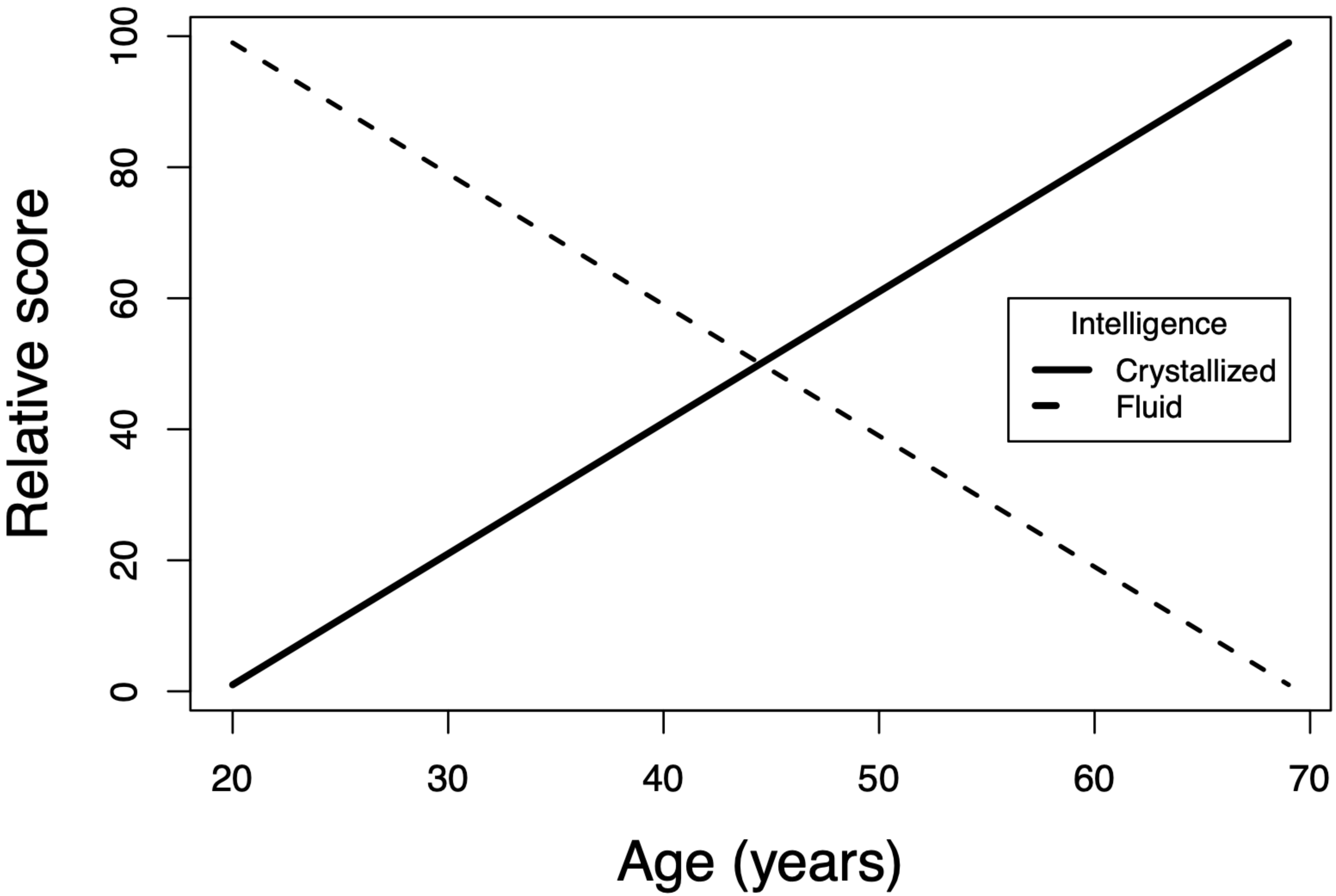
- Part 4 — Models and processes on networks

Every structure has a process story

An example with Aging

BNS Chapter 12; Hills (2025) Psychological Review.

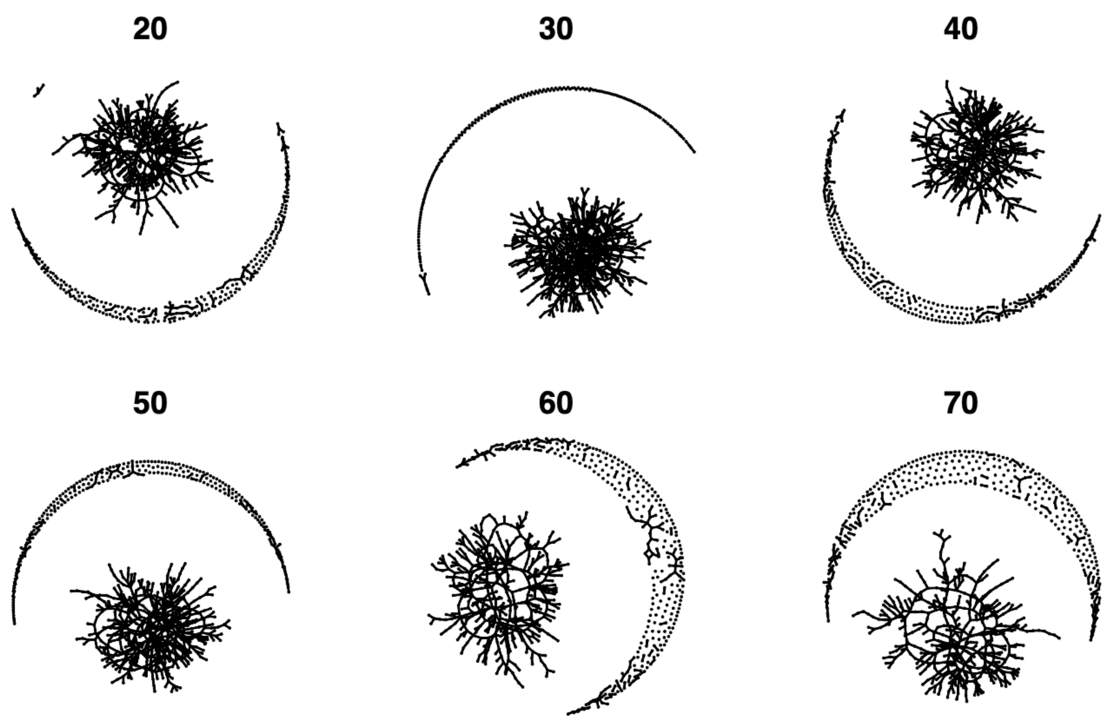
Aging

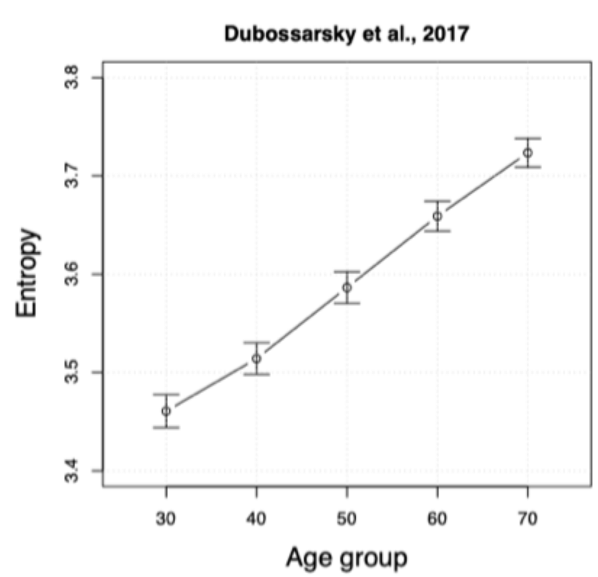


Relative score
0
20
40
60
80
100
20
30
40
50
60
70
Age (years)
Intelligence
Crystallized
Fluid

