window that accepted some predefined commands and forwarded them to the input system of the video game. Thus, **anyone could join the stream and control the character** by just writing one of those actions in the chat.

- Players were allowed to control simultaneously the same character of a Pokémon game without any kind of central authority.

- Twitch was the 4th largest source of peak internet traffic in the US and nowadays, with over 100 million unique users, it has become the home of the largest gaming community in history.

Streaming video platform

Focuses on video gaming:

- Personal streams of individual players
- Broadcasts of sports competitions
- Gaming-related talk shows
- …

Fourth largest source of peak Internet traffic in the United States

TOP GAMES BY NUMBER OF STREAMERS | JAN 2019

ON TWITCH AND YOUTUBE | GLOBAL

newzoo

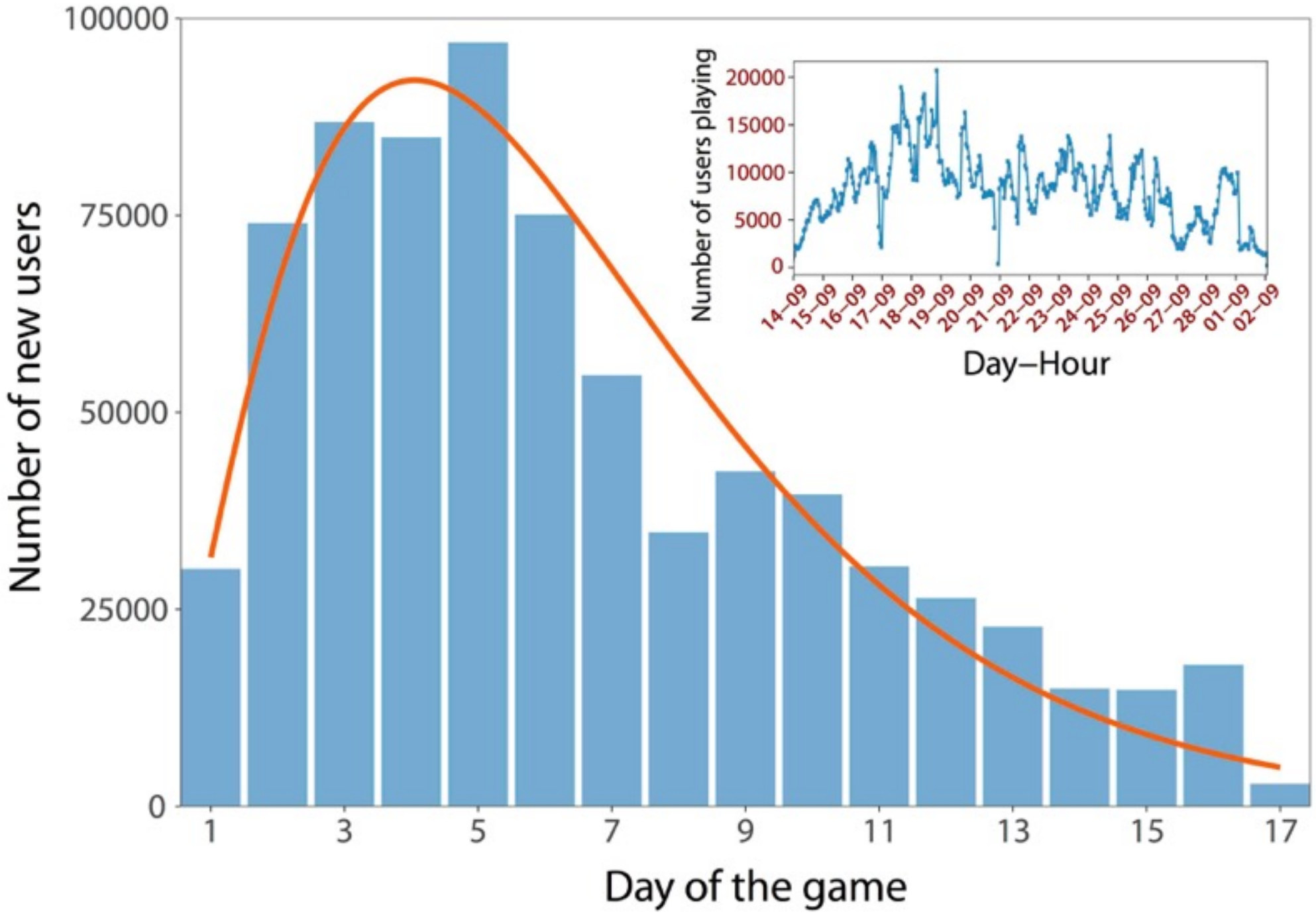
TOTAL STREAMERS IN JANUARY: 63.7K (twitch)

RANK	GAME TITLE	GENRE	STREAMER COUNT
1	Fortnite	Shooter	10.0K
2	League of Legends	Battle Arena	5.2K
3	PLAYERUNKNOWN'S BATTLEGROUNDS	Shooter	4.1K
4	Counter-Strike: Global Offensive	Shooter	4.0K
5	Resident Evil 2	Adventure	2.9K
6	Overwatch	Shooter	2.8K
7	Call of Duty: Black Ops 4	Shooter	2.3K
8	Dota 2	Battle Arena	2.3K
9	Old School RuneScape	RPG	2.2K
10	Tom Clancy's Rainbow Six: Siege	Shooter	1.9K

TOTAL STREAMERS IN JANUARY: 22.0K (YouTube)

RANK	GAME TITLE	GENRE	STREAMER COUNT
1	Fortnite	Shooter	3.5K
2	PLAYERUNKNOWN'S BATTLEGROUNDS	Shooter	1.7K
3	Minecraft	Adventure	1.6K
4	Garena Free Fire	Shooter	1.2K
5	Counter-Strike: Global Offensive	Shooter	1.1K
6	Resident Evil 2	Adventure	1.0K
7	PUBG Mobile	Shooter	949
8	Grand Theft Auto V	Adventure	893
9	FIFA 19	Sports	615
10	Roblox	RPG	539

© copyright Newzoo 2019 | Top Games by Number of Streamers on Twitch and YouTube January 2019:
newzoo.com/game-streaming-tracker



Total time: 16 days, 7 hours, 50 minutes and 19 seconds.

Pokémon Red is a relatively complex game which can not be progressed effectively at random, however:

- Only 7 commands are needed to complete the game.

- There are 4 movement commands (**up, right, down and left**), 2 actions commands (**a** and **b, accept** and **back/cancel)** and 1 system button (**start,** which opens the game's menu).

- The character is moved around the map using the four movement commands.

