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Opinion Dynamics and Cultural Conflict
in European Spaces

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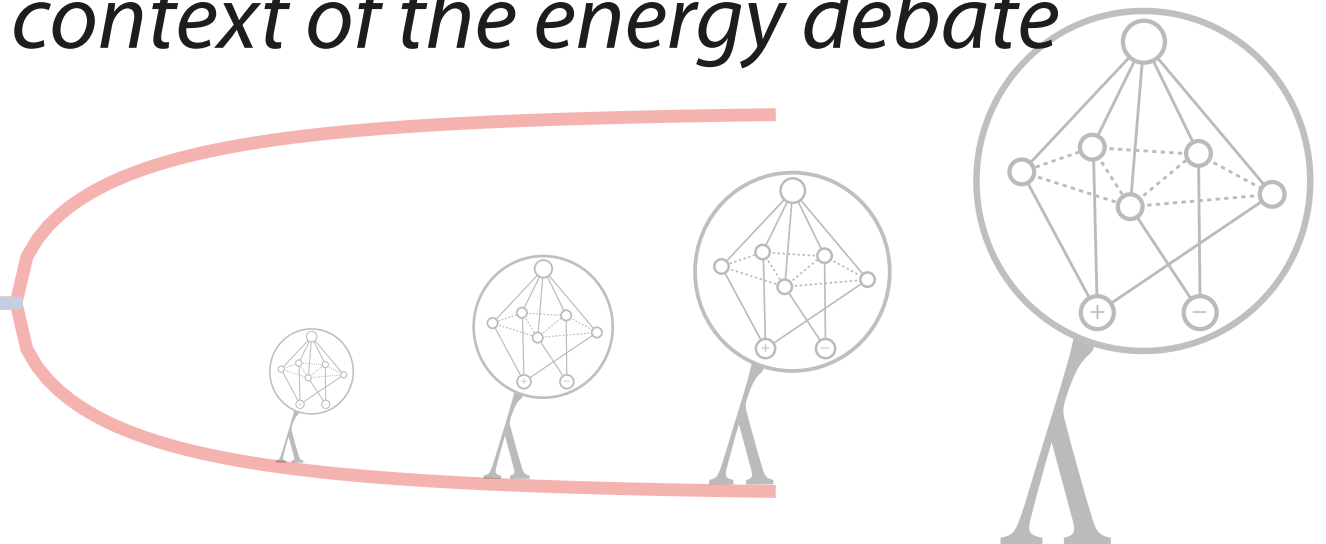
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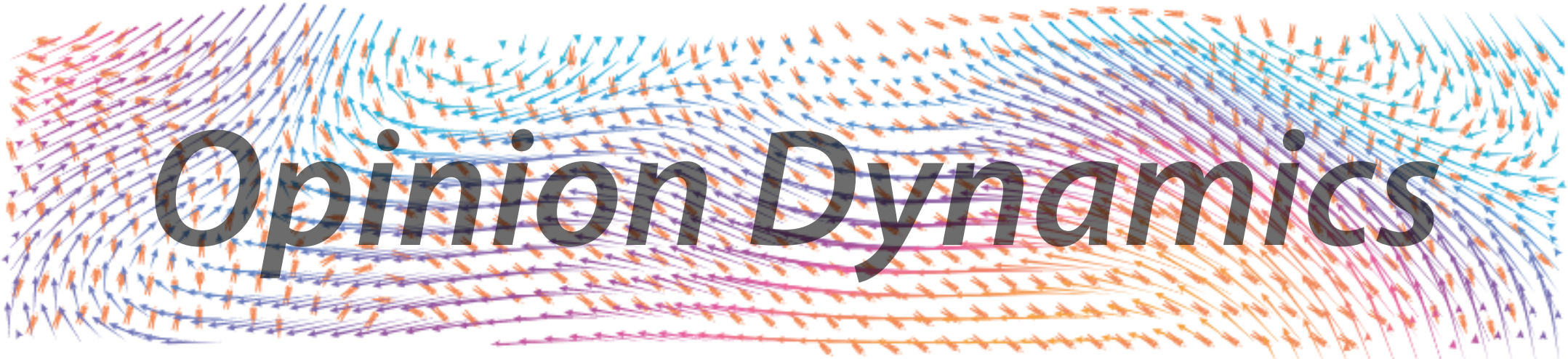
Biased processing and opinion polarisation *experimental refinement of argument communication* *theory in the context of the energy debate*

Sven Banisch (MPI Leipzig)

and

Hawal Shamon (FZ Jülich)



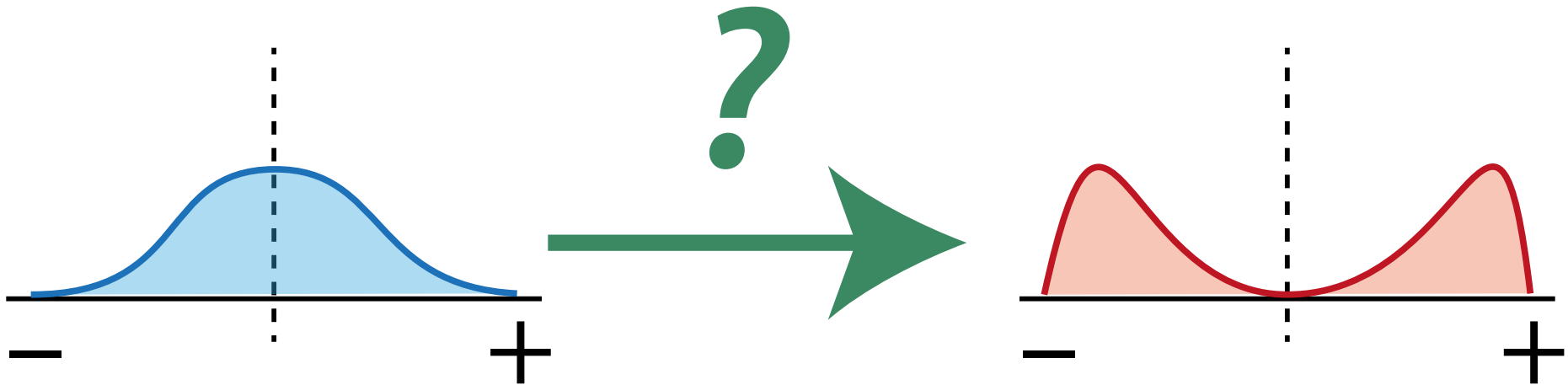


Opinion Dynamics

Opinion dynamics is a field that develops theoretical models of collective opinion processes to understand the mechanisms behind the emergence of consensus, polarisation and conflict.

The Puzzle of Polarisation

- ▶ *How does a population with moderate initial opinions diverge into groups of agents that strongly support opposing views?*



Opinion polarization by learning from social feedback

S. Banisch^a and E. Olbrich^a

^aMax Planck Institute for Mathematics in the Sciences, Leipzig, Germany

ABSTRACT

We explore a new mechanism to explain polarization phenomena in opinion dynamics in which agents evaluate alternative views on the basis of the social feedback obtained on expressing them. High support of the favored opinion in the social environment is treated as a positive feedback which reinforces the value associated to this opinion. In connected networks of sufficiently high modularity, different groups of agents can form strong convictions of competing opinions. Linking the social feedback process to standard equilibrium concepts we analytically characterize sufficient conditions for the stability of bi-polarization. While previous models have emphasized the polarization effects of deliberative argument-based communication, our model highlights an affective experience-based route to polarization, without assumptions about negative influence or bounded confidence.

ARTICLE HISTORY

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KEYWORDS

Opinion Formation;
Polarization; Reinforcement
Learning; Social Feedback;
Computational Sociology

An Argument Communication Model of Polarization and Ideological Alignment

Sven Banisch¹ and Eckehard Olbrich¹

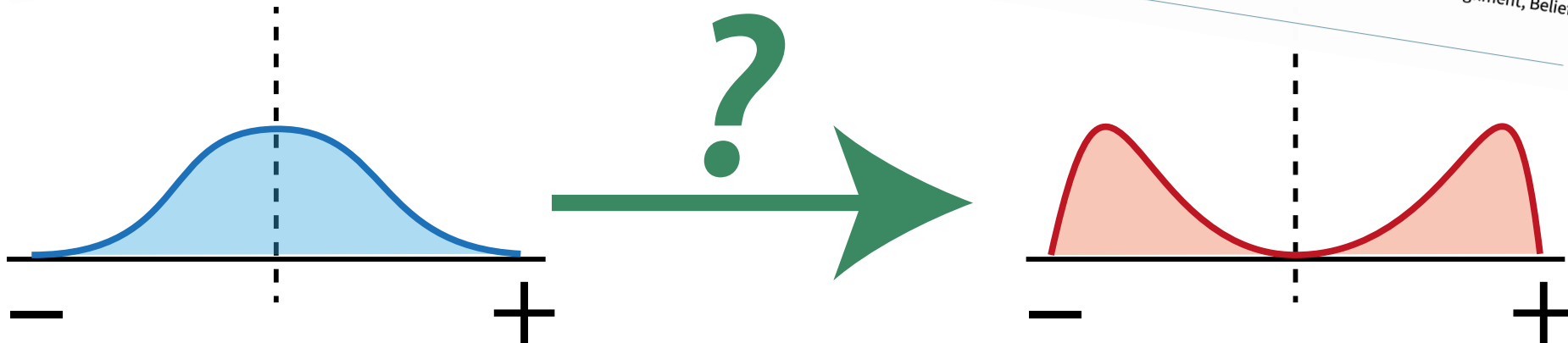
¹Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany
Correspondence should be addressed to sven.banisch@UniVerseCity.de

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Abstract: A multi-level model of opinion formation is presented which takes into account that attitudes on different issues are usually not independent. In the model, agents exchange beliefs regarding a series of facts. A cognitive structure of evaluative associations links different (partially overlapping) sets of facts to different political issues and determines an agents' attitudinal positions in a way borrowed from expectancy value theory. If agents preferentially interact with other agents that hold similar attitudes on one or several issues, this leads to biased argument pools and increasing polarization in the sense that groups of agents selectively believe in distinct subsets of facts. Besides the emergence of a bi-modal distribution of opinions on single issues that most previous opinion polarization models address, our model also accounts for the alignment of attitudes across several issues along ideological dimensions.

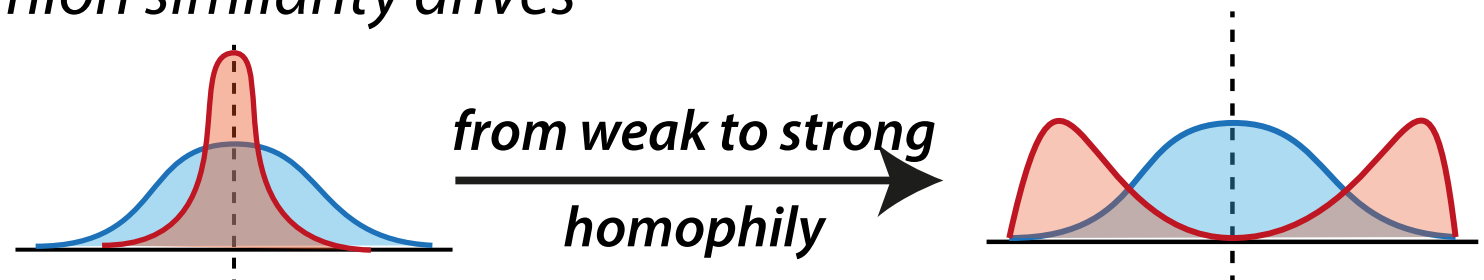
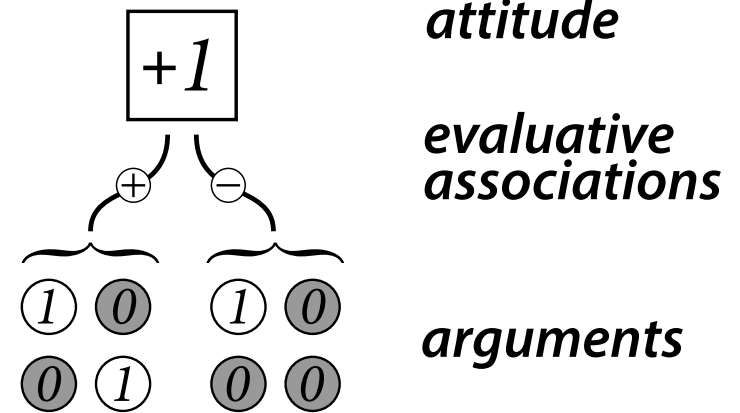
Keywords: Argument Communication Theory, Opinion Dynamics, Polarization, Ideological Alignment, Belief Systems, Cognitive-Evaluative Maps, Attitudes