Networks become more sparse with age

Age



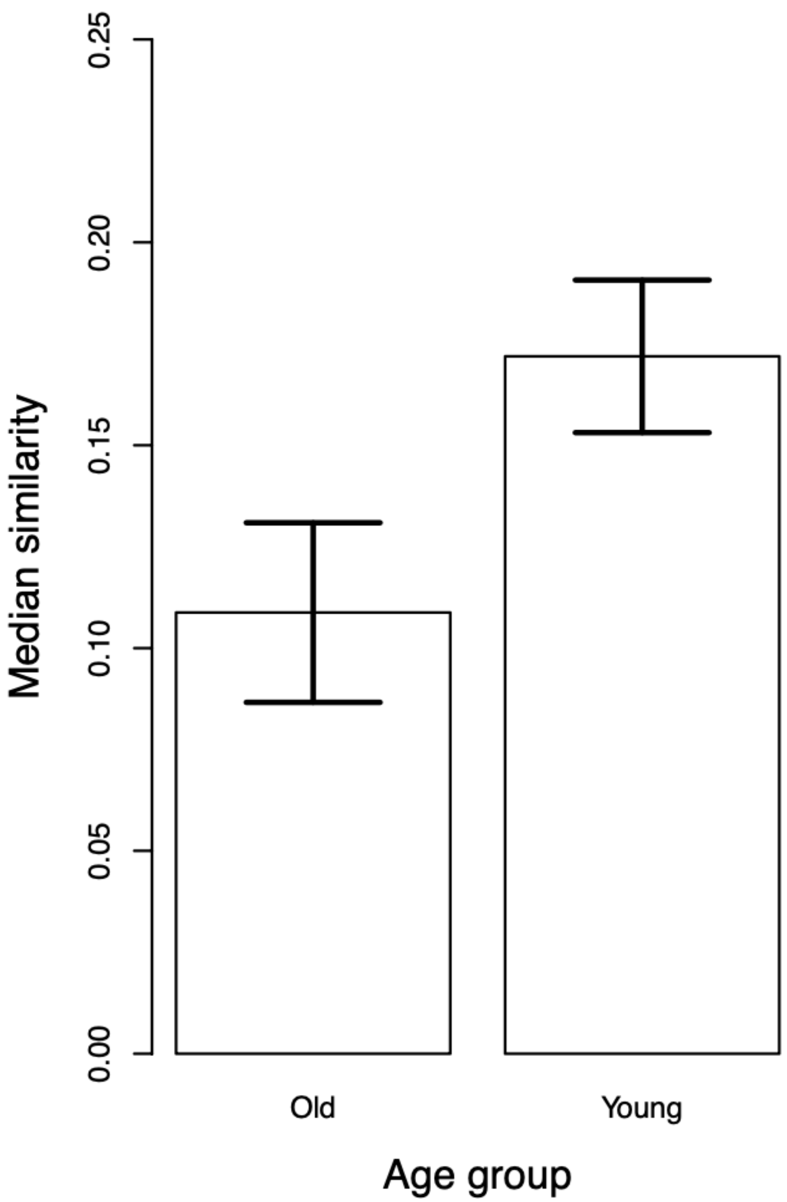


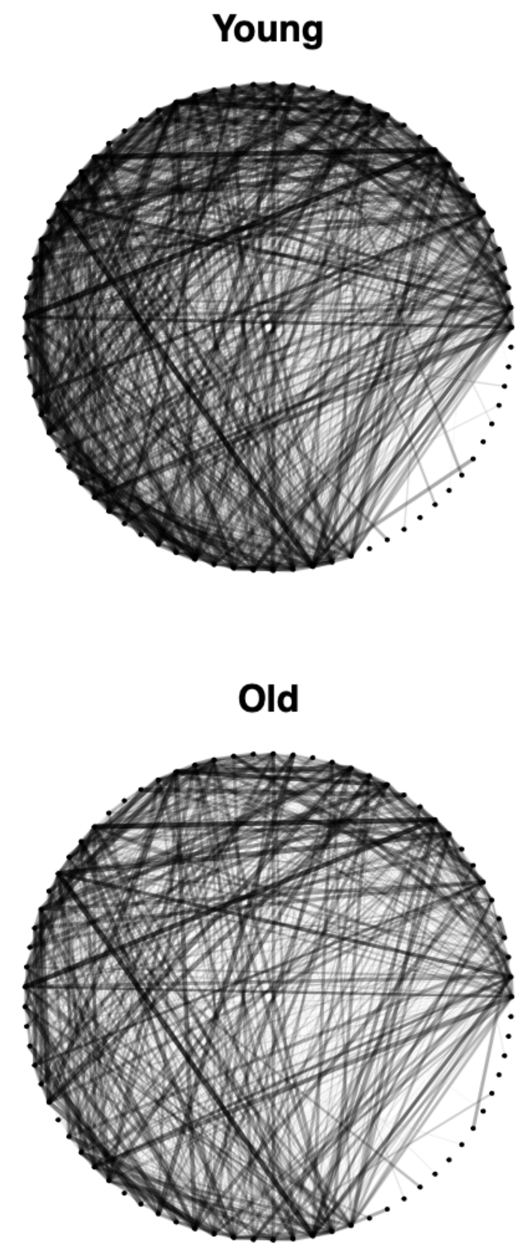
Networks created by thresholding free association networks with 420 cues connected together when they produce similar associates.

This is also associated with rising entropy. Associations become less predictable with age.

Dubossarsky, De Deyne, Hills, 2017

Older adults say that animals are less similar to one another





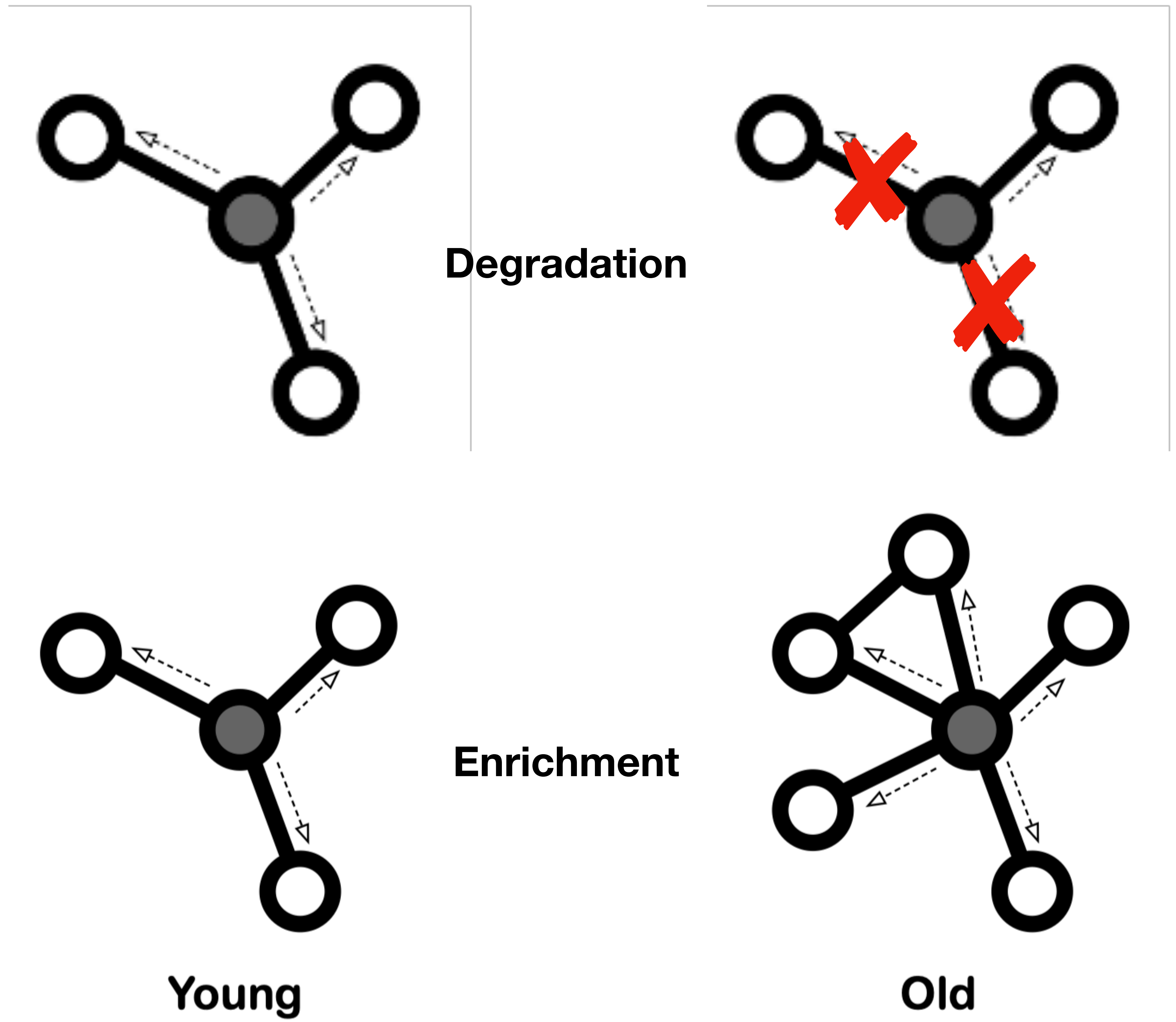
Older and younger adults rated the similarity of multiple pairs of animals over a period of several weeks.