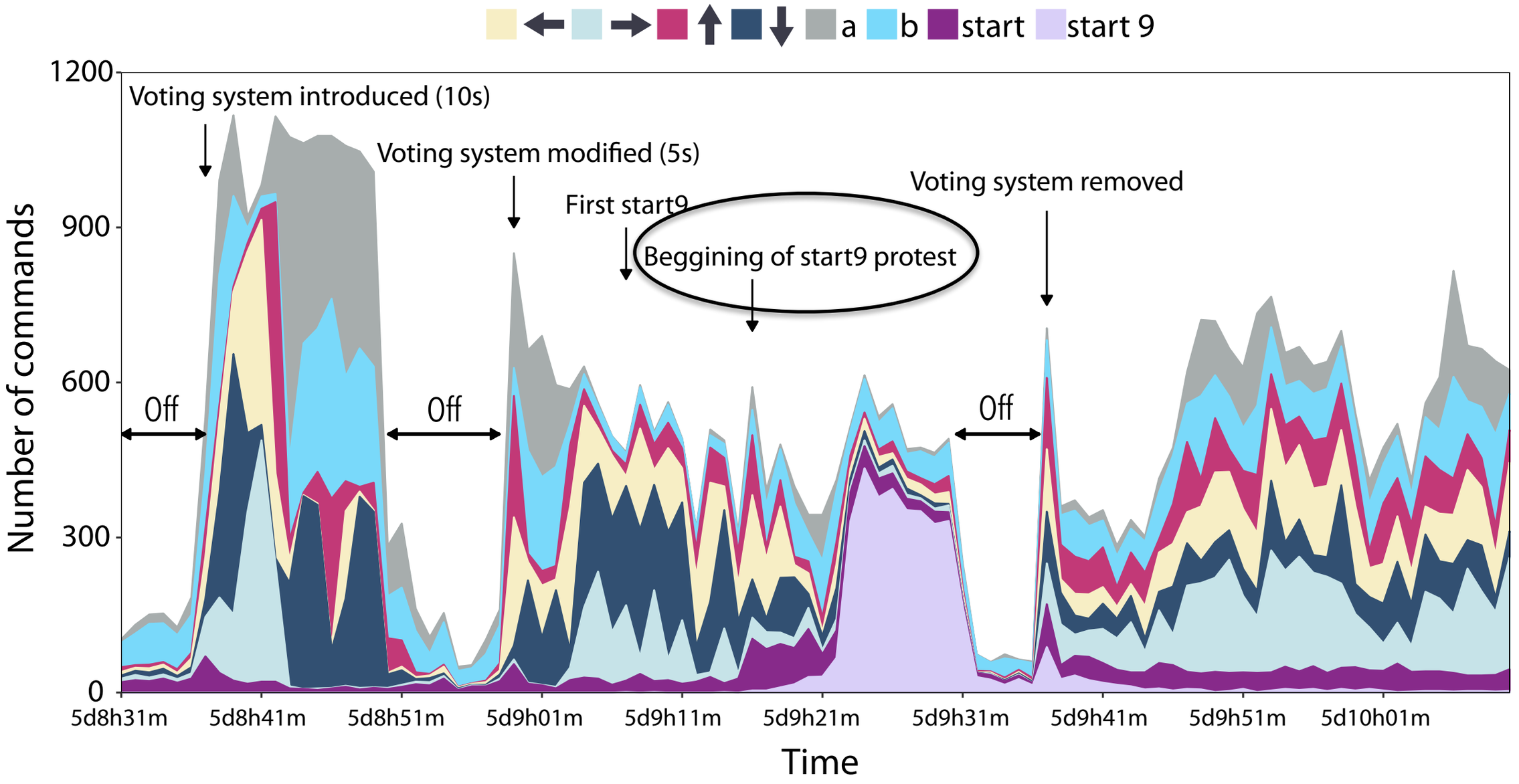
- If you encounter a wild Pokémon you will have to fight it with the choice of capturing it.

- Then, you will have to face the Pokémons of trainers controlled by the machine in order to obtain the 8 medals needed to finish the game.

- Combats are all turn-based so that time is not an important factor.

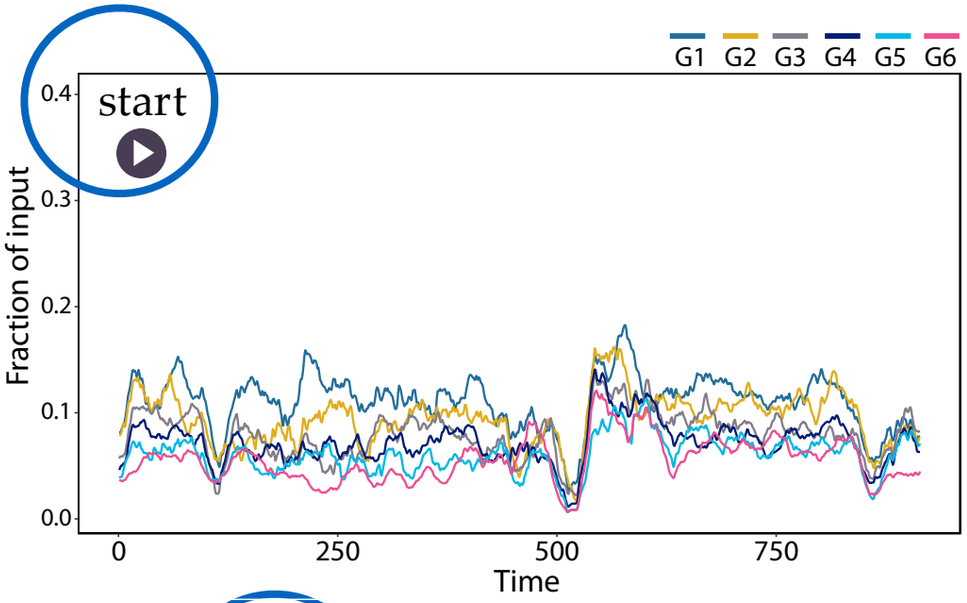
The gameplay was much more complex during TPP due to the **huge number of players sending commands at the same time and the lag** present in the system.