Argument Communication Theory

► Models of collective deliberation by social exchange of pro and con arguments regarding a certain issue (attitude object)

- Agents communicate arguments and update them in memory
- Attitudes/opinions as number of pro versus con arguments are updated after peer exposure to an argument
- **Homophily**: Opinion similarity drives interaction



Argument Communication Theory

- ▶ *ACT provides a promising setting. Research within the framework is advancing towards **applied opinion dynamics!***
- ▶ *Applications:*
 - *What is the role of cultural diversity and demographic faultlines in group decision and team processes? (Michael Mäs and others)*
 - *How to opinions across multiple related topics align along ideological lines? (our JASSS paper)*
- ▶ *Limitations:*
 - *Lack of a realistic model of argument processing.*
 - ***Selective information processing is a robust cognitive mechanism which must be included to arrive at better models of group deliberation!***

Argument Communication Theory

Online Demos

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Research – Curriculum – Papers – Demos

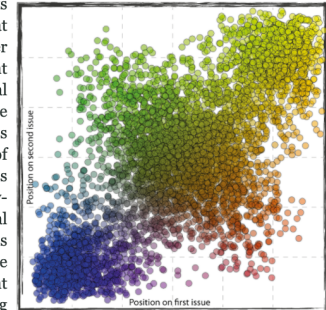
Interactive Exploration of Opinion Models

What is the purpose of models? Opinion dynamics is an exciting field which has given rise to the development of a considerable number of models by which agents (ex)change opinions in interaction. The number of different proposals is in fact hard to oversee and, that said, the question of how these models should be used is particularly relevant for the field. One can, on the one hand, develop models that contain as much as possible the different approaches in one encompassing tool in order to facilitate model comparison. On the other hand, models are mostly developed and articulated as addressing how particular assumptions on inter-individual influence processes play out at the macroscopic scales of groups or societies. In order to understand this connection from mechanisms to macroscopic outcomes, it is often more convenient to concentrate on a particular mechanism and provide (interactive) control on the main parameters of opinion

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[/index.php?site=demos](http://www.universecity.de/index.php?site=demos)

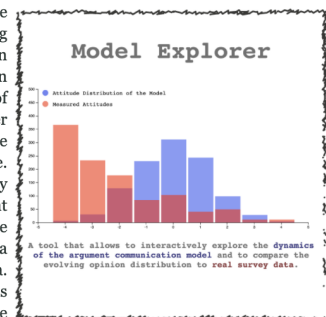


From Attitude Structure to Political Spaces. Arguments in a discussion often address different aspects of the issue at stake. But, some of these aspects are also relevant for other issues, which induces correlations between opinions on different issues. Those correlations could originate from factual interdependencies between the considered processes in the world, but they give also rise to ideologies and group identities which can induce further dependencies on their part. Many of the classical models of opinion dynamics studied in sociophysics are not able to address these issues. Drawing upon expectancy-value models in attitude research and the theory of conceptual spaces we developed a multi-level representation of opinions which allows to study of opinion dynamics on multiple interrelated issues. The model is based on three different ingredients: (1) interacting agents align their views regarding the significance of different argumentative domains; (2) different (partially overlapping) sets of these domains are associated with different political issues and an agent's attitude is a function of the importance assigned to the argument domains and their evaluative relevance for the issues; and (3) agents preferentially interact with other agents that hold similar attitudes. Under some conditions these combined processes give rise to polarization and reinforce correlations between attitudes towards multiple political issues. (See [arxiv](#))



1. **Argument Communication Model with 1000 agents** ([run it](#)) (This version accompanies a paper that will appear in *JASSS*. See the [brief guide to the model](#) for how to use the demo.)
2. **Argument Communication Model with 5000 agents** ([run it](#) - time is ok)

Argument Communication with Biased Processing. We look at data from an experiment on biased argument processing from the perspective of the cognitive architecture employed in argument communication models of collective opinion formation. The empirical experiment realized in the context of attitudes toward energy reveals a strong tendency to consider arguments aligned with the current attitude more persuasive and to downgrade those speaking against the current attitude. This is integrated into a theoretical model of cognitive agents by assuming that the coherence of an argument with the current attitude controls the probability to adopt it and to change the attitude accordingly. The strength of this bias is included as a free parameter which can be estimated from experimental data. We find a clear signature of moderate biased processing. This tool allows to explore simulations with interacting cognitive agents that exchange arguments. It relates the opinion distributions emerging in the model to surveyed attitude distributions (coal, gas, wind, photovoltaic, biomass). A good match is found transitory periods of the model and with unbiased external information.



1. **Argument Communication Model with 1078 agents** ([run it](#))

Overview

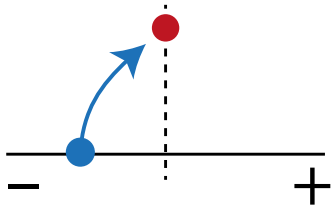
- ▶ *Experiment*
- ▶ *Cognitive model*
- ▶ *Expected attitude changes (under »computerized« experiment)*
- ▶ *How good is the model given the data?*
- ▶ *Collective deliberation with biased processing*
- ▶ *Impact of homophily and selective exposure*

The Psychological Puzzle

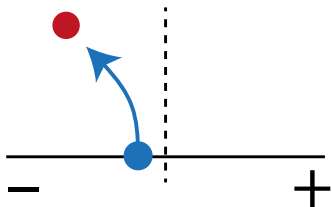
individuals

(attitude change)

(argument persuasion experiments)



attitude moderation
versus
attitude polarisation



- *Humans process information in a biased way: **attitude-congruent arguments are favoured over incongruent ones!***
- *A lot of experimental research has been invested on the question **whether biased processing implies attitude polarisation when subjects are exposed to conflicting arguments.***
- *Attitude polarisation refers to an intra-individual effect of becoming more extreme after exposure*
- ***Empirical evidence is mixed!***

Experiment

- ▶ Hawal Shamon carefully designed an experiment in which subjects received a **balanced set of pro and con arguments regarding six technologies for energy production.**



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Volume 55, September 2019, Pages 106-121



Original research article

Changing attitudes and conflicting arguments: Reviewing stakeholder communication on electricity technologies in Germany

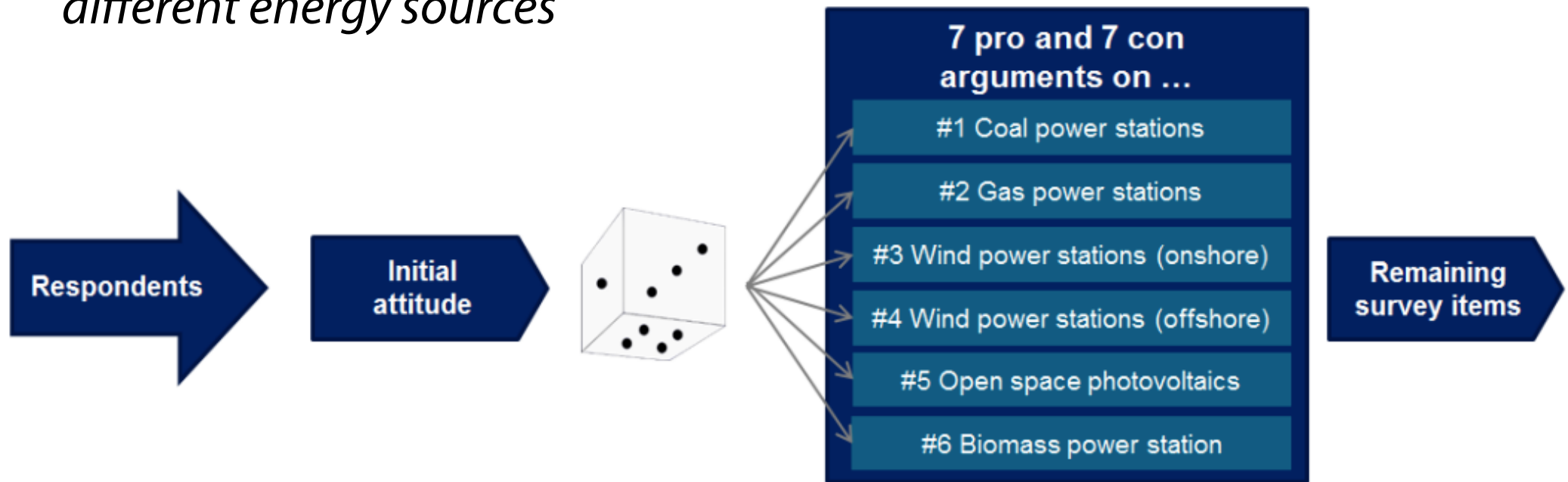
Hawal Shamon  , Diana Schumann, Wolfgang Fischer, Stefan Vögele, Heidi U. Heinrichs, Wilhelm Kuckshinrichs

Institute of Energy and Climate Research – Systems Analysis and Technology Evaluation (IEK-STE), Forschungszentrum Jülich, Wilhelm-Johnen-Straße, Jülich 52425, Germany

Experiment

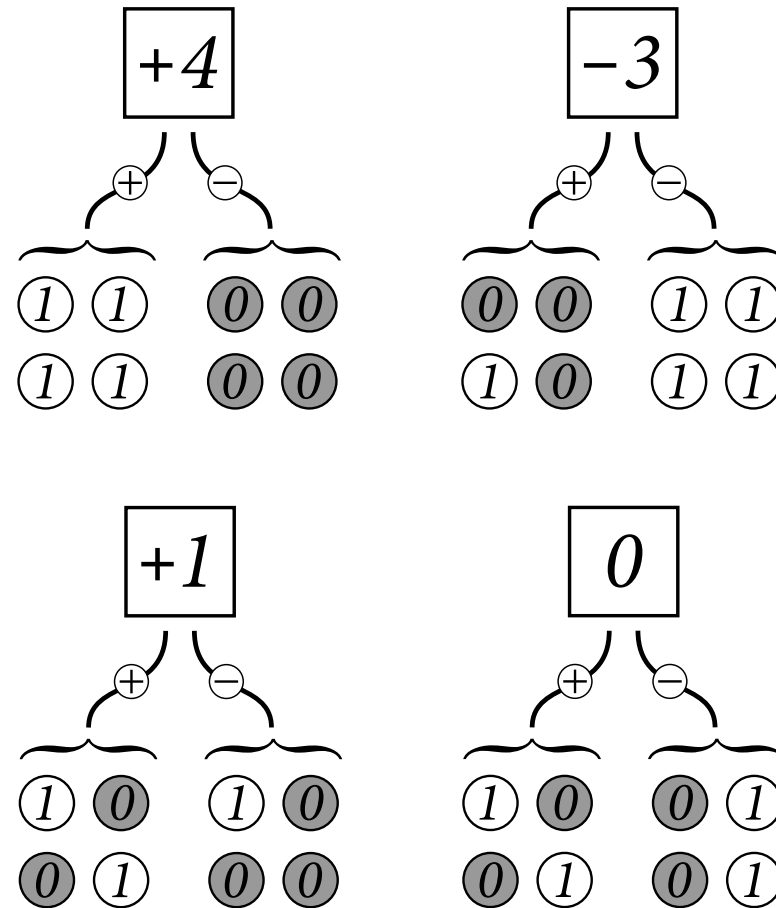
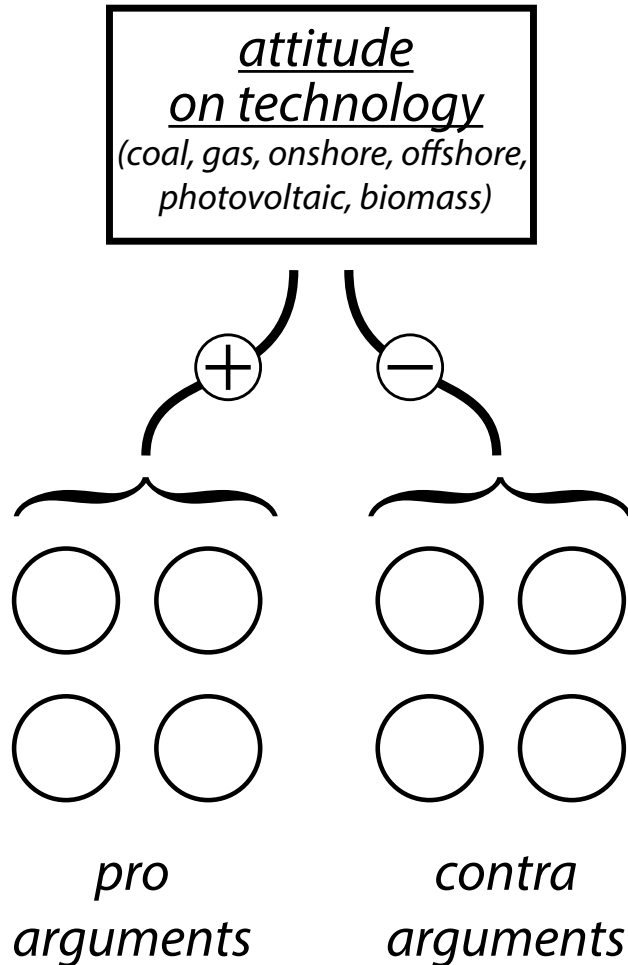
- ▶ *Attitudes measured before and after exposure to 7 pro and 7 con arguments*
- ▶ *Attitude change data on 6 different energy sources*

