Networks Decide for Us:

When networks shape behavior more than intentions

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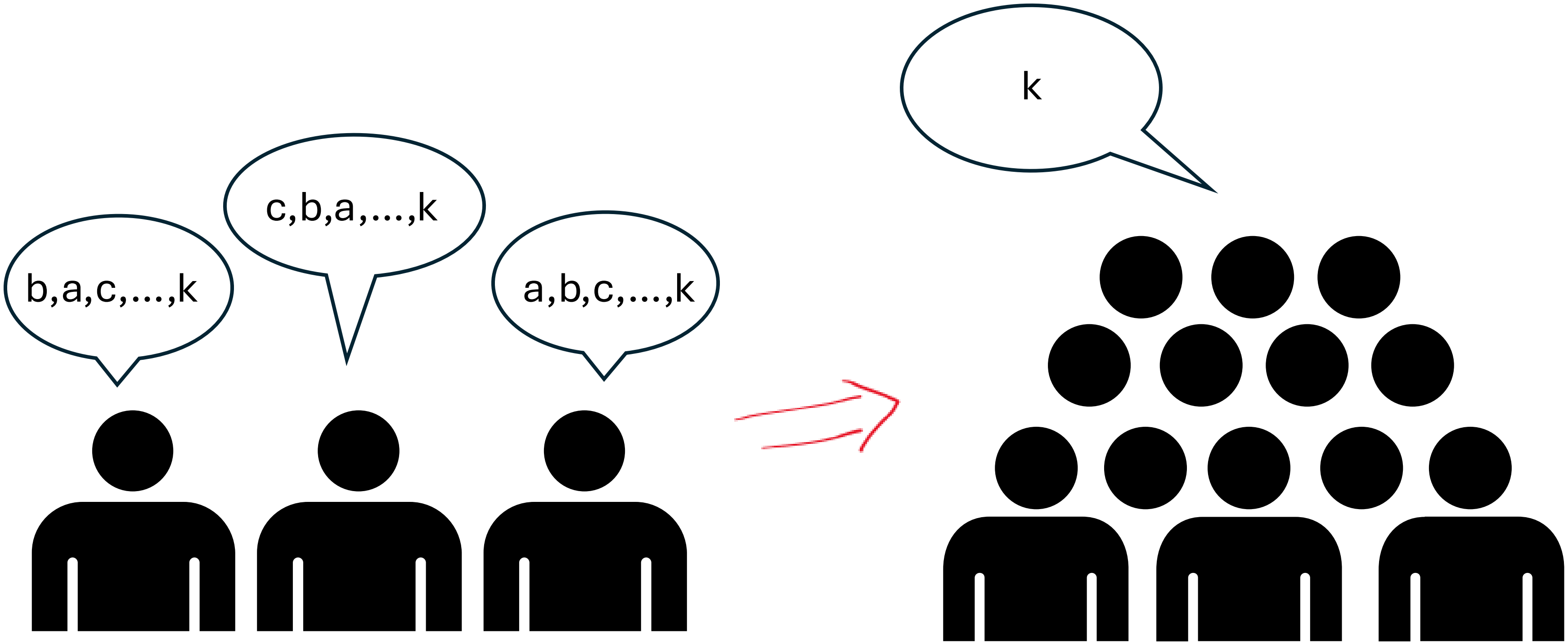
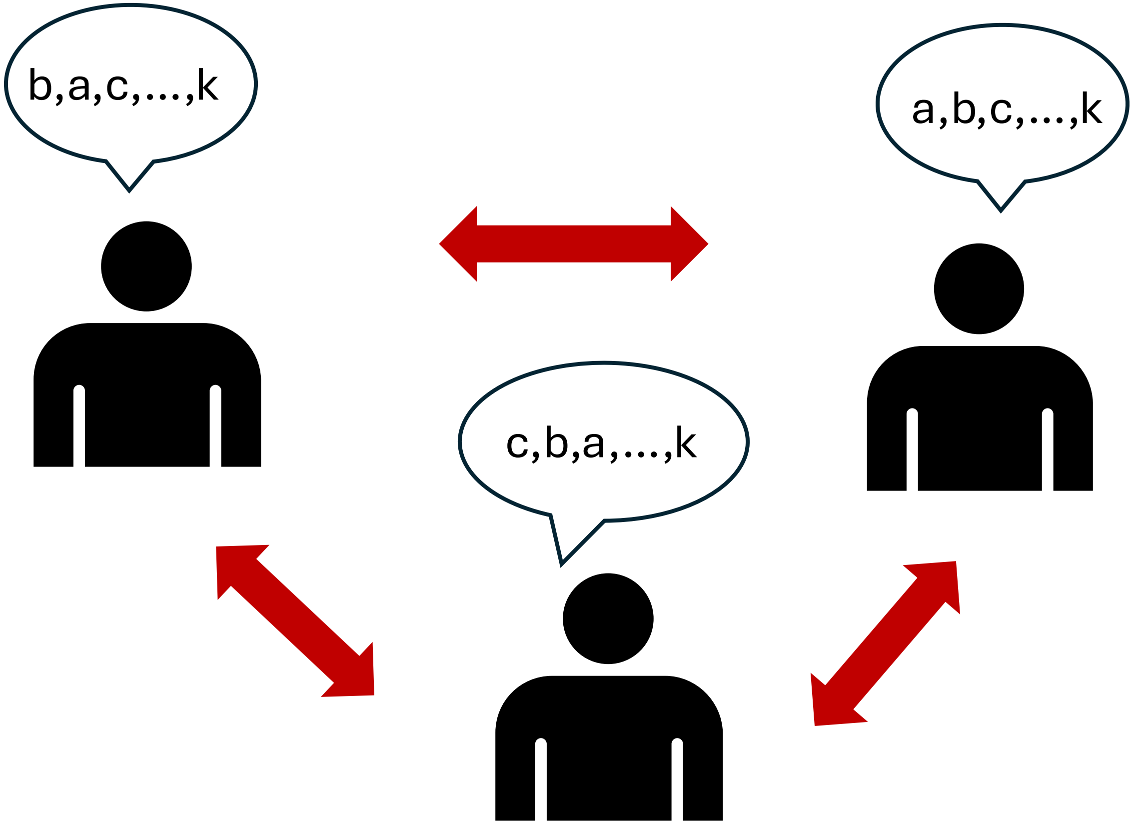
1. Motivation
    1. Collective behaviors
    2. Previous works
    3. Addressing the flaws
2. The model
    1. Rational choice
    2. Social reinforcement with selective influence
3. Setting up
    1. Imputing a Network Structure to a Survey
    2. Running the simulations
4. Results up
    1. Heatmaps
    2. Regression tables
5. Conclusion

Motivation

Collective behaviors



Collective behaviors



Some examples

Google Trends: Chess

Some examples

Some examples

Home > Initiatives > Save bees and farmers ! Towards a bee-friendly agriculture for a healthy environment

Save bees and farmers ! Towards a bee-friendly agriculture for a healthy environment

Commission registration number: ECI(2019)000016

Initiative progress

Registered
30/09/2019

Collection start date
30/09/2019

Collection

Information from the European Commission

30/09/2019
Commission Decision on the registration of the citizens' initiative

Answer of the European Commission

05/04/2023
Commission's answer and follow-up

Communication
English Download

Available languages (23)

Some examples

HOME SEARCH

The New York Times

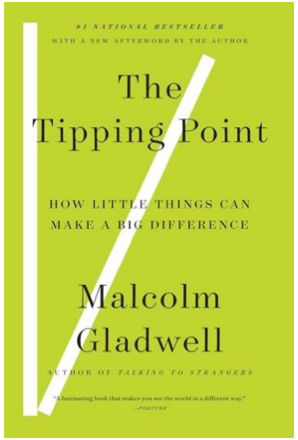
of Rare Earths Has U.S. Find Alternatives	U.S. Expands Antidrug Campaign With Strike on Boat in Pacific Near Colombia	Former Biden and Senate Counsel to Lead Progressive Legal Group	Maine U.S. Senate Candidate Says He Covered Up Tattoo That Had Nazi Imagery	The NATO chief and Trump will discuss support for Ukraine.	Nancy Pelosi Hasn't 2026 Plans. Scott Wi Anyway.

Crowd Scientists Say Women's March in Washington Had 3 Times as Many People as Trump's Inauguration

By TIM WALLACE and ALICIA PARLAPIANO UPDATED JAN. 22, 2017

Collective behaviors

1. Hush Puppies rapid growth in 95'
2. East New York and Brownsville crime reduction
3. Abrupt growth of fax users
4. Book: Divine Secrets of the Ya-Ya Sisterhood



[1]

Collective behaviors

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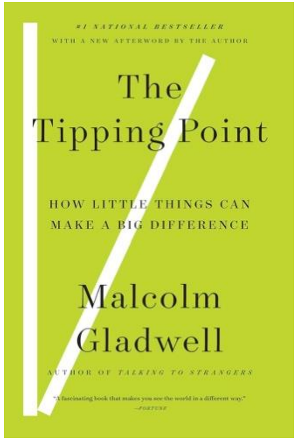
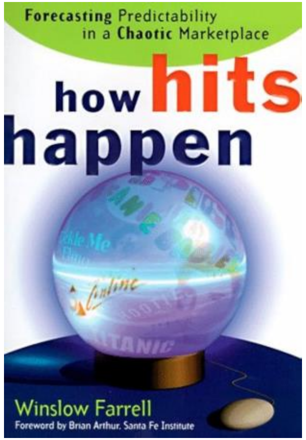


[1]



[2]

1. Movies: The Full Monty
2. Market Share: AT&T
3. Literature: Hootie & the Blowfish

How are those collective behaviors studied?

