"When her family finds [out] you are using the wrong metric"

Dilemmas and trade-offs in the diffusion of conventions

Lucas Gautheron

2025/03/12, Institut Jean-Nicod


microscopic reversibility
Define
observable

The metric signature in fundamental physics

- Relativistic theories (general relativity, quantum field theory, ...) require a unified description of space-time and a notion of distance between "events" (t, x, y, z)

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$$\begin{pmatrix} +1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix} \text{ or } \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & +1 & 0 & 0 \\ 0 & 0 & +1 & 0 \\ 0 & 0 & 0 & +1 \end{pmatrix}$$

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$$(+,-,-,-) \text{ or } (-,+,+,+)$$

- Both "physically" equivalent and equally legitimate, as long as ensuing calculations remain consistent!

The metric signature in fundamental physics

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Will Kinney @WKCosmo · 12 oct. 2022

Be sure to check your kids' candy this year. Just found this **metric** inside a Snickers bar.

20 17 143

Cliff Burgess @CburgesCliff · 10 août 2023

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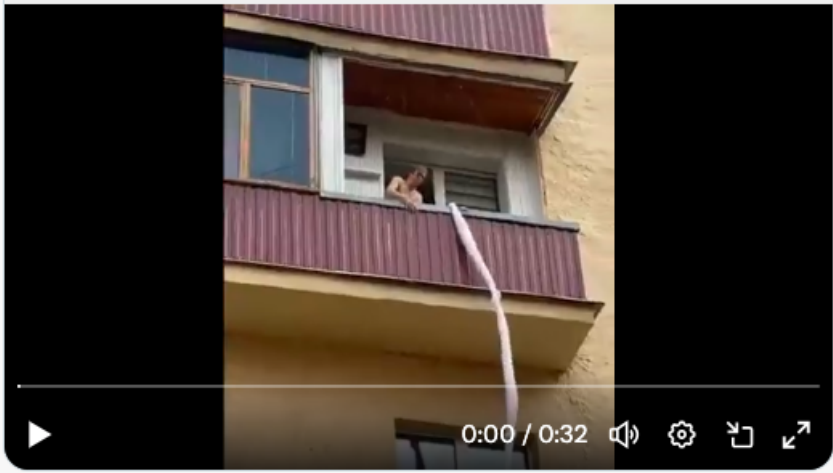
Every pleasure in life has a price



4 4 32 3 k

The metric signature in fundamental physics

Greg Trayling @GregTrayling · 27 avr.
Metric convention reveal parties for graduating physics majors, hear me out.

1 · 8 · 1 k

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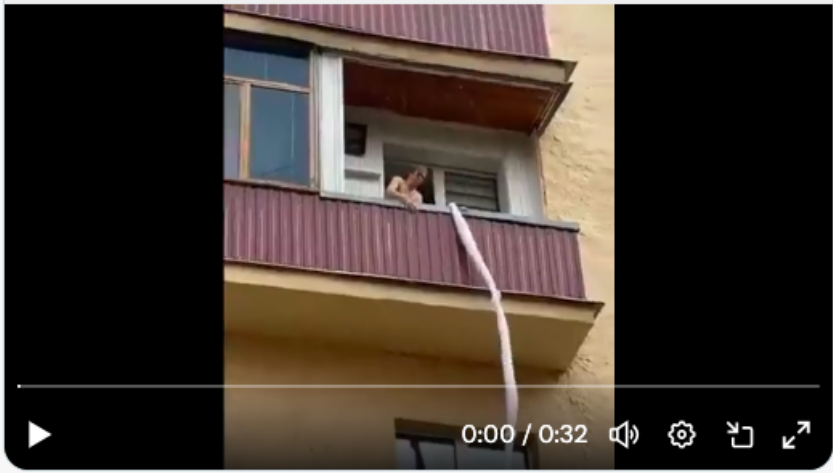


4 · 4 · 32 · 3 k

The metric signature in fundamental physics

When do norms fail to emerge?

Summary

Conventions in the wild: beyond social coordination

- Three dimensions of conventions
- Sequential and contextual consistency in the metric signature
- Reconstructing cultural landscapes of conventions

Bottom-up versus top-down coordination

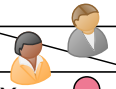
- Two kinds of processes of preference-formation
- Reverse-engineering the process of preference-formation?

Optimality versus decision costs in group judgments

- How do individuals resolve conflicting preferences in collaborations?

Summary

Three dimensions of conventions

	$x_j =$ 🔴	$x_j =$ 🟢
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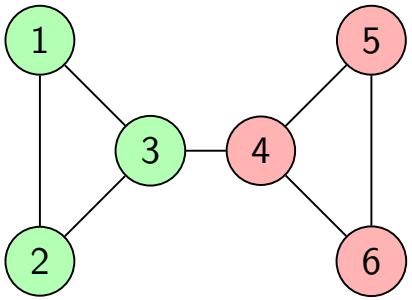

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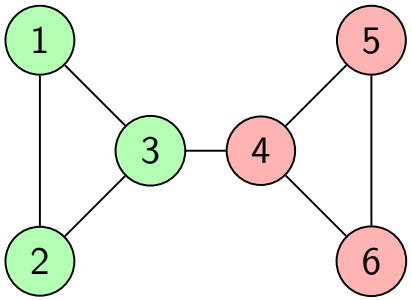

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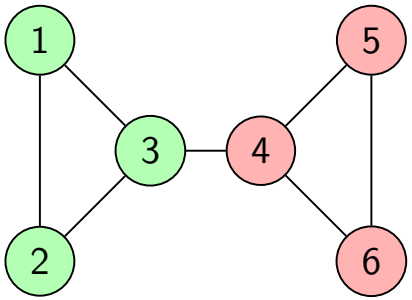

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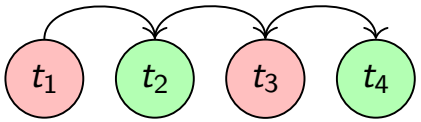

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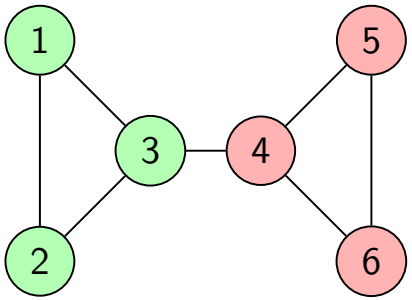

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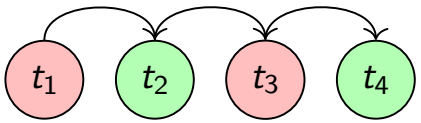

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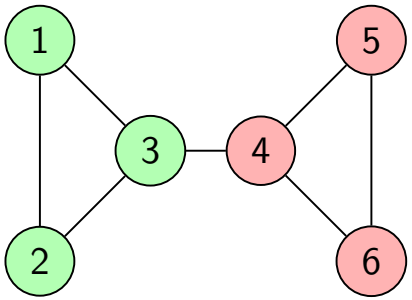

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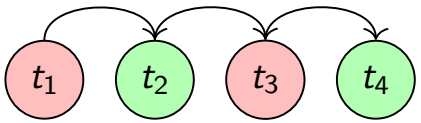

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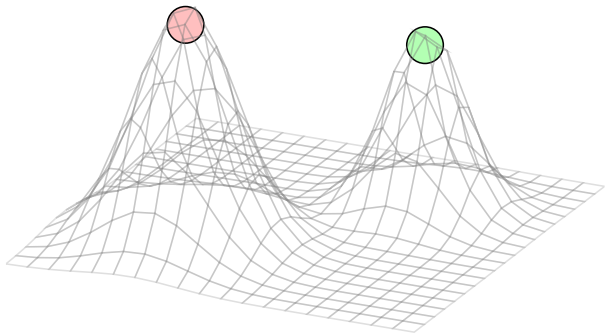

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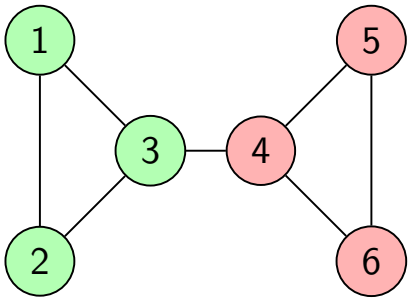

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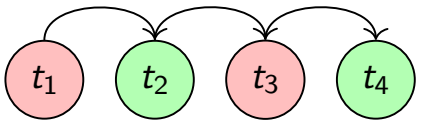