| Setting | Gross sample | Analytical dataset |
|--------------------------------|--------------|--------------------|
| Coal power stations | 203 | 170 |
| Gas power stations | 207 | 171 |
| Wind power stations (onshore) | 207 | 172 |
| Wind power stations (offshore) | 207 | 189 |
| Open space photovoltaics | 213 | 197 |
| Biomass power plants | 208 | 179 |
| | n | |
| | 1,245 | 1,078 |



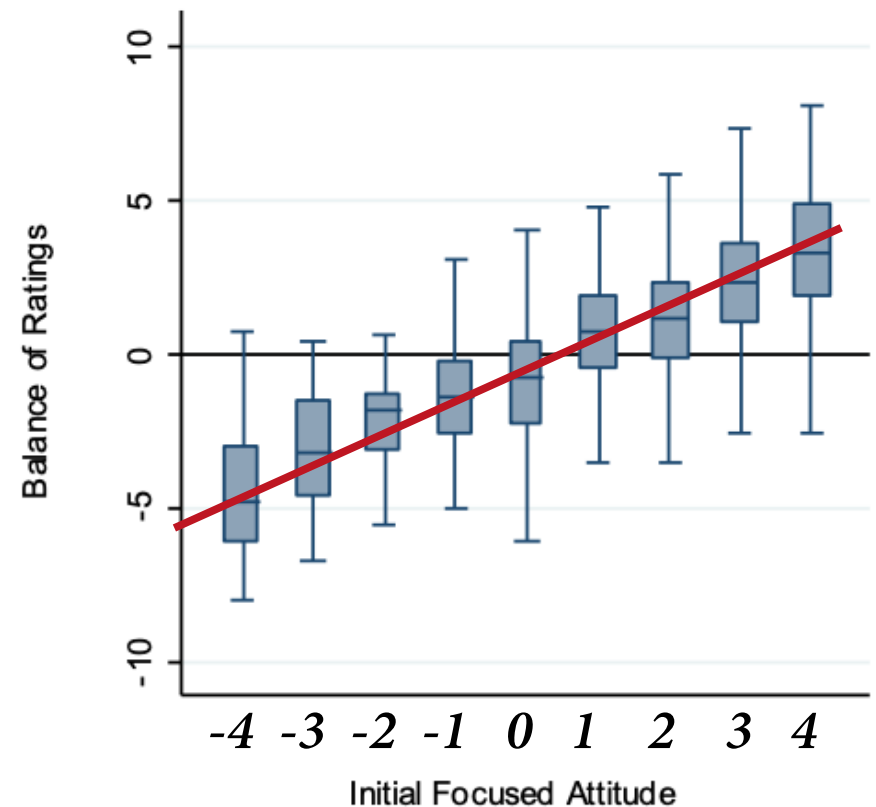
Cognitive Model of Argument Processing

► Attitude **structure** borrowed from ACT



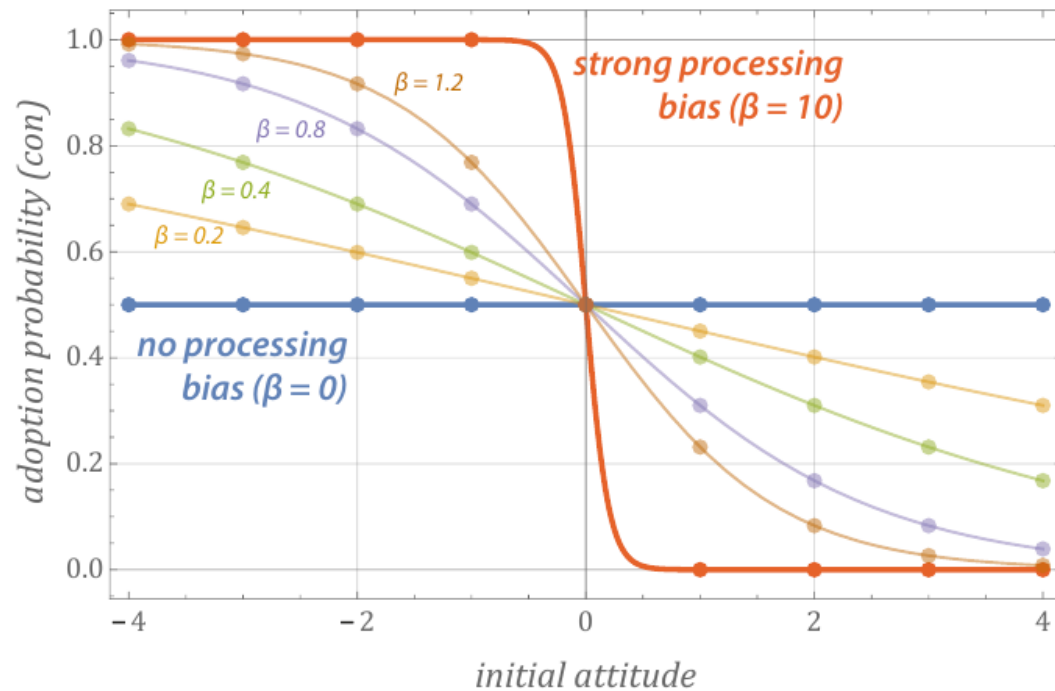
Cognitive Model of Biased Processing

- ▶ Argument **evaluation** aligned to experimental data and formalised in terms of cognitive coherence
 - Positive evaluation of an argument (a) which is coherent with the opinion (o)
 - Attitude strength ($|o|$) determines the size of this effect
 - Evaluation $V(a)$ becomes a linear function of the initial opinion
- **Matches with experimental data on evaluation bias for a pro argument**



Cognitive Model of Argument Processing

- ▶ Argument **adoption** is assumed to depend on the evaluation $V(a)$ and the strength of biased processing β by



$$p_{\beta}(V(a'_i)) = \frac{1}{1 + e^{-\beta V(a'_i)}}$$

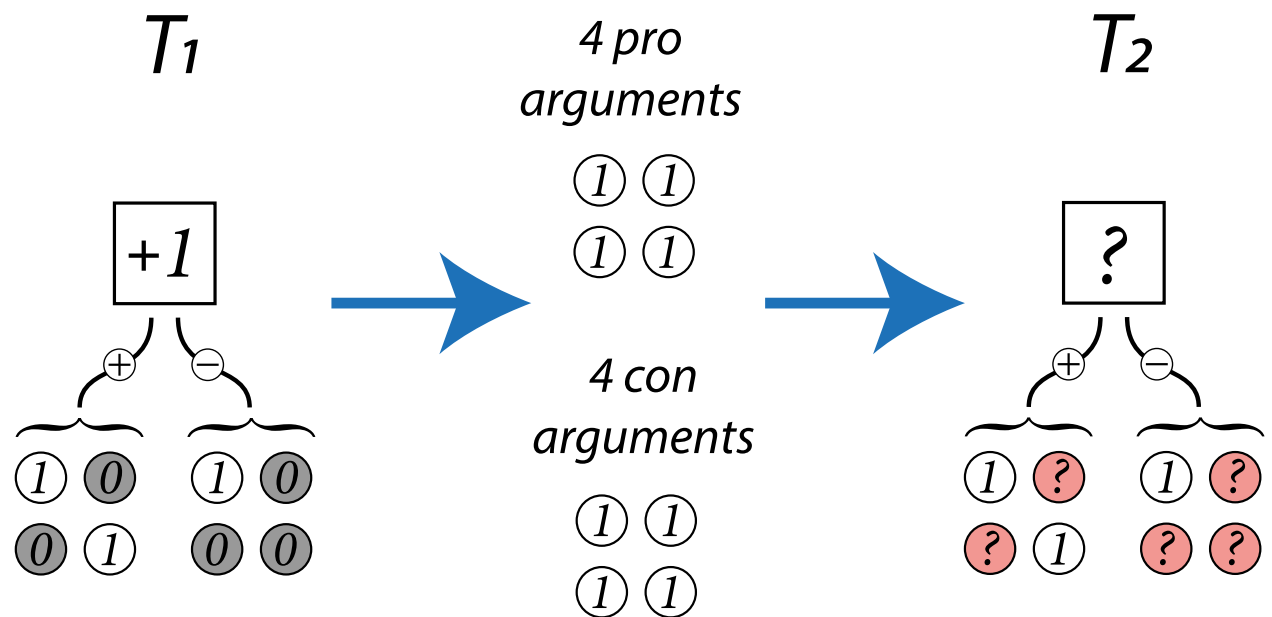
- We are not rational optimizers of cognitive coherence
- The free parameter β accounts for the strength of biased processing
- $\beta = 0$ means unbiased adoption and if β is large only coherent arguments are adopted

Expected Attitude Change (virtual experiment)

- ▶ How would artificial agents react to the same experimental treatment? What is their expected attitude change?