Two main pathways of research - Collective Actions [3]

Collective action: *"any action which provides a collective good."*

1. (**Pre Olson**): people with shared interests would naturally act together. It was the *inaction* that required explanation.
2. ***The Logic of Collective Action** (65')*, Olson argued that self-interested individuals will not act to achieve their common interests. Collective action is "*Irrational*".
3. **Individual Decision Models:** pure economic models, costs and benefits. Types of *incentives*: material (money, jobs), solidary (social status, friendship, praise), and purposive (the moral satisfaction of "doing the right thing").
4. **Collectivity Models:** they examine how individual actions are aggregated into a collective outcome through social *interaction* and *coordination*.
   4.1 **Critical Mass Theory:** collective action depends not on the "average" member, but on a small core of highly interested and resourceful individuals.
   4.2 Granovetter's **Threshold Model** (78')**:** an individual's willingness to act depends on the number of others who are already participating.

Two main pathways of research - Collective Actions [3]

Threshold Models [4] :

*"The **threshold** is simply that point where the perceived benefits to an individual of doing the thing in question exceed the perceived costs."*

	The Group's Thresholds	Final Result
Case A:	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	Total Actors = 10
Case B:	[0, 2, 2, 3, 4, 5, 6, 7, 8, 9]	Total Actors = 1

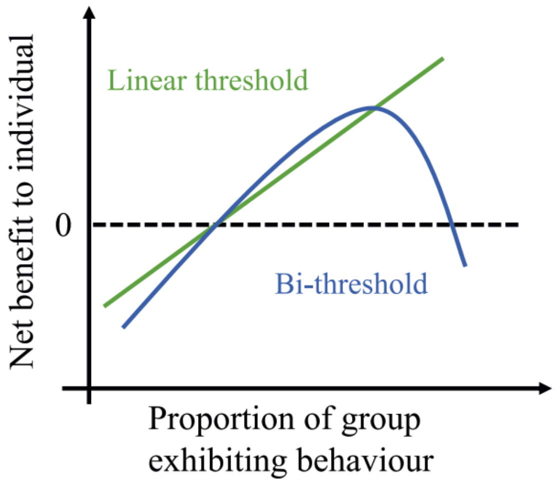
Almost identical group composition produces opposite results.

*"… the analysis is meant to apply to any appropriate binary decision. (…) Rumors, Strikes, Voting, **Diffusion of Innovation**, etc."*

Two main pathways of research - Collective Actions [3]

Threshold Models [4] :

"The ***threshold*** *is simply that point where the perceived benefits to an individual of doing the thing in question exceed the perceived costs."*



Thresholds denote the point where utility is positive, **not preferences**.

Two main pathways of research - Diffusion of Innovations [5]

Diffusion of Innovations [4] : *"a theoretical approach used to explain how new ideas and practices spread within and between communities."*

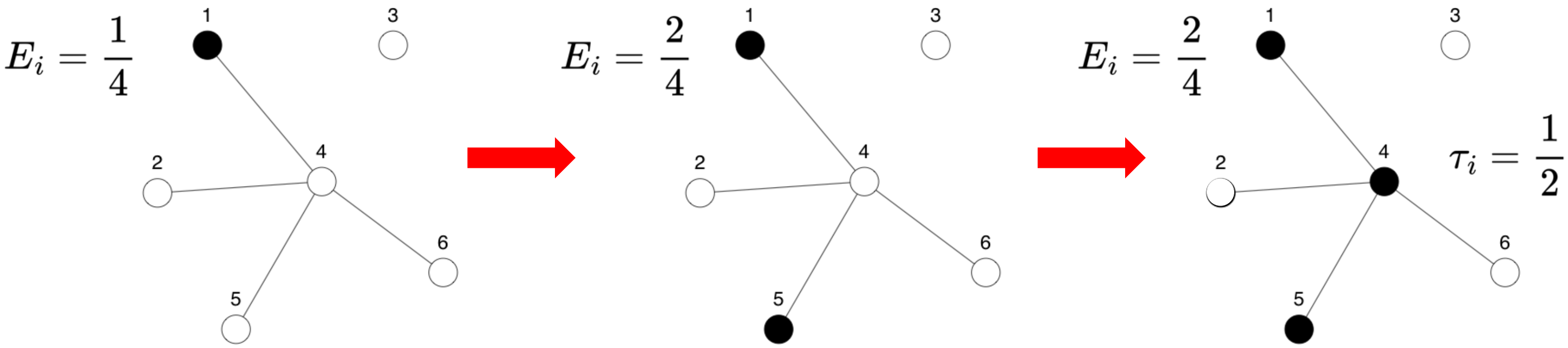
1. Roger's **S-shaped** curve of adoption (70'). Innovators - Early Adopters - Early Majority - Late Majority -Laggards. It answered *who* adopts and *when*, and the *why* was largely attributed to psychological profiles.
2. Granovetter's **Threshold Model** (78')**:** adoption act depends on the number of others who are already participating. No relational structure.
3. Valente's **Network Threshold Model** (95'): Your decision to adopt a new technology isn't based on national statistics; it's based on your personal social network.

$$E_i \equiv \frac{\sum_{j \neq i} \mathbf{X}_{ij} a_j}{\sum_{j \neq i} \mathbf{X}_{ij}}, \quad a_i = \begin{cases} 1 & \text{if } \tau_i \leq E_i \\ 0 & \text{otherwise} \end{cases}$$

Two main pathways of research

Valente's **Network Threshold Model** [5] :

$$E_i \equiv \frac{\sum_{j \neq i} \mathbf{X}_{ij} a_j}{\sum_{j \neq i} \mathbf{X}_{ij}}, \qquad a_i = \begin{cases} 1 & \text{if } \tau_i \leq E_i \\ 0 & \text{otherwise} \end{cases}$$



Two main pathways of research

Table 10–2. Event History Analysis of Factors Associated with Adoption for the Three Diffusion Network Datasets

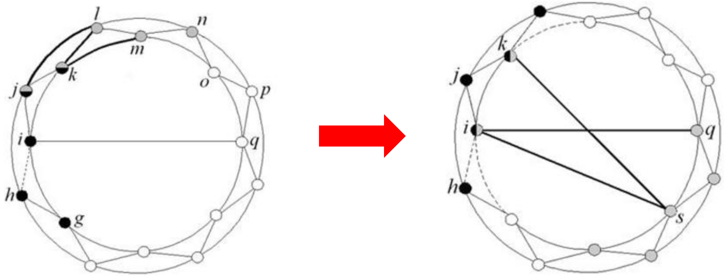
	Medical Innovation	Brazilian Farmers	Korean Family Planning
No.	947	10,092	7,103
Time	132.7**	5.14	4.34
Cumulative adoption	0.03	2.27	0.32
Number sent	1.04	0.99	1.02
Number received	1.05	1.01	1.05**
Cohesion exposure	1.05	1.93**	2.08**
Structural equivalence exposure	1.04	5.01**	1.34
Science orientation	0.65**		
Journal subscriptions	1.67		
Cosmopolitan-ness		1.00	
Income		1.14**	
Number of children			1.23**
Media exposure			1.03*

Coefficients are adjusted odds ratios for likelihood of adoption. Estimates adjusted for clustering within community.
$^*p < .05$; $^{**}p < .01$.

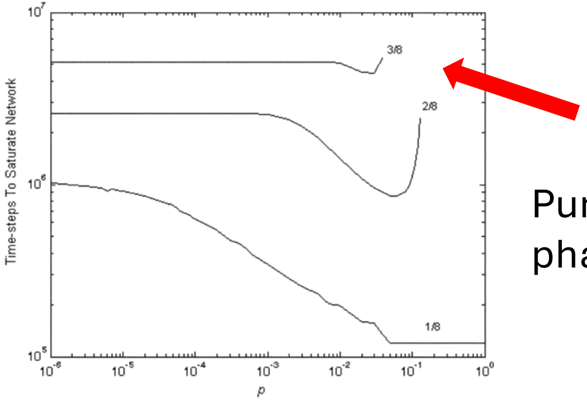
Previous works

Centola [6] called it **Complex Contagion.**

- While the rewiring is higher:



- We get an abrupt barrier in diffusion:



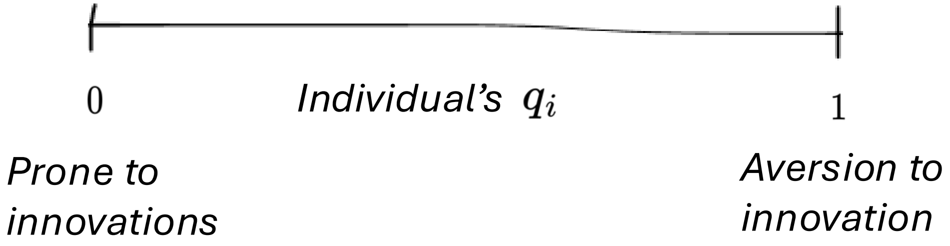
Pure structural phase transition

Previous works

Others [4, 5] use *Percolation Theory* instead to construct a word-of-mouth diffusion model.