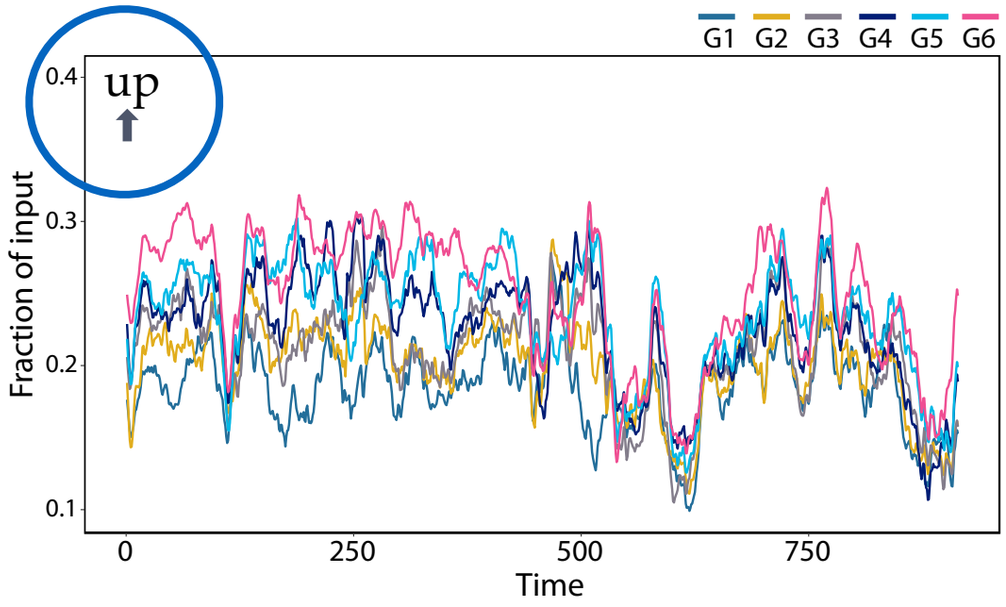
Start9 Riot

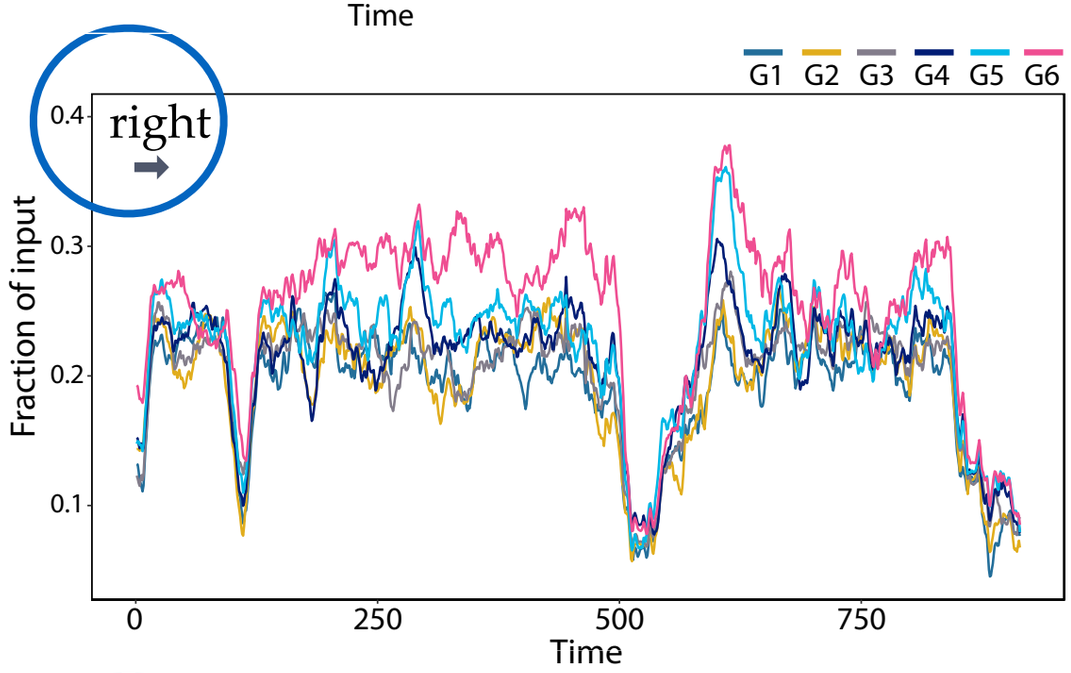


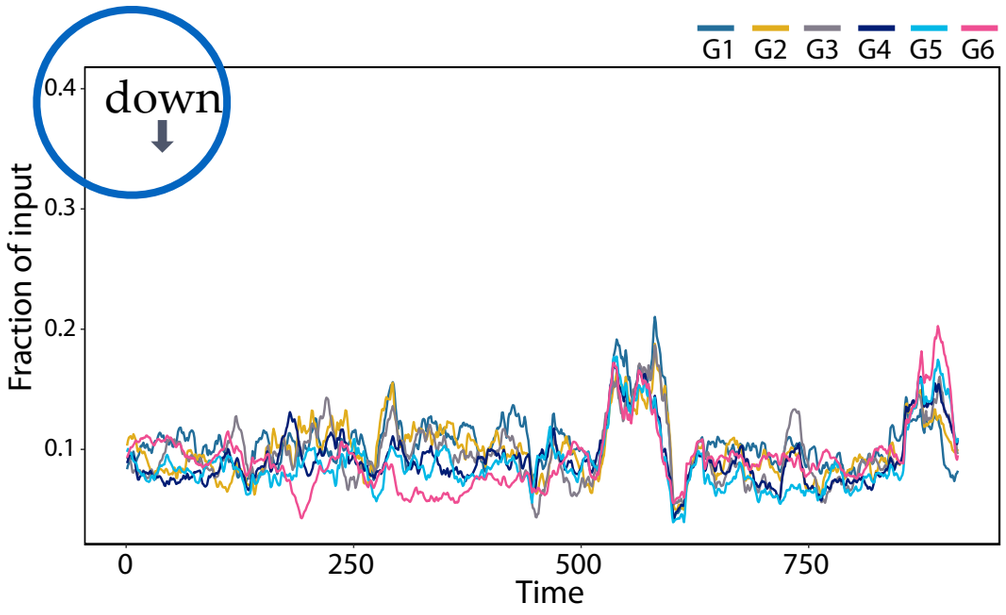
The first start9 was sent at 5d9h8m but went almost unnoticed. Few minutes after it was sent again but this time it got the attention of the crowd. **In barely 3 minutes it went from 4 start9 per minute to over 300, which stalled the game for over 8 minutes**.