Wulff et al., 2022

What might cause these effects?

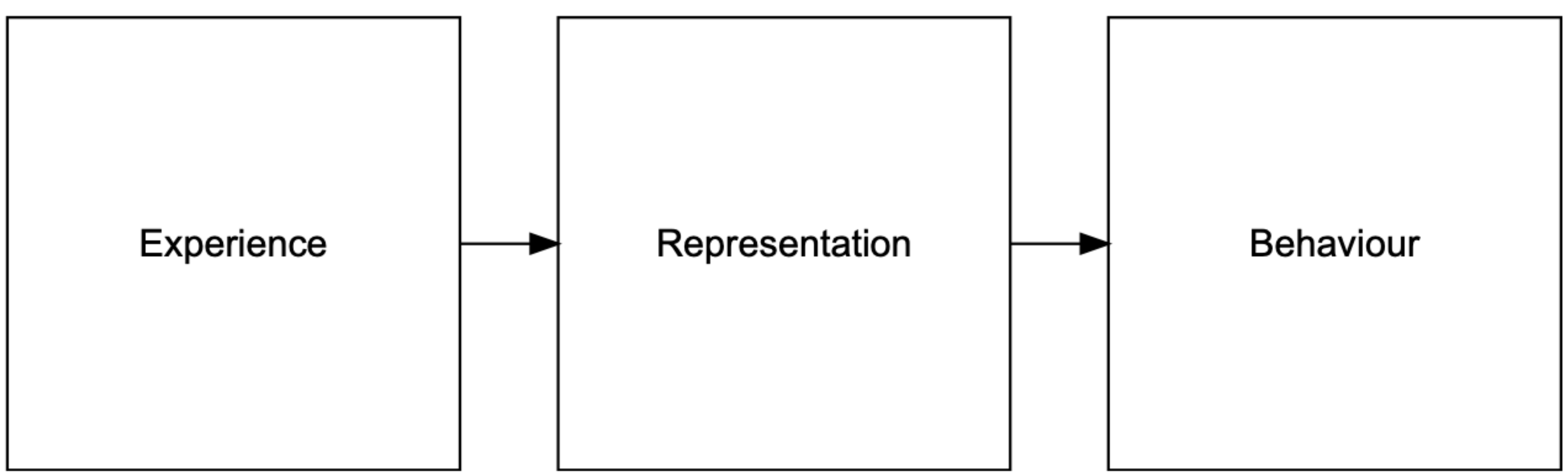
The Aging Mind—two competing explanations

- *Common cause theory of aging*
- *Enrichment*


Degradation
Enrichment
Young
Old

We can model these effects using standard models in cognitive science

- We will use a Rescorla-Wagner learning process
- That learns an environmental representation (which we can also degrade)
- Then the individual will make decisions based on their representation using spreading activation

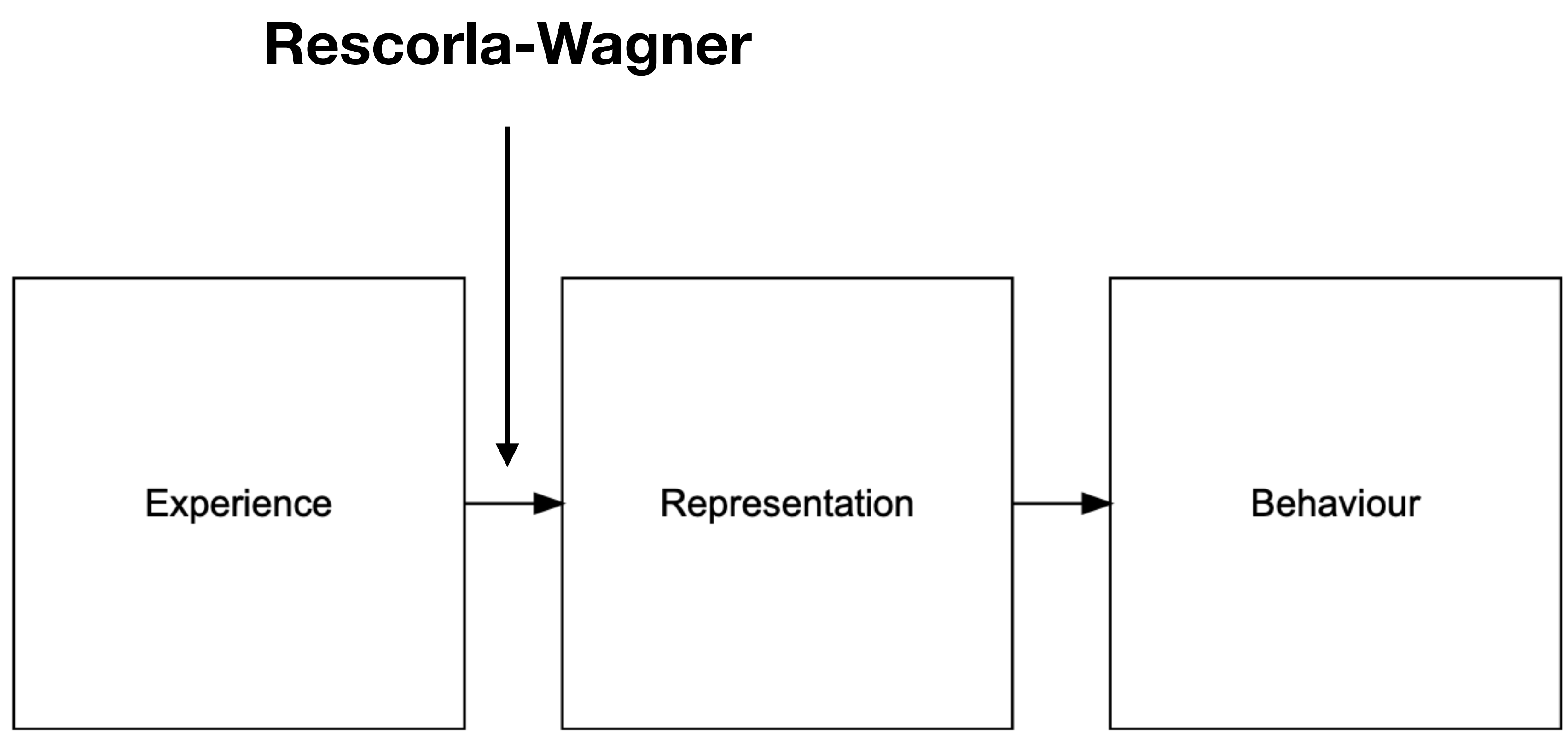


Rescorla-Wagner learning
(Prediction error modeling)

$$\Delta V_{C\to U} = \alpha_C \beta_U (\lambda_U - V_{C\to U})$$

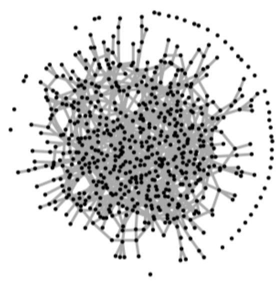
$$V_{C\to U,t+1} = V_{C\to U,t} + \Delta V_{C\to U,t}$$

- λ_U is the observed value
- $V_{C\to U}$ is the expected
- The difference is the prediction error: $\lambda_U - V_{C\to U}$
- This updates $V_{C\to U}$ to approach the true value of λ_U.