- An innovation has an *Intrinsic Utility Level* (IUL) $\Gamma \in [0, 1]$

- Individuals are entirely characterized by
  - 1) their network position
  - 2) an attribute of *Minimum Utility Requirement* (MUR) $q_t^i \in [0, 1]$



Preferences!

Previous works

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- Individuals are entirely characterized by
  - 1) their network position
  - 2) an attribute of *Minimum Utility Requirement* (MUR) $q_t^i \in [0, 1]$

- There is an influence driven by adopters

$$q_t^i = q_0^i \left(\frac{1}{\sum_{j \neq i} \mathbf{X}_{ij} a_j} \right)^{\alpha}, \quad \alpha > 0$$

- Finally adopt if $q_t^i \leq \Gamma$.

Their fails

But the models use only synthetic data:

1. Small World topology
2. Random MUR from a distribution $X \sim U(0,1)$
3. Global influence parameter α

$$q_t^i = q_0^i \left(\frac{1}{\sum_{j \neq i} \mathbf{X}_{ij} a_j} \right)^{\alpha}$$

When it comes to peer influence, those dyads that are more similar to each other have greater influence [8].

Their fails

But the models use only synthetic data:

1. Small World topology
2. Random MUR from a distribution $X \sim U(0,1)$
3. Global influence parameter α

Some criticism has arisen due to the *‘structural reductionism’* of these works:

- *“This literature often treats agents as cognition-free ‘structural dopes,’ operating like **relay stations** whose only purpose is to automatically respond to external stimuli.”* [6]
- ***Fewer attention to more realistic setups.***

Addressing the flaws

We want to see the effect of word-of-mouth diffusion with:

1. Plausible network topologies
2. The right MUR distribution
3. Tie-specific influence parameter $\alpha = \alpha_{ij}$

The model

3. Tie-specific influence parameter $\alpha = \alpha_{ij}$

The model

1. Let's assume an 'innovation' has an *Intrinsic Utility Level* (IUL) $\Gamma \in [0,1]$, which characterize the attractiveness of that innovation.

0 *innovation's* Γ 1

less attractive *more attractive*

2. And individuals with *Minimum Utility Requirement* (MUR) $q_i \in [0,1]$.

0 *Individual's* q_i 1

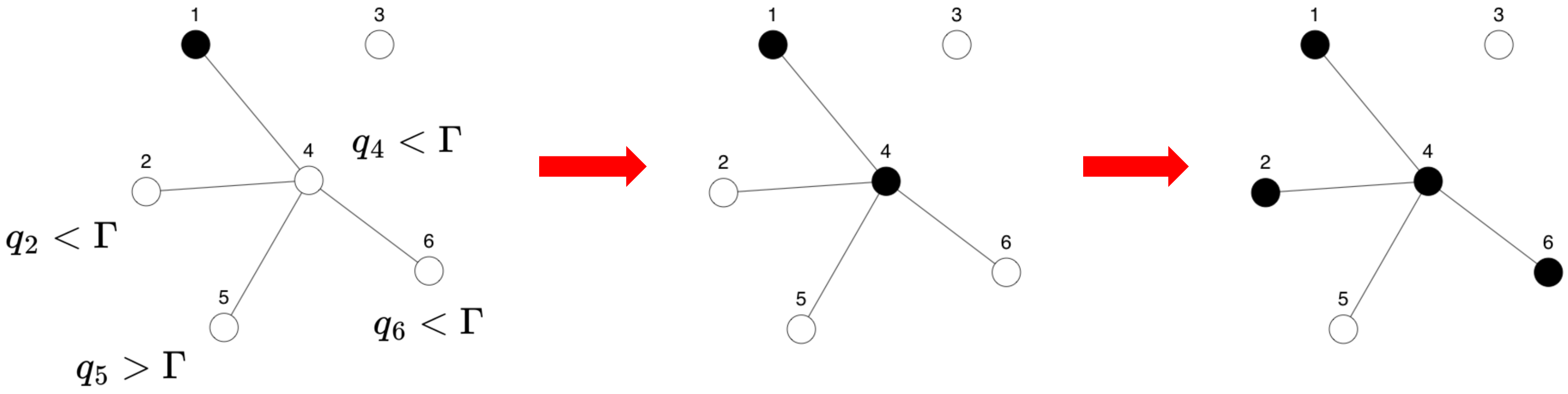
Prone to innovations *Aversion to innovation*

The model

Adoption can happen in two ways:

1) <u>Rational Choice:</u> i adopt if *Minimum Utility Requirement* ≤ *Intrinsic Utility Level*

$$q_i \leq \Gamma \qquad \Rightarrow a_i = 1$$



The model

2) <u>Selective Social Influence:</u>

$$E_i \equiv \frac{\sum_{j \neq i} \mathbf{X}_{ij} a_j}{\sum_{j \neq i} \mathbf{X}_{ij}}, \quad a_i = \begin{cases} 1 & \text{if } \tau_i \leq E_i \\ 0 & \text{otherwise} \end{cases}$$

The model

2) <u>Selective Social Influence:</u>

$$\tilde{E}_i \equiv \frac{\sum_{j\neq i} \mathbf{X}_{ij}\tilde{a}_j}{\sum_{j\neq i} \mathbf{X}_{ij}}, \qquad a_i = \begin{cases} 1 & \text{if } \tau_i \leq \tilde{E}_i \\ 0 & \text{otherwise} \end{cases}$$

Here, $\tilde{a}_i$ accounts for those infected individuals who *are influential*:

$$\tilde{a}_i = 1 \Leftrightarrow a_i = 1 \wedge U_{ij} \leq \sigma\left(h - d_{ij}\right), \qquad U_{ij} \sim \mathrm{Unif}(0,1).$$

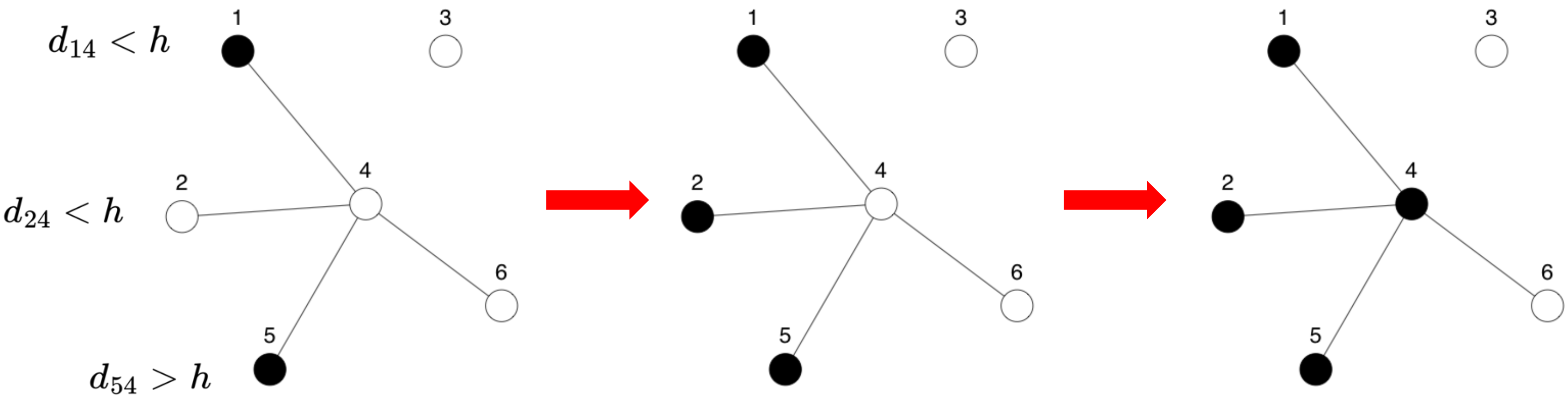
where:

1. d_{ij} is the social distance between individuals i and j,
2. h is the *Maximum Social Proximity* (MSP), which measures the flexibility to be influenced by a person with different demographics.

The model

2) <u>Selective Social Influence:</u>

Let's set $\tau_4 = 0.5$; then, because the variability among the ties [6]...