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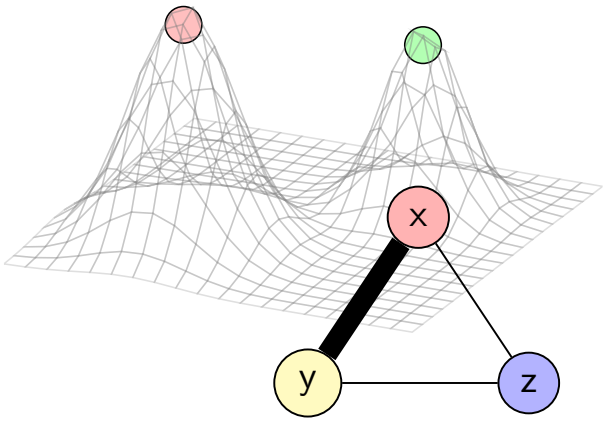
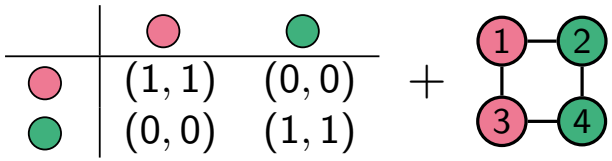


A statistical physics approach to conventions

- Social, sequential, contextual consistency $\sim$ two-person coordination games on a graph.
- Given behavioral data, we can recover the payoff matrix & the graphs involved! (Correia et al., 2022; Zimmaro et al., 2024)



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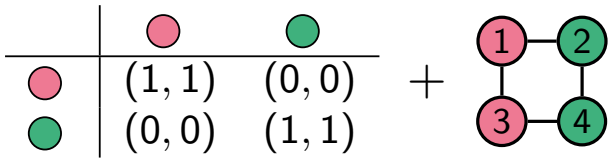

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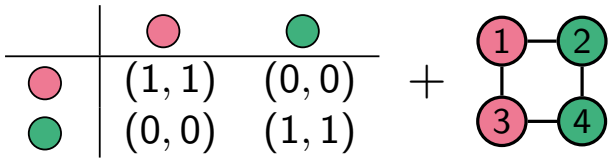

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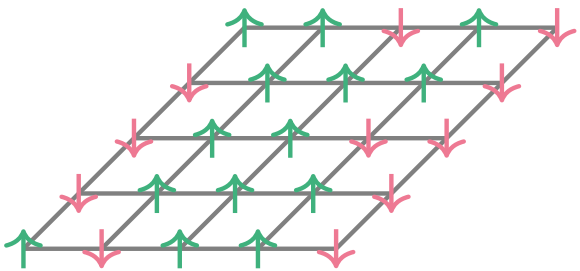
- The **Ising model**



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"The Ising model celebrates a century of interdisciplinary contributions" (Macy et al., 2024)[collective behavior in material, artificial, biological, & social systems]

Applying the framework

- Data: LaTeX source of high-energy physics publications (arXiv) and authorship/citation metadata (Inspire-HEP)
- Four categories: phenomenology, theory, gravitation & cosmology, astrophysics
- Metric signature identified in 22 500 papers using regular expressions.

Sequential and contextual consistency

- Solo-authored papers (~~social consistency~~)
- At time t,  publishes in category

  $c_t \in \{\text{phenomenology, theory, ...}\}$. What determines which convention she uses?

$$P(x_t = +1 | \theta(\text{  }), b(c_d)) = \frac{1}{Z} e^{\beta[\overbrace{\theta(\text{  })}^{\text{Author's preference}} + \overbrace{b(c_t)}^{\text{Effect of research area}}]}$$

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- b_c is the unobserved bias associated with research area c
- If $|\theta| \gg |b|$, individual preferences dominate the need to adapt to a given research area

Sequential and contextual consistency

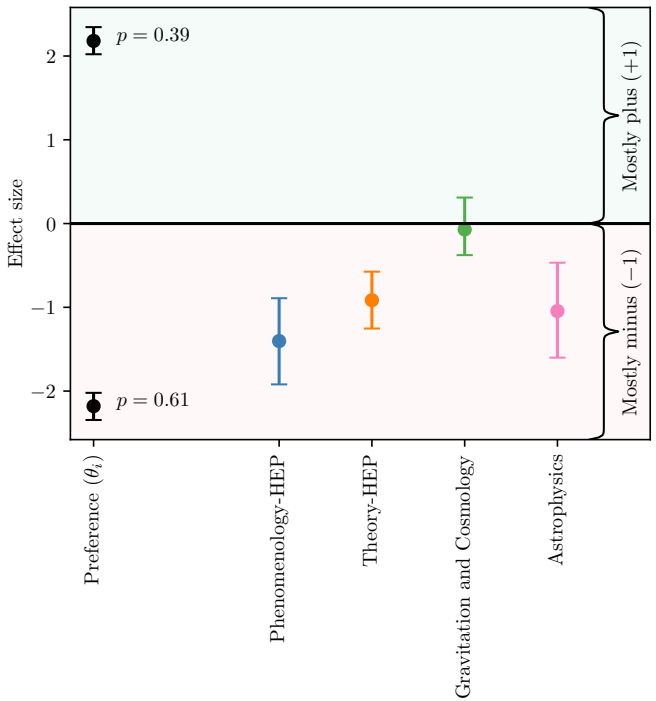
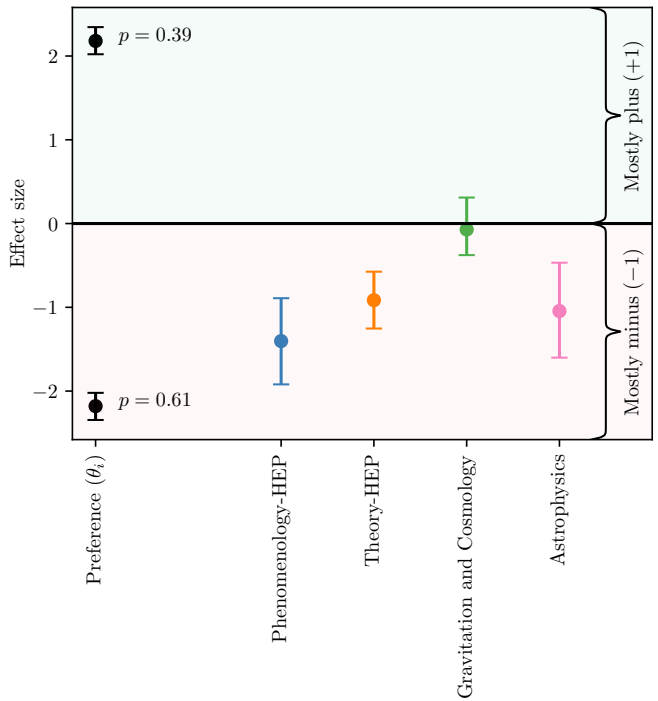


Figure: Sequential consistency (preferences) matter the most, but adaptation to the context also occurs.

Sequential and contextual consistency



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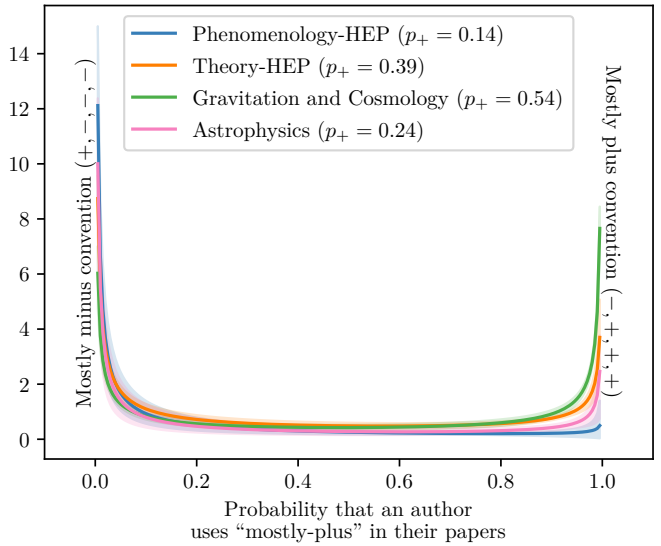

Figure: Physicists tend to always be using the same convention.