Rescorla-Wagner
Experience
Representation
Behaviour

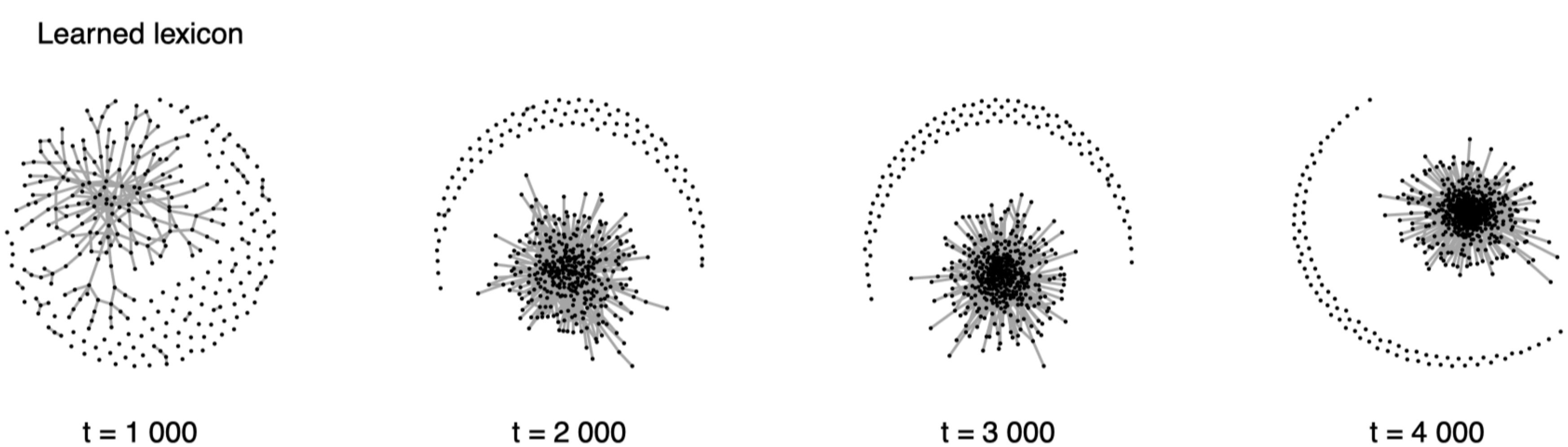
The story of aging has formation

SUPPOSE YOU JUST LEARN FROM EXPERIENCE WITH THE WORLD



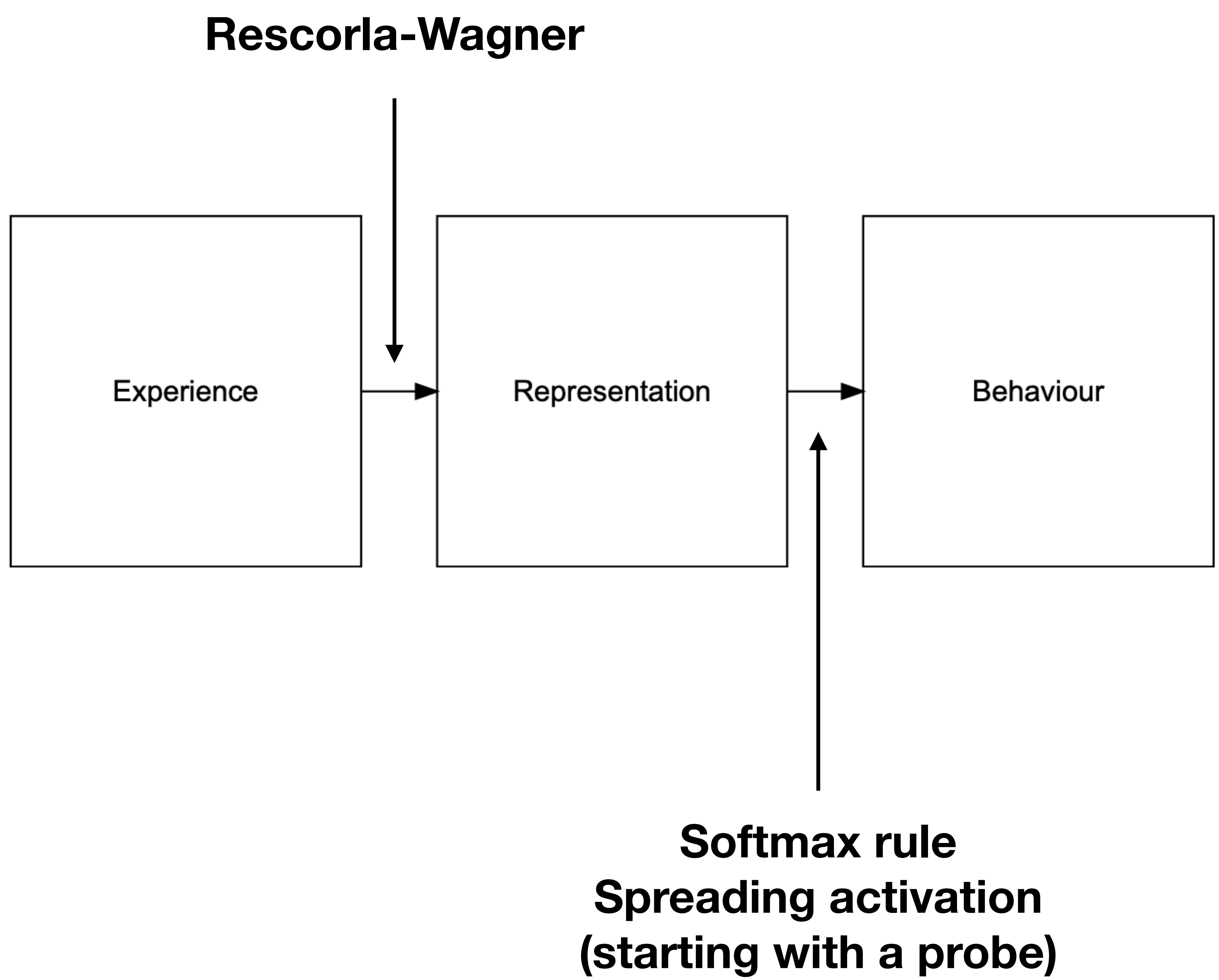
The world is a network of associations

OVER TIME YOUR REPRESENTATION OF THE WORLD IS ENRICHED



The size of the giant component increases, number of edges increase, node strength increases, etc.

We're letting 1000 learning events happen over each of 4 epochs.