- ▶ $M = 4$ pro and con arguments (to match the 9-point attitude scale)
- ▶ How many new arguments are adopted?
- ▶ What is the respective attitude change?

computational implementation
(of balanced argument treatment)



Expected Attitude Change (virtual experiment)

- ▶ probability of adopting k pro-arguments

$$Pr_{n_{pro}}[\Delta n_{pro} = k] = (p_{\beta}^+)^k (1 - p_{\beta}^+)^{N_{pro} - n_{pro} - k} \binom{N_{pro} - n_{pro}}{k} \quad (6)$$

- ▶ probability of adopting k con-arguments

$$Pr_{n_{con}}[\Delta n_{con} = k] = (p_{\beta}^-)^k (1 - p_{\beta}^-)^{N_{con} - n_{con} - k} \binom{N_{con} - n_{con}}{k} \quad (7)$$

- ▶ probability of attitude change k

$$Pr_{n_{pro}, n_{con}}[\Delta o = k] = \sum_{l=k}^M Pr_{n_{pro}}[\Delta n_{pro} = l] Pr_{n_{con}}[\Delta n_{con} = l - k]. \quad (8)$$

- ▶ expected attitude change

$$\mathbb{E}[\Delta o | n_{pro}, n_{con}] = \sum_{k=-M}^M k Pr_{n_{pro}, n_{con}}[\Delta o = k]. \quad (9)$$

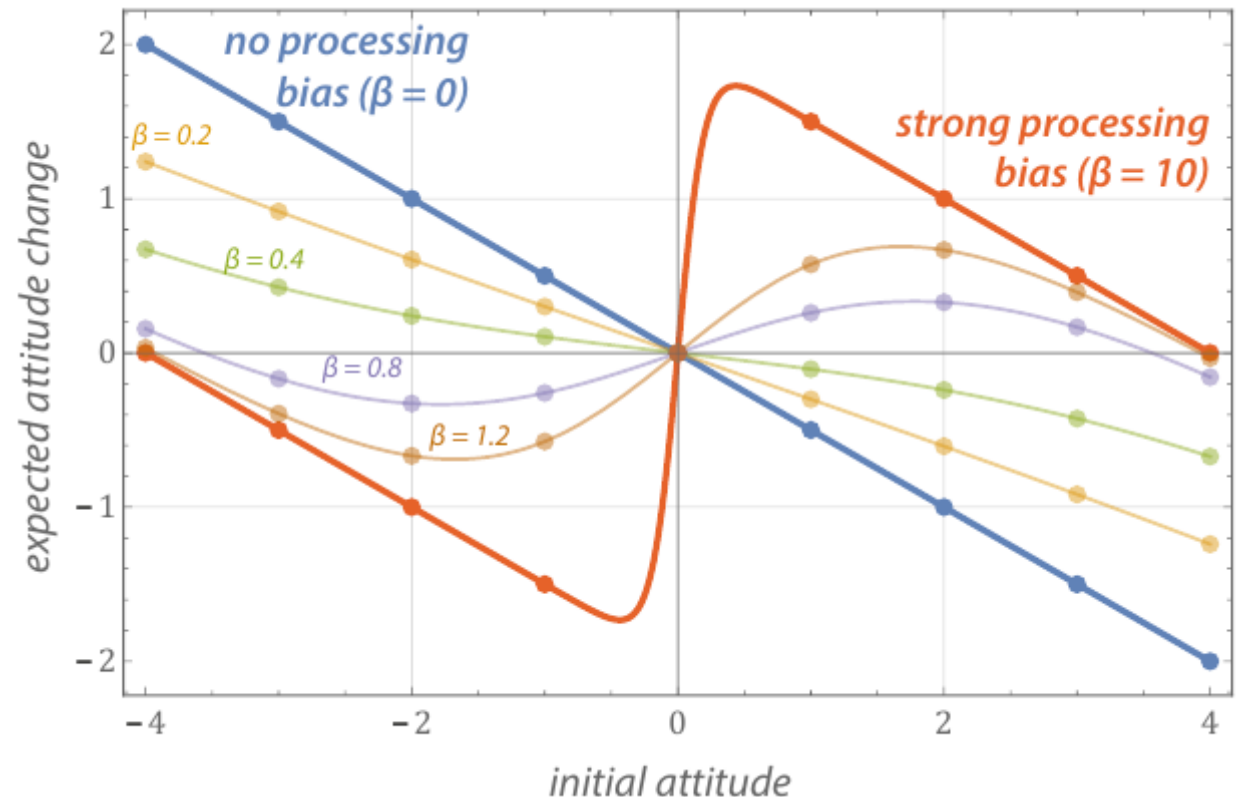
- ▶ assuming symmetric distribution over n_{pro} and n_{con}

$$\mathbb{E}[\Delta o | o] = 2 \tanh\left(\frac{\beta o}{2}\right) - \frac{2o}{M}$$

Expected Attitude Change (virtual experiment)

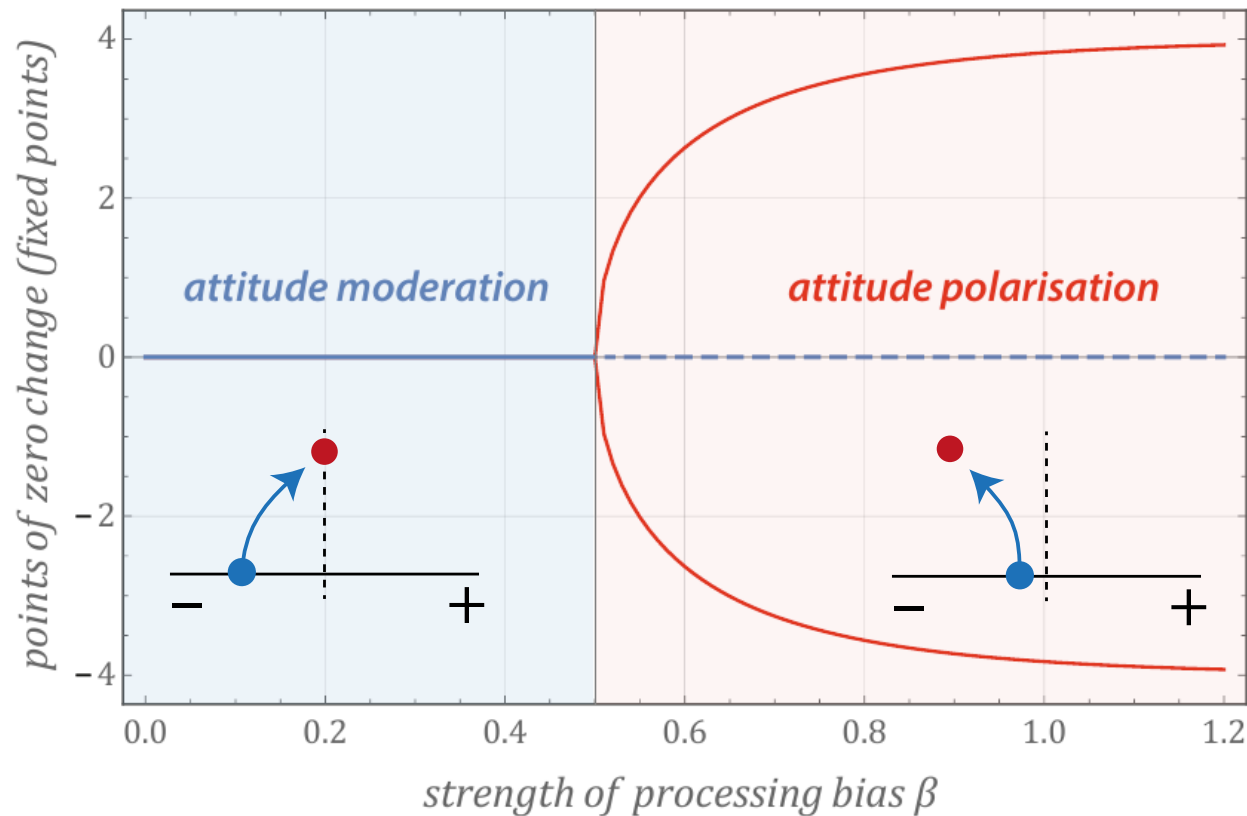
$$\mathbb{E}[\Delta o|o] = 2 \tanh\left(\frac{\beta o}{2}\right) - \frac{2o}{M}$$

- ▶ **Attitude moderation** if bias $\beta = 0$. Negative opinions become more positive and vice versa.
- ▶ **This is what current models assume!**
- ▶ **Attitude polarisation** if β is large. Negative opinions become more negative and vice versa.



The psychological puzzle: attitude moderation versus attitude polarisation

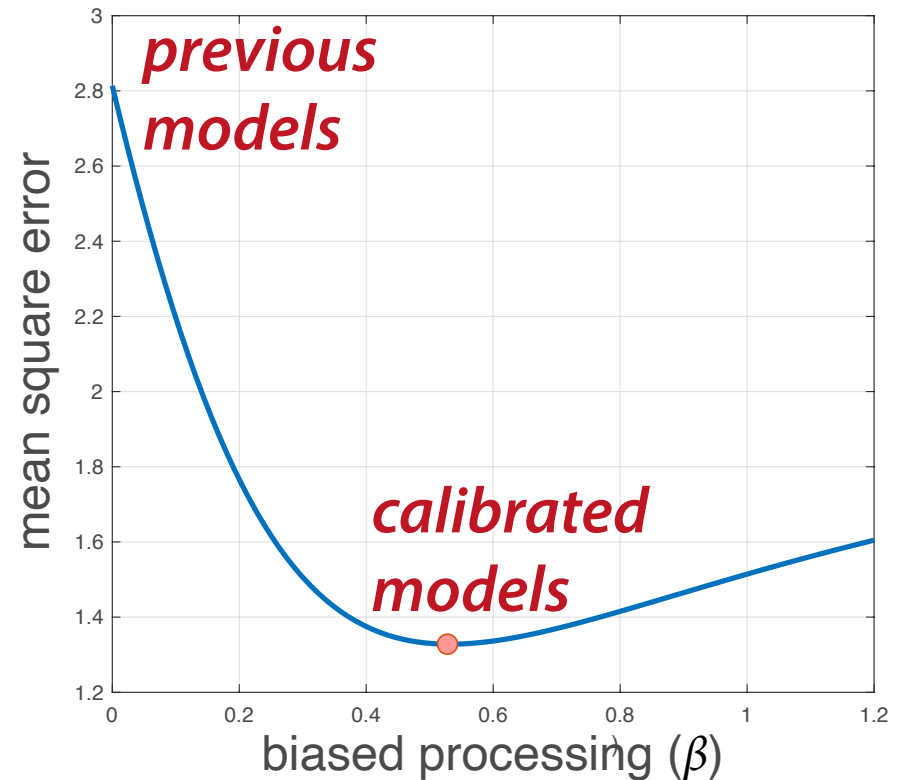
$$\mathbb{E}[\Delta o|o] = 2 \tanh\left(\frac{\beta o}{2}\right) - \frac{2o}{M}$$



- ▶ **Bifurcation** from attitude moderation to attitude polarisation if β crosses a critical value of $1/2$
- ▶ Biased processing leads to attitude polarisation only if the bias is strong
- ▶ **This strength may vary across topics that experiments have addressed**

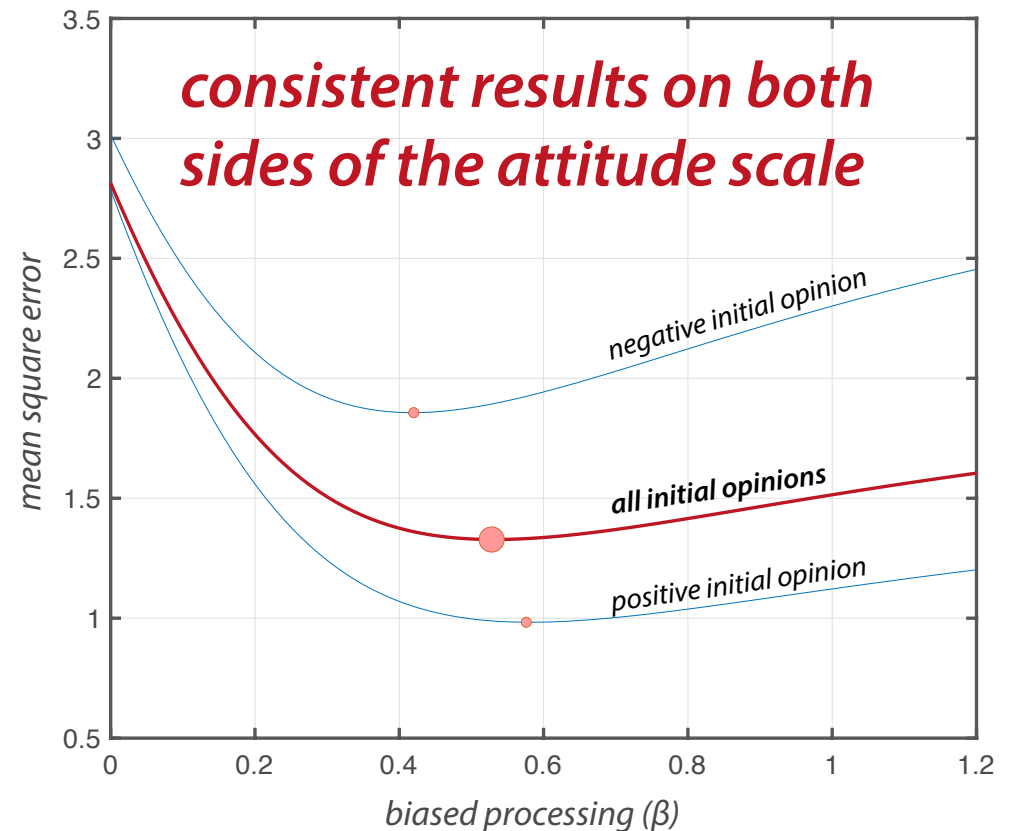
Calibration with Experimental Data

- ▶ *Assuming that agents adapt by argument exchange (as in ACT models), what is the adequate choice for the processing bias β ?*
- ▶ *Least square error of theoretical prediction of mean attitude changes to the data (N = 1078)*
- ▶ *Best match for β close to the critical point 1/2!*
- ▶ ***Clear signature that the refined model with moderate biased processing improves ACT***