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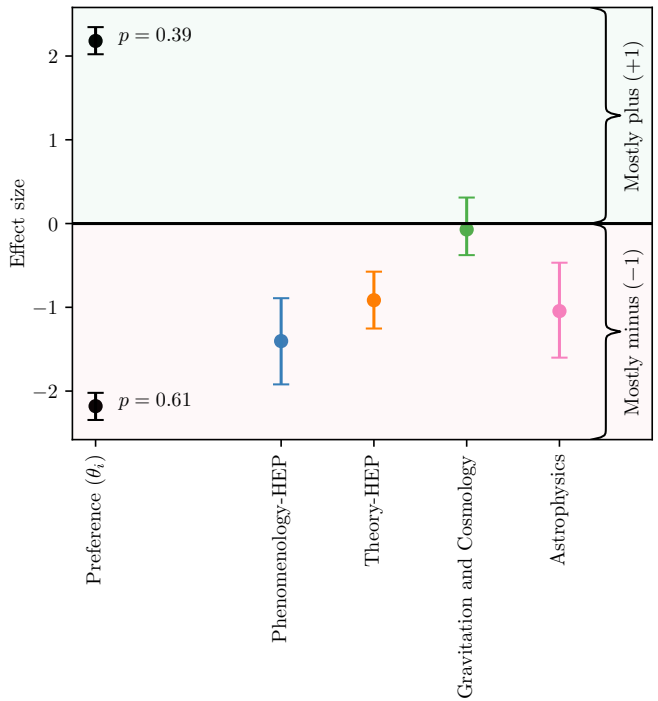

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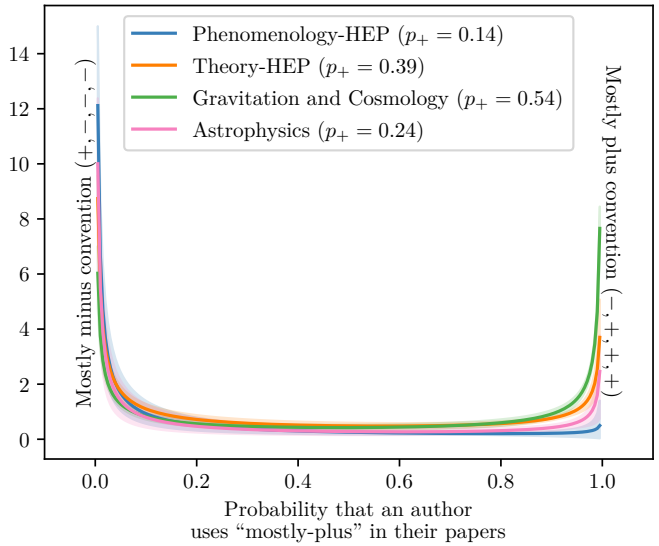

Figure: Physicists tend to always be using the same convention.

- (i) Individuals generally follow their preference (avoiding switching costs) & (ii) They tend to develop preferences adapted to their cultural context.

Reconstructing cultural landscapes using the Ising model

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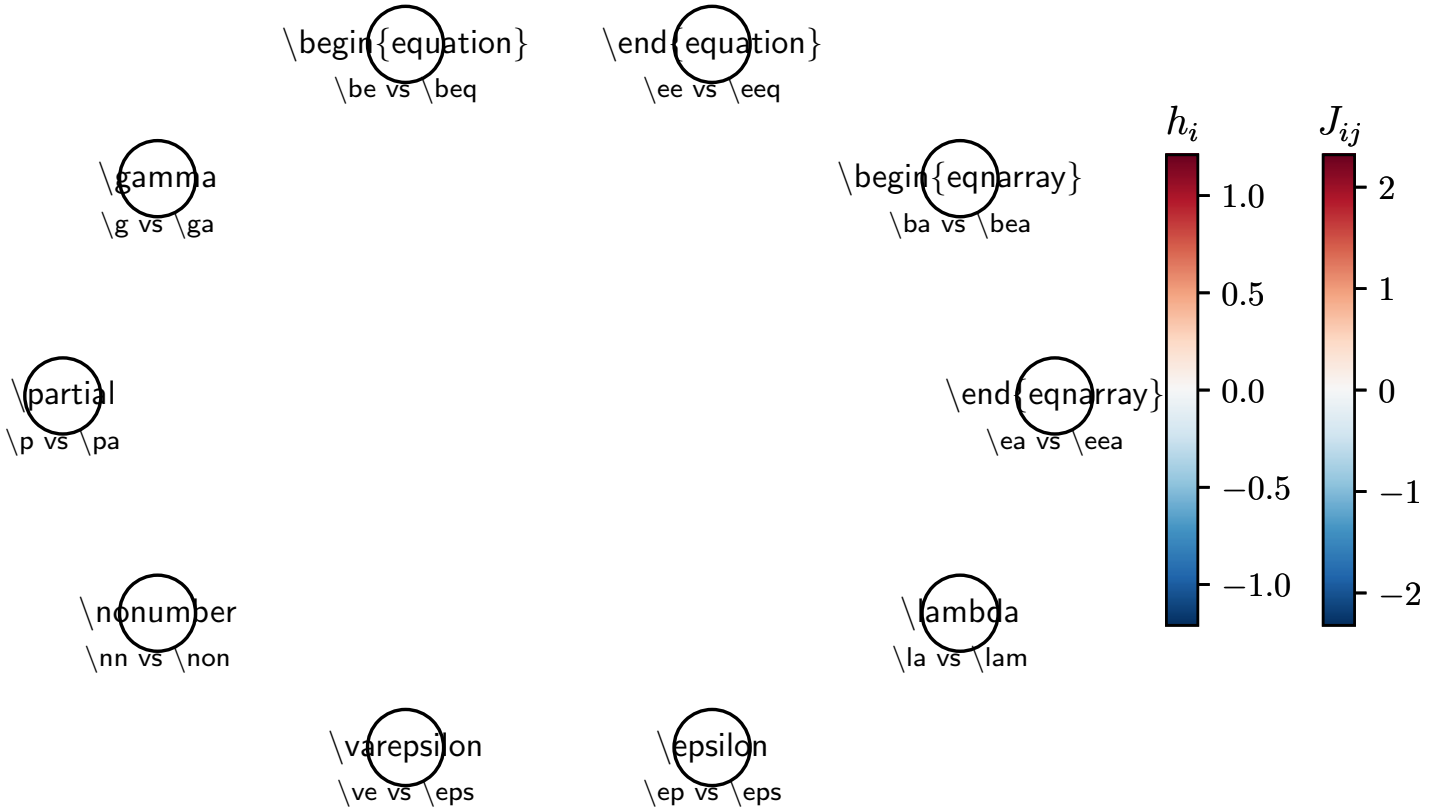
Reconstructing cultural landscapes of conventions



$$U(x_1, \ldots, x_n) = \underbrace{\sum_{ij} J_{ij} x_i x_j}_{\text{interactions between traits}} + \underbrace{\sum_{i} h_i x_i}_{\text{intrinsic trait advantage}} \quad (x_i = \pm 1)$$

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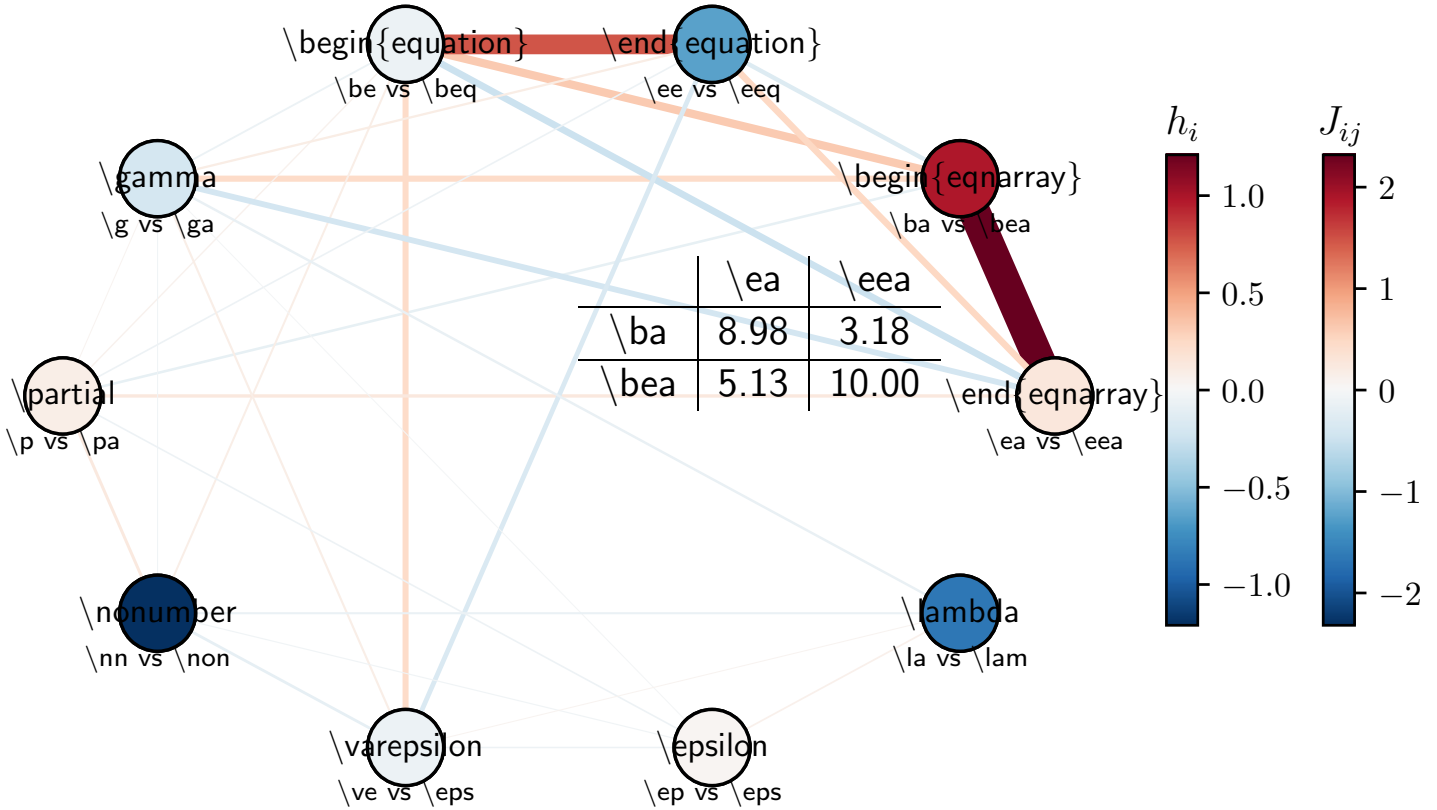