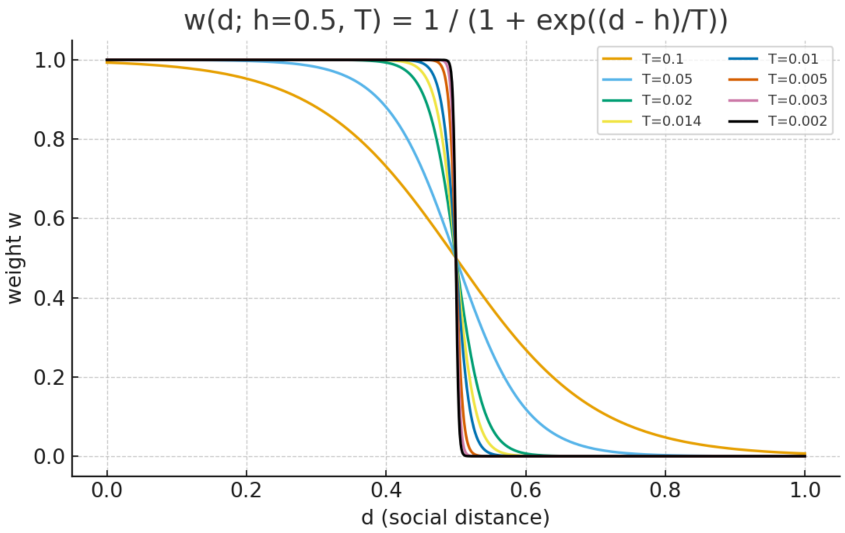
The model

2) Selective Social Influence:

$$\tilde{a}_i = 1 \Leftrightarrow a_i = 1 \wedge U_{ij} \leq \sigma\left(h - d_{ij}\right), \quad U_{ij} \sim \mathrm{Unif}(0,1).$$

Where:

$$\sigma(z) = \frac{1}{1+\exp(-z/T)}$$



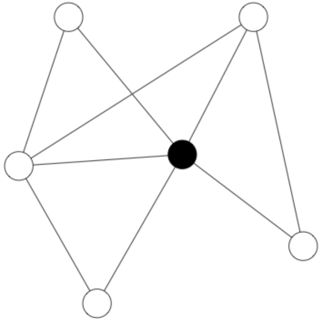
Setting up
–
Diffusion of Innovations

1. Plausible network topologies
2. The right MUR distribution

Imputing network structure to a Survey

Following McPherson and Smith (2019) [7], **you can impute a network structure** on any other survey if:

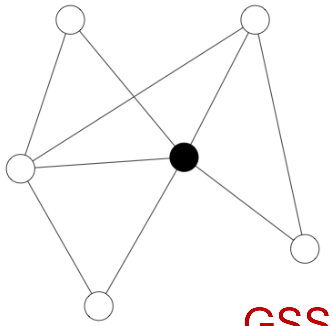
1) There is a survey with representative EGO-data,
2) Both are representative of the same population,
3) Both have some basic demographic variables.



Imputing network structure to a Survey

General Social Survey (GSS 2004):

1. Representative of the US population
2. Demographics:
   Age - Sex - Years of Educ – Race - Religion
3. EGO data



GSS 2004

American Trends Panel (ATP 2014):

1. Representative of the US population
2. Demographics:
   Age - Sex - Years of Educ – Race - Religion

~~3. EGO data~~ ‘*Openness to Innovations*’ items

	id_1	id_2	id_3	...
Age	36	27	41	...
Educ	12	15	16	...
q_i	.54	.67	.32	...
...	...	...	...	...

ATP 2014

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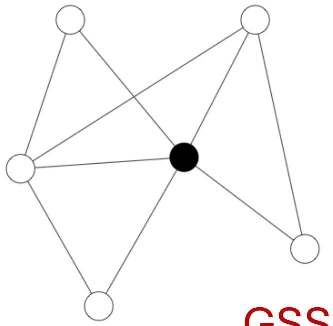

GSS 2004

Homophilic strength
in the m-th
social dimension

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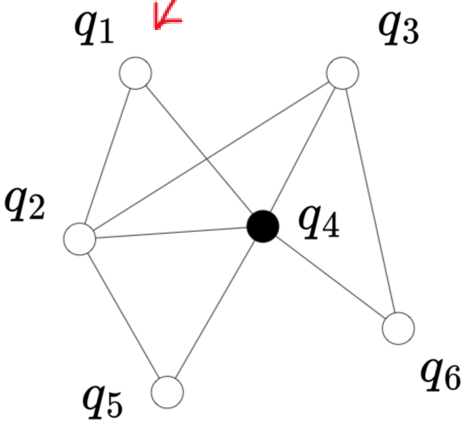
3. ~~EGO data~~ '*Openness to Innovations*' items

Nodes have '*Openness to Innovations* ***Score***'

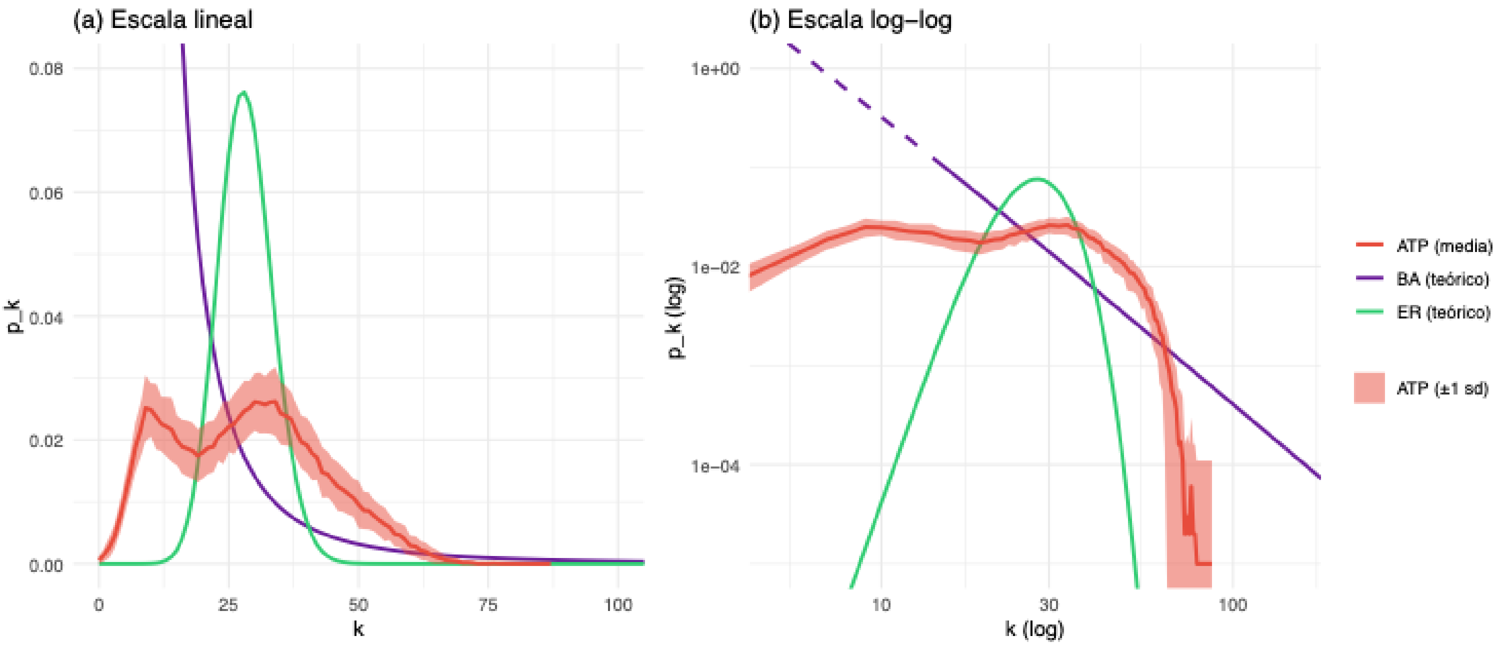
MRU



ATP 2014 +
Network structure

Imputing network structure to a Survey

We can use that procedure to create networks with the **right topology** [8] via ERGM.



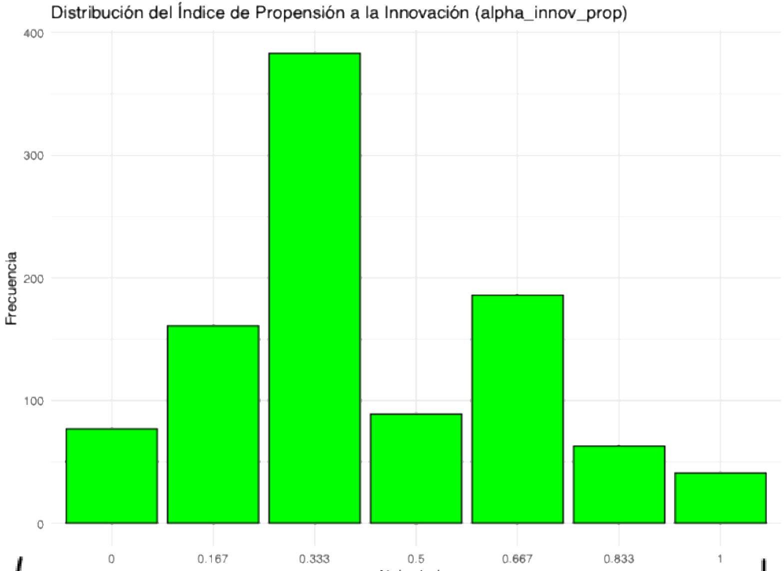
Imputing network structure to a Survey

Items to create the '*Openness to Innovations Score*' from ATP 2014 **(binary):**

1. Usually try new products before others do.	→ pro-innov.
2. Prefer my tried and trusted brands.	→ **anti**-innov.
3. Like being able to tell others about new brands and products I have tried.	→ pro-innov.
4. Like the variety of trying new products.	→ pro-innov.
5. Feel more comfortable using familiar brands and products.	→ **anti**-innov.
6. Wait until I hear about others' experiences before I try new products.	→ **anti**-innov.

Imputing network structure to a Survey

Items to create the '*Openness to Innovations Score*' from ATP 2014 **(binary):**



Prone to innovations

0 *Individual's* q_i 1

Aversion to innovation

Comprehensive Simulation Methodology

Using the ATP-networks (N=1000 nodes):

Parameter Space Exploration:

- **IUL** (Γ): 41 levels (0.0 to 1.0).
- **MSP** (h): 13 levels (0.0 to 1.0).
- **Thresholds** (τ_i): Normally distributed $\tau_i \sim \mathcal{N}(\mu_\tau, \sigma_\tau)$
  - Means (μ_τ): 4 levels (0.3, 0.4, 0.5, 0.6).
  - SD (σ_τ): 4 levels (0.08, 0.12, 0.16, 0.20).
- **Seeding Strategies:**
  Random, Central, Marginal, Closeness, and Eigenvalue.