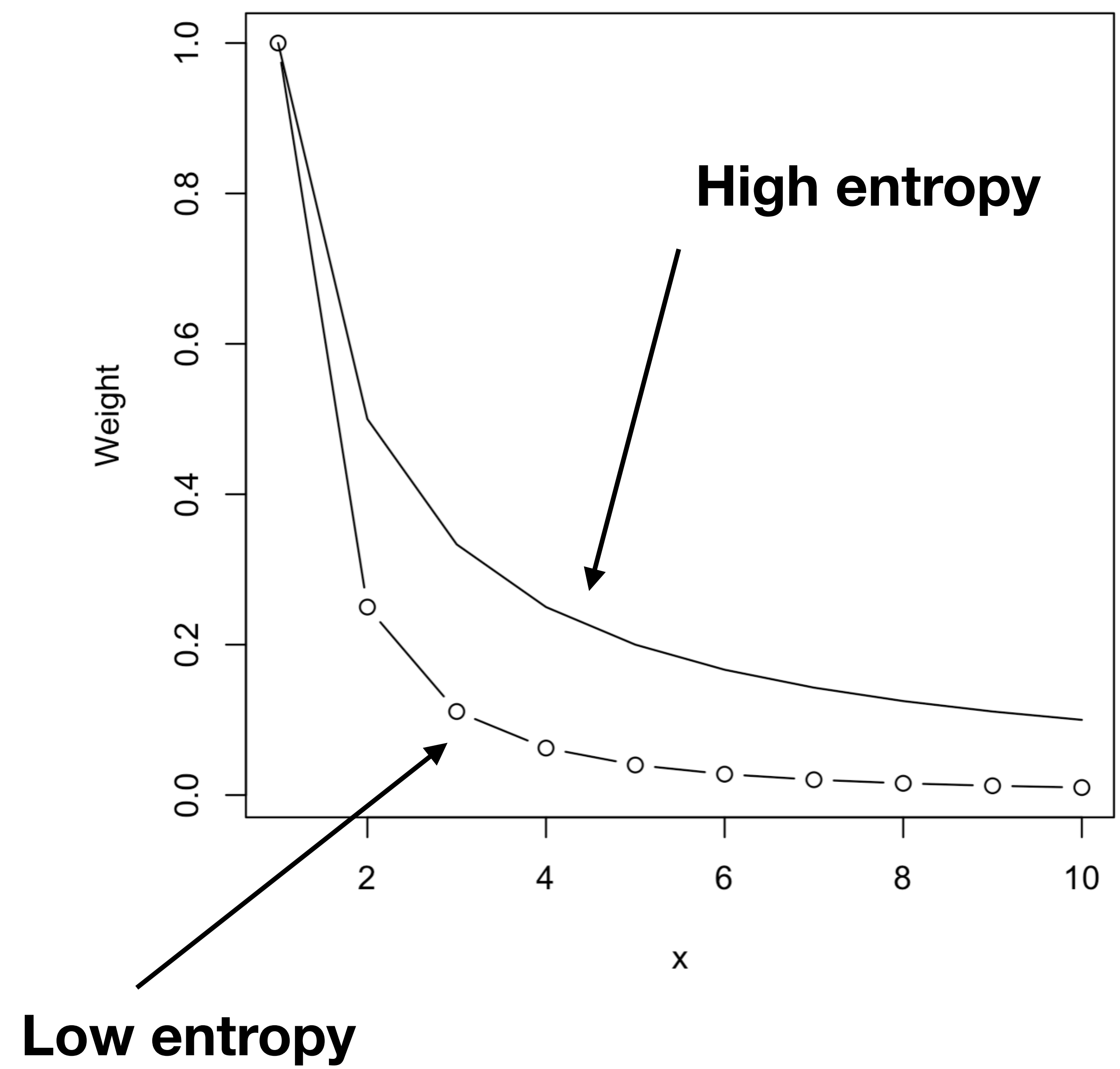
Rescorla-Wagner
Experience
Representation
Behaviour
Softmax rule
Spreading activation
(starting with a probe)

How do we model entropy?

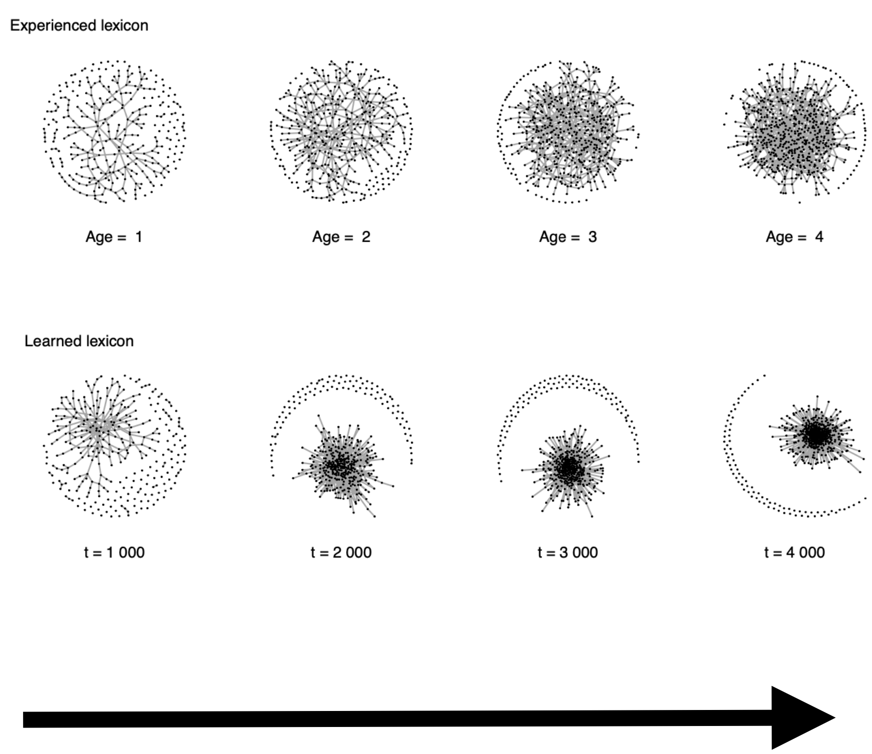
- p = vector of normalized edge weights from a cue

$$H = -\sum_{i=1}^{k} p_i log(p_i)$$

This is basically like letting a softmax rule run thousands of times to capture the true probabilities of every association.



With increased learning, entropy increases



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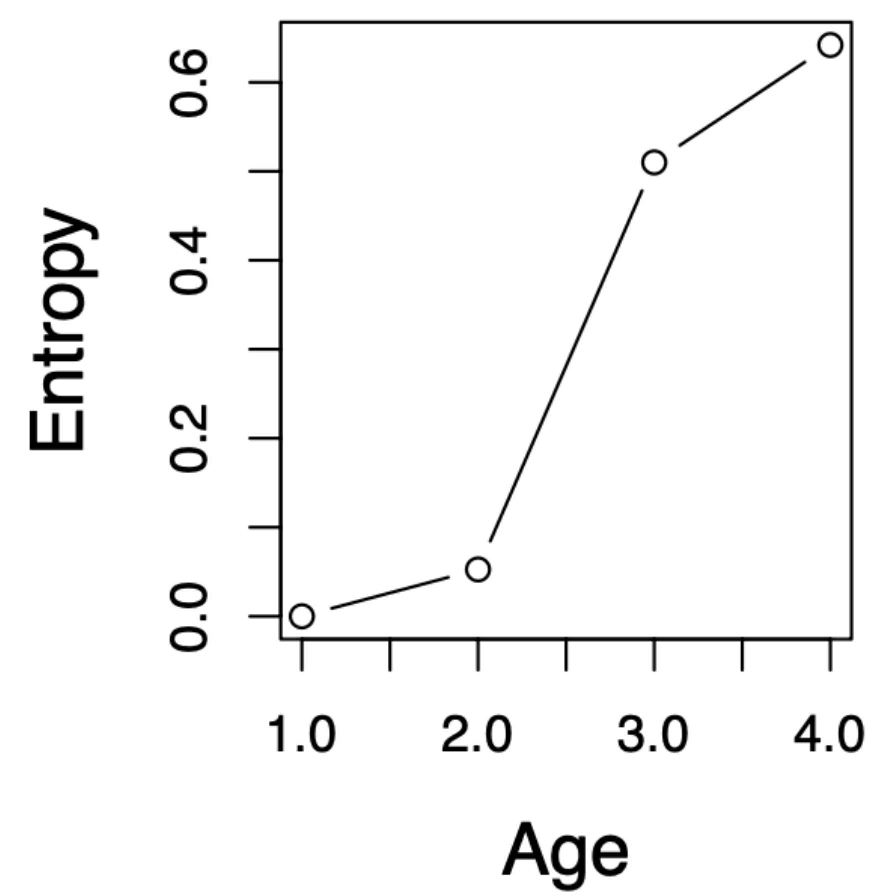
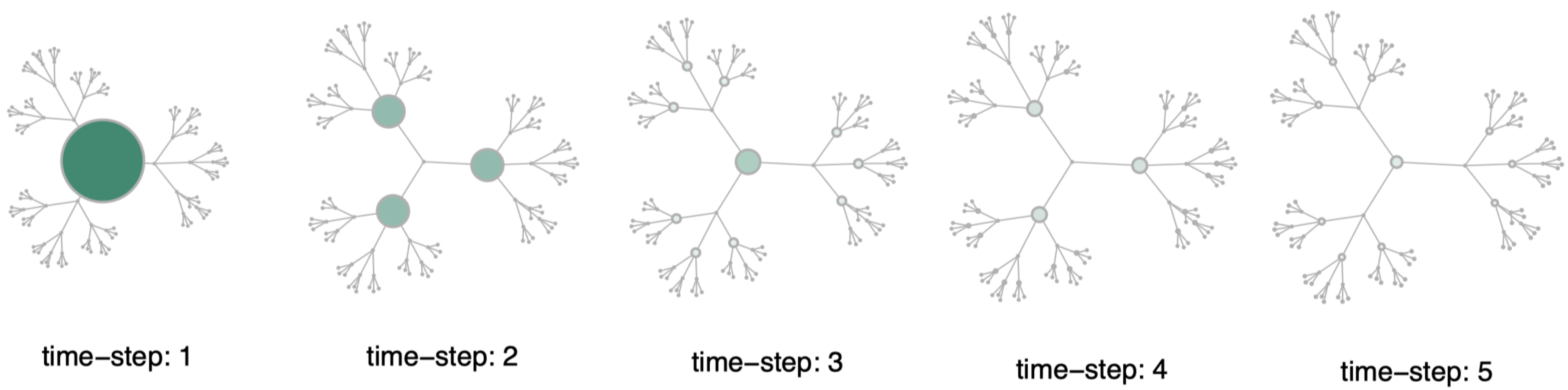


How do we model similarity judgments?