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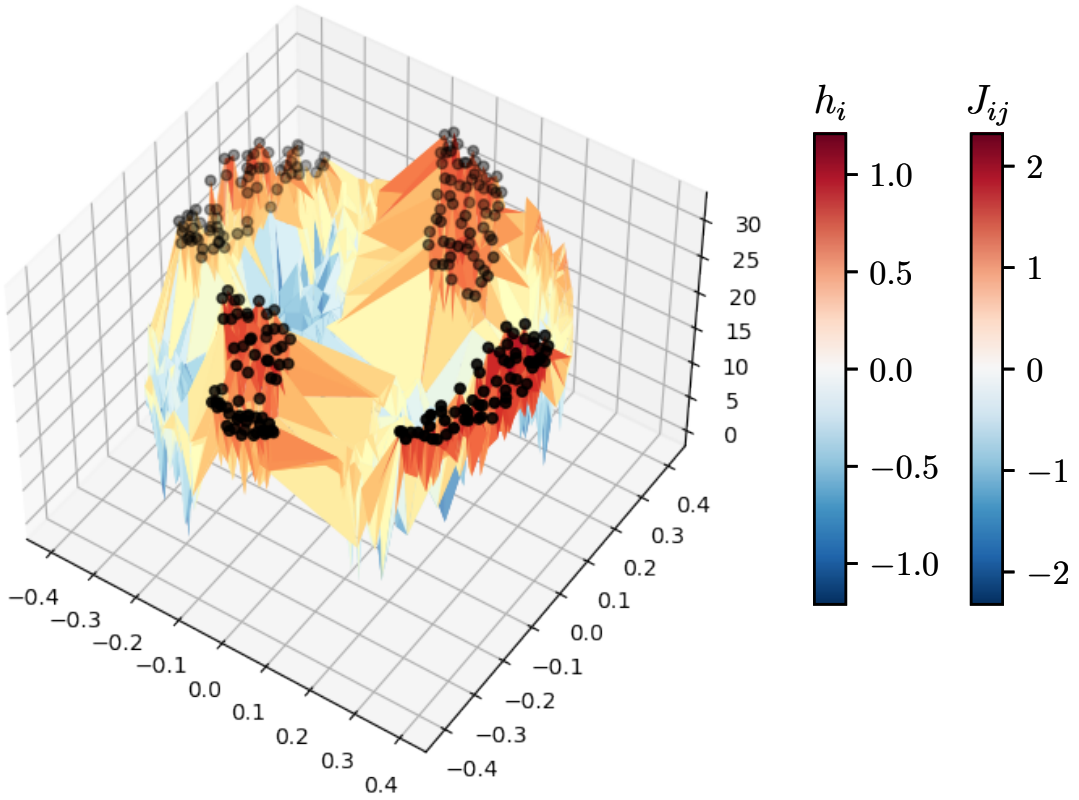
\ba	8.98	3.18
\bea	5.13	10.00

$$U(x_1, \ldots, x_n) = \underbrace{\sum_{ij} J_{ij} x_i x_j}_{\text{interactions between traits}} + \underbrace{\sum_{i} h_i x_i}_{\text{intrinsic trait advantage}} \quad (x_i = \pm 1)$$

Reconstructing cultural landscapes of conventions



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Summary

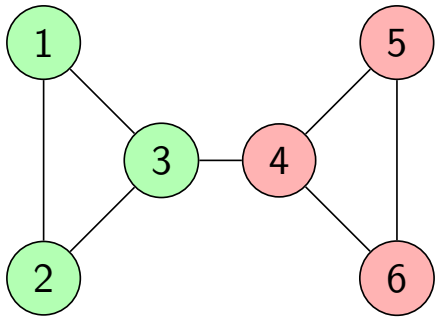
How do preferences form?

Metric signature preferences in the co-author network. Each node is an author. Edges represent co-authorship relationships between authors. Nodes' colors indicate authors' preferences (pink for -1, green for $+1$).

$$\langle x_i x_j \rangle = \frac{\sum_{ij} w_{ij} x_i x_j}{\sum_{ij} w_{ij}} = 0.32$$

Local (bottom-up) versus global (top-down) coordination

Local (bottom-up)
imitation, adaptation
throughout the social network



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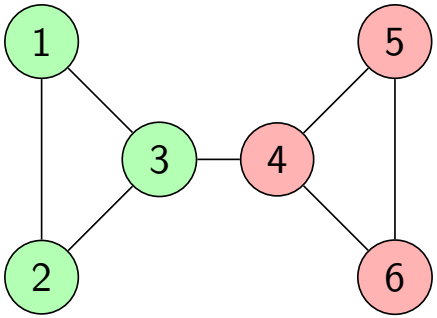
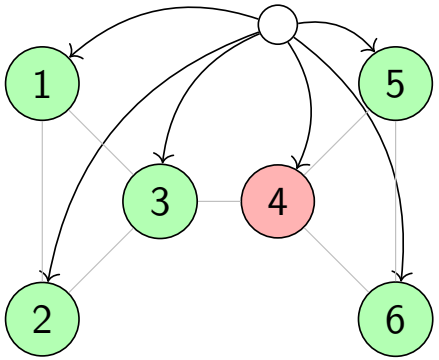


Global (top-down)
shared culture, institutions
transcends the graph



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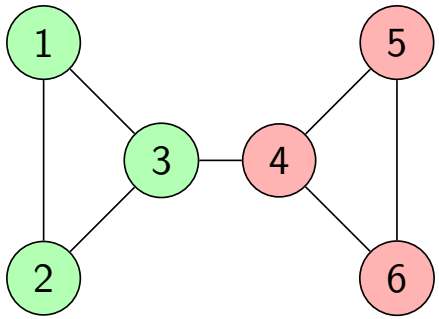

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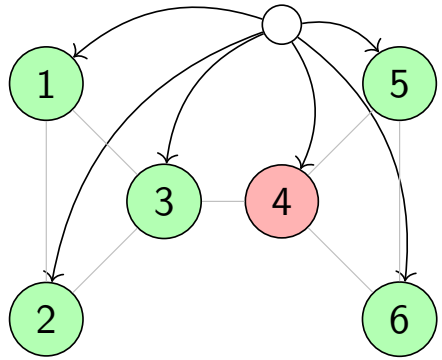

$$P(①,②,③,④,⑤,⑥) = \begin{cases} \frac{1}{Z} e^{J \sum_{ij} w_{ij} x_i x_j} \text{ (local)} \\ \frac{1}{Z} e^{B \sum_i x_i} \text{ (global)} \end{cases}$$

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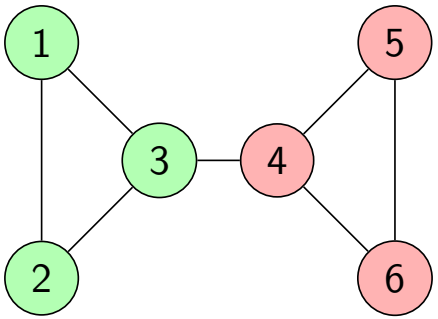

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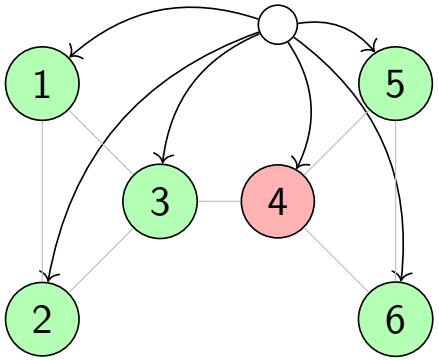

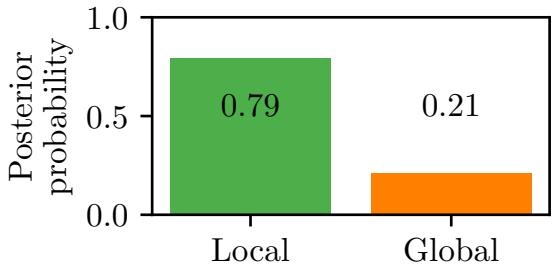

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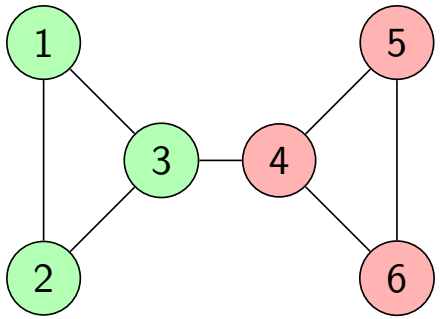