Scale of Simulation:

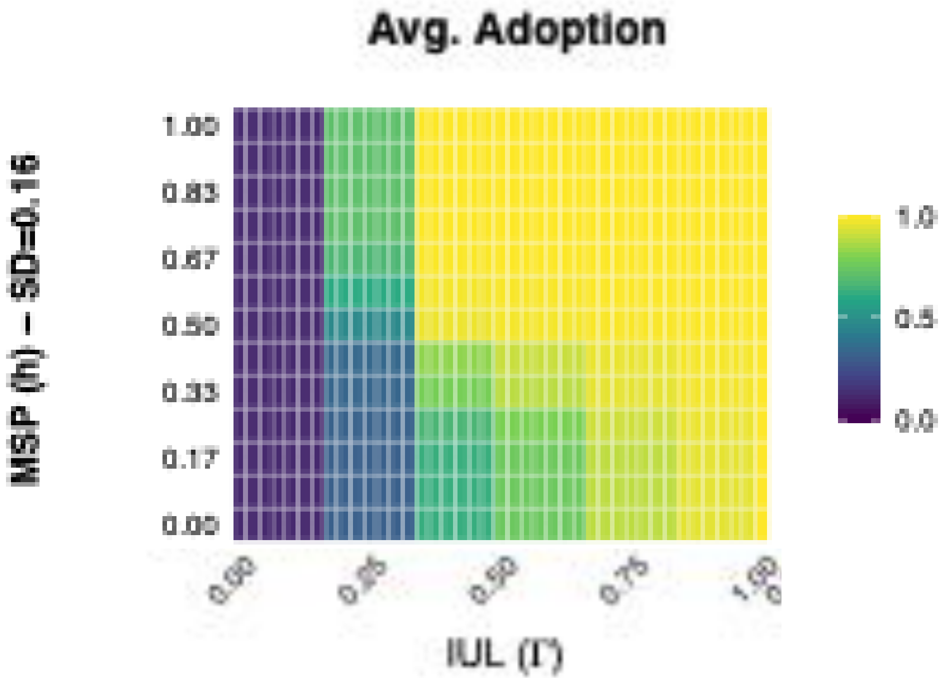
- 96 simulations for each combination of parameters
- Total simulations: $41 \times 13 \times 4 \times 4 \times 5 \times 96 \approx 4 \times 10^6$!

Results

-

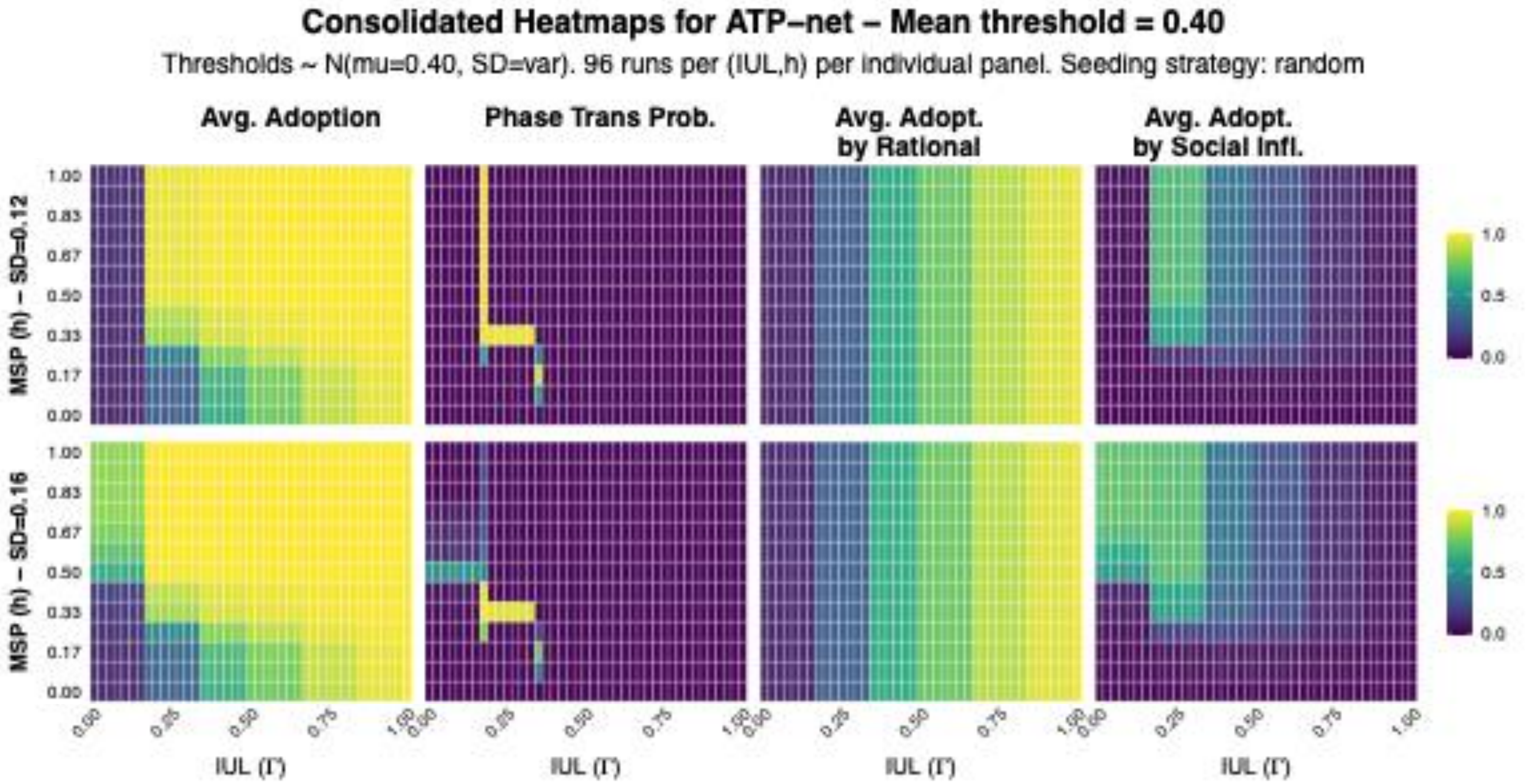
Diffusion of Innovation

Results



Avg. Adoption
1.00
0.83
0.67
0.50
0.33
0.17
0.00
MSP (h) – SD=0.16
0.00
0.25
0.50
0.75
1.00
IUL (Γ)
1.0
0.5
0.0

Results


Consolidated Heatmaps for ATP–net – Mean threshold = 0.40
Thresholds ~ N(mu=0.40, SD=var). 96 runs per (IUL,h) per individual panel. Seeding strategy: random
Avg. Adoption
Phase Trans Prob.
Avg. Adopt. by Rational
Avg. Adopt. by Social Infl.
MSP (h) – SD=0.12
MSP (h) – SD=0.16
1.00
0.83
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0.50
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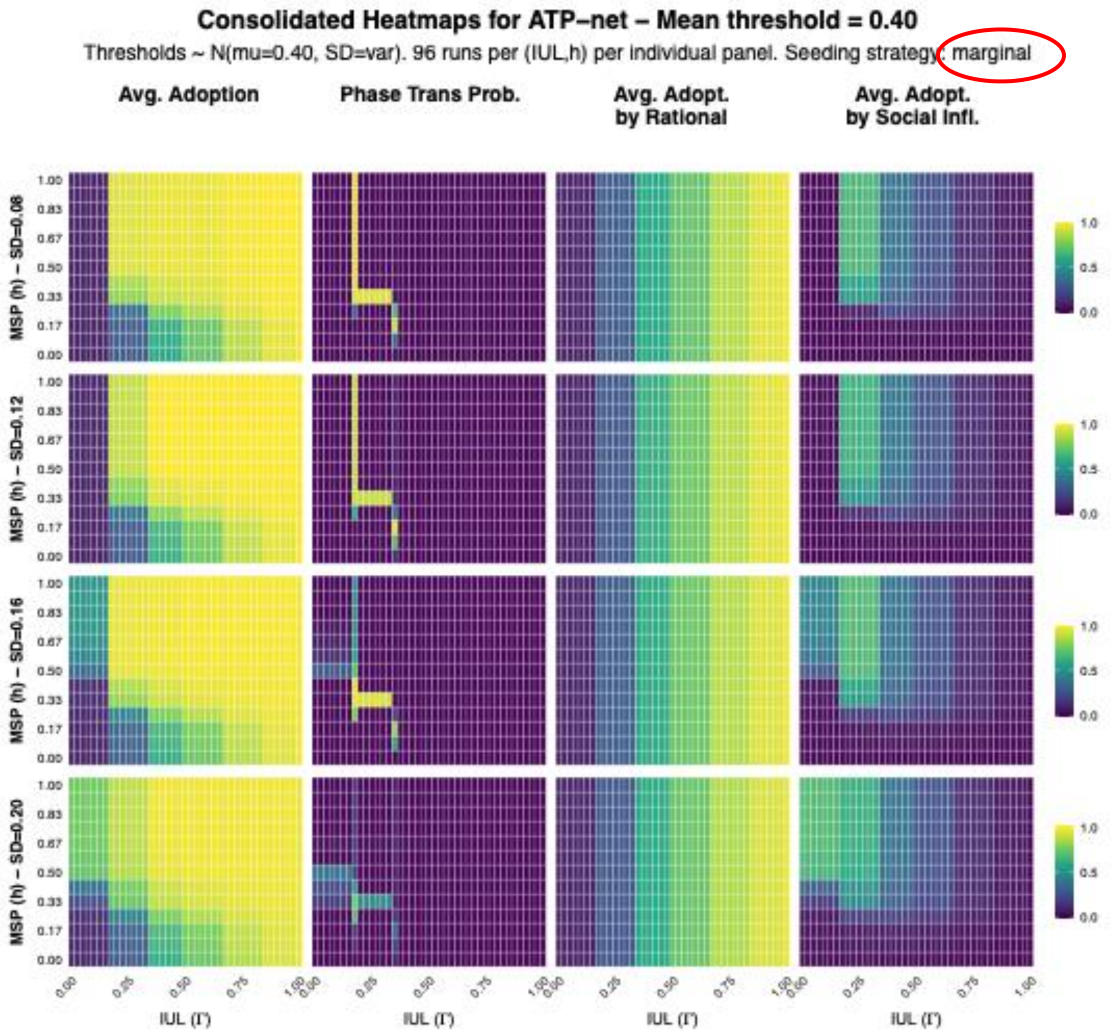
0.00
0.00
0.25
0.50
0.75
1.00
IUL (Γ)
1.0
0.5
0.0