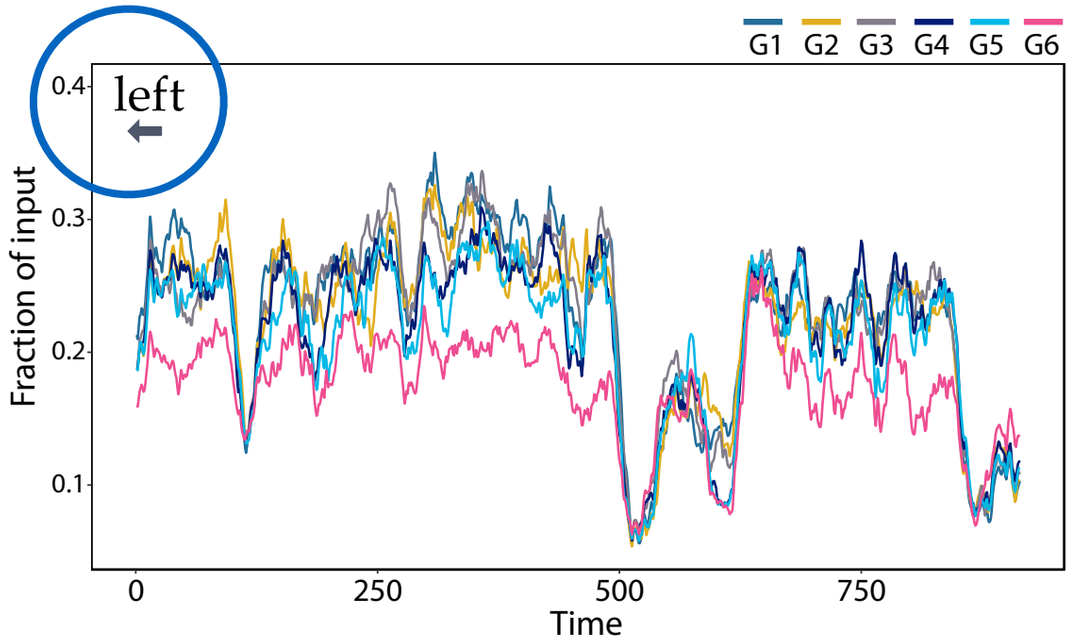
Comands & classification of players into groups according to the total number of commands they sent.











- **G1**, users with 1 or 2 commands (46% of the users)
- **G2**, 3 or 4 commands (18%)
- **G3**, between 5 and 7 commands (13%)
- **G4**, between 8 and 14 commands (12%)
- **G5**, between 15 and 25 commands (6%)
- **G6**, more than 25 commands (5%).

The groups were defined so that the total number of messages sent by the first three is close to 50,000 and 100,000 for the other three.

THE LEDGE

Quite clear optimal strategy
Hard challenge for the crowd (red nodes)

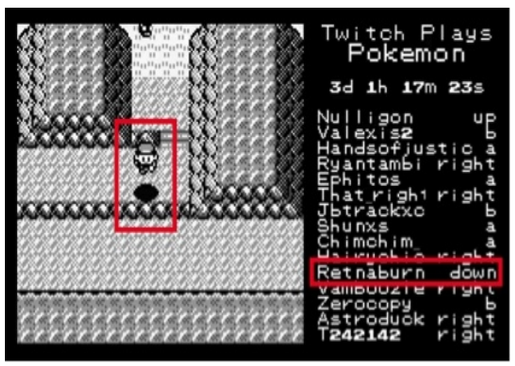
Analysis of Collective Behavior at short timescales

Red nodes= ledges

One step in this region (***the ledge***) does not cancel a bad step.
The character would be trapped down the ledge and
would have to find another path to go up

A region highly vulnerable to actions deviated from the norm

(by mistake or by griefers=trolls)
Just a troll entering "down"
is enough to send you back to the start

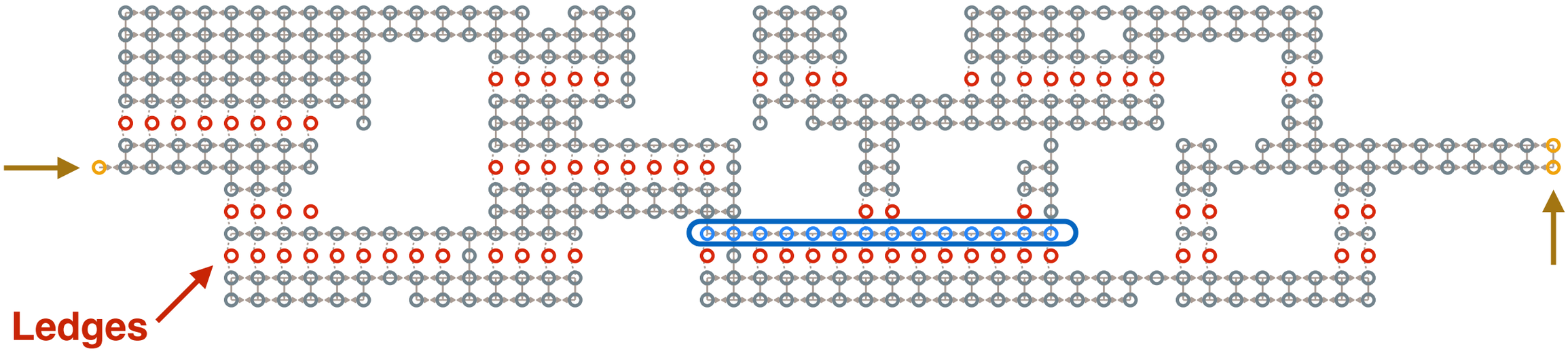


15 hours to finish vs a few minutes
needed by a single player

- Ledges are obstacles in the game that can be passed through on one side, but not on the other.
- The ledge is a great case study of the behavior of the crowd because the mechanics needed to complete it is really simple (just moving from one point to another).



Network representation of the ledge area



- Each node of the graph represents a tile of the game.

- The character starts on the yellow node on the left part of the network and has to exit through the right part.

- There are paths (see blue nodes) where only the command right is needed and which are next to a ledge so that the command down, will force the crowd to go back and start the path again.

- Red nodes are ledges which can only be traversed going downwards (region is highly vulnerable to actions deviating from the norm).

- Great case study of the collective behavior of the crowd at short timescales (long time- hard challenge- anarchy/democracy modes had not been introduced yet).