Spreading activation

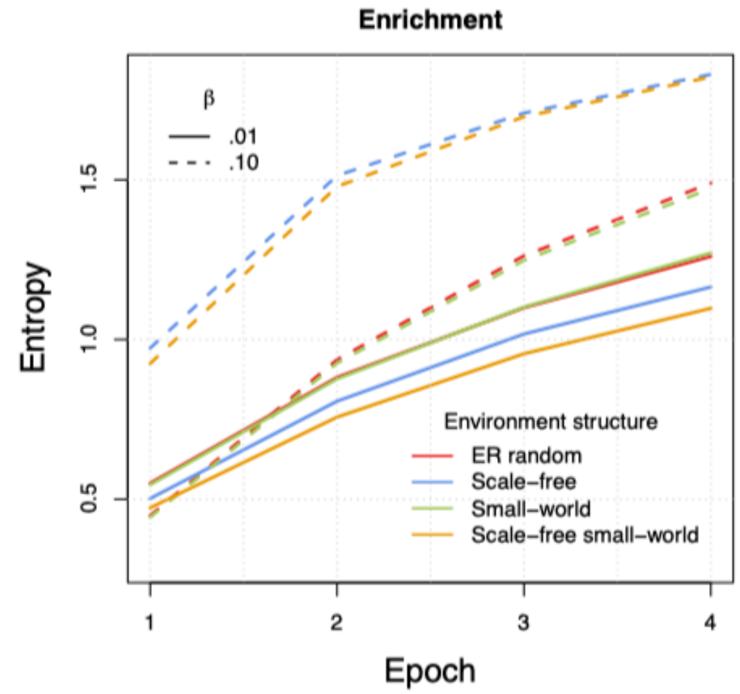


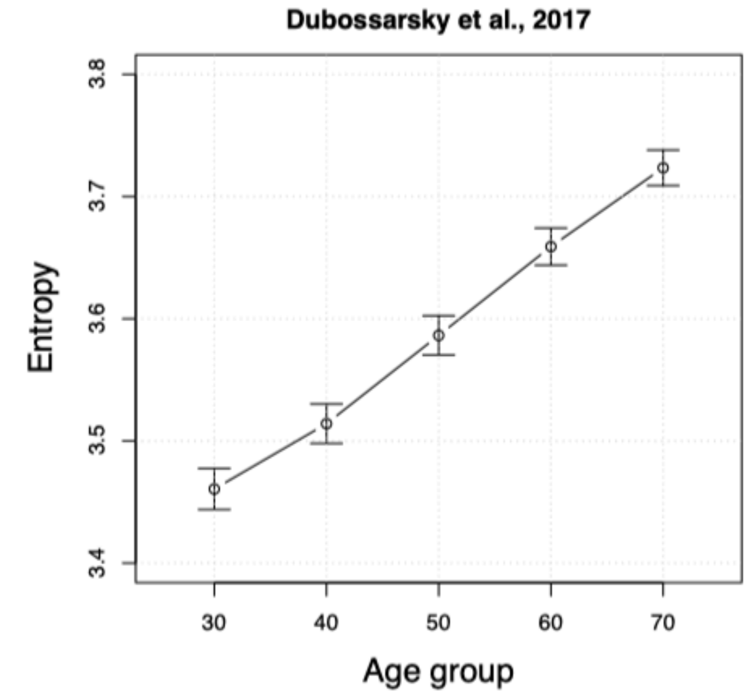
Spreading activation usually works by releasing activation at one node, letting it flow along edges, and then measuring it at other locations.

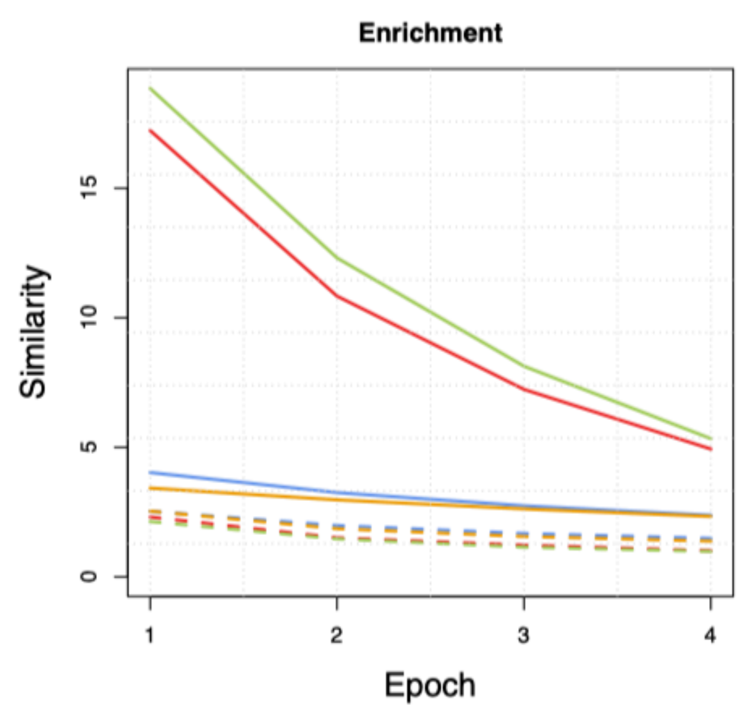
If we do it both ways, we have a measure of co-activation (similarity):