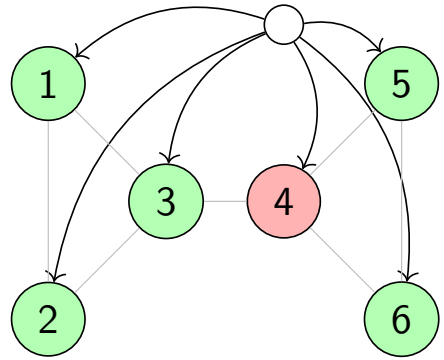

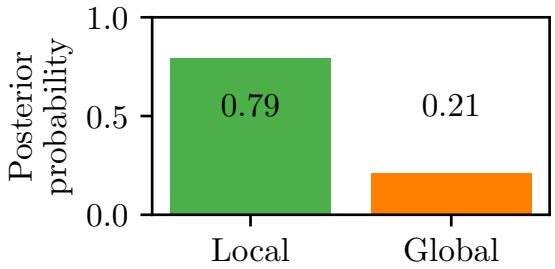

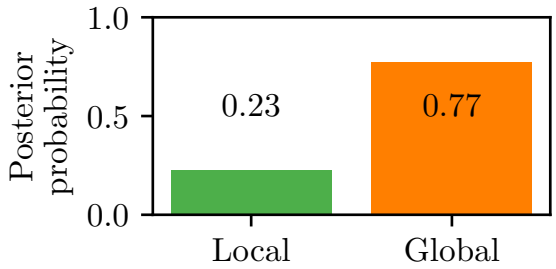

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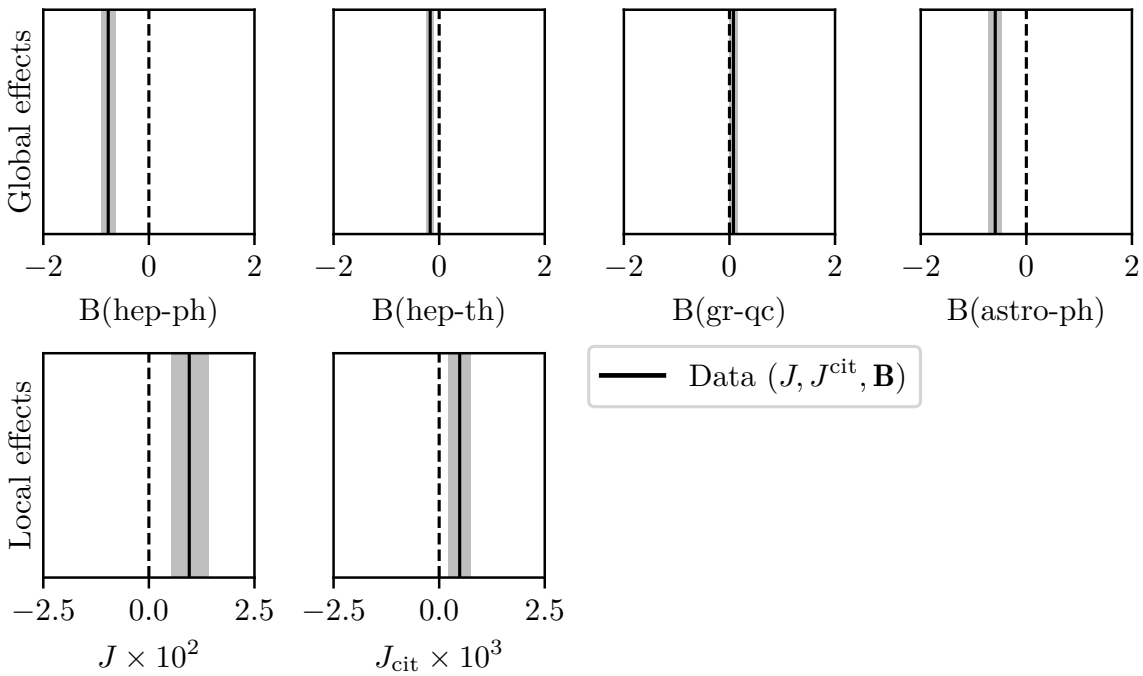
The competition between local and global coordination

Table: J measures the synergetic benefit of coordination, and (B_i, B_j) measures the inclinations of i and j, due to their positions in the cultural landscape.

	$x_j =$ ●	$x_j =$ ●
$x_i =$ ●	$(+J - B_i, +J - B_j)$	$(-J - B_i, -J + B_j)$
$x_i =$ ●	$(-J + B_i, -J - B_j)$	$(+J + B_i, +J + B_j)$

$$U(x_1, \ldots, x_n) = \underbrace{J \sum_{ij} w_{ij} x_i x_j}_{\text{local coordination}} + \underbrace{\sum_{i} k_i B_i x_i}_{\text{global coordination}}$$

Local and global preference formation: the metric signature



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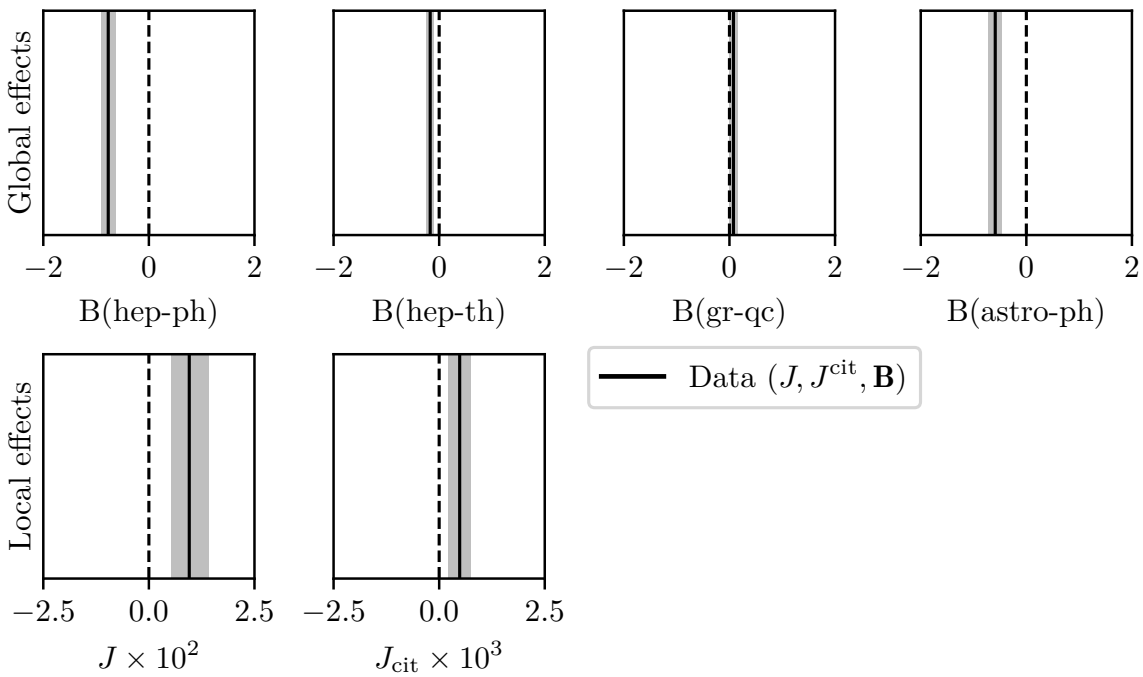
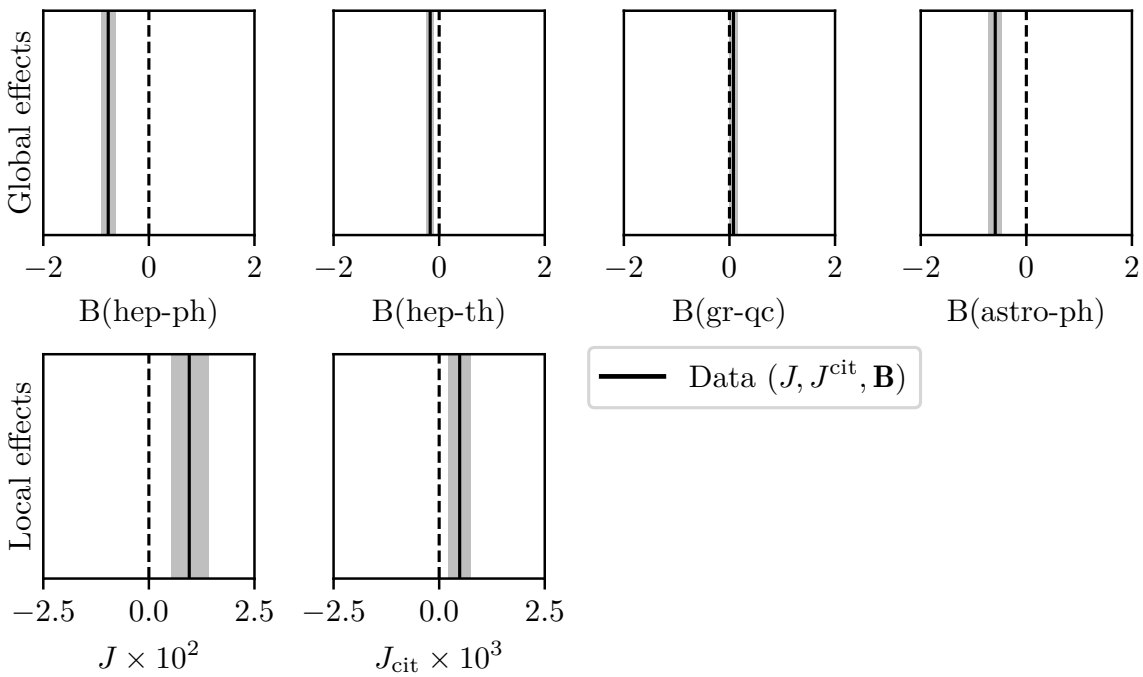


- Local effects exceed and reverse global effects for 7% of the sample of 2 277 authors ($\text{CI}_{95\%} = [3\%–15\%]$).