Consolidated Heatmaps for ATP–net – Mean threshold = 0.40
Thresholds ~ N(mu=0.40, SD=var). 96 runs per (IUL,h) per individual panel. Seeding strategy: marginal
Avg. Adoption
Phase Trans Prob.
Avg. Adopt. by Rational
Avg. Adopt. by Social Infl.
MSP (h) – SD=0.08
MSP (h) – SD=0.12
MSP (h) – SD=0.16
MSP (h) – SD=0.20
IUL (Γ)
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0.25
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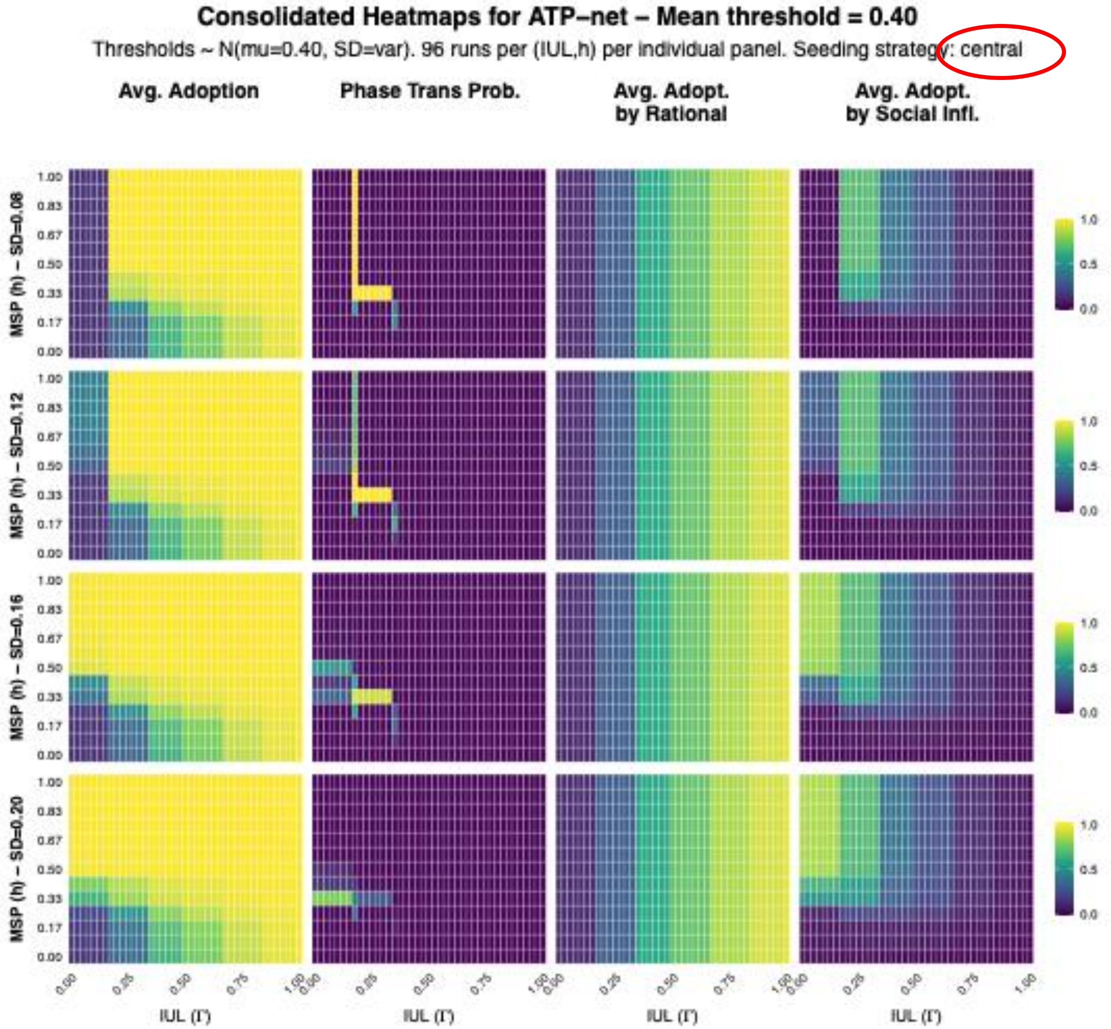
1.0


Consolidated Heatmaps for ATP–net – Mean threshold = 0.40
Thresholds ~ N(mu=0.40, SD=var). 96 runs per (IUL,h) per individual panel. Seeding strategy: central
Avg. Adoption
Phase Trans Prob.
Avg. Adopt. by Rational
Avg. Adopt. by Social Infl.
MSP (h) – SD=0.08
MSP (h) – SD=0.12
MSP (h) – SD=0.16
MSP (h) – SD=0.20
IUL (Γ)

Conclusions – 1st part

Conclusions – 1st part

So, what have we learned?

- Social influence plays a relevant role in adoption, even for configurations where the innovation is **not particularly attractive**.
- The model offers consistent results across several parameter configurations.
- The regimens where social influence is on are separated abruptly by **first-order phase transitions**.
- There are non-structural barriers to word-of-mouth diffusion.

Setting up

–

Collective Action

1. Plausible network topologies
2. The right MUR distribution

Imputing network structure to a Survey

General Social Survey (<u>GSS 2004</u>):

1. Representative of the US population
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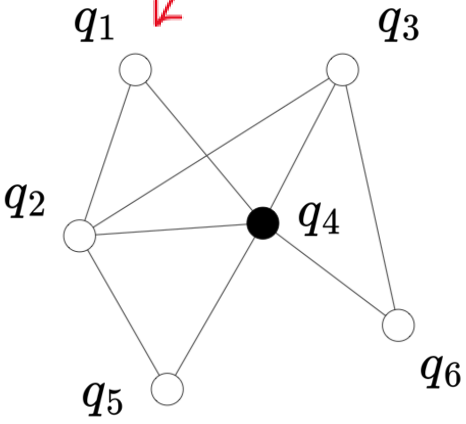
   Age - Sex - Years of Educ – Race - Religion
3. EGO data
4. ‘*Collective Action Propensity Score*’ items

‘*Collective Action Propensity* ***Score***’