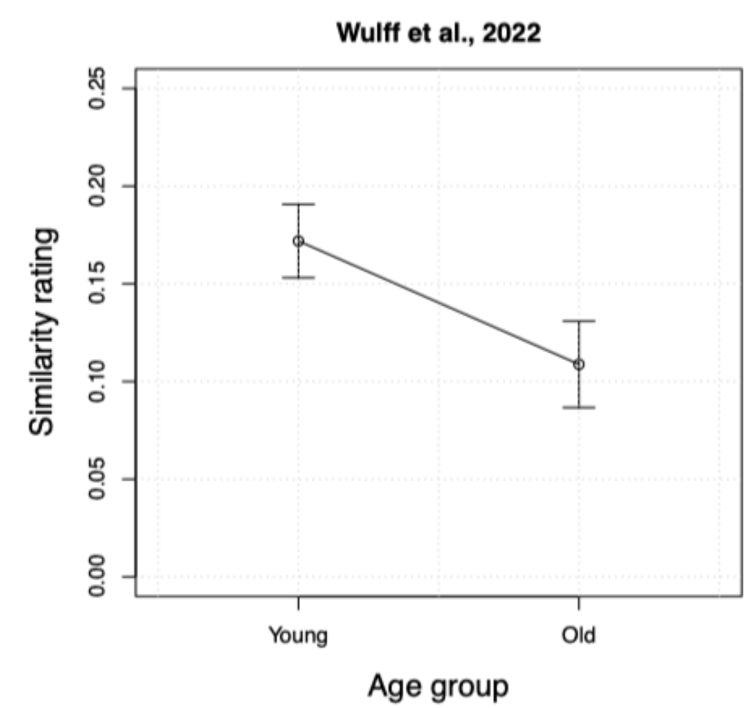
$$S = A_{j \to k} + A_{j \to k}$$

Enrichment increases entropy and reduces similarity judgments









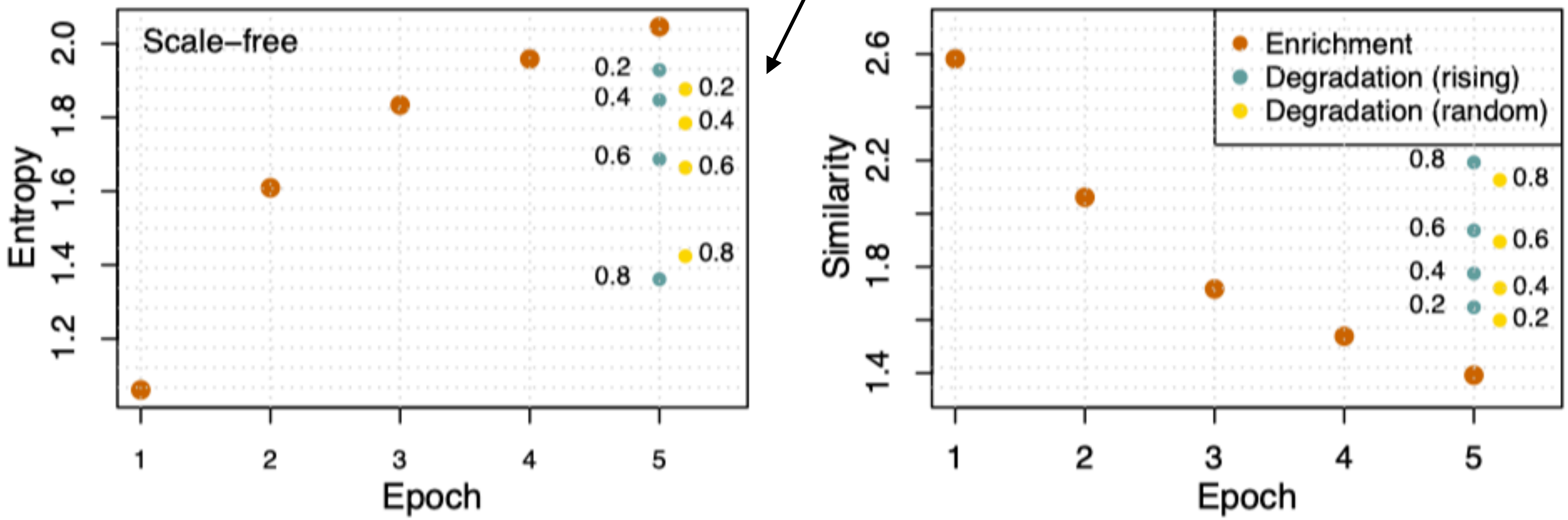
So far we have a nice proof of principle model. It works.

But what about degradation? Might that work.

We can compare degradation with enrichment.

What happens when we compare enrichment and degradation?

proportional degradation



Degradation produces the opposite pattern to that observed in the empirical data. Entropy falls and Similarity rises.

SUMMARY

- We can model the lifelong development of a cognitive representation.
- We can model the impacts of that representation on behavior.
- This follows nicely calls from the cog sci community to model not only the representation but the processes underlying behavior.

Summary of aging as enrichment

- We can model the lifelong development of a cognitive representation.
- We can model the impacts of that representation on behavior.
- This follows nicely calls from the cog sci community to model not only the representation but the processes underlying behavior.

Lesson two: Social structure can explain false beliefs

The Dark Side of Information Proliferation

Perspectives on Psychological Science
1–8

DOI: 10.1177/1745691618803647
www.psychologicalscience.org/PPS
SAGE

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Abstract
There are well-understood psychological limits on our capacity to process information. As information proliferation—the consumption and sharing of information—increases through social media and other communications technology, these limits create an attentional bottleneck, favoring information that is more likely to be searched for, attended to, comprehended, encoded, and later reproduced. In information-rich environments, this bottleneck influences the evolution of information via four forces of cognitive selection, selecting for information that is belief-consistent, negative, social, and predictive. Selection for belief-consistent information leads balanced information to support increasingly polarized views. Selection for negative information amplifies information about downside risks and crowds out potential benefits. Selection for social information drives herding, impairs objective assessments, and reduces exploration for solutions to hard problems. Selection for predictive patterns drives overfitting, the replication crisis, and risk seeking. This article summarizes the negative implications of these forces of cognitive selection and presents eight warnings that represent severe pitfalls for the naive “informavore,” accelerating extremism, hysteria, herding, and the proliferation of misinformation.

False consensus effect

Most people tend to overestimate the number of people who share their views.

Ross, Greene, and House (1977) found that people's beliefs about others were strongly biased in favor of their own views.

People who themselves favored public spending on an unmanned space program believed that view was more popular than it actually was, and vice versa.

Can we model this as a function of opinion dynamics?

Schelling Segregation Model

(People only need a preference for equal representation to get segregation)

Two individuals chosen at random, swap positions if they are in the minority.