Local and global preference formation: the metric signature

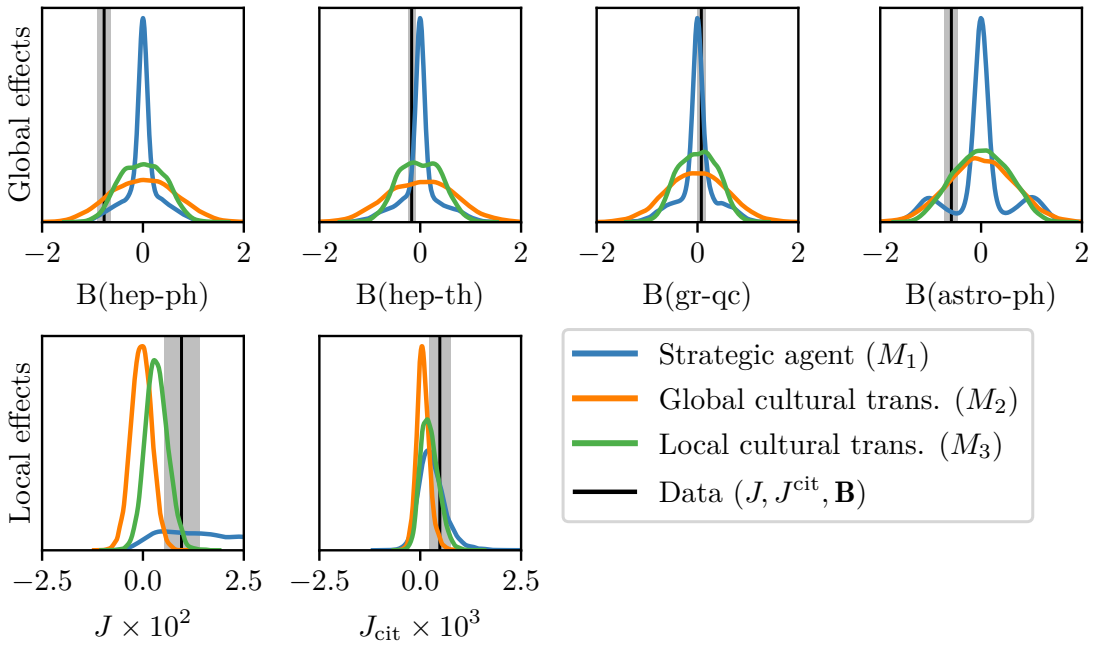


- Local effects exceed and reverse global effects for 7% of the sample of 2 277 authors ($\text{CI}_{95\%} = [3\%–15\%]$).
- Local effects marginally improve the model's predictive accuracy, from 67.7% to 70.2%.

How do physicists' preferences get formed?

- Let's three "realistic" models of the formation of physicists' preference towards the convention:
  1. A **"strategic agent" model** (M_1): individuals navigate three costs (coordination costs, switching costs, and maladaptation costs) depending on their collaborators' preferences and the research areas in which they publish.
  2. A **global cultural transmission model** (M_2): physicists settle once and for all for a specific convention with a certain probability that depends on their primary research area (textbooks?)
  3. A **local cultural transmission model** (M_3): physicists copy the preference of their first collaborator.

Recovering the mechanisms of preference-formation



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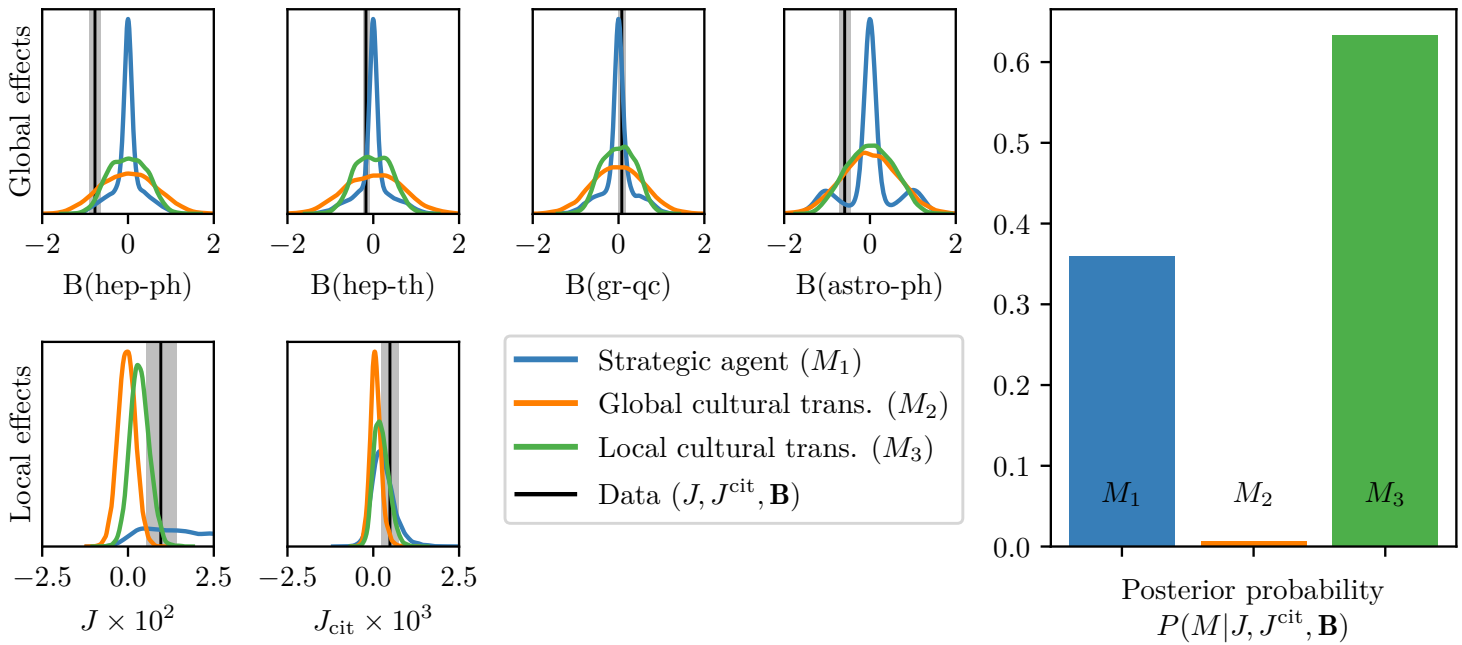

Figure: Simulation-based inference using the magnitude of local and global coordination as summary statistics.

Summary

Inferring preference-aggregation mechanisms in conflicts

How do scientists resolve conflicting preferences in collaborations?