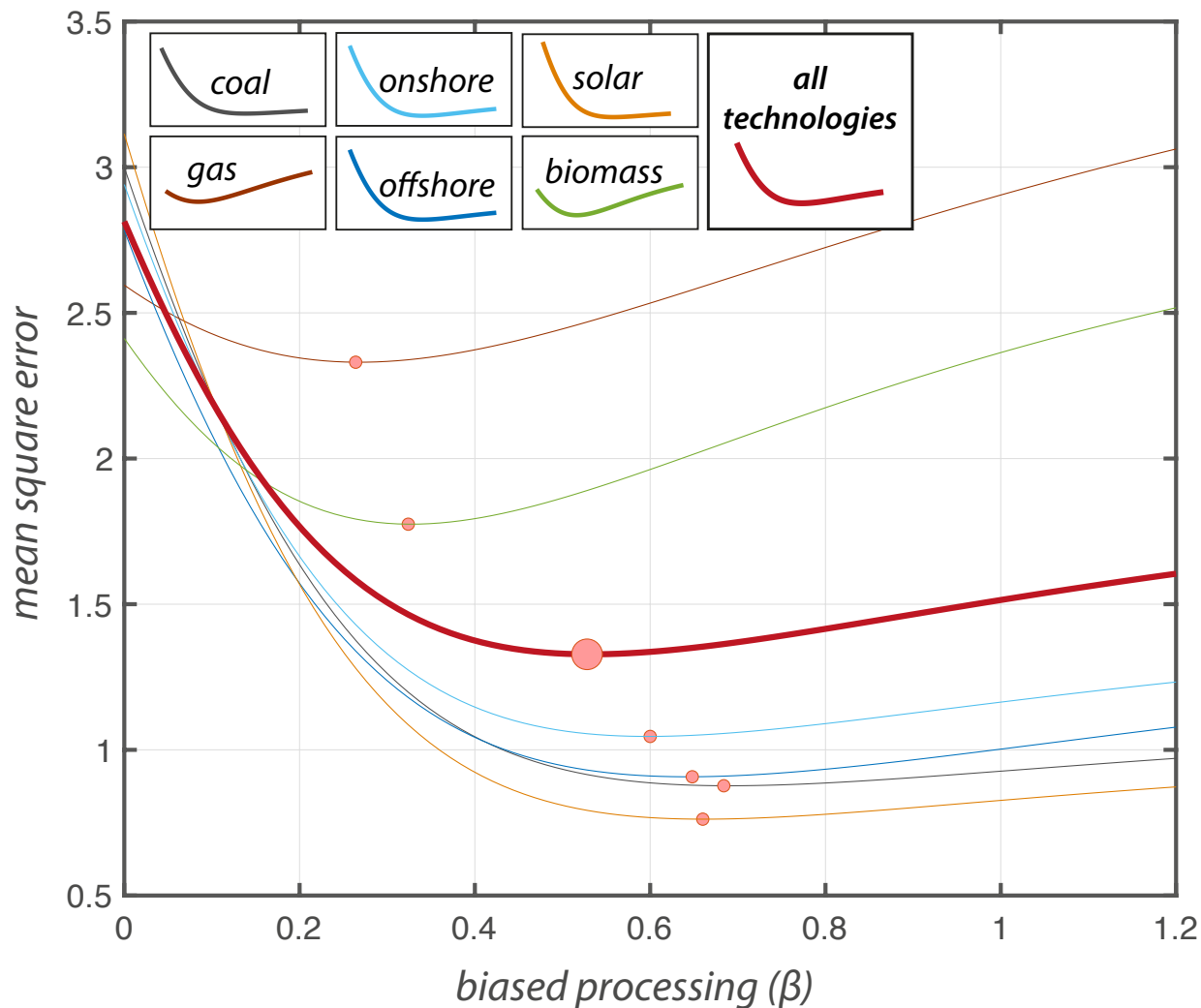


Calibration with Experimental Data

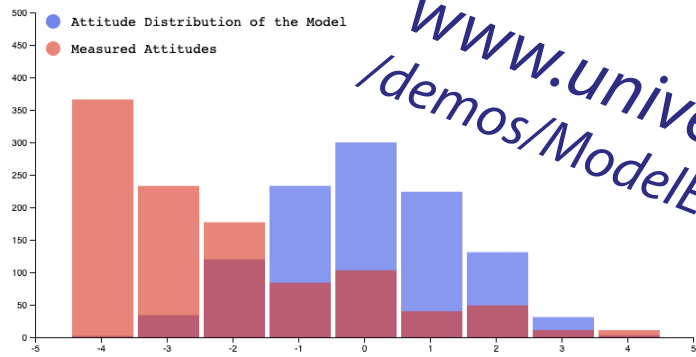
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Differences across topics



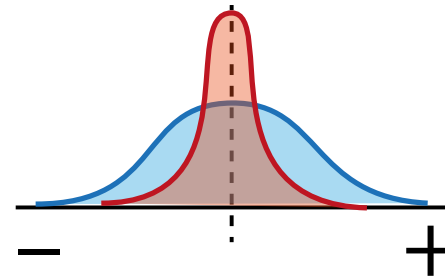
- ▶ *Least square error of theoretical prediction of mean attitude changes to the data ($N \approx 170$ per topic)*
- ▶ *Indication that bias is weak (< 0.5) for new issues (biomass, gas) and stronger for long-debated issues (> 0.5)*
- ▶ *Attitude moderation in the former cases, attitude polarisation in the latter ones*



www.universecity.de/demos/ModelExplorer.html

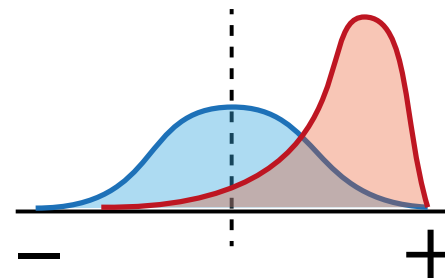
A tool that allows to interactively explore the dynamics of the argument communication model and to compare the evolving opinion distribution to real survey data.

Collective Dynamics



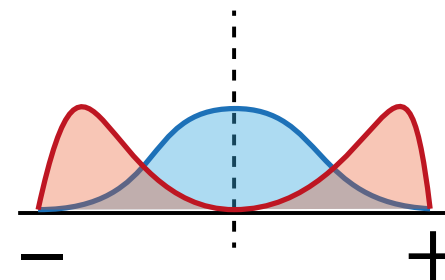
moderate
consensus

versus



choice
shift

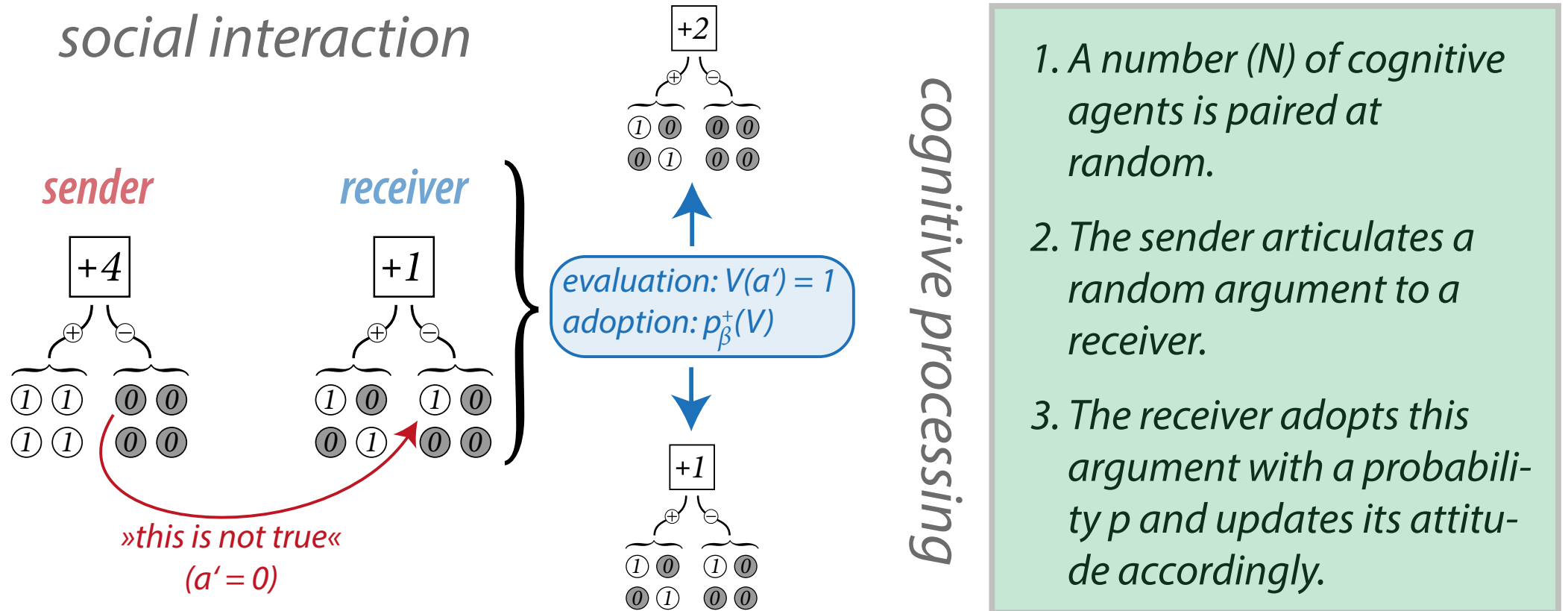
versus



collective
polarisation

Collective Deliberation with Processing Bias

- *Argument communication models describe processes of collective attitude formation as repeated social exchange of arguments*

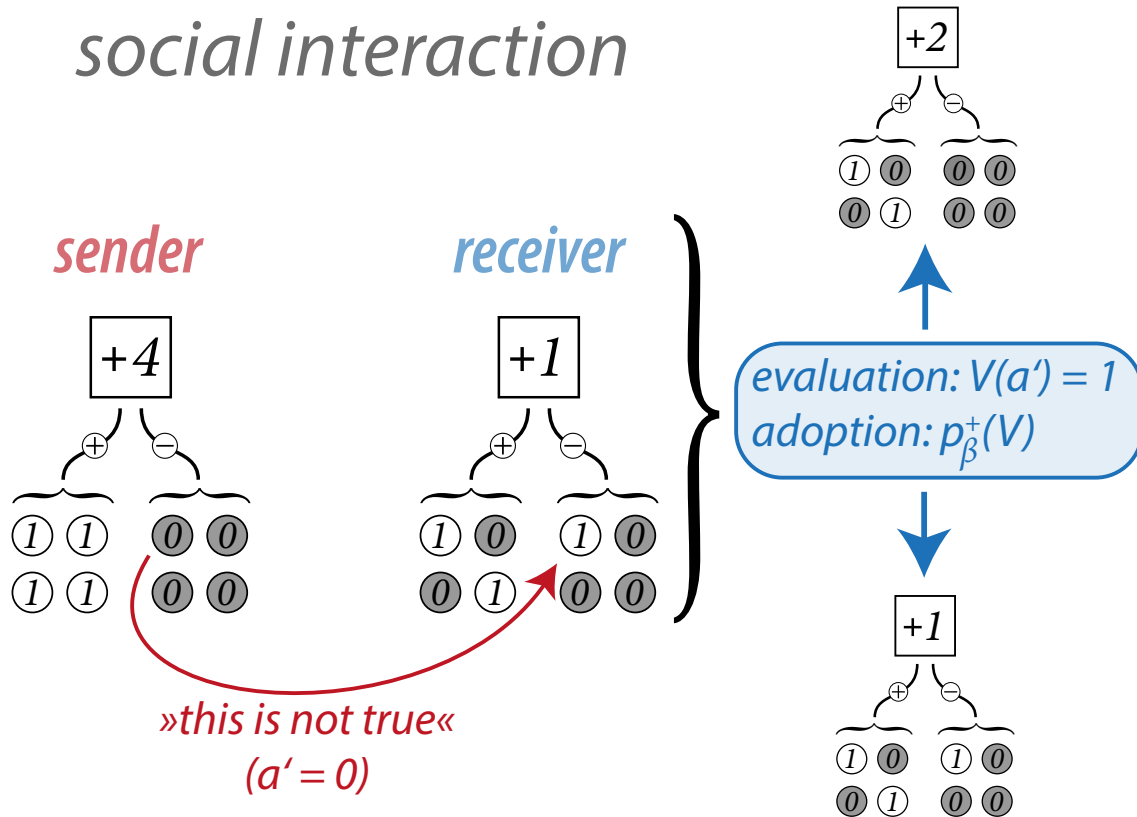


1. A number (N) of cognitive agents is paired at random.
2. The sender articulates a random argument to a receiver.
3. The receiver adopts this argument with a probability p and updates its attitude accordingly.