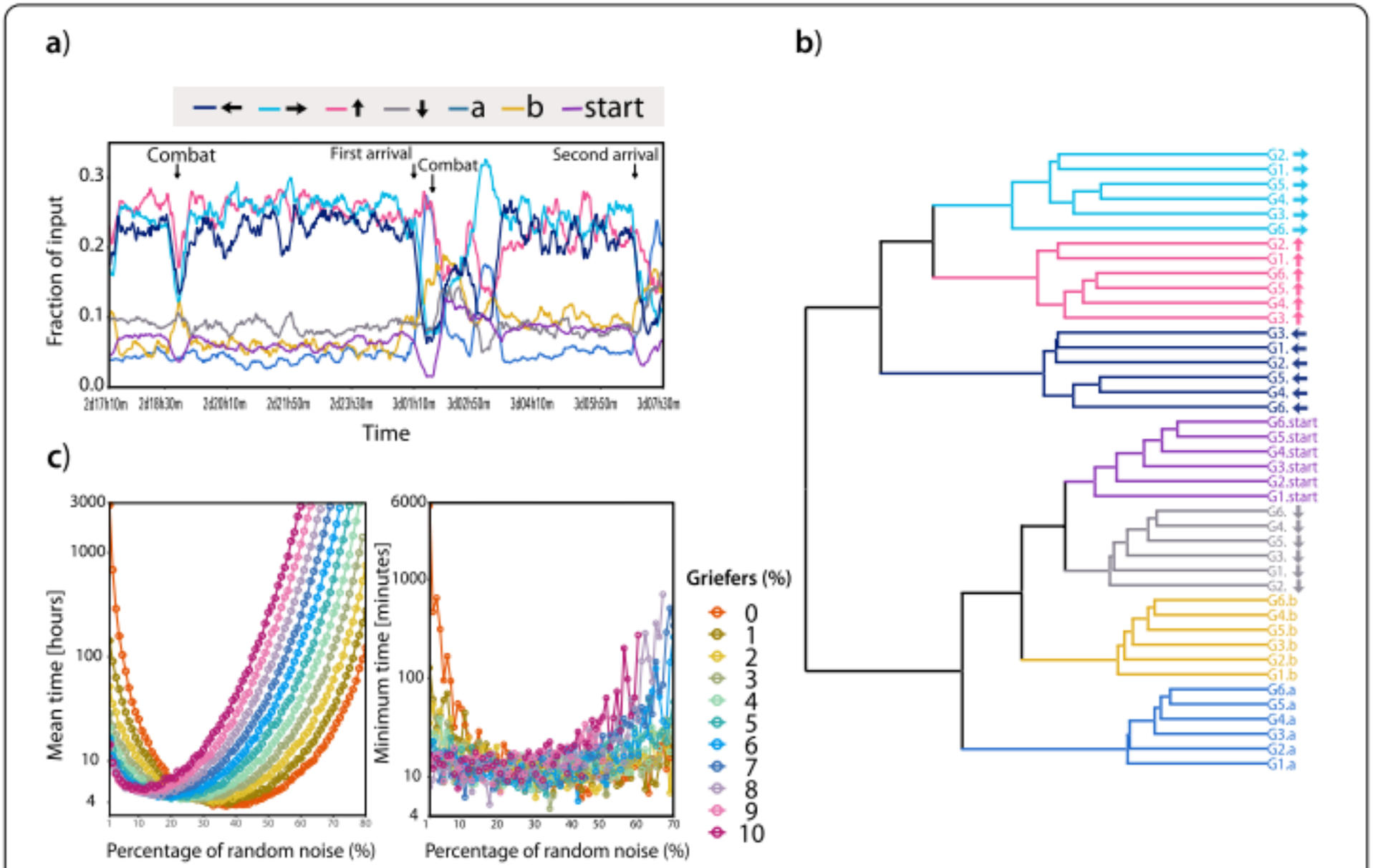


Figure 4 Study of the Ledge event. (**a**) Time evolution of the fraction of commands sent each minute. Note that a single player should be able to finish this area in a few minutes, but the crowd needed 15 hours. The time series has been smoothed using moving averages. (**b**) Hierarchical clustering of the time series of each group of users (see main text for details). (**c**) Left: Mean time needed to exit the area according to our simulations as a function of the fraction of griefers in the system and the noise in it. Right: 1% quantile of the time needed to exit the area, note that the *y* axis is given in minutes instead of hours

Analysis of Figure 4:

- **Panel a)** Time evolution of the amount of messages containing each command (the values have been normalized to the total number of commands sent each minute) since the beginning of this part until they finally exited. We can observe a pattern from ***2d18h30m*** to the first time they were able to reach the nodes located right after the blue ones, approximately ***3d01h10m***.

- **Panel b)** The behavior of users with medium and large activities are not only similar to each other, but they are also equivalent to the ones coming from the aggregation of the users who only sent 1 or 2 commands. **We can infer the behavior of the whole crowd by looking at the behavior of the most active players. group 6**.

- **Panel c)** The addition of noise to the herd breaks the loops and allows the crowd to get to the exit. As we increase the noise, time is quickly reduced with an optimal noise level of around 40% of the crowd.

- Conversely, the introduction of griefers in the model, increases the time needed to finish this part in most cases.

- For low values of the noise, the addition of griefers can be beneficial for the crowd. Indeed, by breaking the herding effect, these players are unintentionally helping the crowd to reach their goal.

Users deviating from the norm, regardless of being griefers, noise or even very smart individuals, were the ones that made finishing this part possible.