MRU



GSS 2004 +
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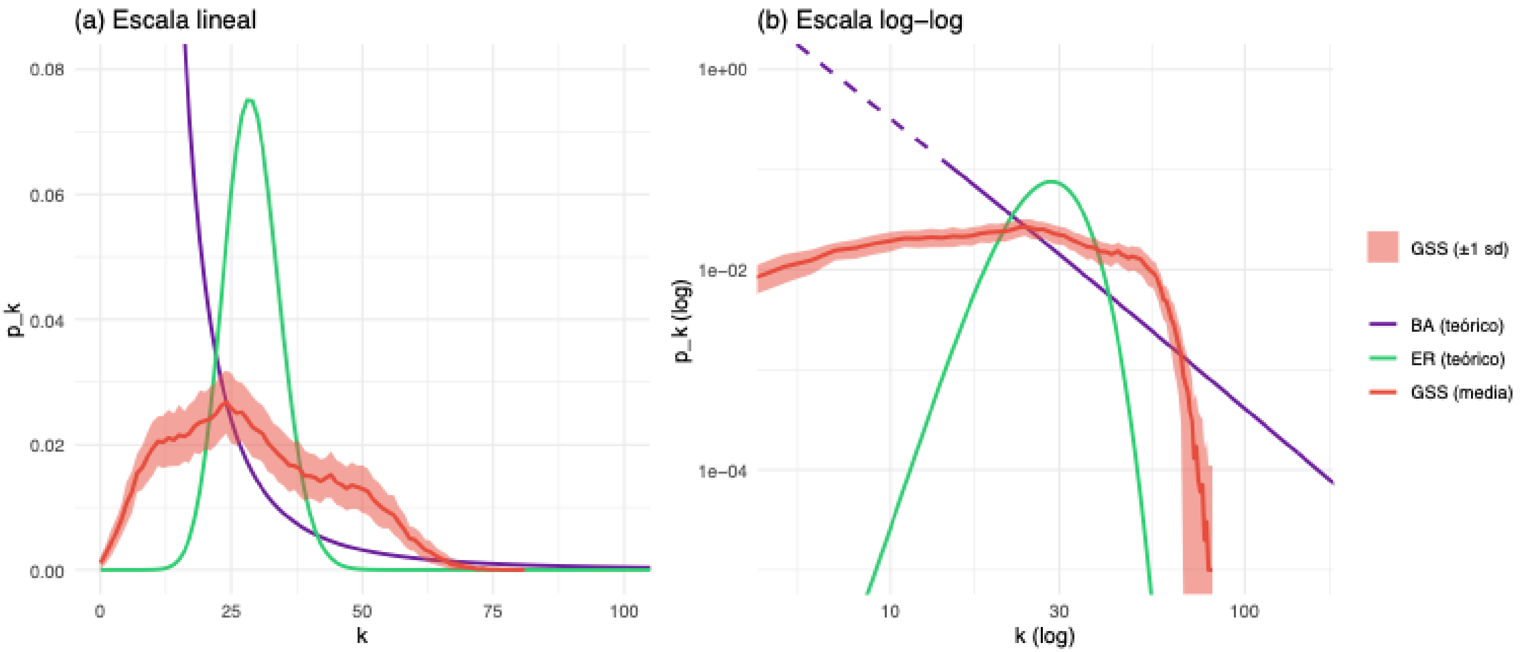
Imputing network structure to a Survey

We can use that procedure to create networks with the **right topology** [8] via ERGM.



Imputing network structure to a Survey

Here are some forms of political and social action that people can take.
Please indicate, for *each one*,

(0) whether you have done any of these things in the **past year**,
(1) have done it in the **more distant past**,
(2) have not done it but **might do it**,
(3) or have not done it and **would never**, under any circumstances, do it.

1. Signed a petition
2. Boycotted, or deliberately bought, certain products for political, ethical or environmental reasons.
3. Took part in a demonstration.
4. Attended a political meeting or rally.
5. Contacted, or attempted to contact, a politician or a civil servant to express your views.
6. Donated money or raised funds for a social or political activity.

Imputing network structure to a Survey

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Please indicate, for *each one*,

(0) whether you have done any of these things in the **past year**,

(1) have done it in the **more distant past**,

(2) have not done it but **might do it**,

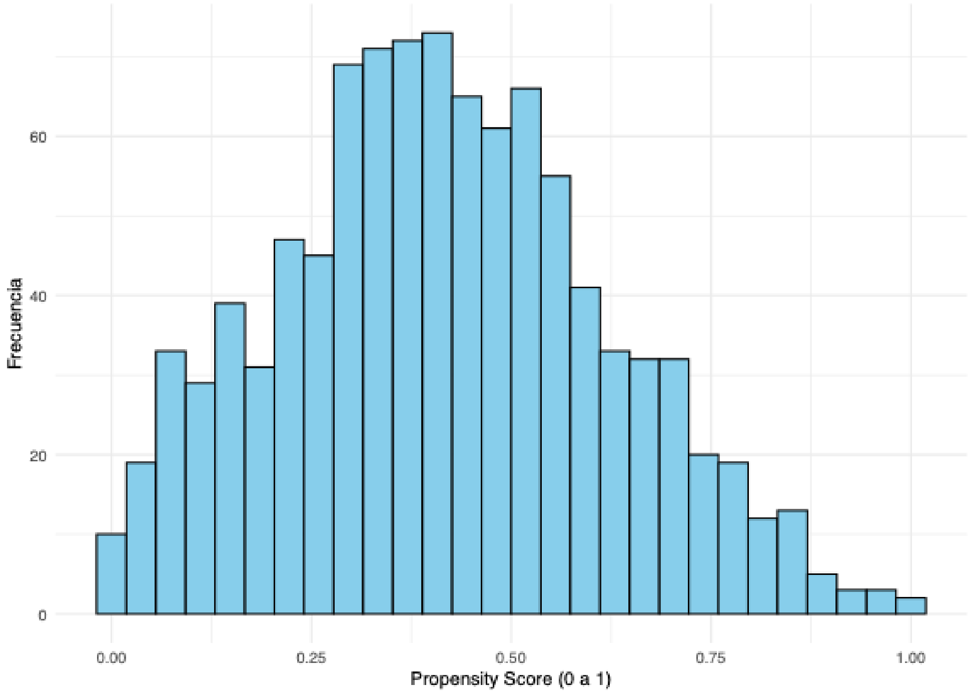
(3) or have not done it and **would never**, under any circumstances, do it.

7. Contacted or appeared in the media to express your views.
8. Joined an Internet political forum or discussion group.

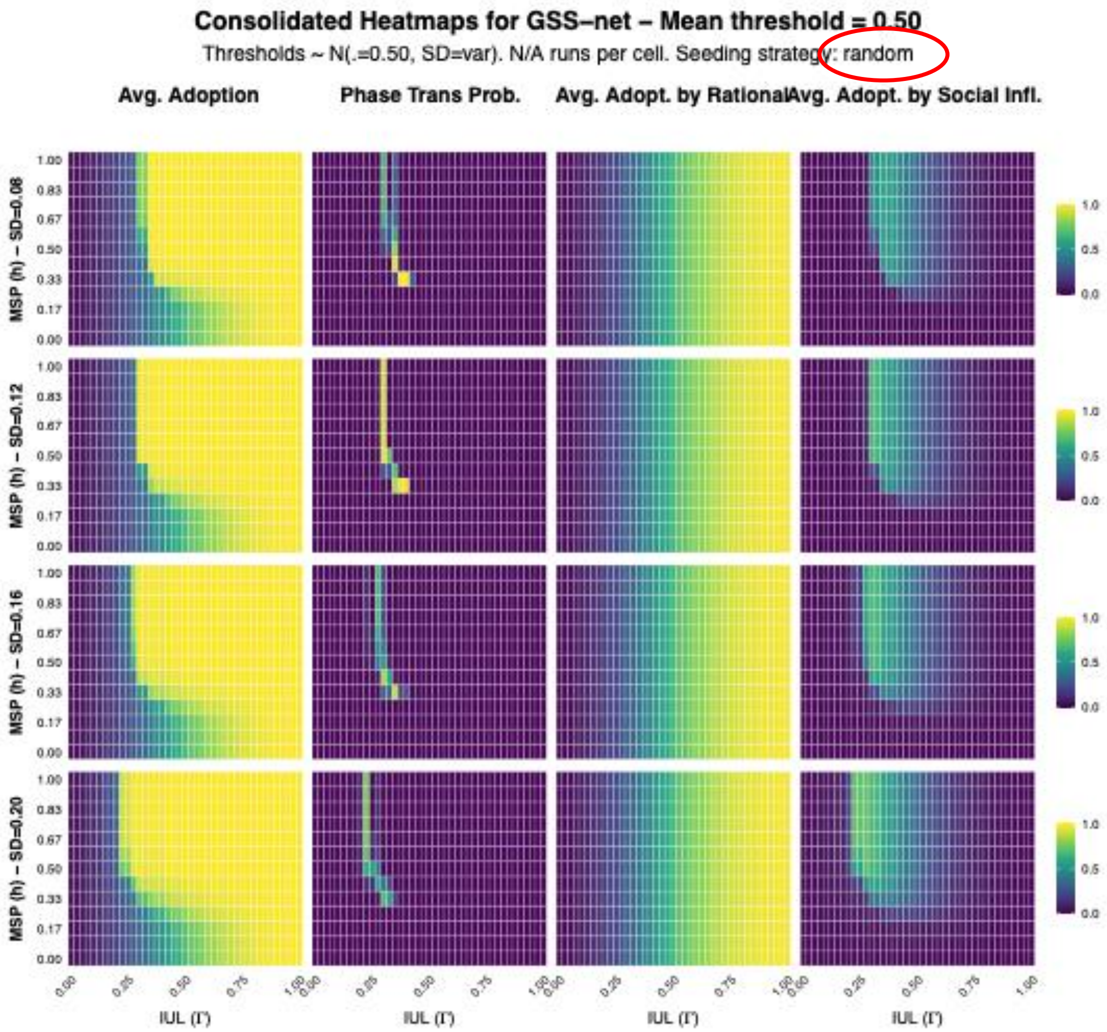
9. Suppose a law were being considered by the Congress that you considered to be unjust or harmful. If such a case arose, how likely is it that you, acting along or together with others, would be able to try to do something about it?

0) Very likely 1) Fairly likely 2) Not very likely 3) Not at all likely

Imputing network structure to a Survey



Results
-
Collective Action



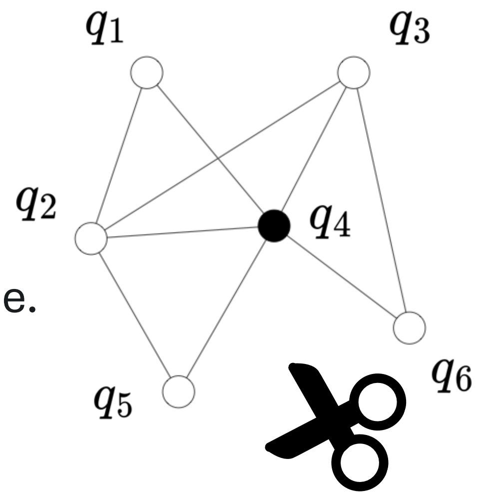
Diffusion of Innovation results remain almost the same for Collective Action!