Collective Deliberation with Processing Bias

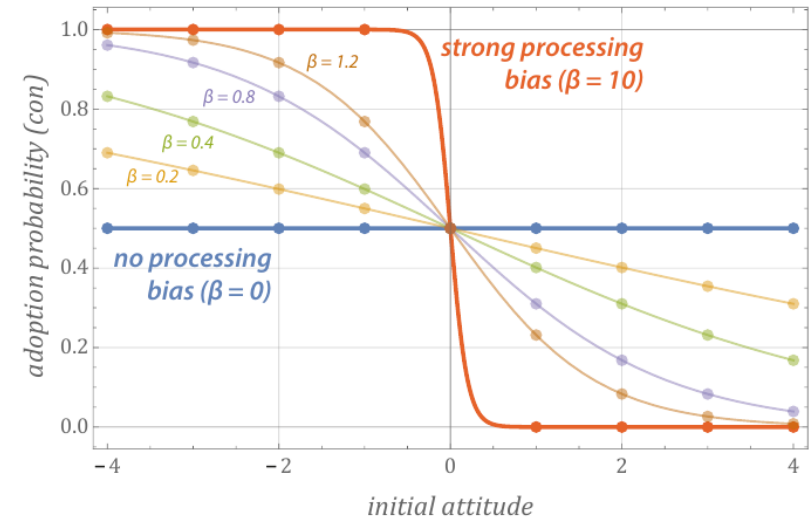
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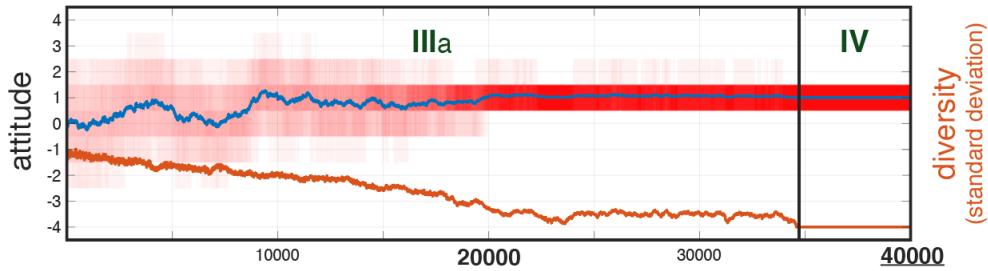
social interaction



cognitive processing

$$p_{\beta}(V(a'_i)) = \frac{1}{1 + e^{-\beta V(a'_i)}}$$



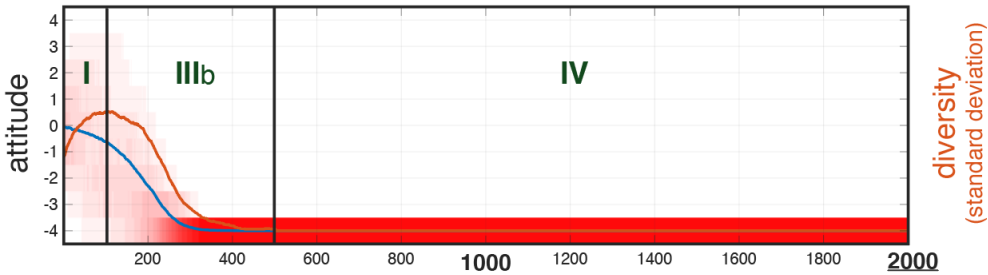


A

no biased processing ($\beta = 0$)

IIIa: long process of diversity reduction

IV: final moderate consensus



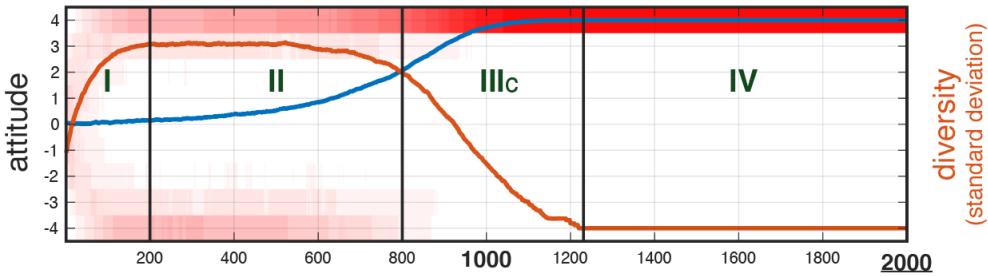
B

weak biased processing ($\beta = 0.4$)

I: initial diversification

IIIb: one-sided diversity reduction

IV: extreme consensus



C

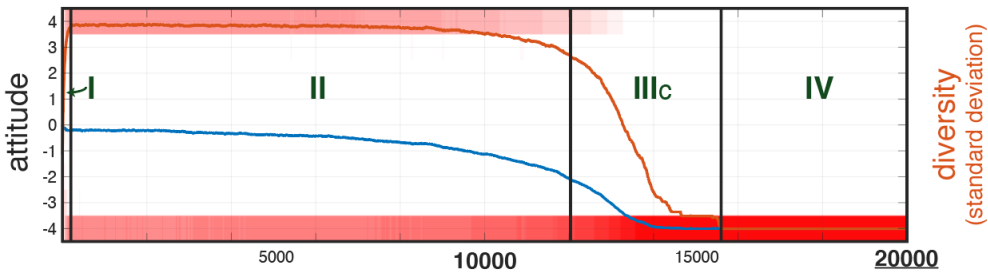
strong biased processing ($\beta = 0.8$)

I: initial diversification

II: bi-polarization

IIIc: resolution of one group

IV: extreme consensus



D

strong biased processing ($\beta = 1.2$)

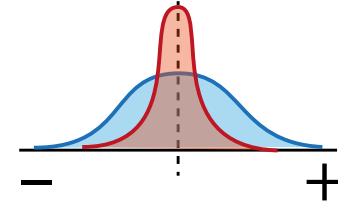
I: initial diversification

II: bi-polarization

IIIc: resolution of one group

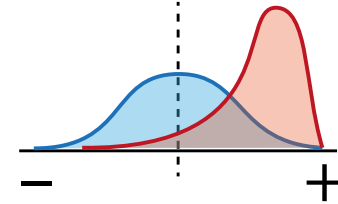
IV: extreme consensus

time (total number of steps varies)



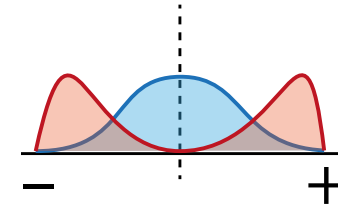
consensus formation

versus



choice shift

versus



collective polarisation

Model
Phenomenology

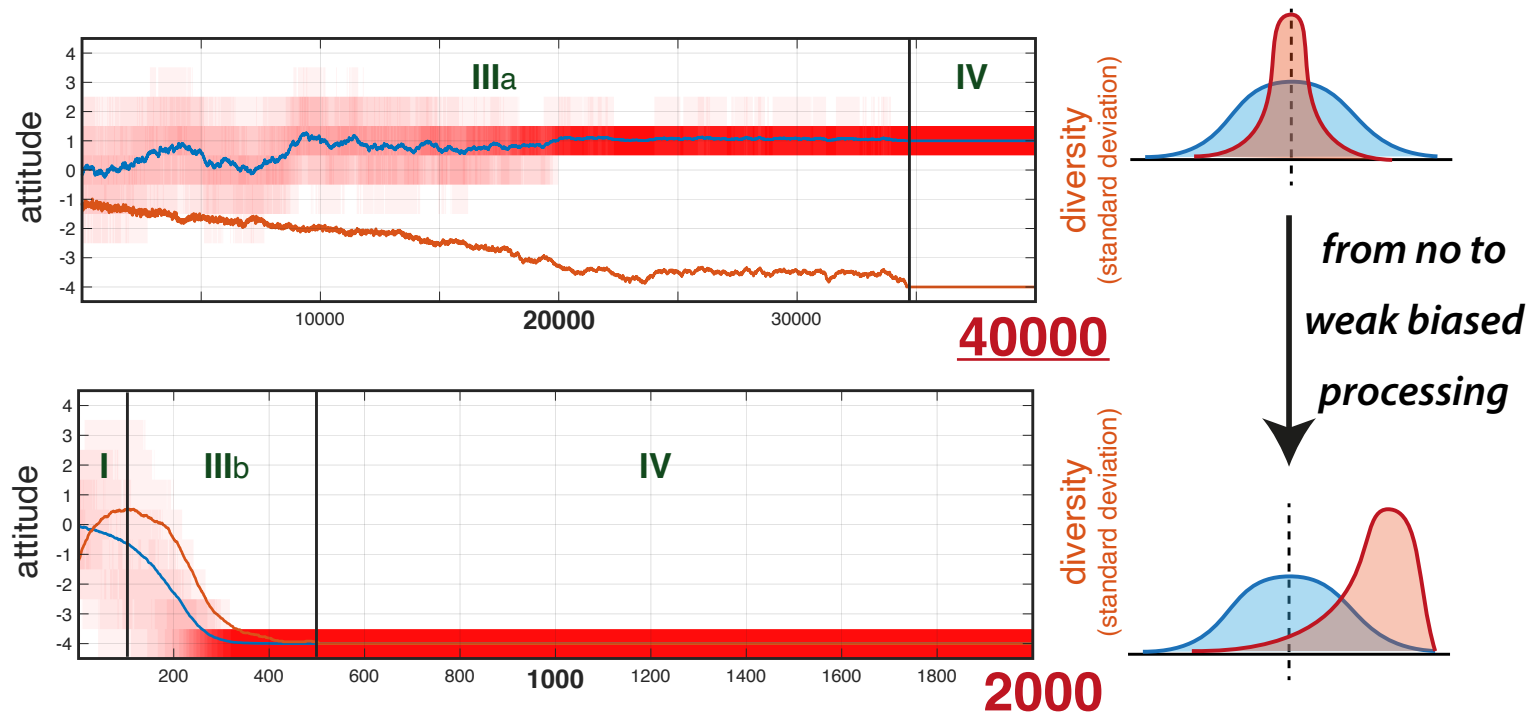
First Transition

► *The introduction of **weak biased processing speeds up group decision processes by two orders of magnitude***

