Effects of in-group bias and homophily on opinion dynamics

Conference on Complex Systems 2022

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Climate change debate is social

[Young people's] message is clear: the older generation has failed, and it is the young who will pay in full — with their very futures.

– United Nations

www.un.org/en/climatechange/youth-in-action

We young people [...] must hold the older generations accountable for the mess they have created.

– Greta Thunberg, Fridays for Future

(2018, CNN Interview)

twitter.com/CNN/status/1077444076176359426

Social identity shapes the formation of individual opinions

Social identity

People affiliate with groups based on characteristics like age, occupation, ...
$\rightarrow$ in-group

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$\Downarrow$

Homophily

People tend to interact predominantly with similar others

(McPherson, Smith-Lovin, and Cook, 2001; Smaldino and Jones, 2021)

$\downarrow$

interaction preference

Social identity shapes the formation of individual opinions

Social identity

People affiliate with groups based on characteristics like age, occupation, ...
$\rightarrow$ in-group

$\Downarrow$

Homophily

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(McPherson, Smith-Lovin, and Cook, 2001; Smaldino and Jones, 2021)

$\downarrow$

interaction preference

In-group favouritism bias (here 'bias')

People tend to perceive in-group members as more informative than out-group members

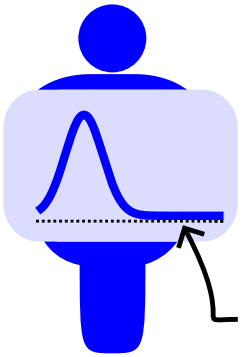
(Tajfel, 1974; Hewstone, Rubin, and Willis, 2002; Brewer, 1979)

$\downarrow$

perception

Model

Model

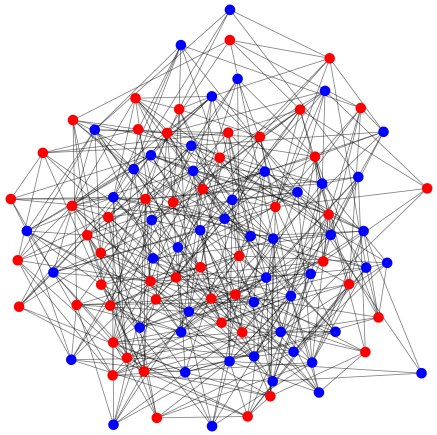


agent

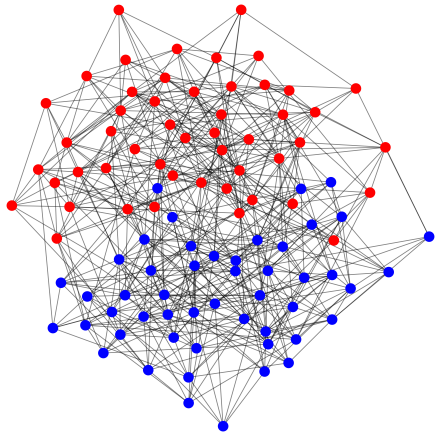
- social identity (red/blue)
- opinion distribution

Model

no homophiliy



homophily



agent

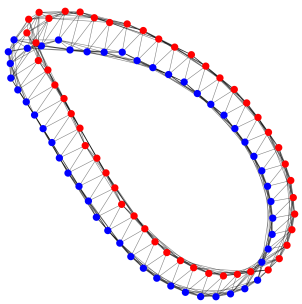
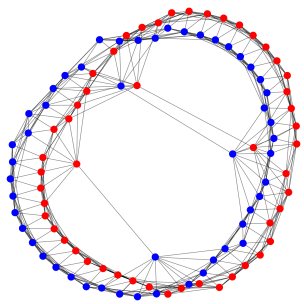
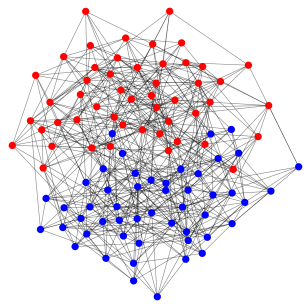
- social identity (red/blue)
- opinion distribution

social network

- homophily
-

Model

structure in networks with homophily:

regular, lattice	small-world	random
$p = 0$	$p = 0.01$	$p = 1.0$
		

agent

- social identity (red/blue)
- opinion distribution

social network

- homophily
- randomness

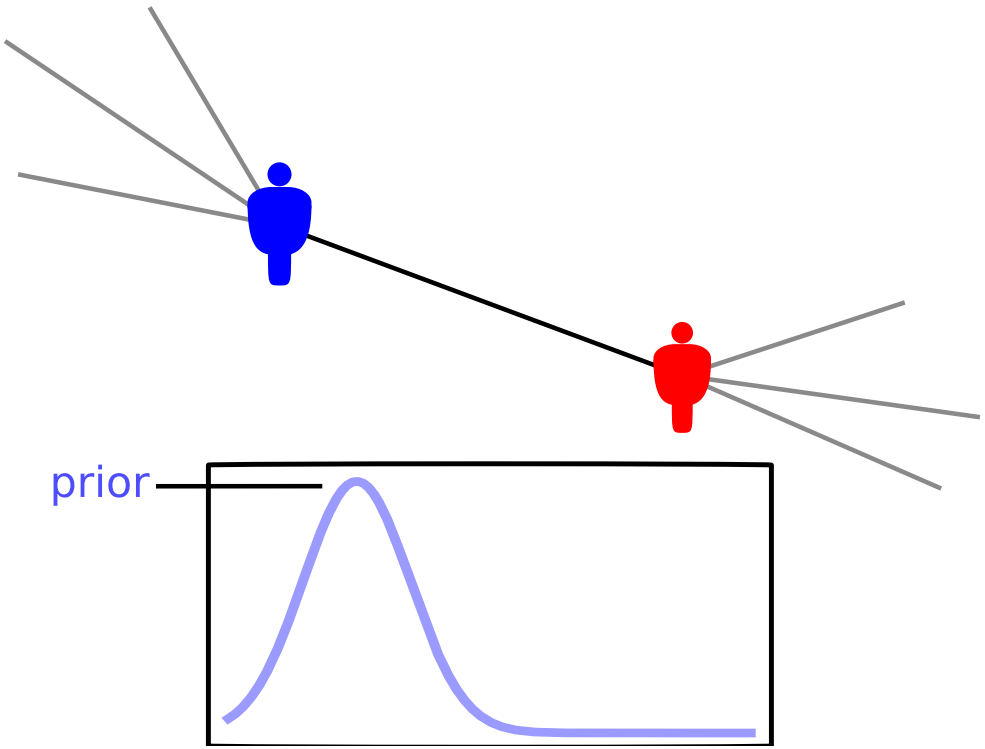
Model

agent
- social identity (red/blue)
- opinion distribution

social network
- homophily
- randomness

opinion update
-

Model

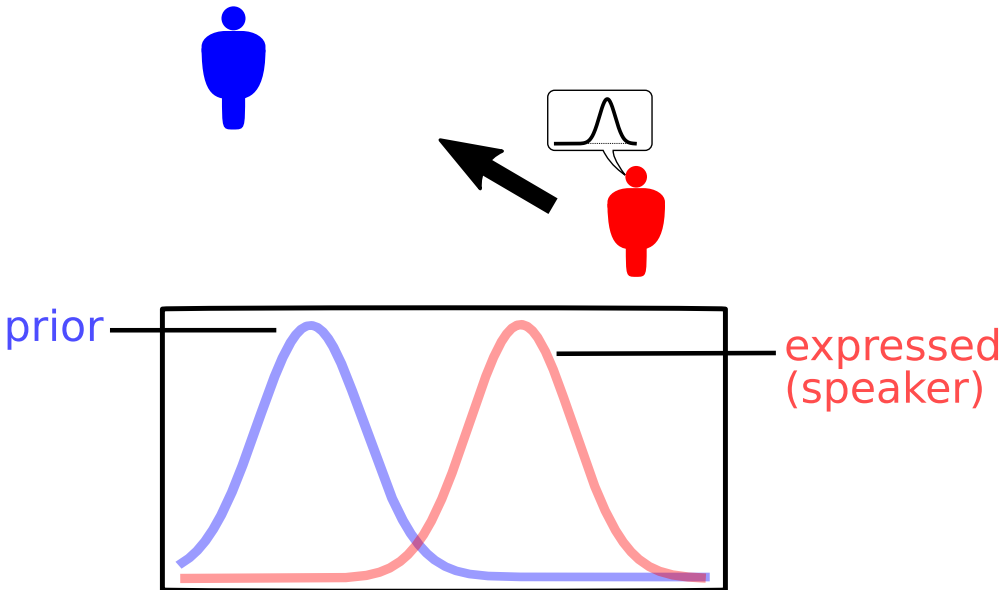


agent
- social identity (red/blue)
- opinion distribution

social network
- homophily
- randomness

opinion update
- social influence
  1
  2
  3
-

Model

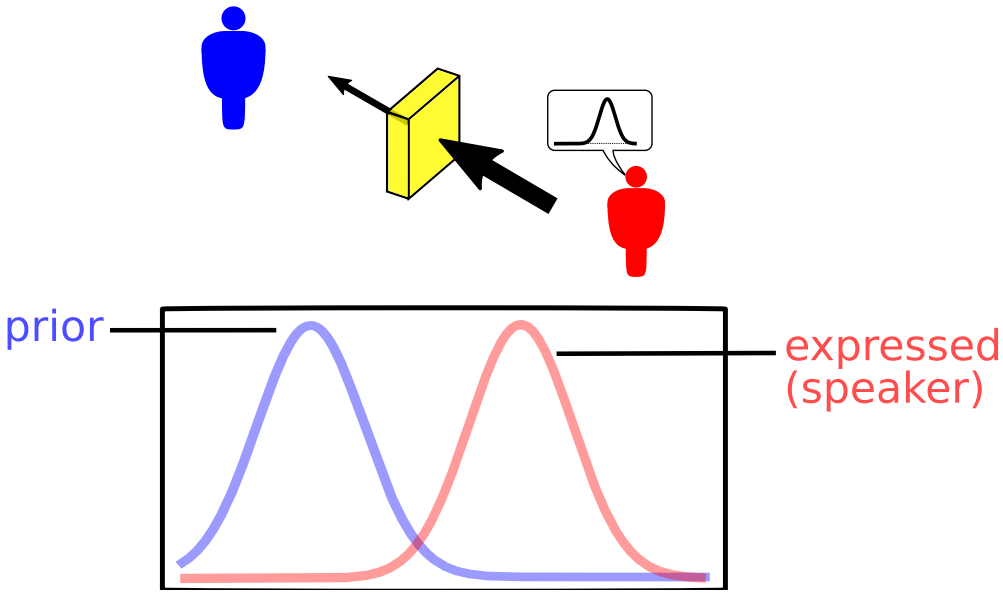


agent
- social identity (red/blue)
- opinion distribution

social network
- homophily
- randomness

opinion update
- social influence
  1. communication
  2.
  3.
-

Model

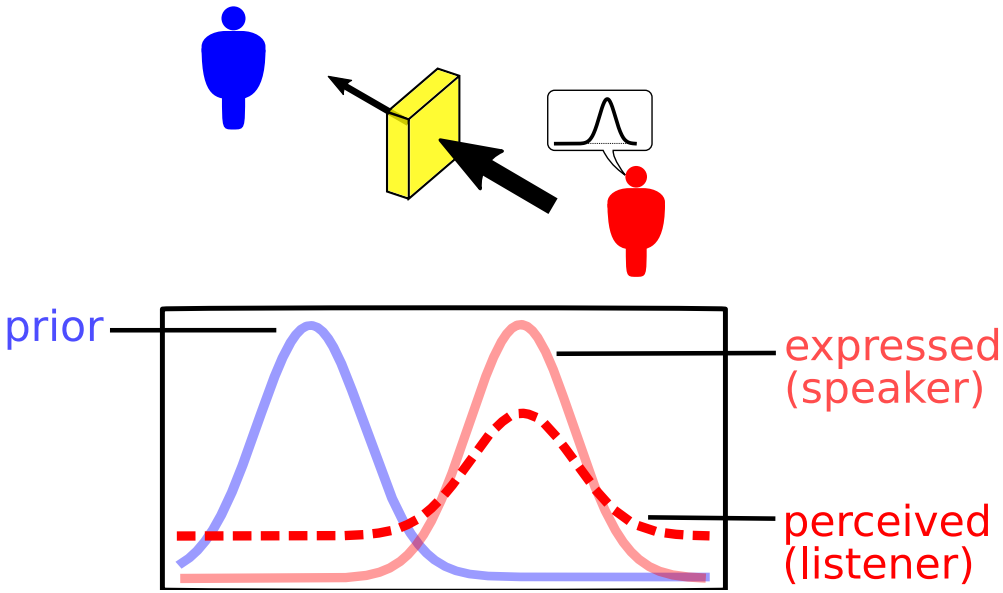


agent
- social identity (red/blue)
- opinion distribution

social network
- homophily
- randomness

opinion update
- social influence
  1. communication
  2. perception
  3.
-

Model



agent
- social identity (red/blue)
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social network
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opinion update
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  1. communication
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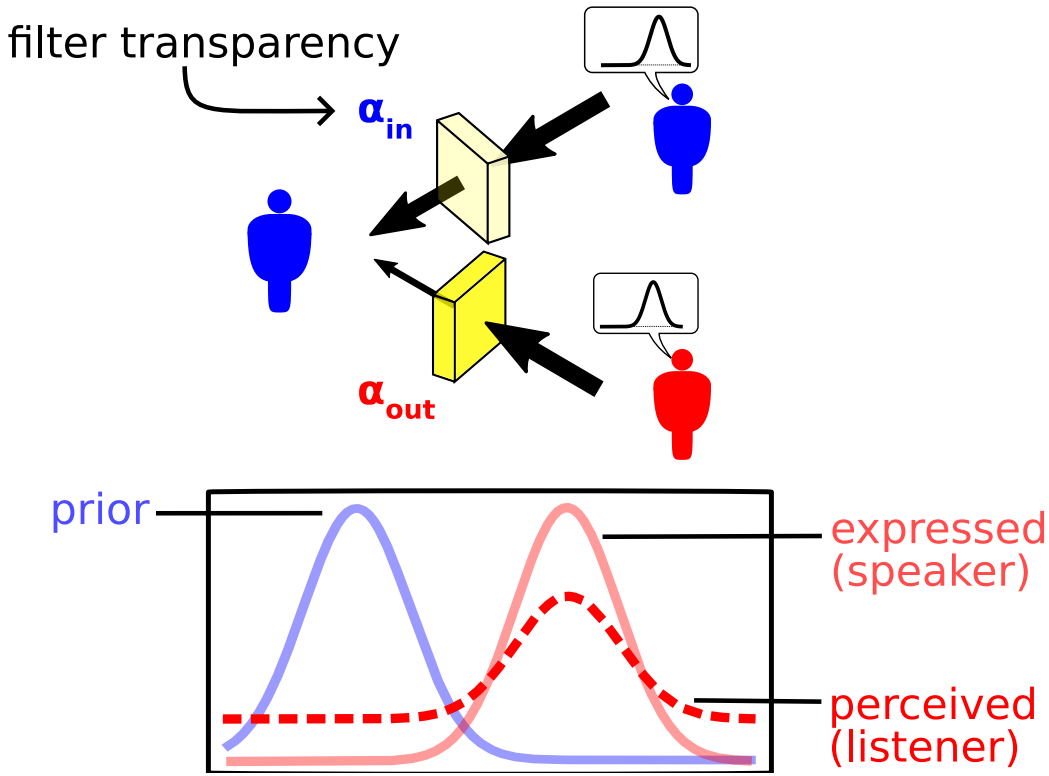
  3.
-

Model

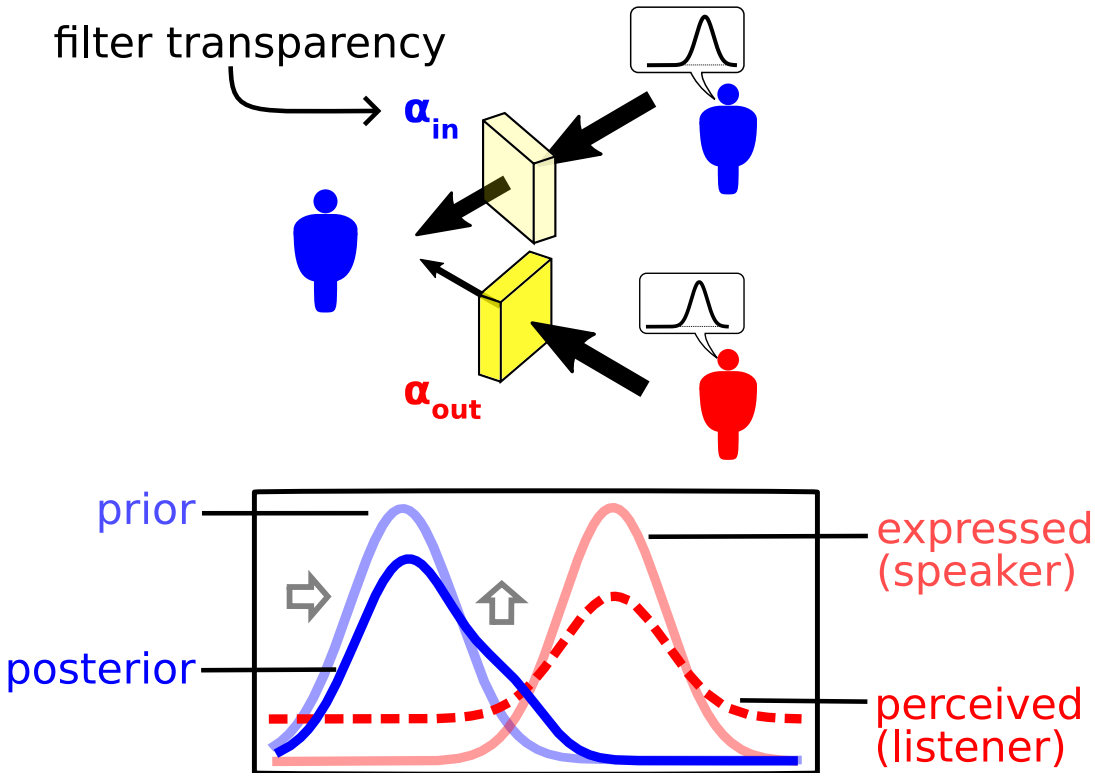


agent
- social identity (red/blue)
- opinion distribution

social network
- homophily
- randomness

opinion update
- social influence
  1. communication
  2. perception
     (in-group bias)
  3.
-

Model

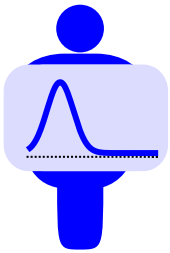


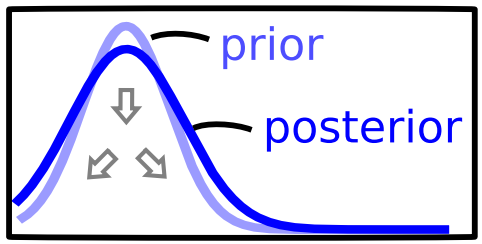
agent
- social identity (red/blue)
- opinion distribution

social network
- homophily
- randomness

opinion update
- social influence
  1. communication
  2. perception (in-group bias)
  3. update (Bayes)
-

Model





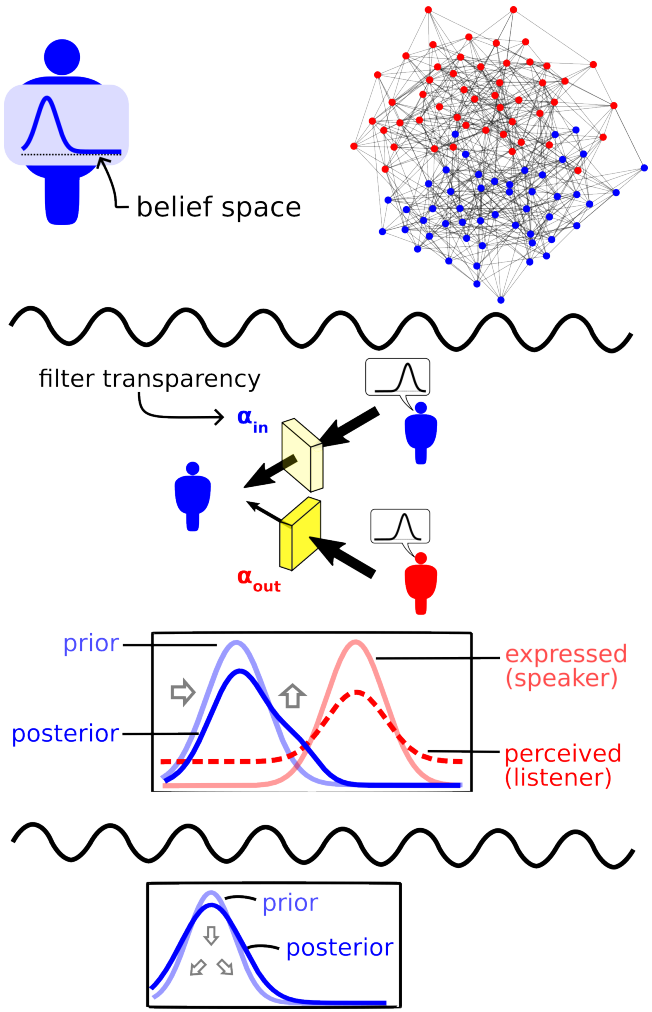
agent
- social identity (red/blue)
- opinion distribution

social network
- homophily
- randomness

opinion update
- social influence
  1. communication
  2. perception (in-group bias)
  3. update (Bayes)
- non-interaction