Setup

Using the ATP-networks (N=1000 nodes):

Parameter Space Exploration:

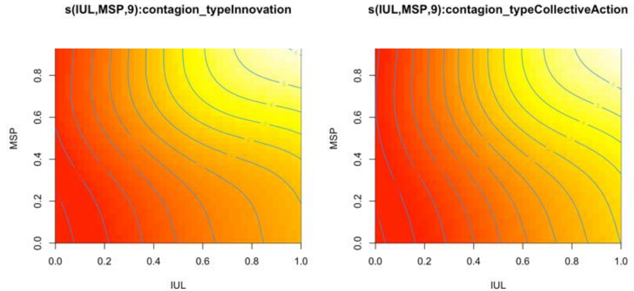
- ~~**IUL** (Γ): 41 levels (0.0 to 1.0).~~
- ~~**MSP** (h): 13 levels (0.0 to 1.0).~~
- **Thresholds** (τ_i): Normally distributed $\tau_i \sim \mathcal{N}(\mu_\tau, \sigma_\tau)$
  - Means (μ_τ): 4 levels (0.3, 0.4, 0.5, 0.6).
  - SD (σ_τ): 4 levels (0.08, 0.12, 0.16, 0.20).
- **Seeding Strategies:**
  Random, Central, Marginal, Closeness, and Eigenvalue.
- **Network Structure:**
  Pseudo-empirical ATP/GSS, Erdös-Rényi.



Results – 2nd part

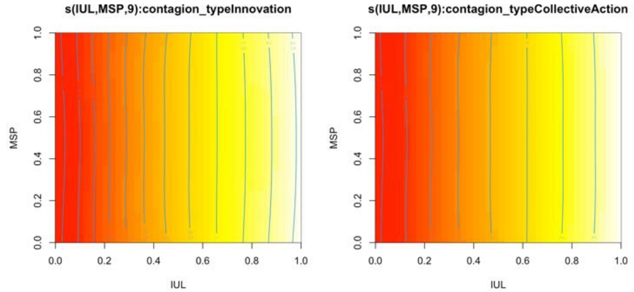
```
Family: binomial
Link function: logit

Formula:
adopt_total ~ s(IUL, MSP, k = 10, by = contagion_type) + tau_mean + tau_sd +
              seed_type + network_type
```



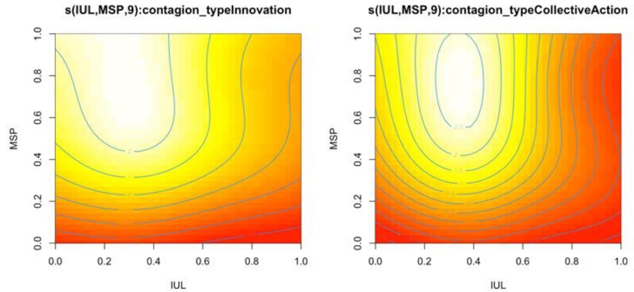

```
Family: binomial
Link function: logit

Formula:
adopt_rational ~ s(IUL, MSP, k = 10, by = contagion_type) + tau_mean + tau_sd +
              seed_type + network_type
```




```
Family: binomial
Link function: logit

Formula:
adopt_social ~ s(IUL, MSP, k = 10, by = contagion_type) + tau_mean + tau_sd +
              seed_type + network_type
```



Results – 2nd part

```
Family: binomial
Link function: logit

Formula:
adopt_total ~ s(IUL, MSP, k = 10, by = contagion_type) + tau_mean + tau_sd +
            seed_type + network_type

Parametric coefficients:
                      Estimate   OR  Std.Error  z value Pr(>|z|)
(Intercept)              5.304    -  1.997e-04   26557   <2e-16 ***
tau_mean                -6.739    -  2.609e-04  -25829   <2e-16 ***
tau_sd                   5.717    -  6.079e-04    9405   <2e-16 ***
seed_typecentral         0.137 1.147 8.527e-05    1610   <2e-16 ***
seed_typecloseness       0.132 1.141 8.525e-05    1548   <2e-16 ***
seed_typeeigen           0.134 1.145 8.526e-05    1581   <2e-16 ***
seed_typemarginal       -0.185 0.831 8.450e-05   -2189   <2e-16 ***
network_typeER          -0.376 0.687 5.411e-05   -6957   <2e-16 ***
---
Approximate significance of smooth terms:
                                         k' edf k-index p-value
s(IUL,MSP):contagion_typeInnovation       9   9    0.95   0.005 **
s(IUL,MSP):contagion_typeCollectiveAction 9   9    0.95  <2e-16 ***
---
R-sq.(adj) =  0.855   Deviance explained = 84.4%
fREML = 8.5075e+08  Scale est. = 1         n = 170560
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

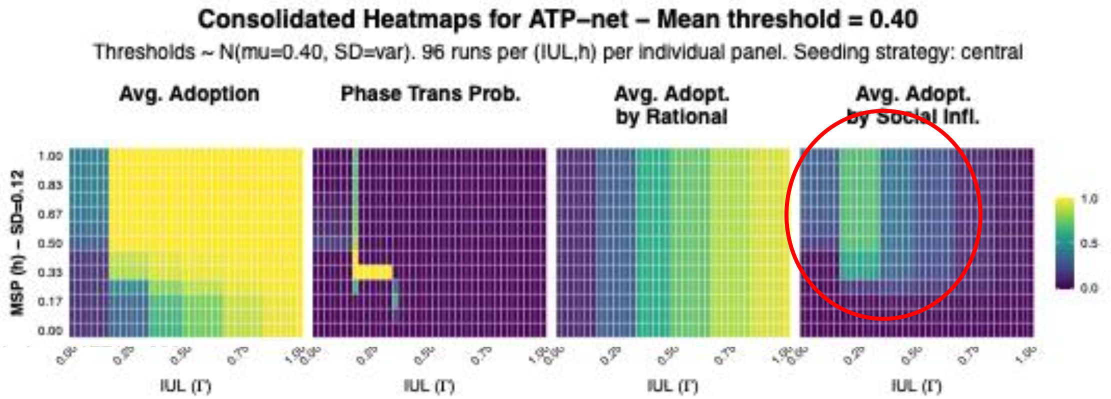
```
Family: binomial
Link function: logit

Formula:
adopt_social ~ s(IUL, MSP, k = 10, by = contagion_type) + tau_mean + tau_sd +
             seed_type + network_type

Parametric coefficients:
                      Estimate   OR  Std.Error  z value Pr(>|z|)
(Intercept)             -0.543    -  1.422e-04  -3822.5   <2e-16 ***
tau_mean                -5.784    -  2.337e-04 -24751.3   <2e-16 ***
tau_sd                   4.703    -  5.550e-04   8474.5   <2e-16 ***
seed_typecentral         0.047 1.048 7.781e-05    608.9   <2e-16 ***
seed_typecloseness       0.045 1.046 7.783e-05    579.1   <2e-16 ***
seed_typeeigen           0.047 1.048 7.781e-05    607.8   <2e-16 ***
seed_typemarginal       -0.080 0.922 7.874e-05  -1027.2   <2e-16 ***
network_typeER          -0.340 0.711 4.951e-05  -6886.1   <2e-16 ***
---
Approximate significance of smooth terms:
                                         k' edf k-index p-value
s(IUL,MSP):contagion_typeInnovation       9   9    0.92  <2e-16 ***
s(IUL,MSP):contagion_typeCollectiveAction 9   9    0.92  <2e-16 ***
---
R-sq.(adj) =   0.67   Deviance explained =   69%
fREML = 9.2894e+08  Scale est. = 1         n = 170560
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Conclusions – 2nd part

Conclusions – 2nd part




```
Family: binomial
Link function: logit

Formula:
adopt_social ~ s(IUL, MSP, k = 10, by = contagion_
             seed_type + network_type

Parametric coefficients:
                     Estimate   OR  Std.Error   z va
(Intercept)            -0.543   -   1.422e-04   -382
tau_mean               -5.784   -   2.337e-04  -2475
tau_sd                  4.703   -   5.550e-04    847
seed_typecentral        0.047 1.048 7.781e-05     60
seed_typecloseness      0.045 1.046 7.783e-05     57
seed_typeeigen          0.047 1.048 7.781e-05    607.8     <2e-16 ***
seed_typemarginal      -0.080 0.922 7.874e-05  -1027.2     <2e-16 ***
network_typeER         -0.340 0.711 4.951e-05  -6886.1     <2e-16 ***
---
Approximate significance of smooth terms:
                                        k'  edf k-index p-value
s(IUL,MSP):contagion_typeInnovation      9   9     0.92  <2e-16 ***
s(IUL,MSP):contagion_typeCollectiveAction 9   9     0.92  <2e-16 ***
---
R-sq.(adj) =   0.67   Deviance explained =    69%
fREML = 9.2894e+08  Scale est. = 1          n = 170560
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

There are cases when the network decides for us!

Thanks!

All the results are available on the GitHub repository !

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Phase Transitions