• *Groups without processing bias may remain in indecision for a long time*

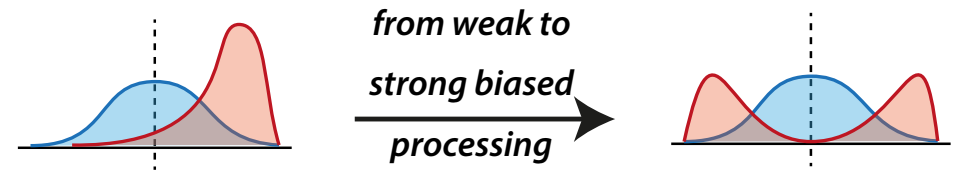
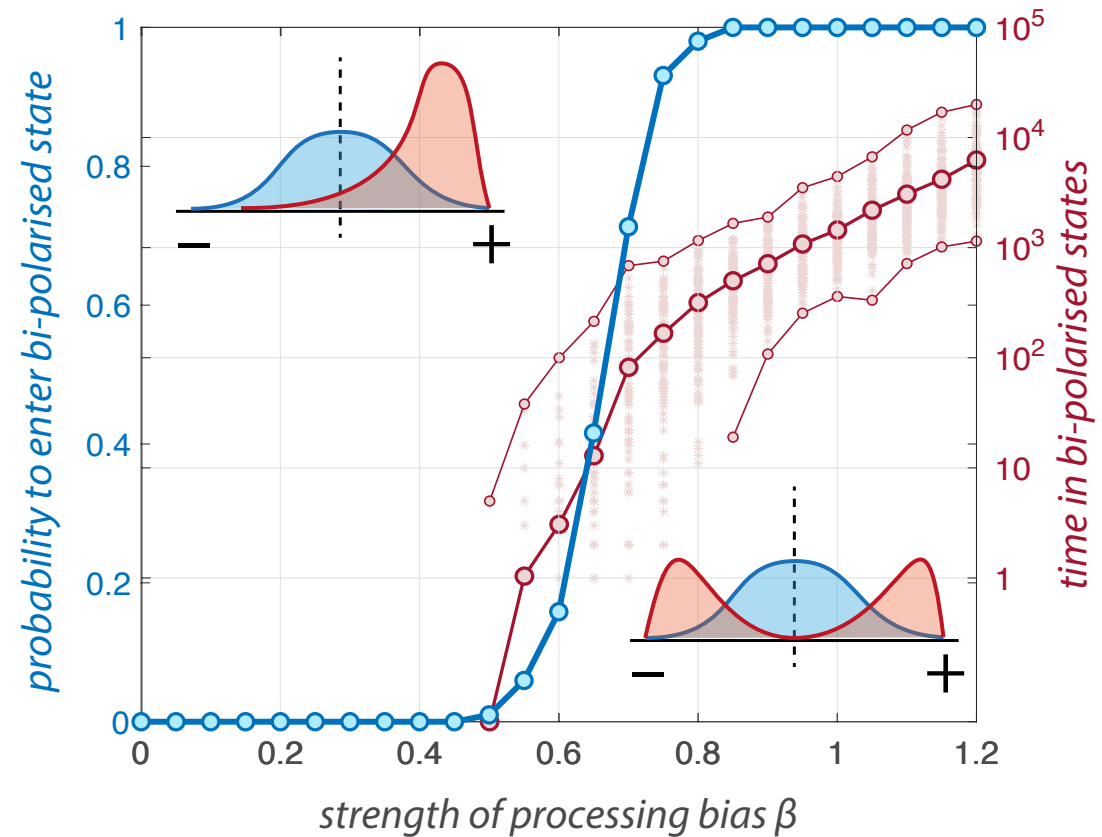
• *Reinterpretation of „extreme consensus“ as an effective group decision process*

• ***Evolutionary origins of biased processing!?***



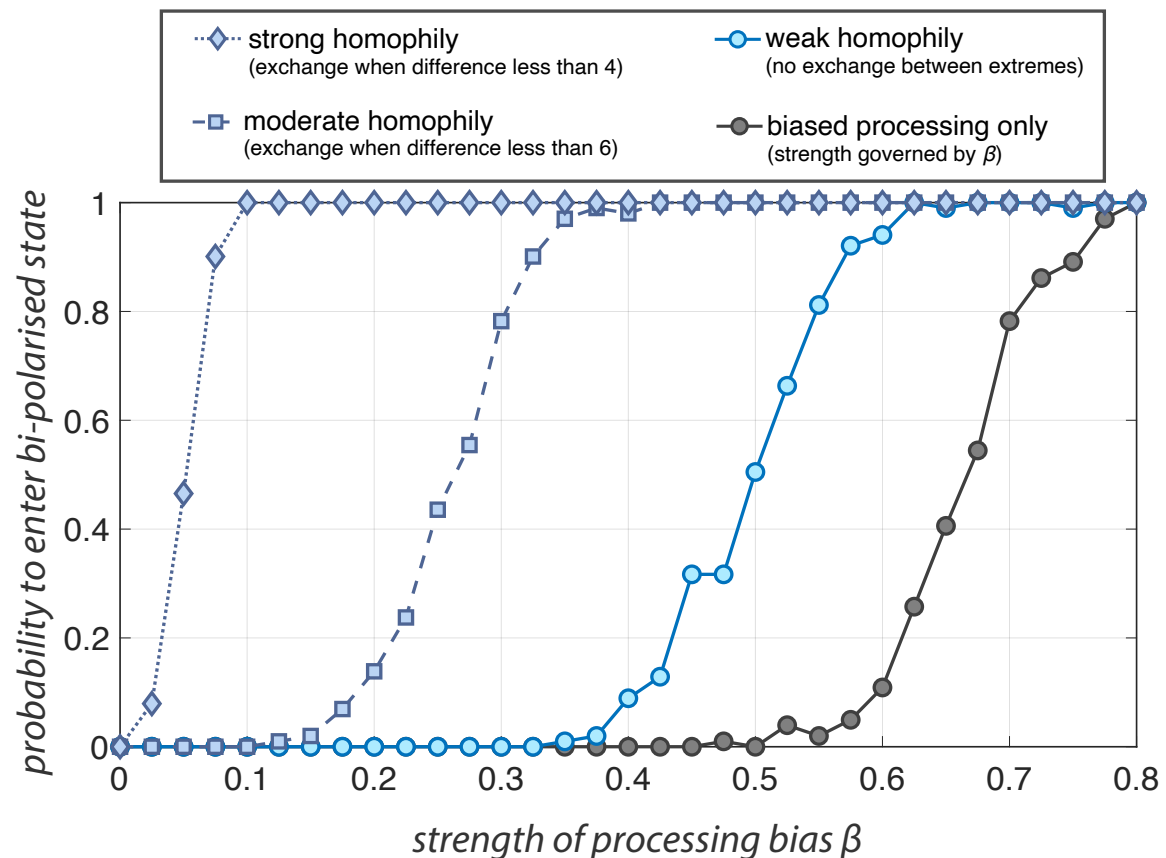
Second Transition

- ▶ *Strong biased processing may lead to persistent intra-group conflict*
- ***Biased processing alone is sufficient for collective bi-polarisation*** (without any assumptions about social composition)
- *Only in the regime of attitude polarisation at individual level*
- ***Strength of processing bias is what matters!*** (depends on topic)



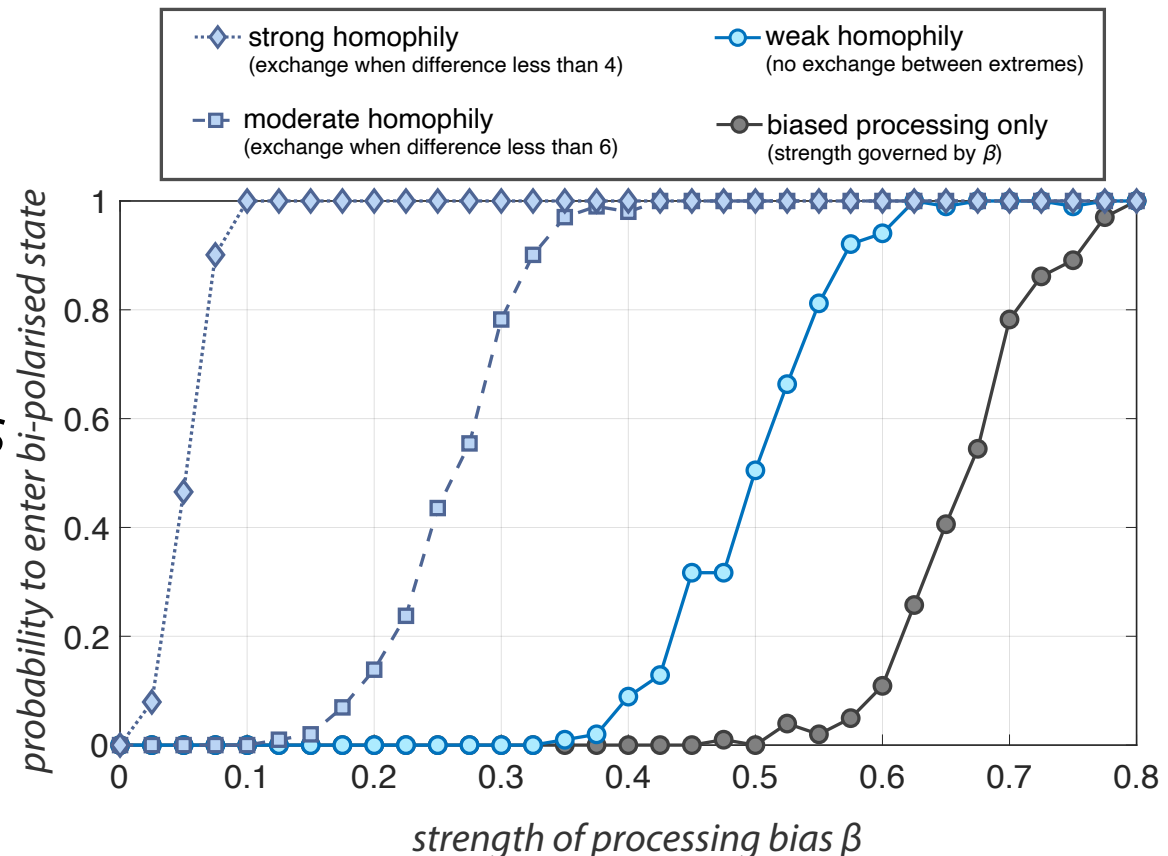
Opinion Homophily

- ▶ *The most prevailing assumptions in opinion dynamics is that the interaction probability depends on the opinion similarity.*
- ▶ *As all previous ACT studies draw on homophily, it is important to understand the interplay of biased processing and homophily*
- ▶ *Assumption: agents do not interact if opinion difference is larger than a threshold*
 - ▶ *weak form: no exchange between extremes ($o_s = -4, o_r = +4$)*



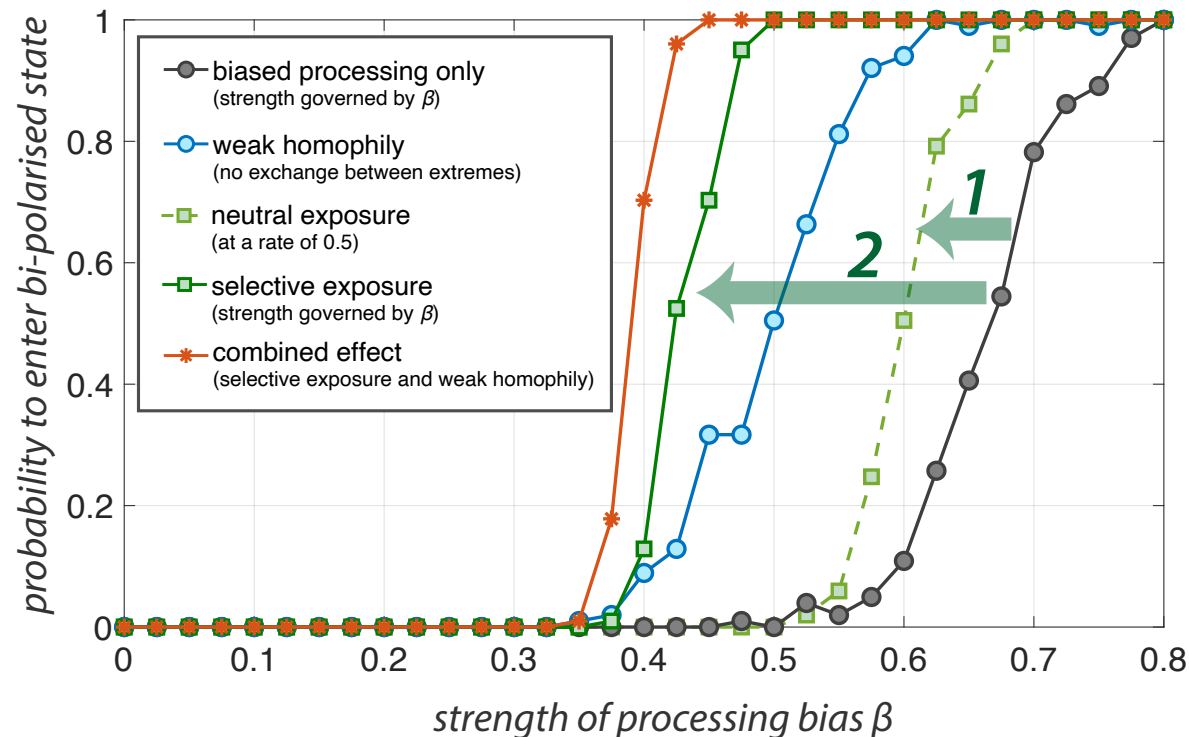
Opinion Homophily

- ▶ One of the most prevailing assumptions in opinion dynamics ...
- ▶ Homophily significantly shifts the critical value of polarisation to a weaker processing bias
 - ▶ Even under the mild assumption that only those at the extreme ends do not talk
- ▶ From the perspective of previous models: biased processing changes the picture completely
- ▶ **We need to check whether previous conclusions still hold!!**