  diffusion

Model



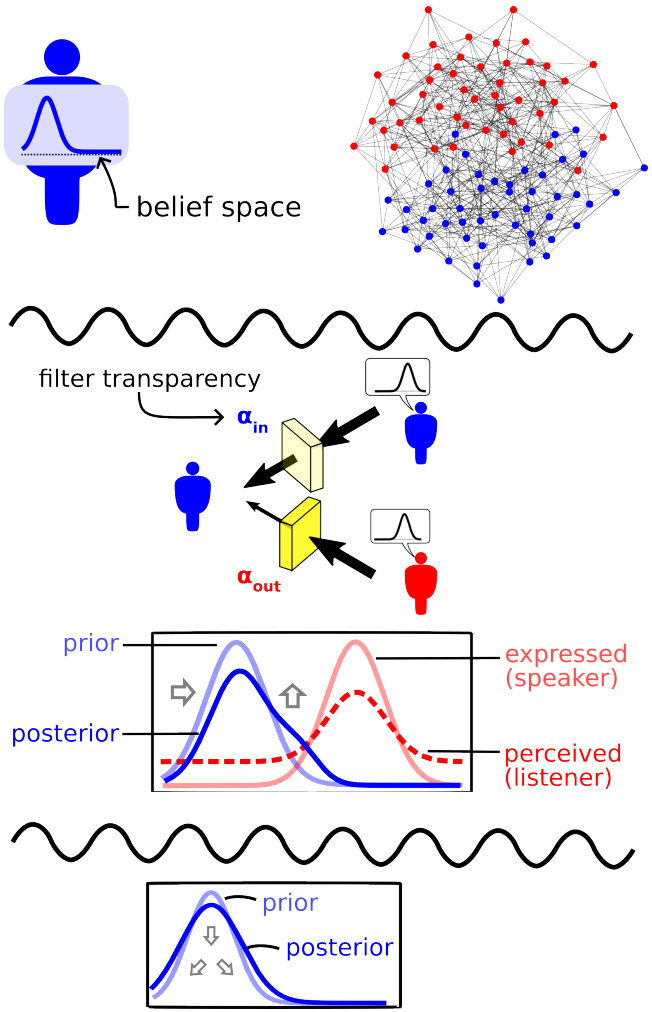
agent
- social identity (red/blue)
- opinion distribution

social network
- **homophily**
- randomness

opinion update
- social influence
  1. communication
  2. perception (**in-group bias**)
  3. update (Bayes)
- non-interaction

  diffusion

Model



agent
- social identity (red/blue)
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social network
- homophily
- randomness

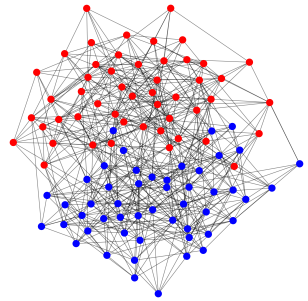
opinion update
- social influence
  1. communication
  2. perception (in-group bias)
  3. update (Bayes)
- non-interaction

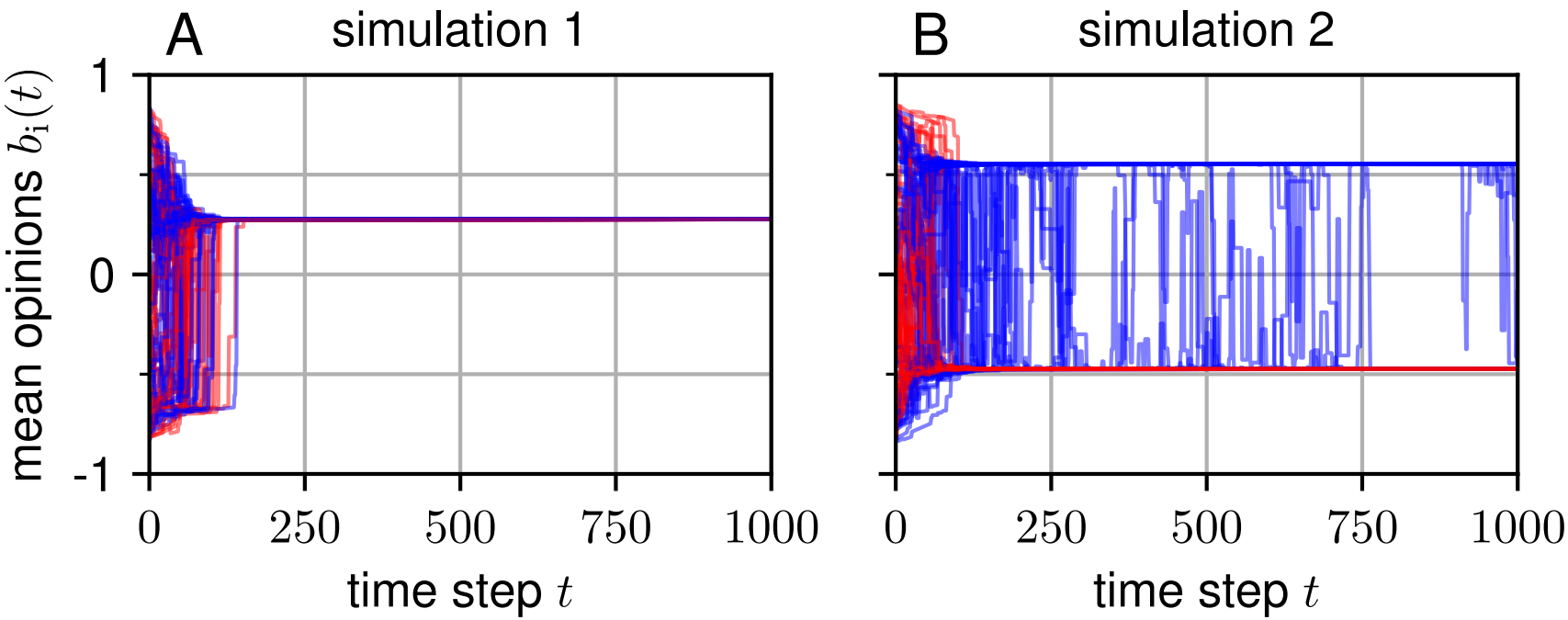
  diffusion

initialisation

Results I

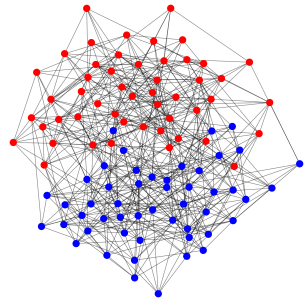
Society with bias ($\alpha_{\text{in}} = 0.8$, $\alpha_{\text{out}} = 0.3$) and homophilic, random network

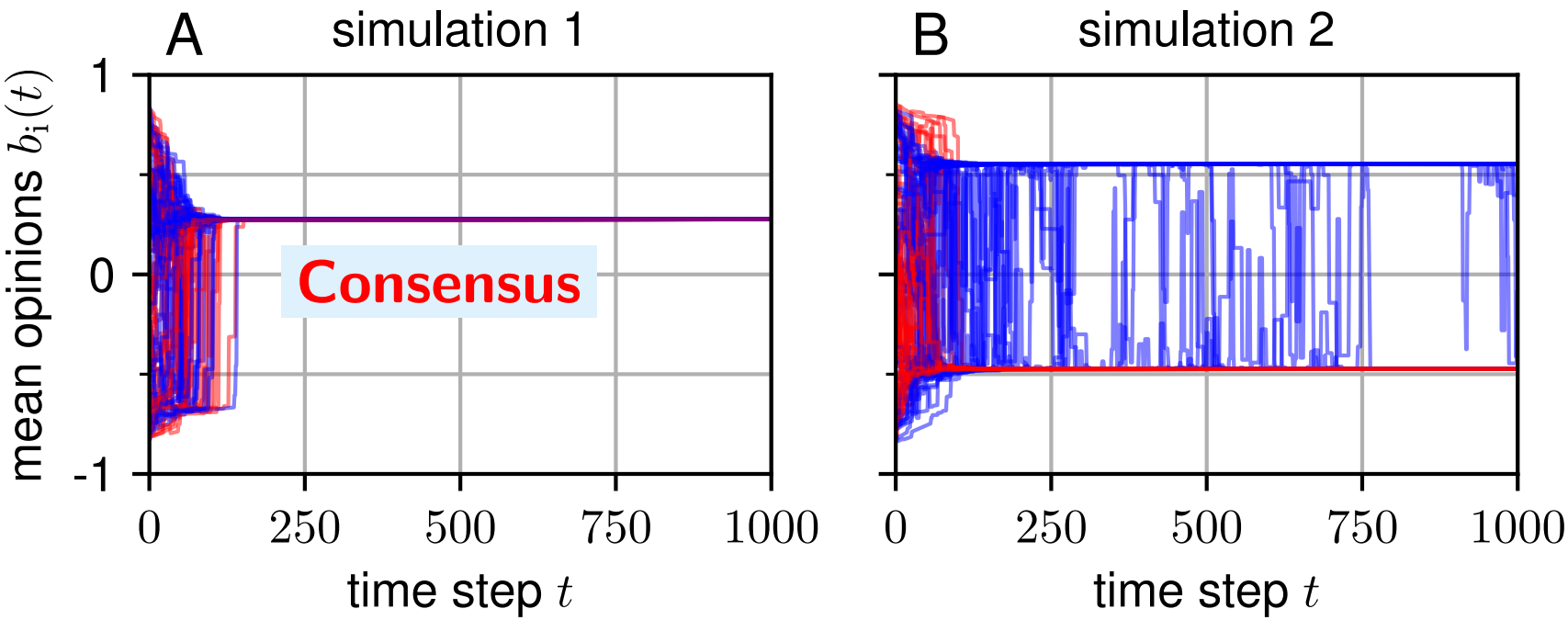




Results I

Society with bias ($\alpha_{\text{in}} = 0.8$, $\alpha_{\text{out}} = 0.3$) and homophilic, random network