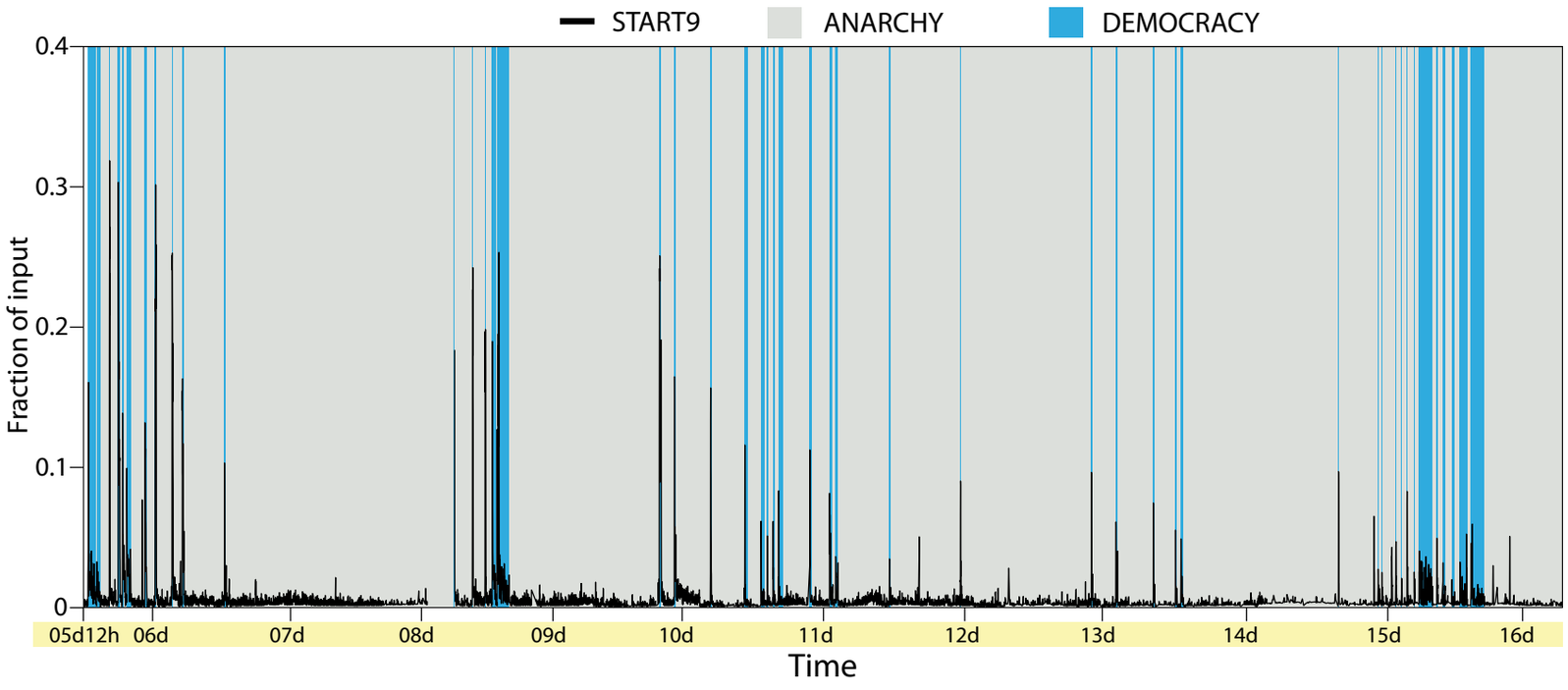
Chronology

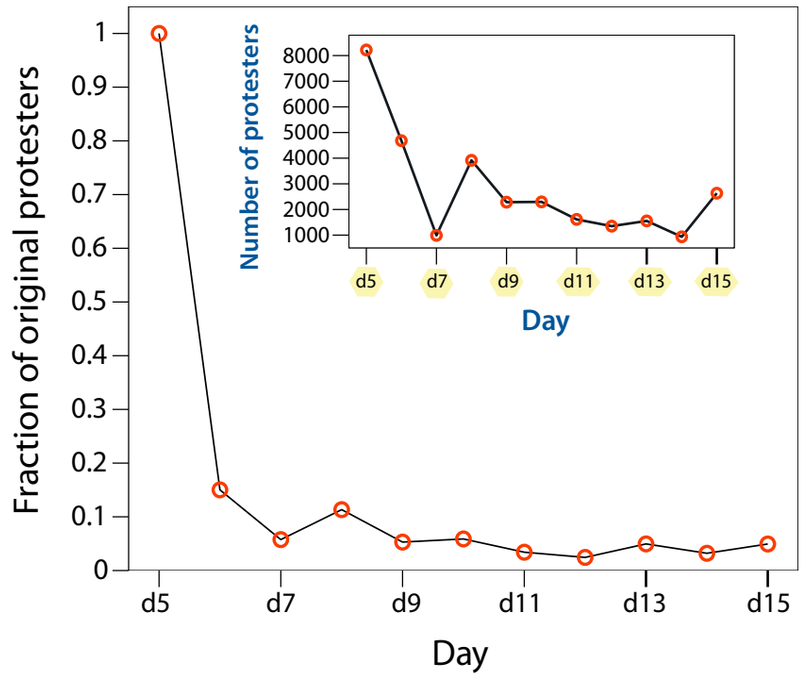
- The 6th day, after the crowd had been stuck in a movement based puzzle for almost 24 hours, **the developer took down the stream and change the code**.

- 15 minutes later the stream was back online, but this time commands were not executed right away. Instead, they were added up, and every 5 seconds the most voted command was executed.

- The crowd did not like this system and **started to protest by sending start9** which would open and close the menu repeatedly impeding any movement. This riot forced the developer to revert the stream to its original rules.

- Two hours later the system was modified again. Two new commands were added: **democracy and anarchy. This new system split the community into: "Democrats" and "Anarchists"** who would then fight for taking control of the game while trying to progress.







Anarchy vs Democracy

An **Anarchy vs Democracy System** was established.

Anarchy: The game was played in the traditional way, with the inputs immediately executed.

Democracy: A 20-second voting period was established. The most popular input during that time period was the one executed.