(Selective) Media Exposure

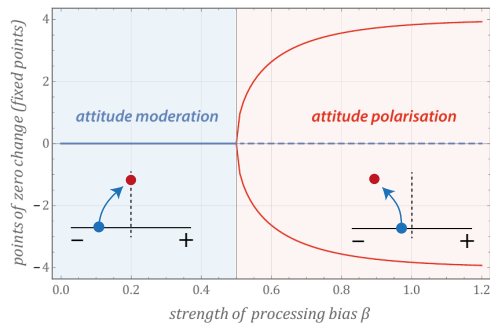
► Empirical work on politicised science issues as climate change suggests that **selective processing and media exposure reinforce one another** (Feldman, 2014)



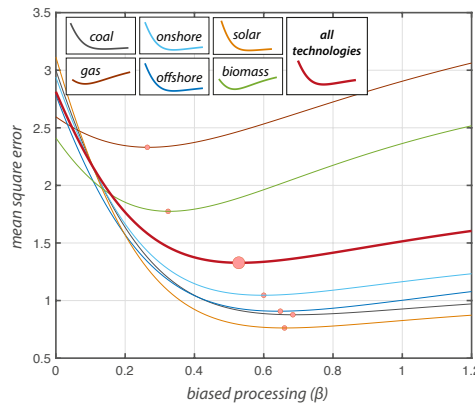
- With a chance of 1/2 agents receive an argument from an external source:
- 1) transition sharpens under neutral exposure!
 - 2) transition shifts to lower levels of bias under selective exposure
- **Information diversity is not helpful if biased processing is strong.**

Conclusions

1. *Biased processing may lead to attitude polarisation; but it crucially depends on the strength of the bias.*



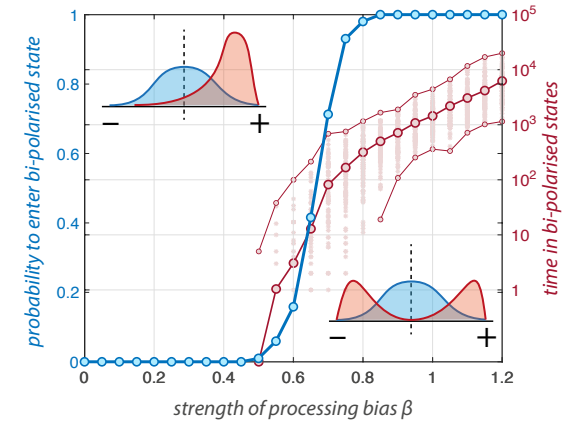
2. *Argument exchange with biased processing matches better with experimental data.*



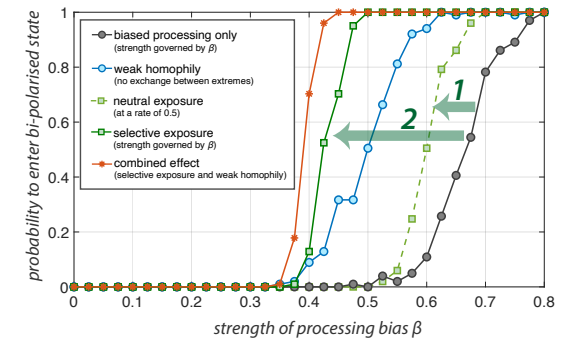
3. *Promising approach to measure the extent to which subjects engage in biased processing.*

4. *Weak biased processing speeds up group decision processes by orders of magnitude*

5. *Strong biased processing is sufficient for persistent intra-group polarisation*



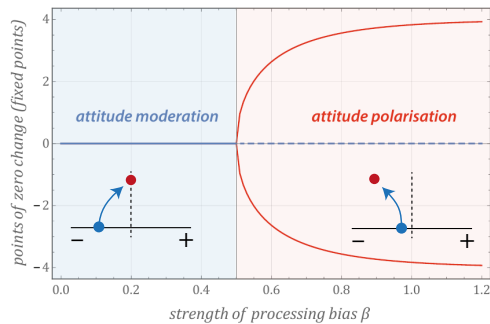
6. *Homophily and selective exposure may lead to intra-group conflict at significantly lower rates of biased processing*



7. *Opinion diversity does not help if biased processing is strong!*

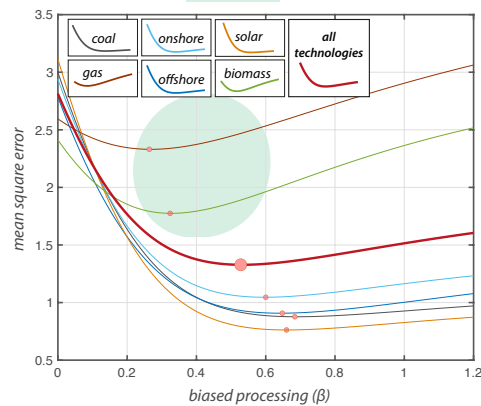
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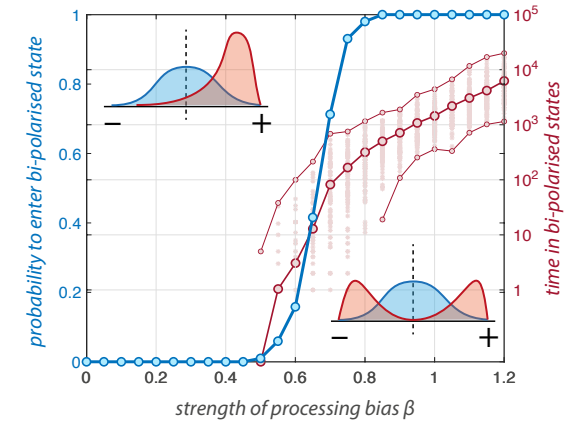
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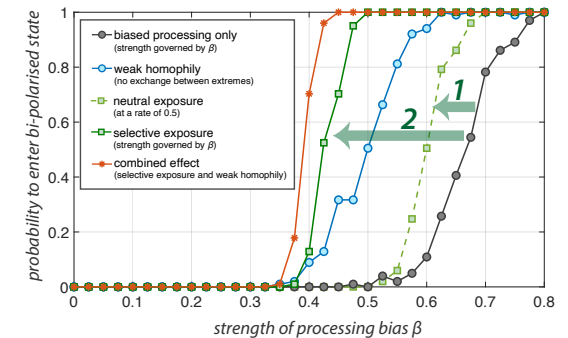
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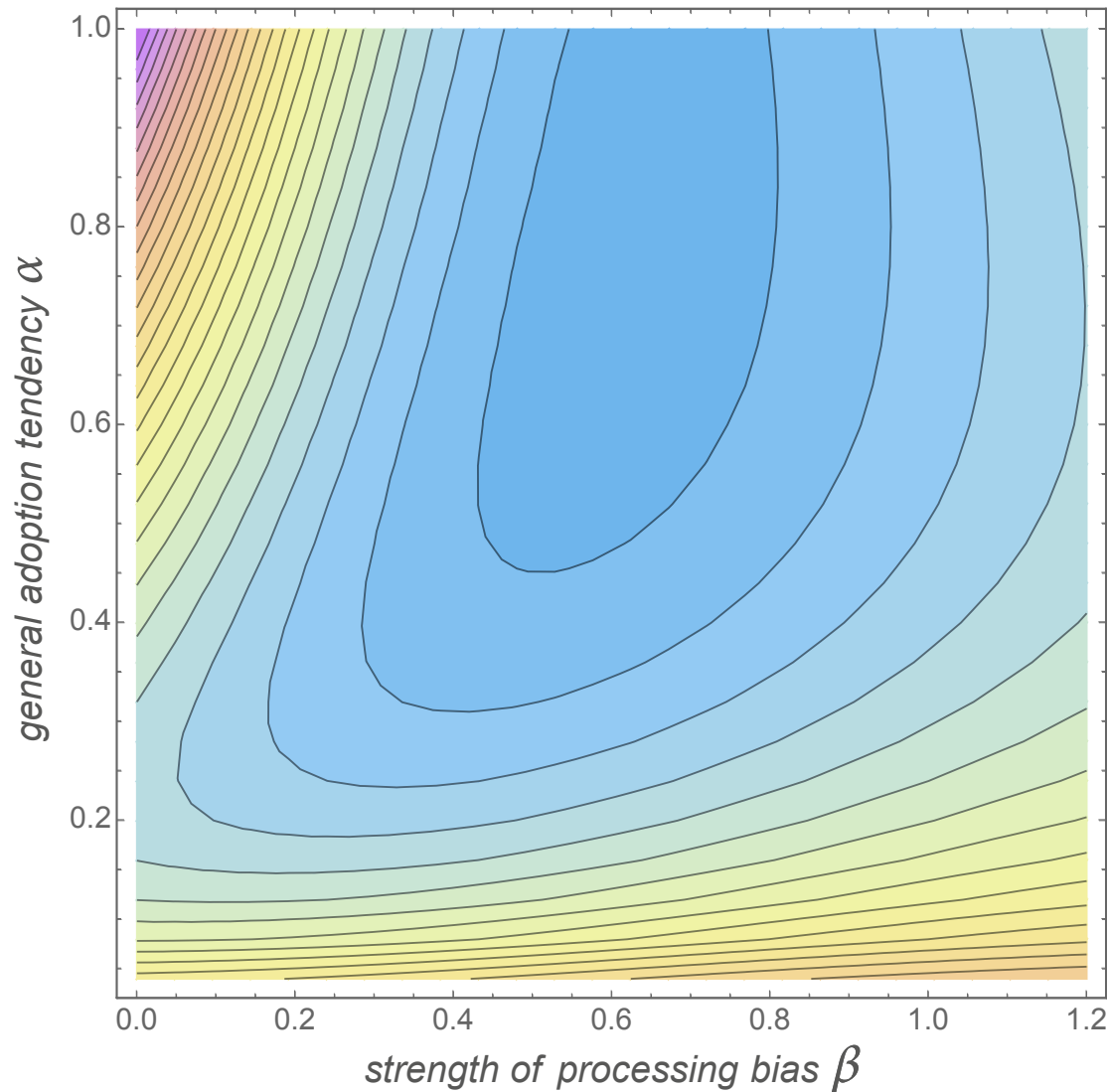
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How Good is the Model Given the Data?



- ▶ *Maximum likelihood test (log likelihood) indicates:*
 - 1. biased argument adoption is relevant ($\alpha > 0$)*
 - 2. a moderate bias $0.4 < \beta < 0.7$ explains observed attitude changes best*
- ▶ *Clear signature that the cognitive agent model provides a valid microfoundation*

Processing bias across topics