Results I

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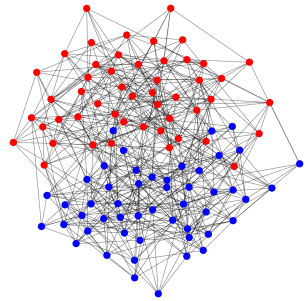
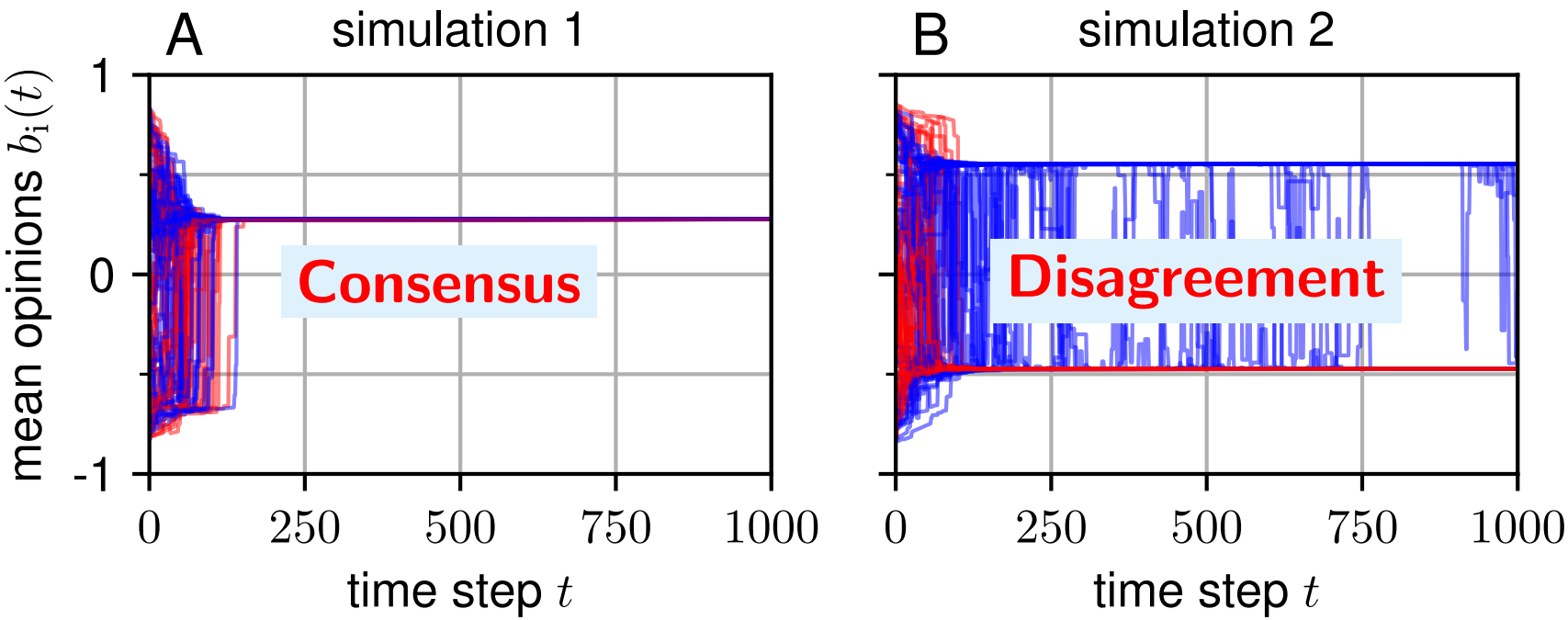
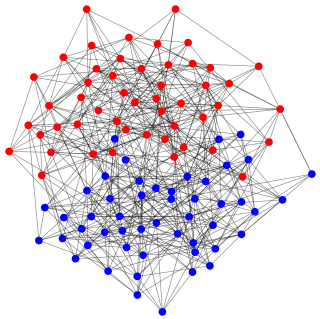