Out of 400.000 players…



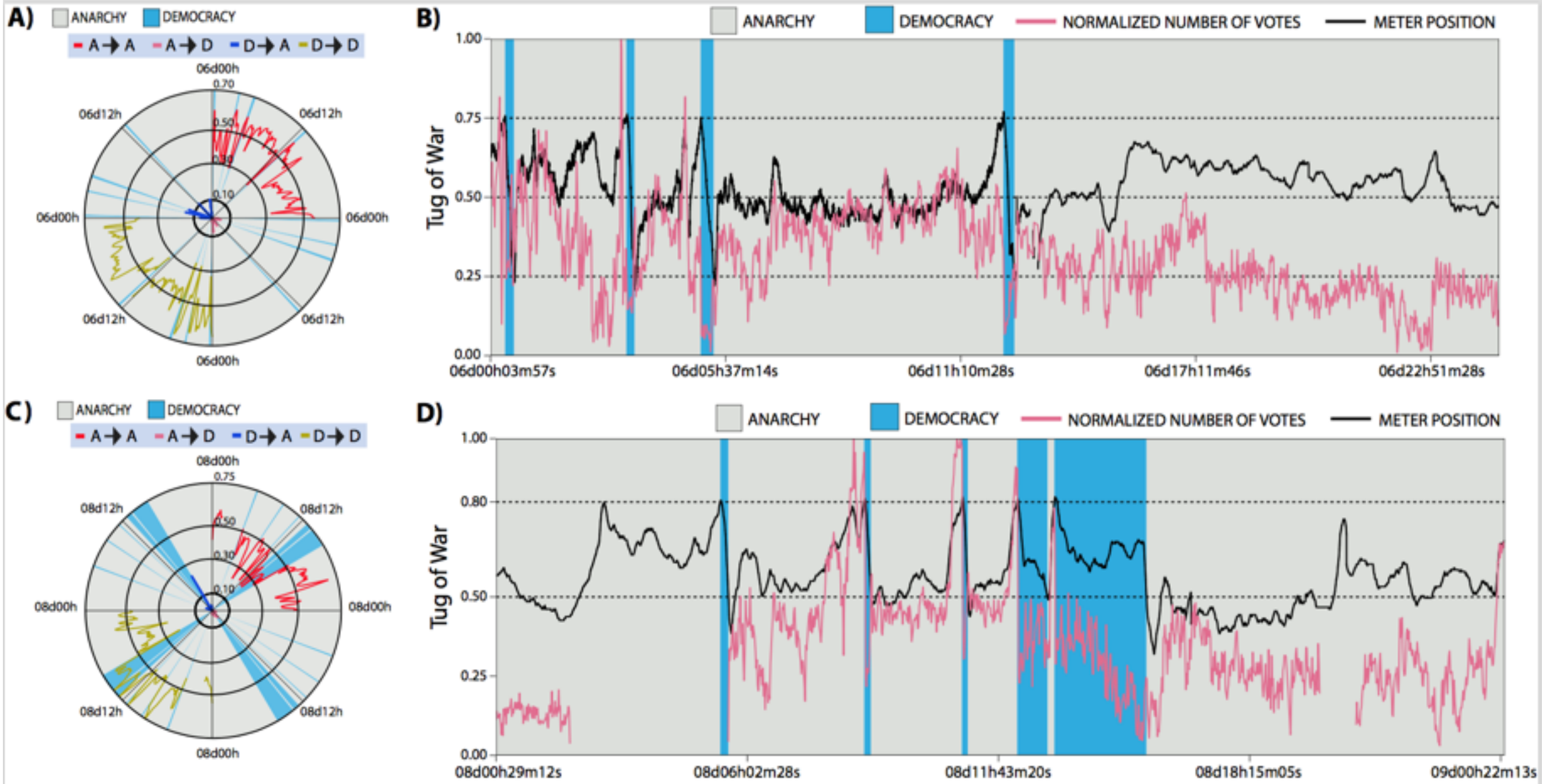
28%



54%

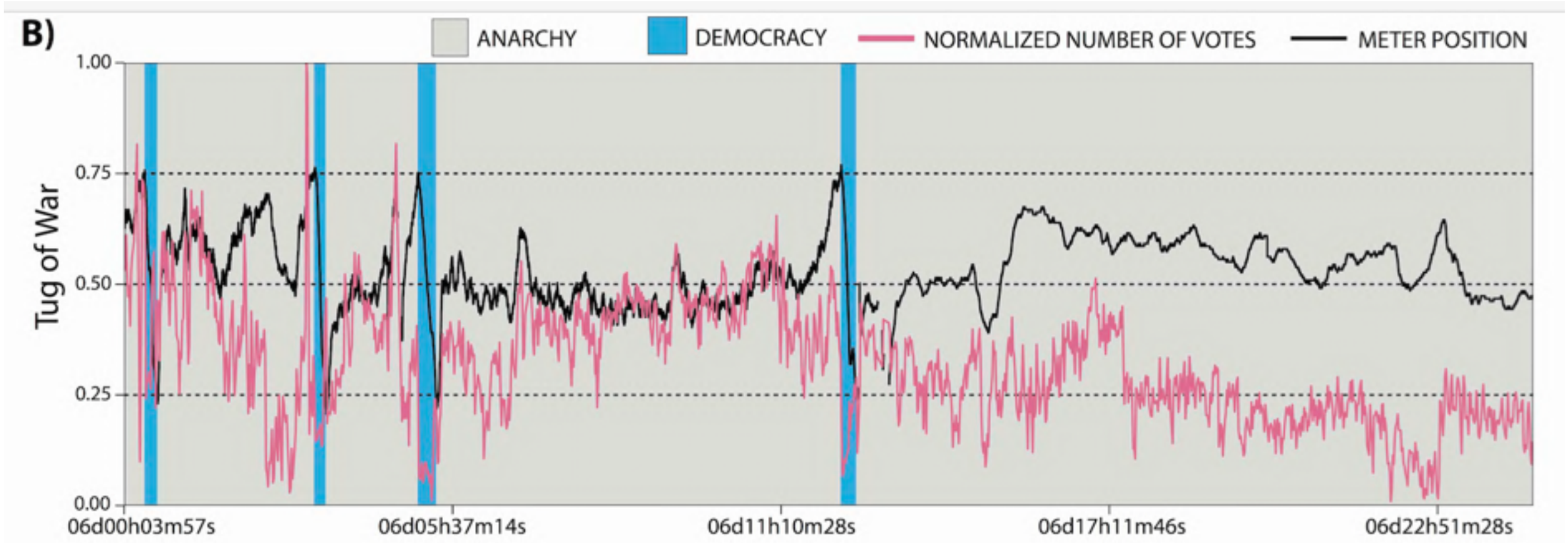
The dynamics governing these two communities are quite complex as even though there were more democrats than anarchists, **most of the game was played under anarchy**.

Polarization



Politics of the crowd. Days 6 (top) and 8 (bottom). In every plot the gray color represents when the game was played under anarchy rules and the blue color when it was played under democracy rules. The polar plots represent the evolution of the fraction of votes corresponding to anarchy/democracy while distinguishing if the user previously voted for anarchy or democracy: **first quadrant**, votes for anarchy coming from users who previously voted for anarchy (A → A); **second quadrant**, votes for democracy coming from anarchy (A → D); **third quadrant**, votes for democracy coming from democracy (D → D); **fourth quadrant**, votes for anarchy coming from democracy (D → A).

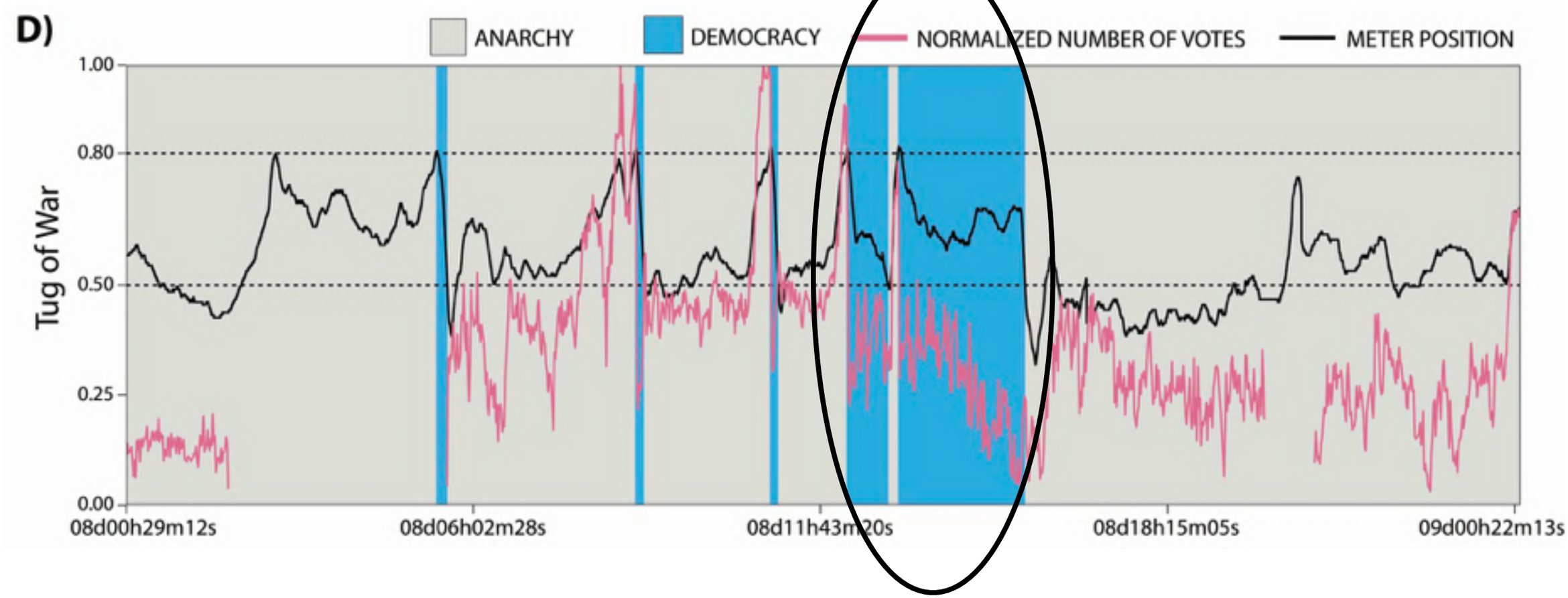
Polarization



- Every time democrats were able to enter into their mode they stopped voting and started playing. This let anarchists regain control even though they were less users, leading to a sharp decay of the tug of war meter. Once they exited democracy mode, democrats started to vote again to try to set the game back into democracy mode.