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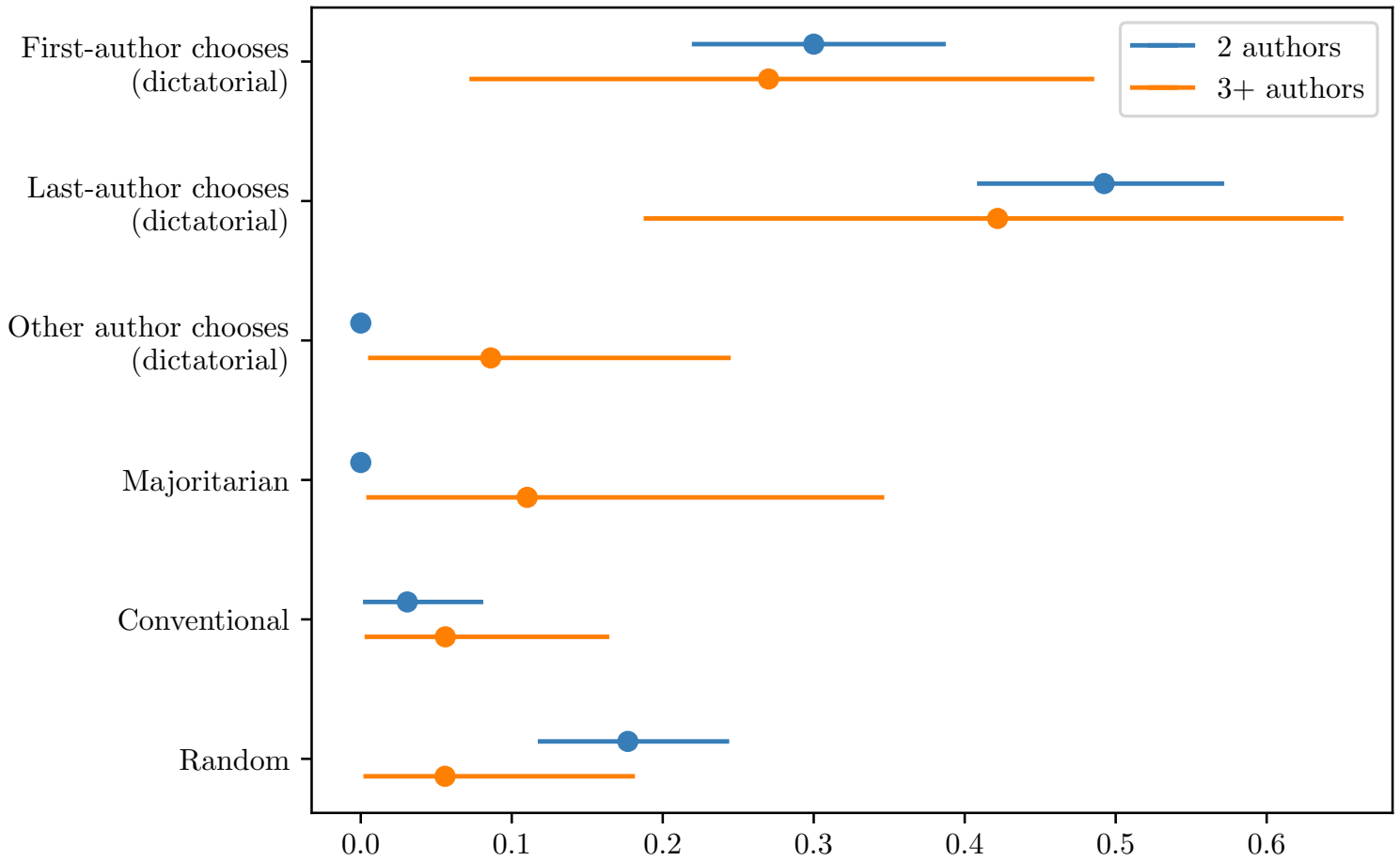
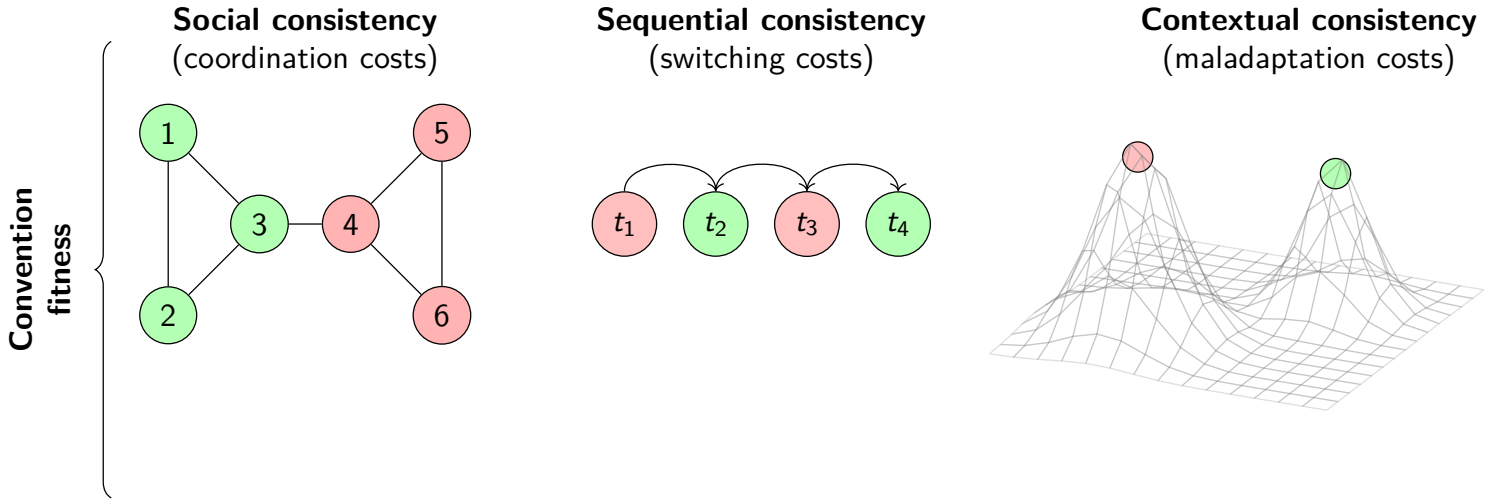
- We can estimate the prevalence of each strategy (π_k) given that they predict different outcomes (different probabilities $P(S_d|\sigma_1, \ldots, \sigma_n, A_k)$)

Inferring preference-aggregation mechanisms in conflicts



Conclusion


Social consistency
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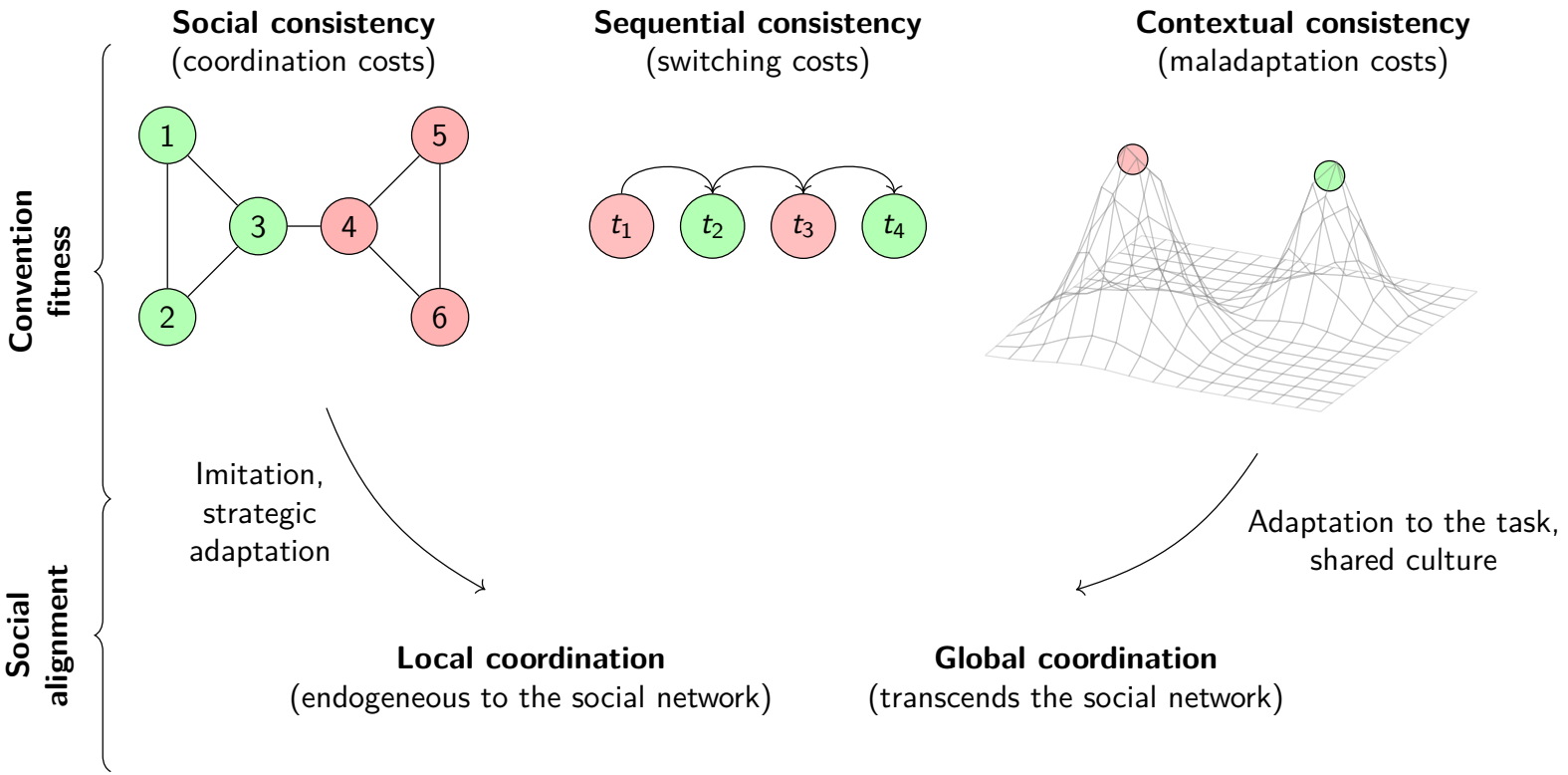
3
4
5
6
t_1
t_2
t_3
t_4