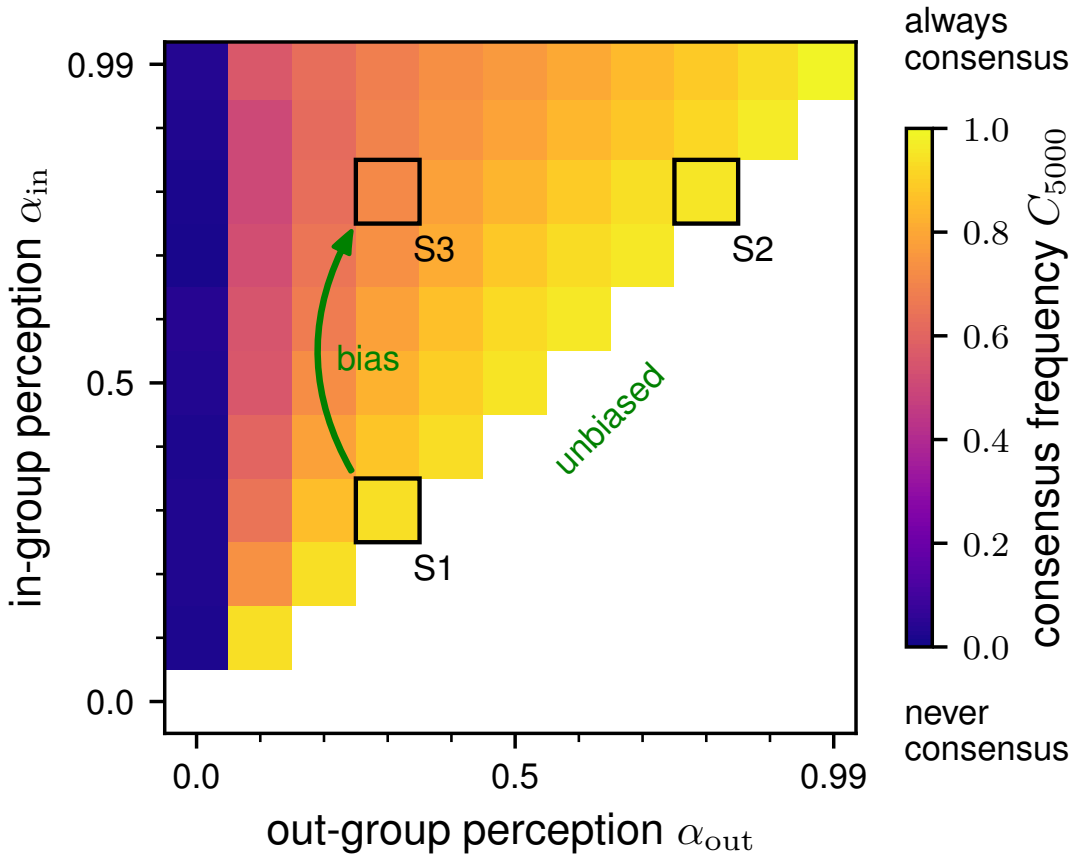


Results II

In societies with homophilic, random networks

-
-

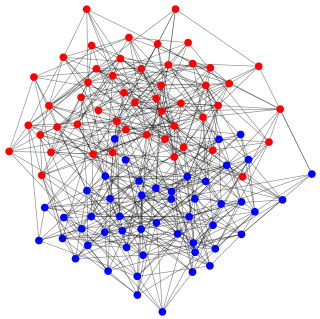


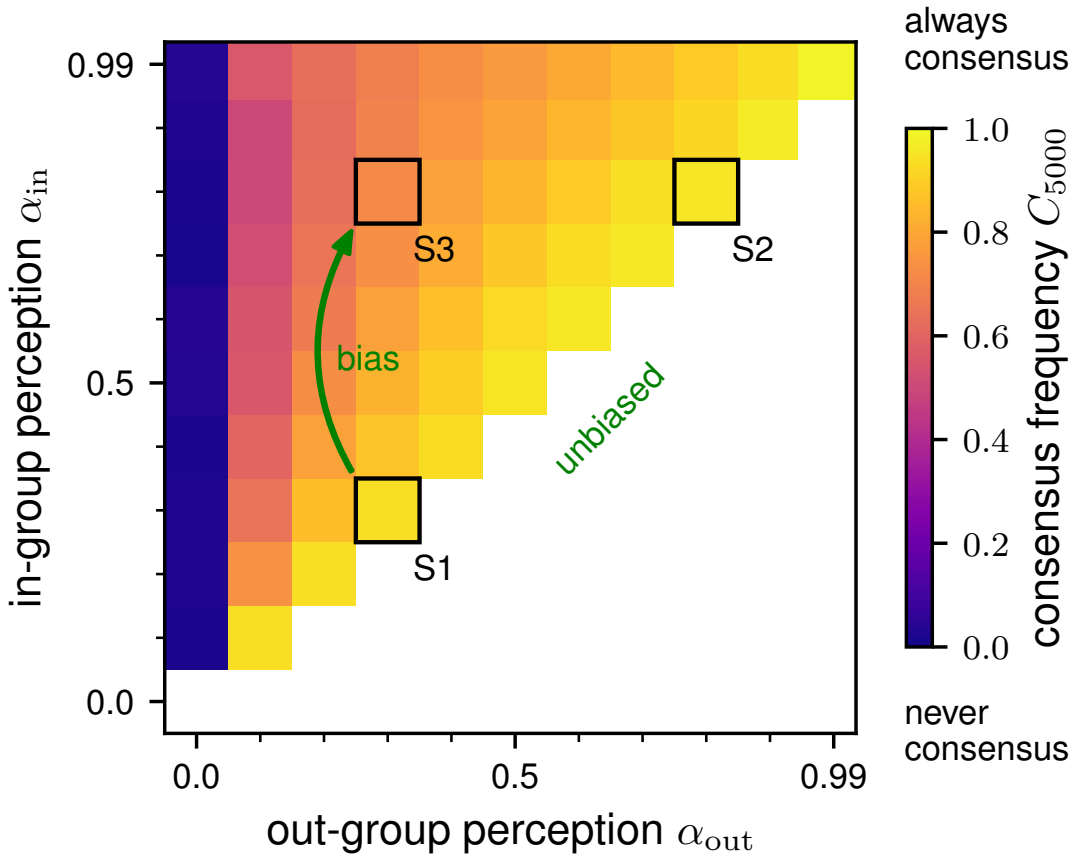


Results II

In societies with homophilic, random networks

- bias impedes consensus . . .
-

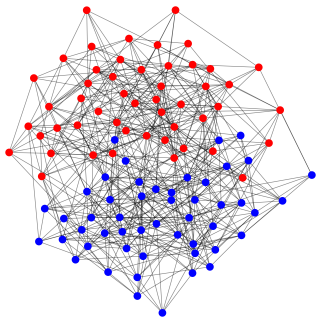


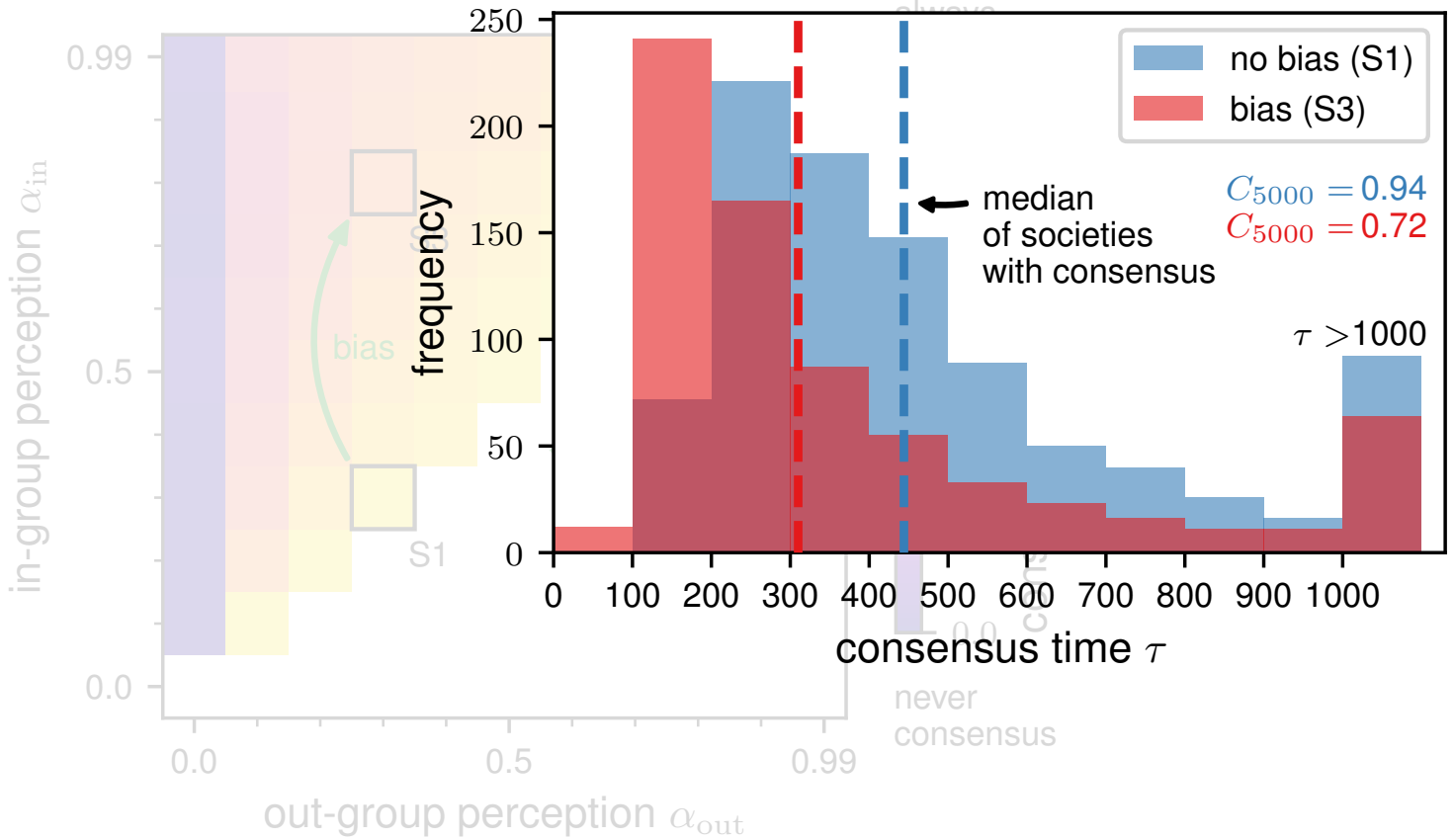


Results II

In societies with homophilic, random networks

- bias impedes consensus . . .
-

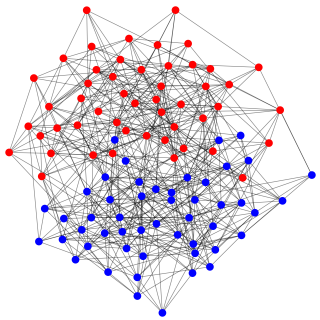


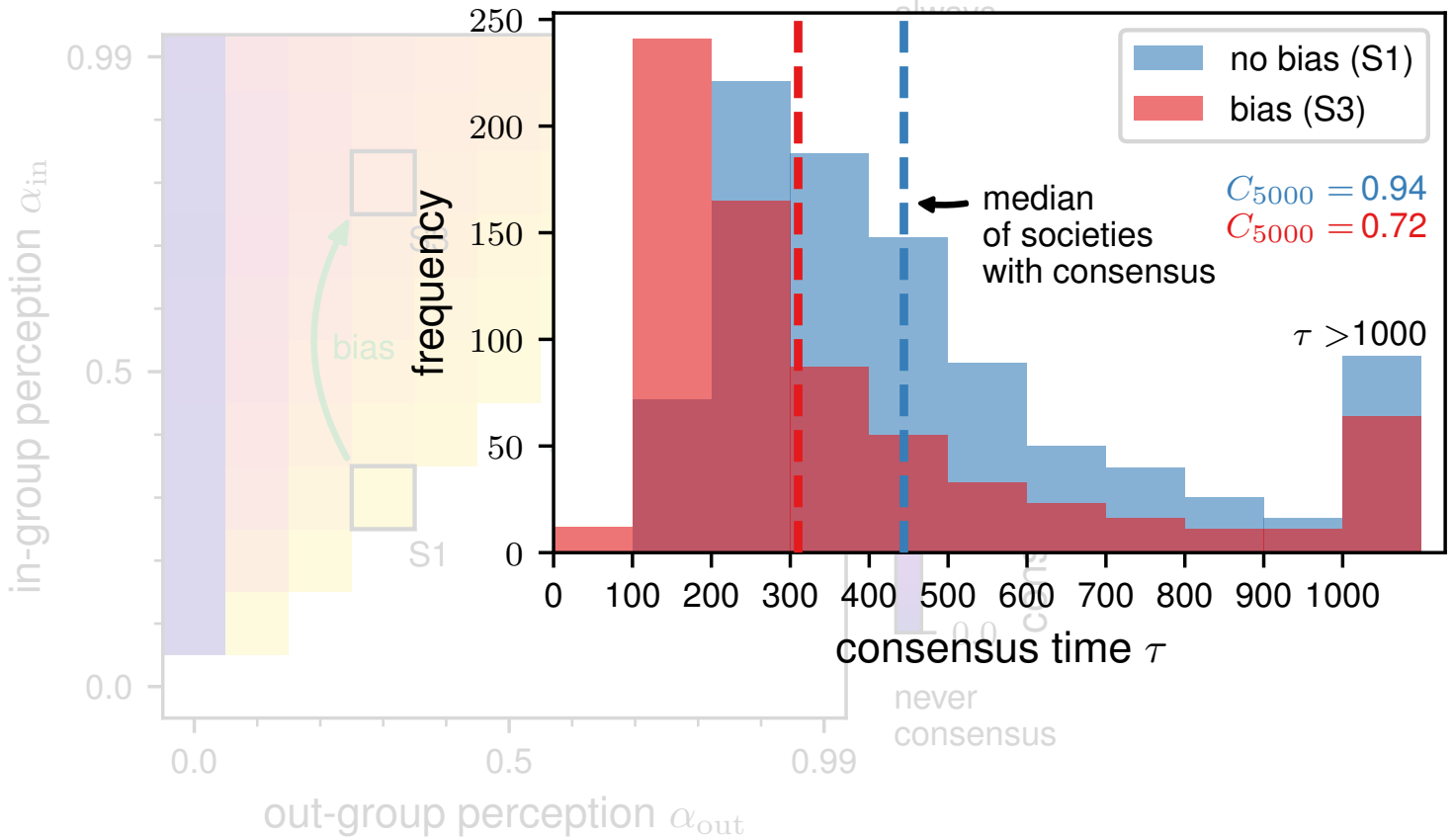


Results II

In societies with homophilic, random networks

- bias impedes consensus . . .
- . . . but sometimes accelerates consensus formation

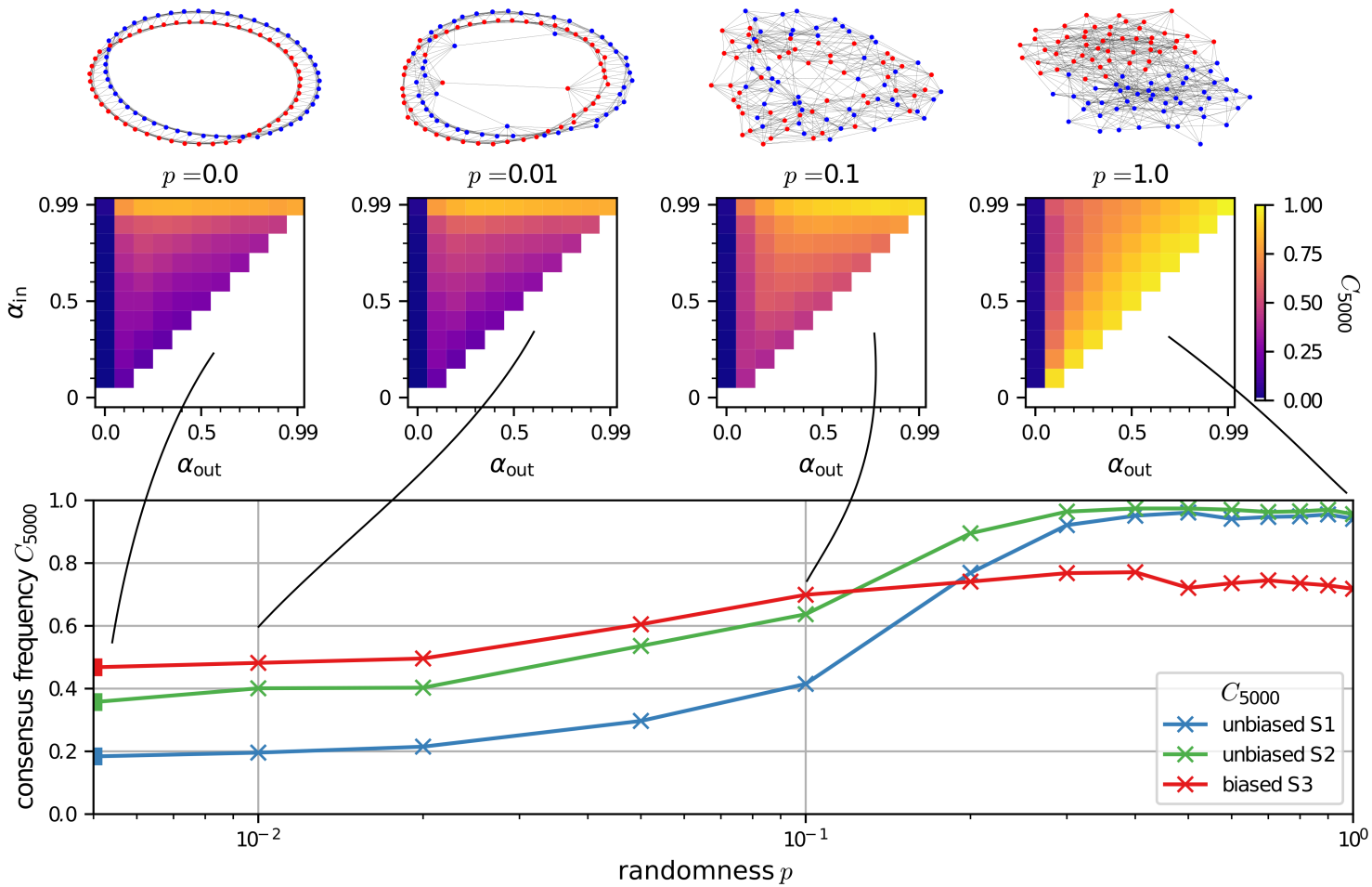




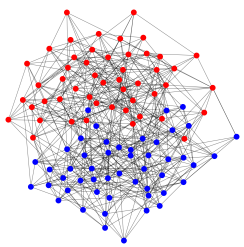
Results III

In societies with homophilic, (quite) regular networks

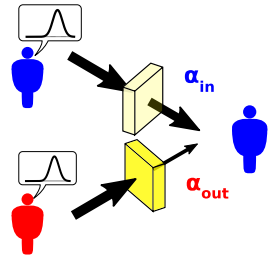
- bias facilitates consensus



Summing up

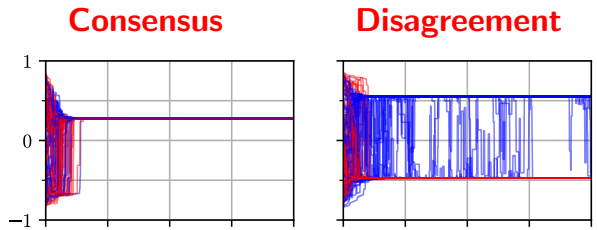


homophily

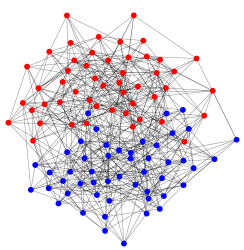


in-group favouritism bias

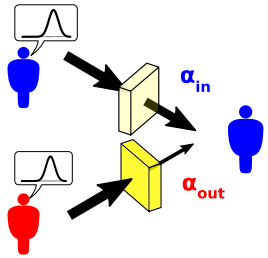
ABM



Summing up



homophily



in-group favouritism bias

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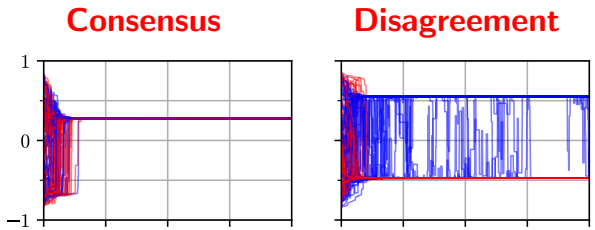


We young people [. . .] must hold the older generations accountable for the mess they have created.