A. Aleta & Y. Moreno, **"Collective social behavior in a crowd controlled game"**, **EPJ Data Science** 8:22 (2019).

Polarization



- The crowd accepted democracy (blue area).
- Democrats learned how to keep their mode active for a period of time.
- After the drop on users voting, democrats keep voting instead of playing, which allowed them to retain control for longer.
- Finally, the position of the meter is barely modified probably due to anarchists finally accepting that they needed democracy mode to finish this part.

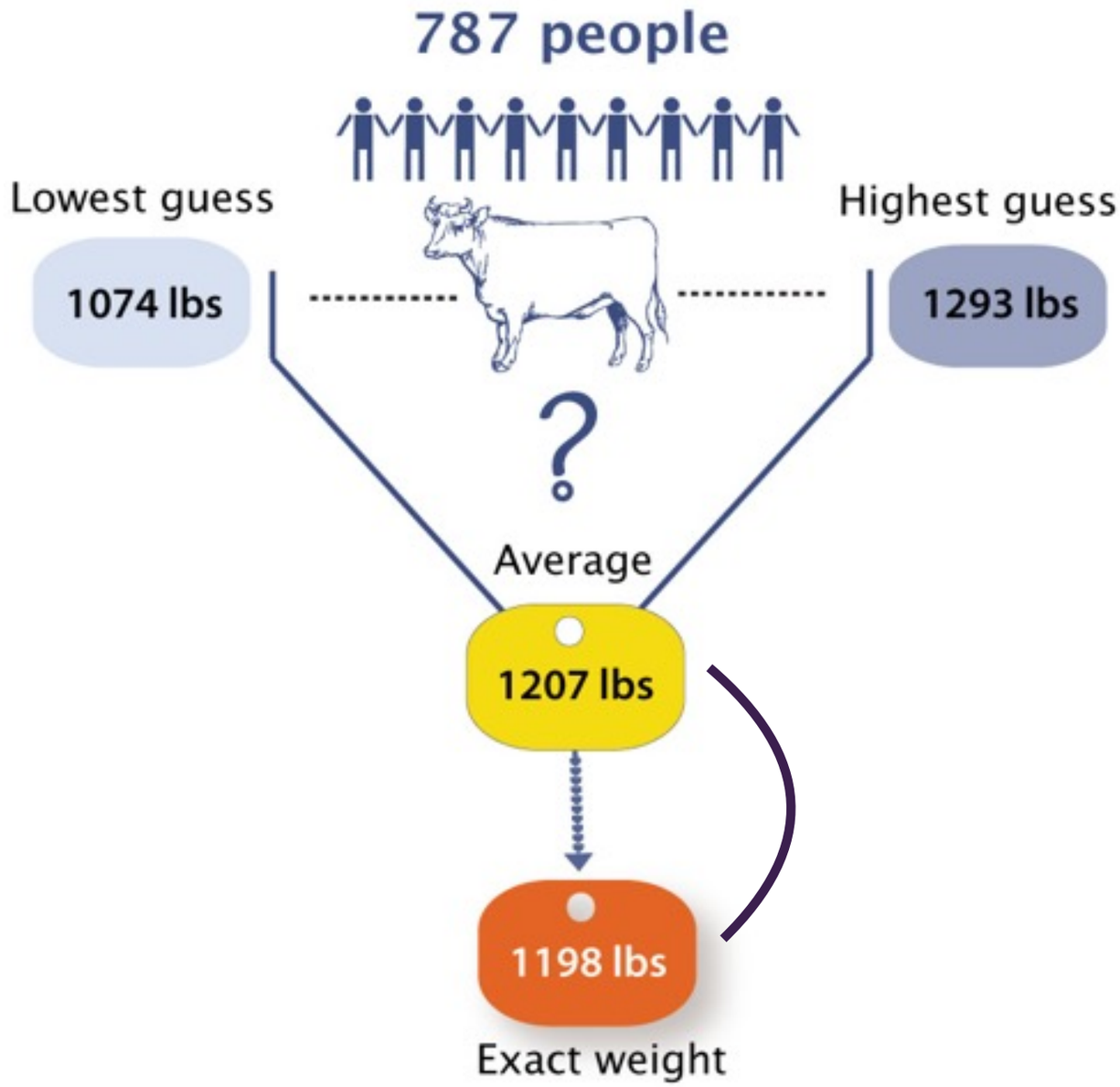
Alberto Aleta and Yamir Moreno, **“Collective social behavior in a crowd controlled game”**, **EPJ Data Science** 8:22 (2019).

The Wisdom of the Crowd

Francis Galton (1822-1911)
Darwin's cousin

Some contributions:

- Application of statistical methods to biological phenomena (Biometrics).
- Psychometrics
- Differential Psychology
- Fingerprinting (method for classifying fingerprints).
- Study of weather systems (Metheorology).
- …and some other studies that were ethically and morally reprehensible and discriminatory.



- According to James Surowiecki (2005), the wisdom of crowd is the phenomenon in which aggregated predictions from a large group of people can be more accurate than most individual judgments and can rival or even beat the accuracy of subject matter experts.



TPP was special for several reasons:

- The reinterpretation of the game and narrative.
- The creativity of the players and the absurd situations that were generated.
- The symbolism.
- The adoption of a new form of online communication.
- The real role of individuals deviating from the norm (*the addition of players not following the actions of the group was, in fact, the key element that allowed to complete the ledge*).
- The demonstration that consensus is not always the best option.
- Mistakes performed by the crowd might have been the reason why this event was so successful. In the midst of chaos, every achievement, every success had a special meaning.
- The value of persuation & communication.
- The power of collectivity. *Enjoyment is not related to what I, as a single individual, have done, but rather to what we, as a group, have done.*
- The fact that anarchy could coexist with the establishment of a democracy mode. The dynamics governing mode changes during the game were really complex.

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Dolfins project

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“Distributed Global Financial Systems for Society”





Science, as well as technology, will in the near and in the farther future increasingly turn from problems of intensity, substance, and energy, to problems of structure, organization, information, and control.

John von Neumann