Conclusion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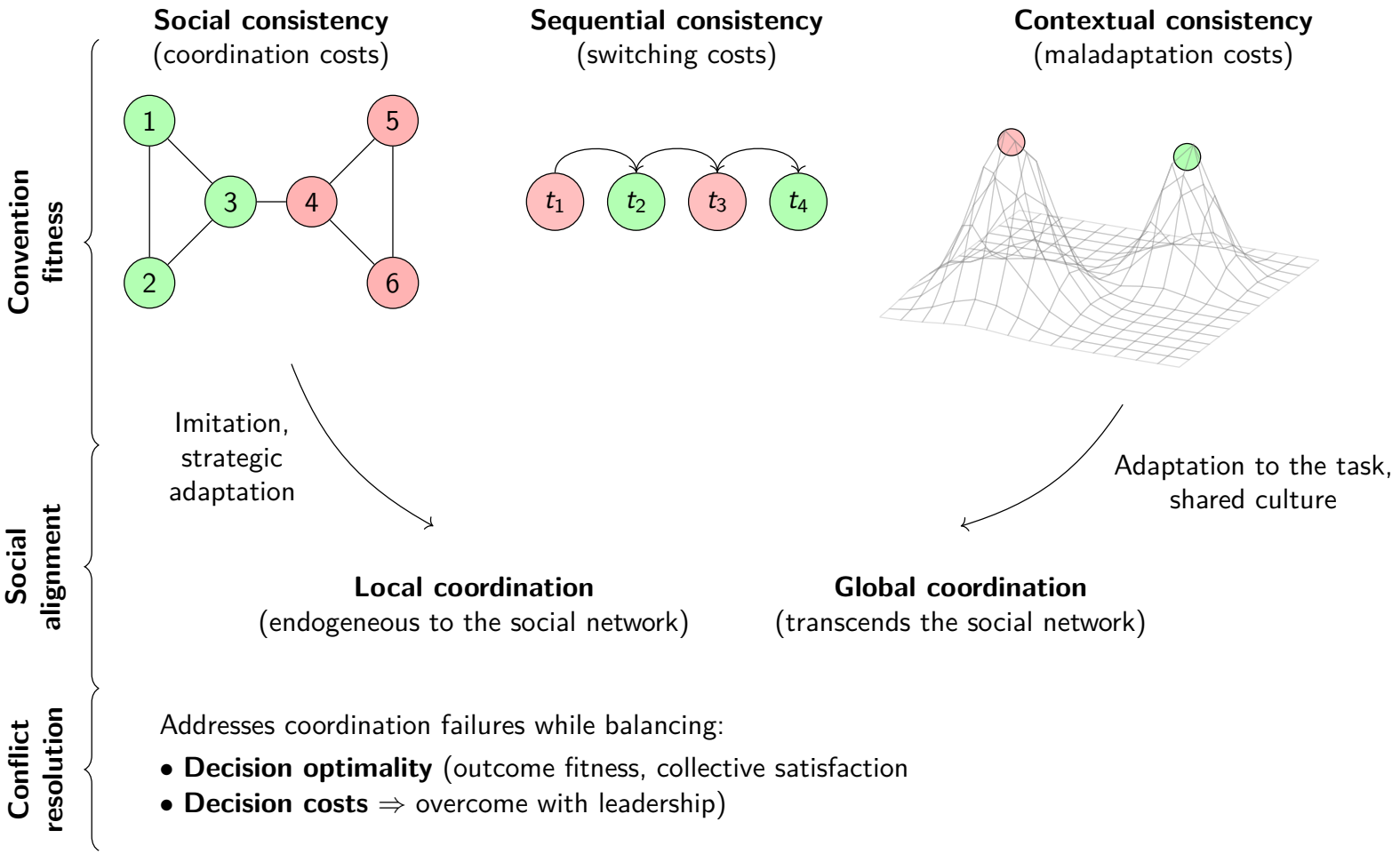
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Conflict resolution
Addresses coordination failures while balancing:
• Decision optimality (outcome fitness, collective satisfaction
• Decision costs ⇒ overcome with leadership)

Thank you

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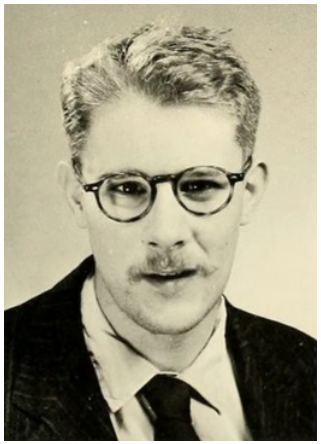
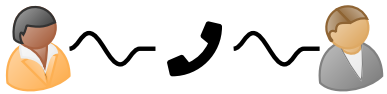
What are conventions about?

Language, culture, economics, science, ...



Lewis (1969)



	Bob calls back	**Bob awaits**
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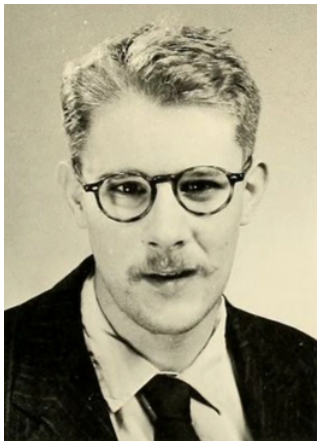

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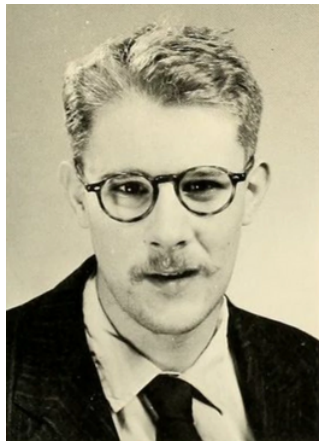
Duhem (1906)

Poincaré (1902)

Quine (1936, 1951)



Lewis (1969)

Conventionalism & epistemological holism

We can't reject individual beliefs, only collections of beliefs.

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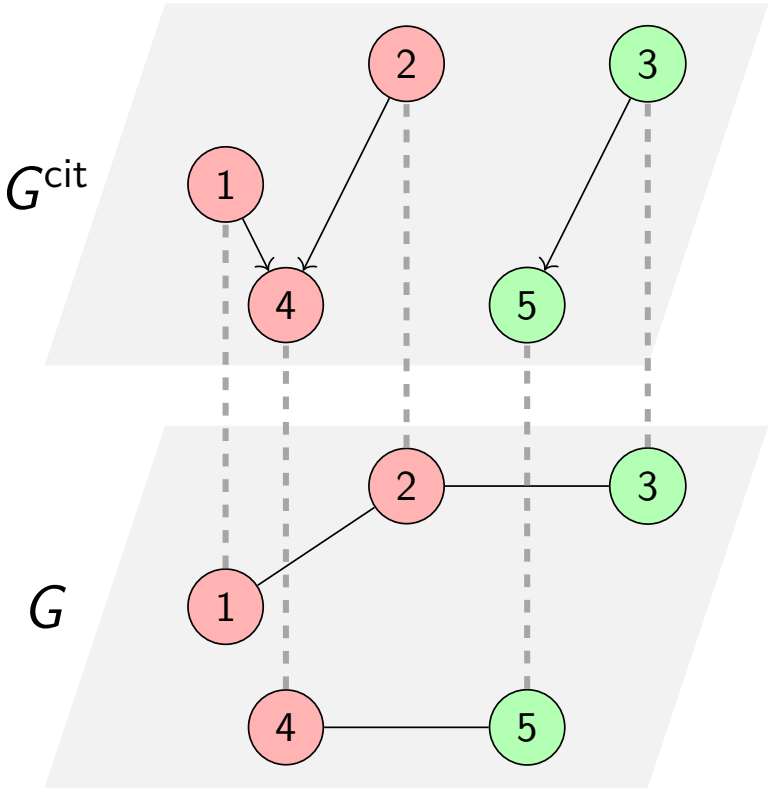
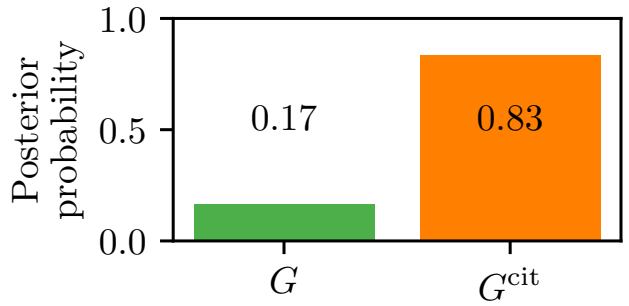
Identifying the relevant networks





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