– Greta Thunberg, Fridays for Future

When social identity is relevant in a public debate,

- in-group bias may impede OR facilitate consensus
  $\rightarrow$ depends on structural properties of the society.
- in-group bias may have different long- and short-term effects for consensus formation

References I

Related work:

- Martins (2009)
- Galesic et al. (2021)
- Sobkowicz (2018)

Brewer, M. B. (1979). "In-Group Bias in the Minimal Intergroup Situation: A Cognitive-Motivational Analysis". In: *Psychological Bulletin* 86.2, pp. 307–324. ISSN: 1939-1455(Electronic),0033-2909(Print). DOI: 10.1037/0033-2909.86.2.307.

Fu, F. et al. (Nov. 2012). "The Evolution of Homophily". In: *Scientific Reports* 2.1, p. 845. ISSN: 2045-2322. DOI: 10.1038/srep00845.

Galesic, M. et al. (2021). "Integrating Social and Cognitive Aspects of Belief Dynamics: Towards a Unifying Framework". In: *Journal of The Royal Society Interface* 18.176, p. 20200857. DOI: 10.1098/rsif.2020.0857.

Hewstone, M., M. Rubin, and H. Willis (2002). "Intergroup Bias". In: *Annual Review of Psychology* 53.1, pp. 575–604. DOI: 10.1146/annurev.psych.53.100901.135109.

Martins, A. C. R. (Feb. 2009). "Bayesian Updating Rules in Continuous Opinion Dynamics Models". In: *Journal of Statistical Mechanics: Theory and Experiment* 2009.02, P02017. ISSN: 1742-5468. DOI: 10.1088/1742-5468/2009/02/P02017.

McPherson, M., L. Smith-Lovin, and J. M. Cook (2001). "Birds of a Feather: Homophily in Social Networks". In: *Annual Review of Sociology* 27.1, pp. 415–444. DOI: 10.1146/annurev.soc.27.1.415.

Smaldino, P. E. and J. H. Jones (2021). "Coupled Dynamics of Behaviour and Disease Contagion among Antagonistic Groups". In: *Evolutionary Human Sciences* 3, e28. DOI: 10.1017/ehs.2021.22.

Sobkowicz, P. (2018). "Opinion Dynamics Model Based on Cognitive Biases of Complex Agents". In: *Journal of Artificial Societies and Social Simulation* 21.4, p. 8. ISSN: 1460-7425. DOI: 10.18564/jasss.3867.

Update rule

- Opinion of agent i: $x_i(b,t)$, where $b \in \mathcal{B}$ belief space $\mathcal{B}$.
- Perception of the opinion of a speaker j:

$$p_i\left(x_j(b,t)\right) = \alpha_i(j) \cdot x_j(b,t) + (1-\alpha_i(j)) \cdot \mathcal{U}(b) \ ,$$

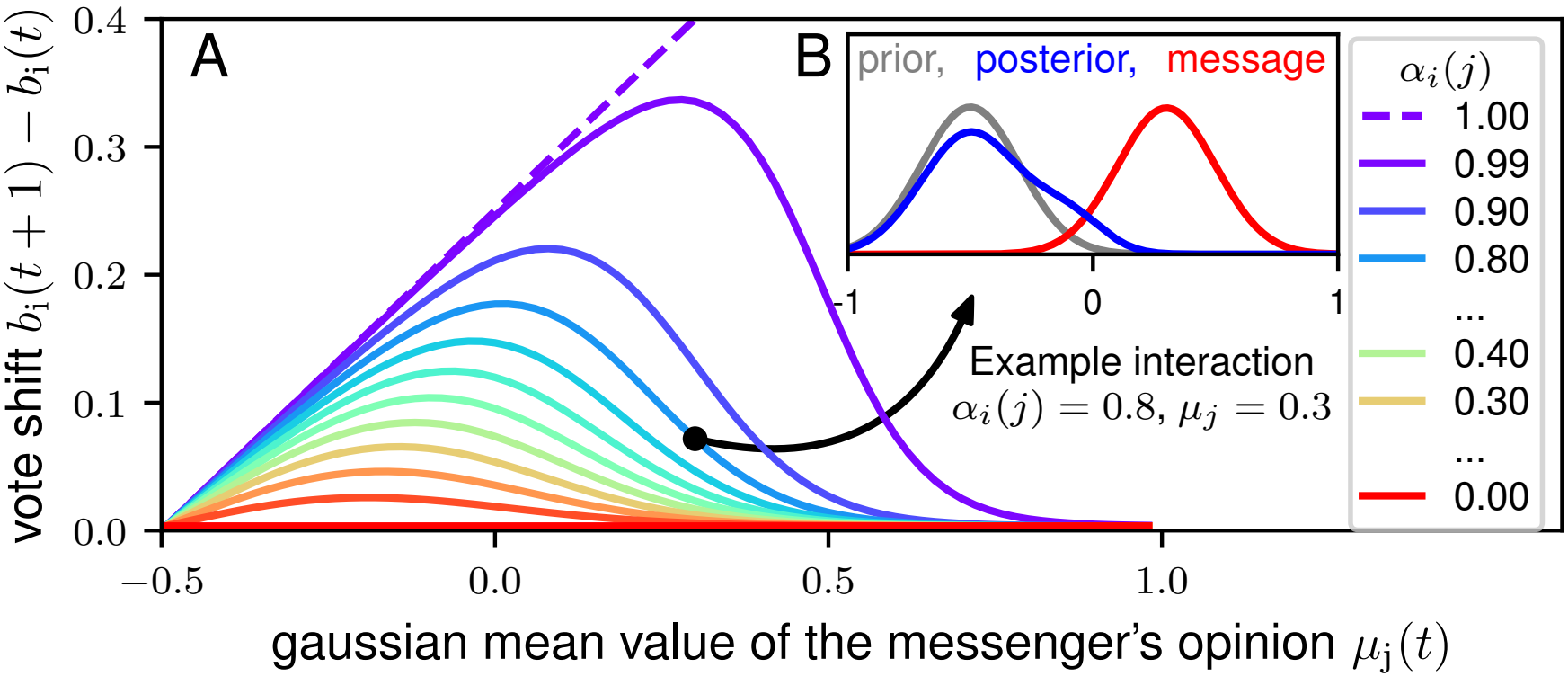
  where $\alpha_i(j)$ is α_{in} if i and speaker j are in-group members and α_{out} else. $\mathcal{U}$ is the uniform distribution.
- Update rule after interaction (before normalisation):

$$x_i(b,t+1) \quad \sim \quad x_i(b,t) \cdot p_i\left(x_j(b,t)\right)$$

- Update during non-interaction (diffusion):

$$\text{integrate for one time step}: \quad \frac{\mathrm{d}}{\mathrm{d}t} x_i(b,t) = \kappa \cdot \frac{\mathrm{d}^2}{\mathrm{d}b^2} x_i(b,t)$$

Impact of single interaction

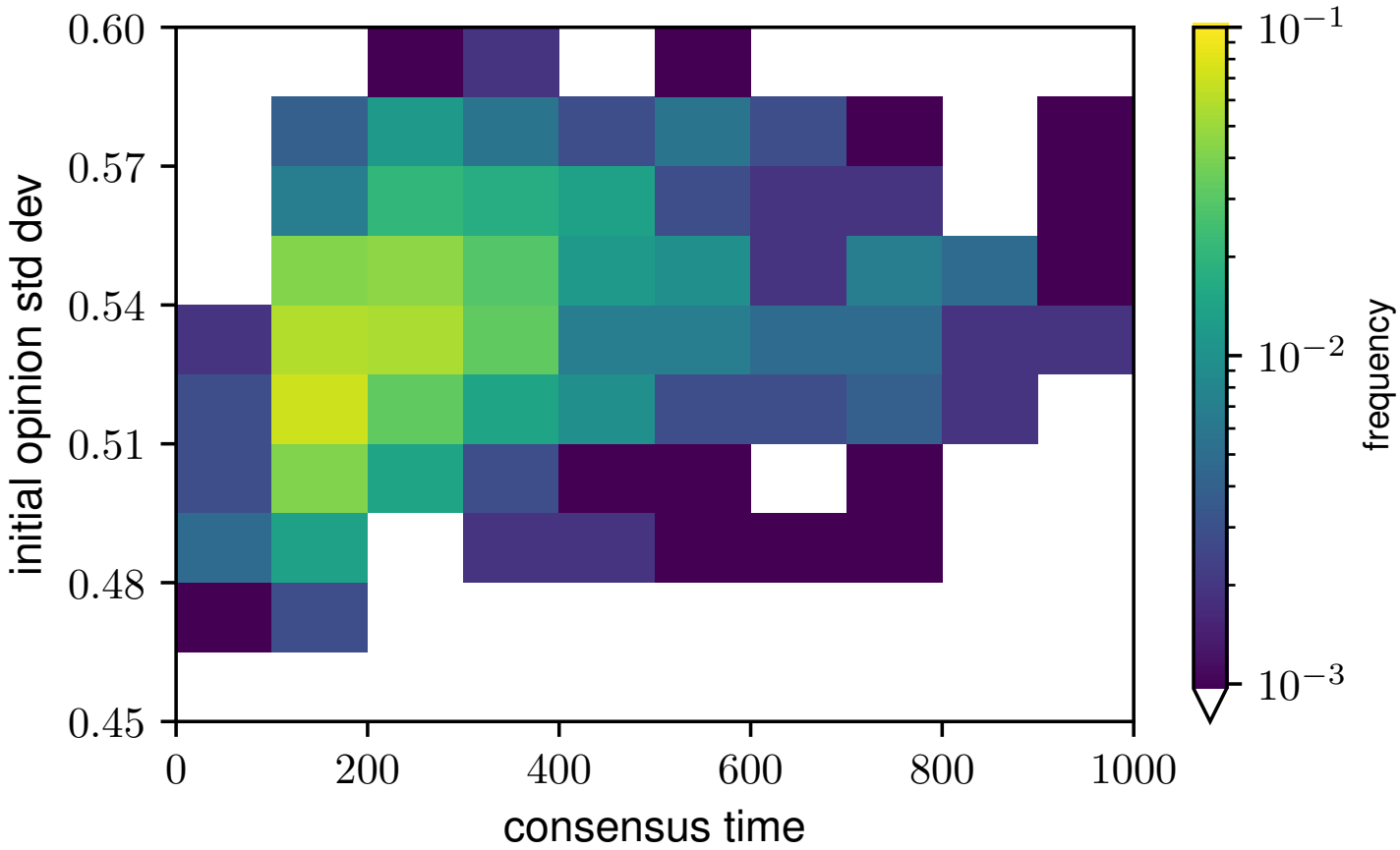


Parameters

Table: Model parameters and the default values.

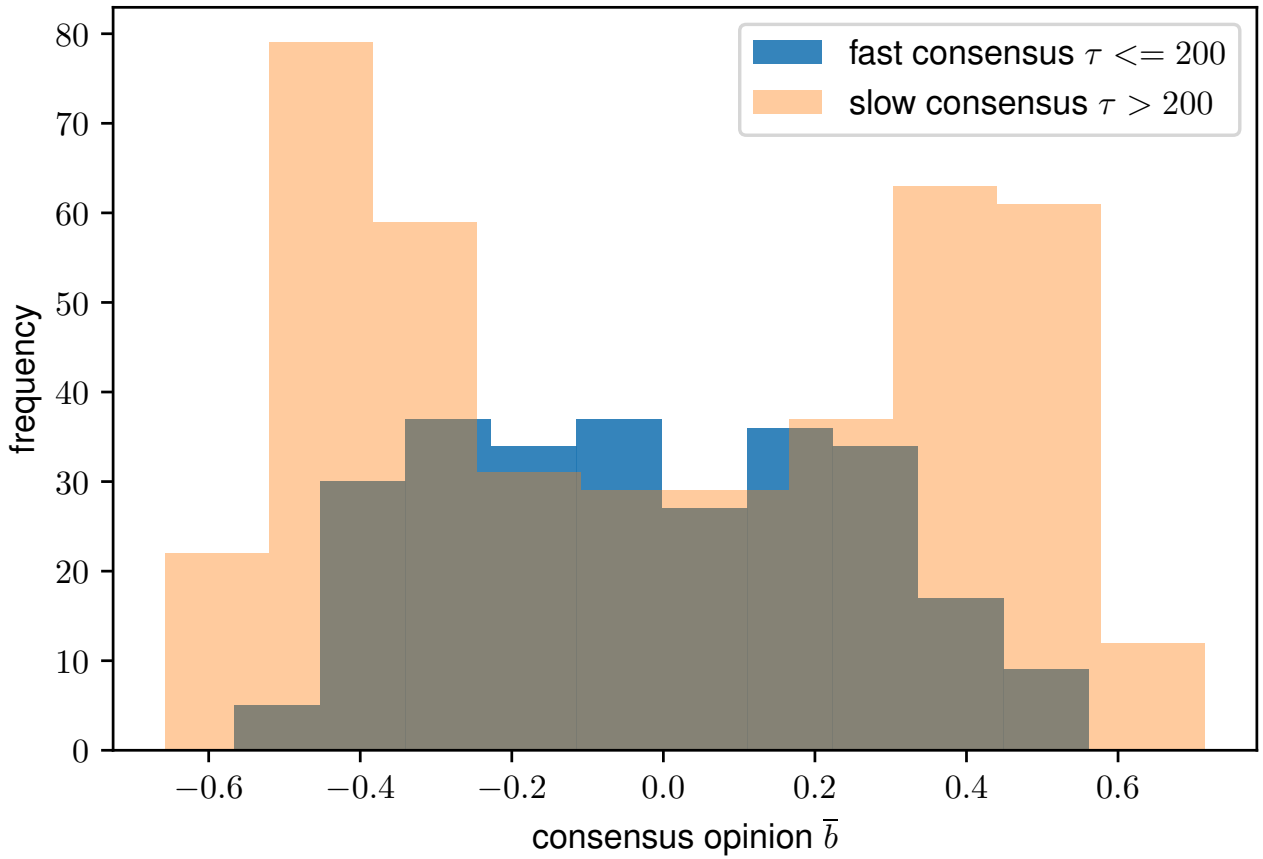
Parameter	Description	Value
N	nr. of agents	100
k	average node degree of an agent	10
S	nr. of social identities (here, evenly sized groups)	2
$\mathcal{B}$	belief space	$\{-0.995, -0.985, \ldots$ $\ldots 0.995\}$
f	frequency of an agent to interact (listen) in a time step	0.2
κ	diffusion constant of the opinion distribution, when the agent does not interact	0.0002
σ_0	variance of initial gaussian opinion distributions for all agents	0.2
h	level of homophily in the network	0 (no homophily), 0.6 (homophily)
α_{in}	perceived informativeness of in-group member	$\in [0, 1[$
α_{out}	perceived informativeness of out-group agent	$\in [0, 1[$
σ_{cons}	threshold of the standard deviation of agent mean opinions that defines consensus at time τ ($\sigma = \frac{1}{N} \cdot \left(\sum_{i \in \{1 \ldots N\}} \left(b_i(\tau) - \overline{b}(\tau)\right)^2\right)^{0.5} < \sigma_{\text{cons}}$)	0.01

Low initial disagreement favours faster consensus



Society with fixed bias ($\alpha_{\text{in}} = 0.8$, $\alpha_{\text{out}} = 0.3$) and fixed homophily ($h = 0.6$)

Fast consensus is mostly moderate

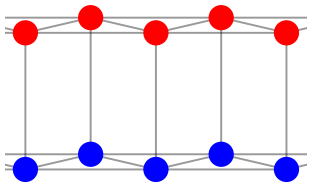


Society with fixed bias ($\alpha_{\text{in}} = 0.8$, $\alpha_{\text{out}} = 0.3$) and fixed homophily ($h = 0.6$)

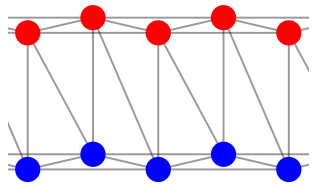
Network construction

network with $k_{\text{in}} = 4$, $p = 0$

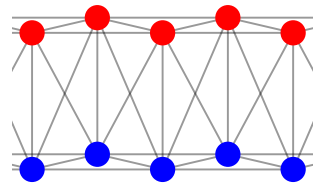
$k_{\text{out}} = 1$



$k_{\text{out}} = 2$



$k_{\text{out}} = 3$



Sensitivity analysis

Random networks $p = 1$

name	C_{5000}(S1)	C_{5000}(S2)	C_{5000}(S3)	$\tilde{\tau}$(S1)	$\tilde{\tau}$(S2)	$\tilde{\tau}$(S3)
default	0.94	0.96	0.72	394.0	210.5	260.0
$f = 0.1$	0.97	0.99	0.83	605.5	317.0	382.5
$f = 0.4$	0.94	0.96	0.63	205.5	119.0	145.0
$n = 1000$	0.98	1.00	0.89	852.0	418.0	543.0
$\kappa = 0.0$	0.76	0.75	0.41	348.0	303.0	nan
$\kappa = 0.0001$	0.93	0.95	0.65	446.5	251.0	300.0
$\kappa = 0.0004$	0.97	0.98	0.79	316.0	161.0	196.0
$\kappa = 0.002$	1.00	1.00	1.00	155.0	95.0	115.0
$h = 0.2$	0.98	1.00	0.85	464.0	249.5	318.0

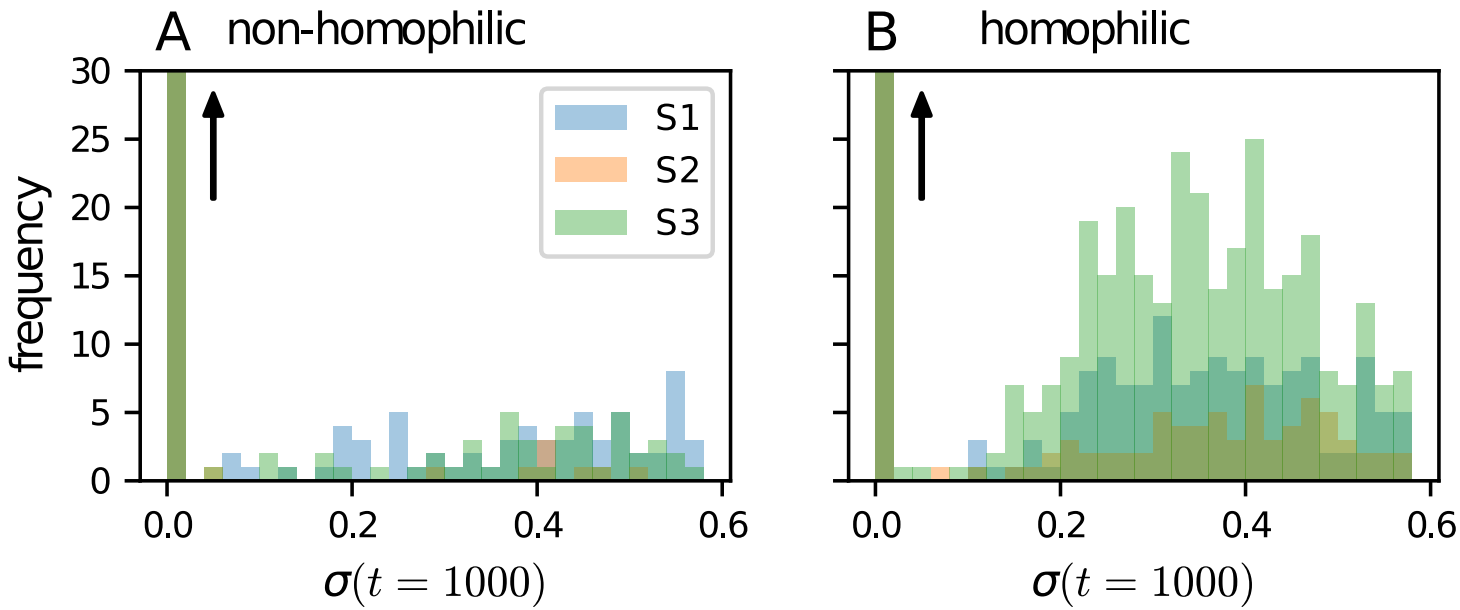
C_{5000} = consensus frequency at $T = 5000$,
$\tilde{\tau}$ = median consensus time (IF consensus before $T = 5000$).

Regular networks $p = 0.0$

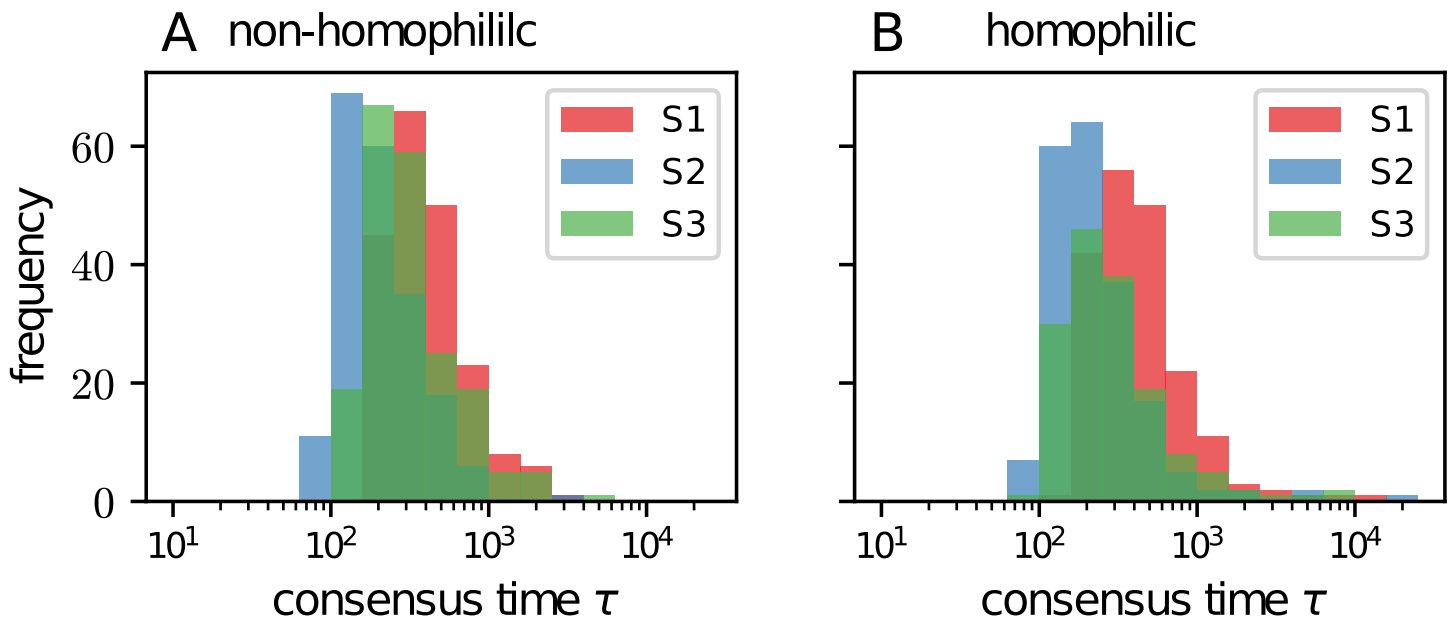
name	C_{5000}(S1)	C_{5000}(S2)	C_{5000}(S3)
default	0.18	0.36	0.47
$f = 0.1$	0.32	0.58	0.63
$f = 0.4$	0.09	0.20	0.36
$n = 1000$	0.00	0.00	0.00
$\kappa = 0.0$	0.00	0.00	0.00
$\kappa = 0.0001$	0.08	0.20	0.30
$\kappa = 0.0004$	0.35	0.63	0.70
$\kappa = 0.002$	1.00	1.00	1.00
$h = 1.5$	0.08	0.23	0.32

C_{5000} = consensus frequency at $T = 5000$,
$\tilde{\tau}$ = median consensus time (IF consensus before $T = 5000$).

Disagreement is qualitatively distinct from consensus

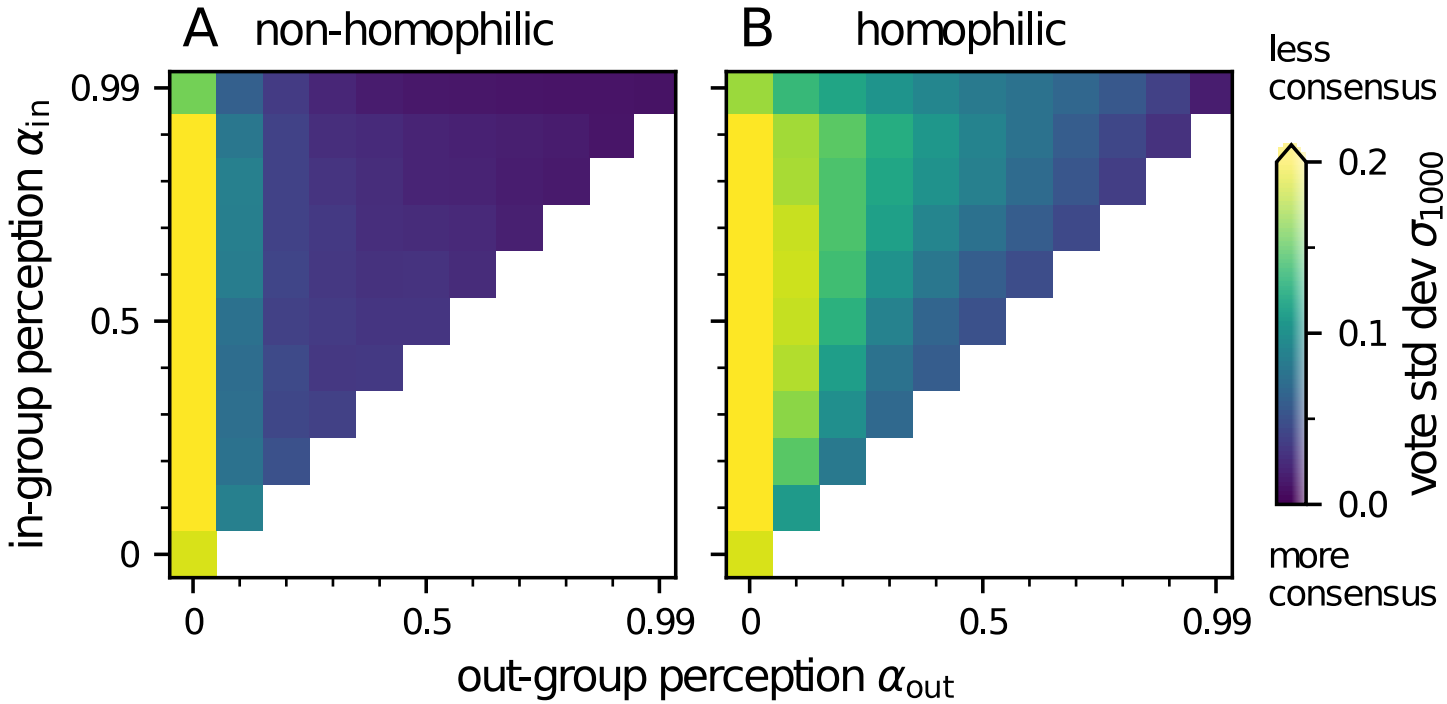


Time horizon



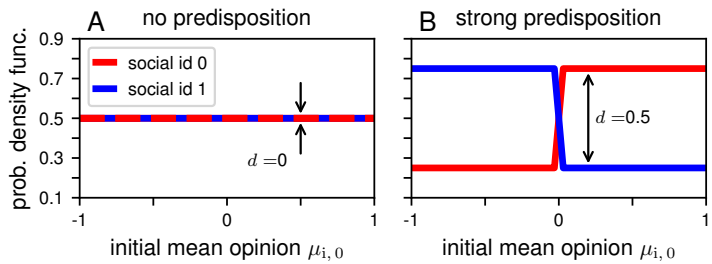
Alternative measure of disagreement

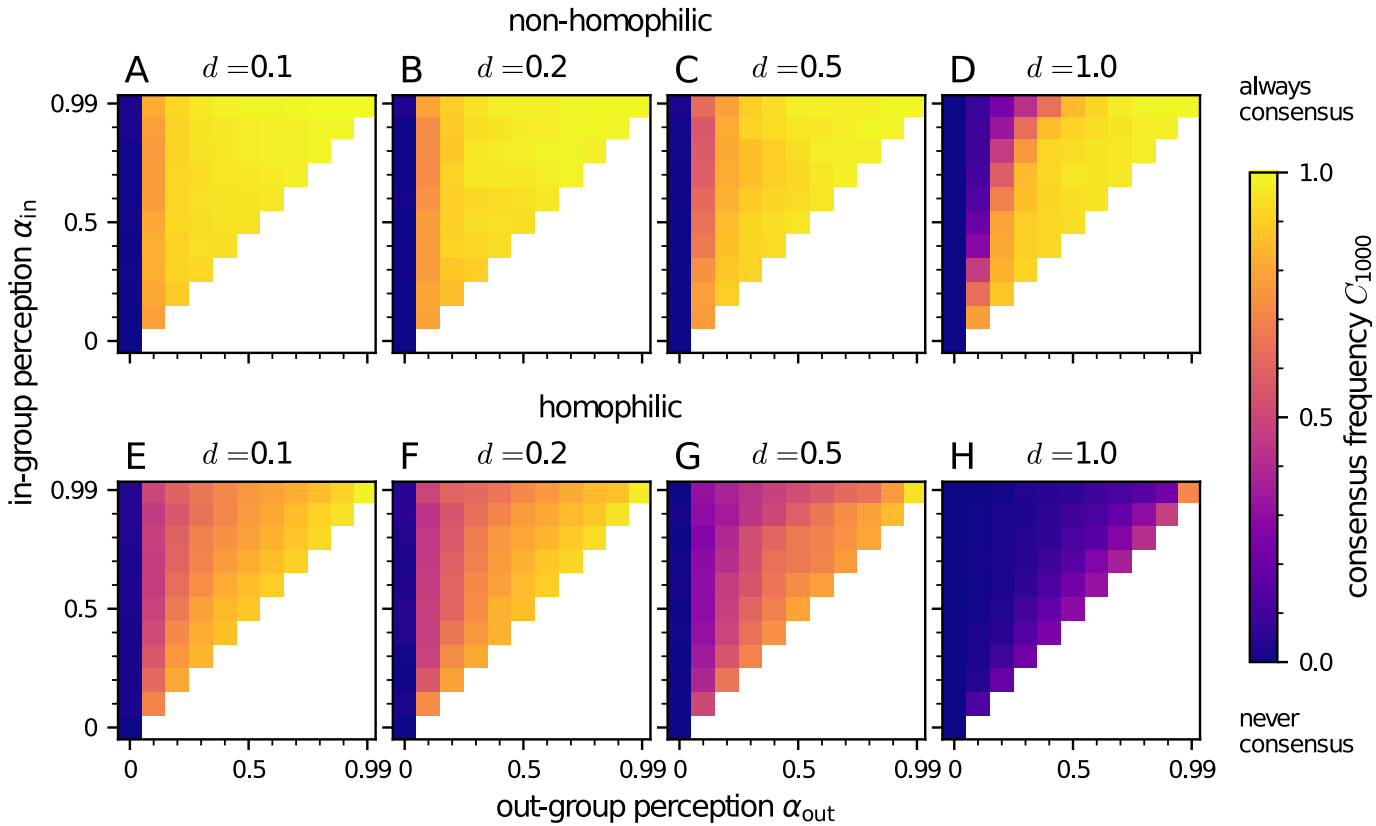
Disagreement = standard deviation of all agent mean opinions



Predisposition

Initial opinion distribution:





No homophily