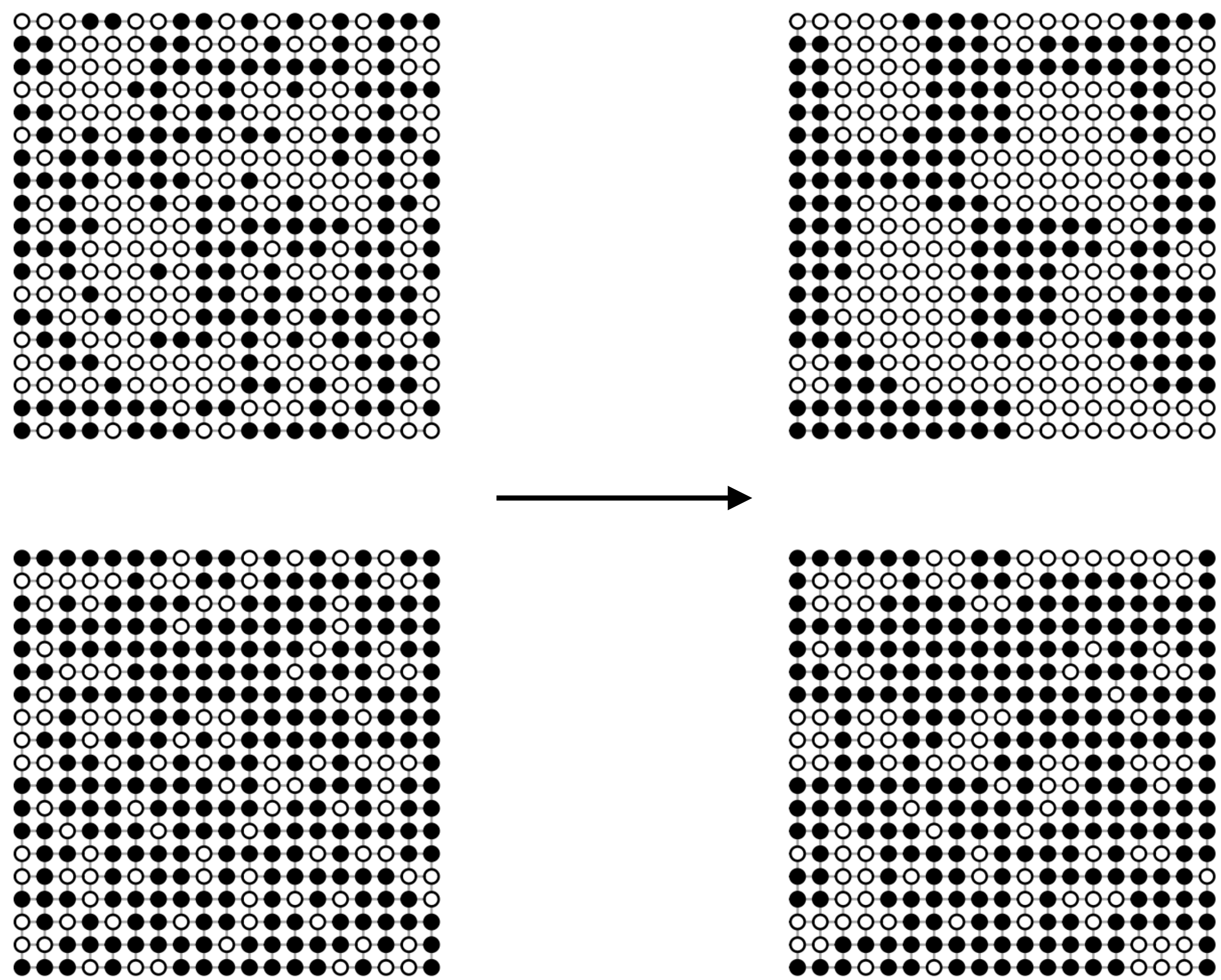
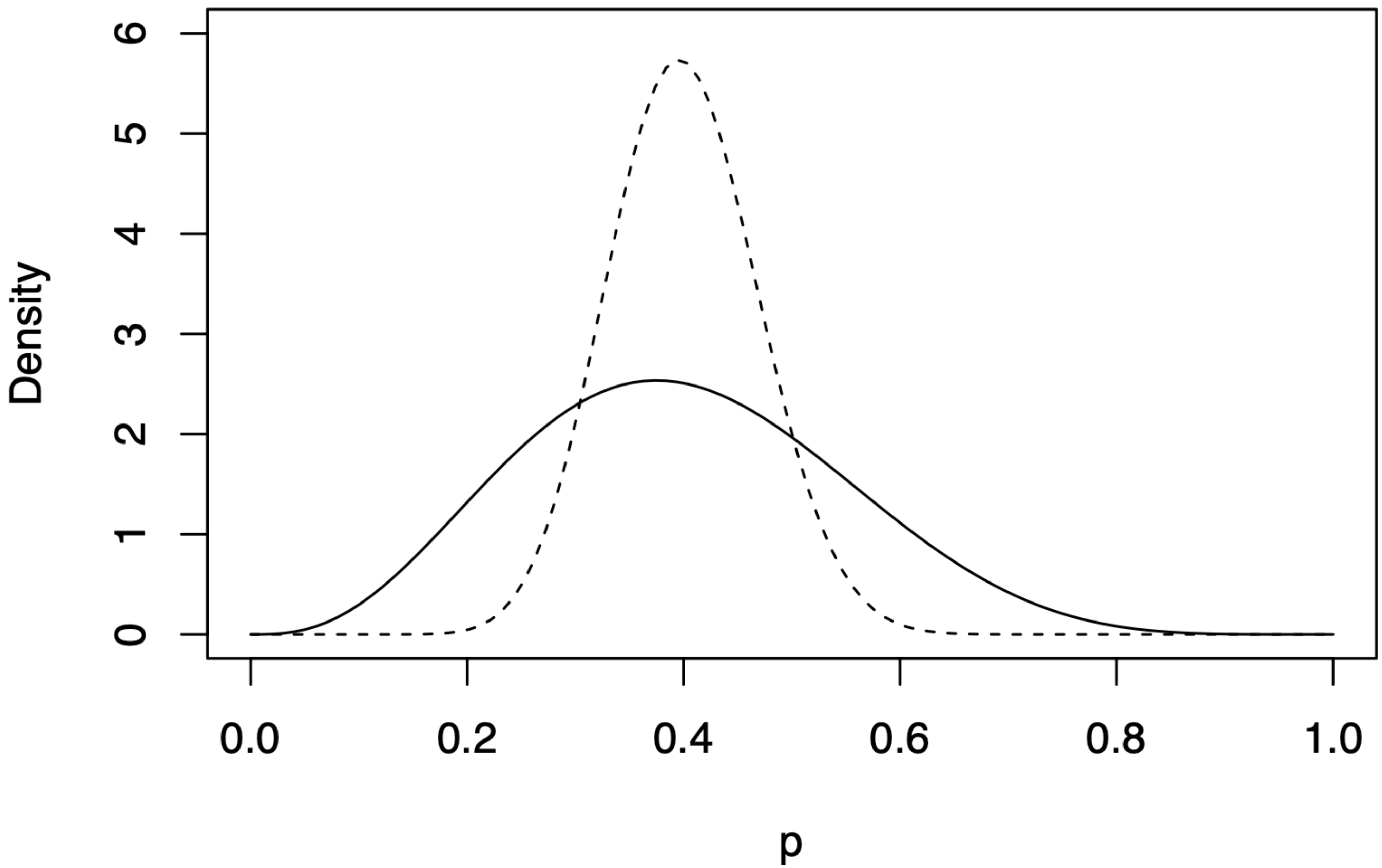


Figure 1: Thomas Schelling's segregation model. All agents prefer to move if they are in the minority color among their neighbors. At each timestep, one white and one black agent who are willing to move are chosen at random and swapped. Panels on the left show the random starting arrangements. Panels on the right show the arrangments after all available swaps are made to the corresponding panel on the left. The top panels show a 50:50 distribution of white to black nodes. The bottom panels are 30:70, white to black.

What if we gave people beliefs?

Social Sampling Theory

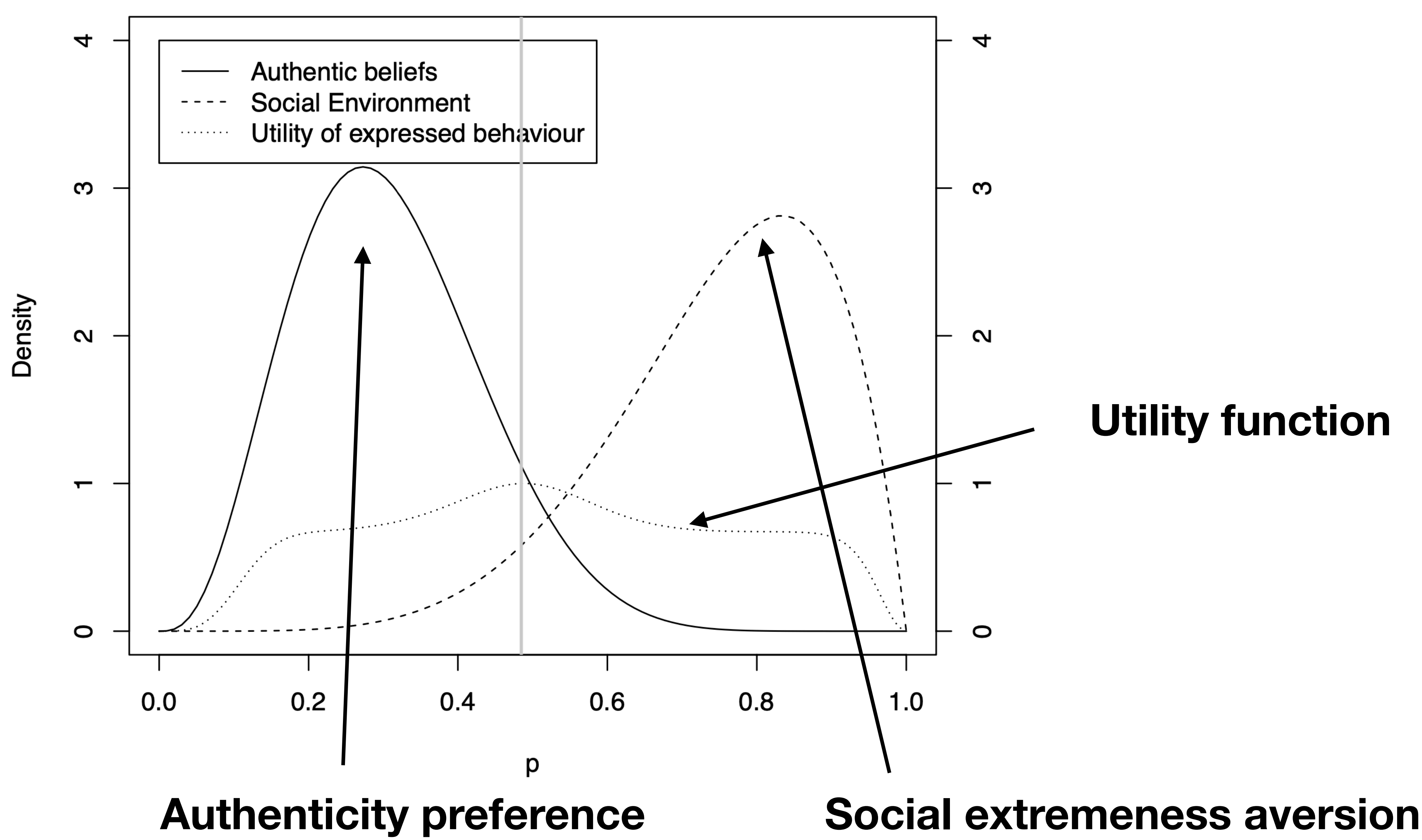
Brown, Lewandowsky, and Huang (2022)



Beliefs are beta distributions

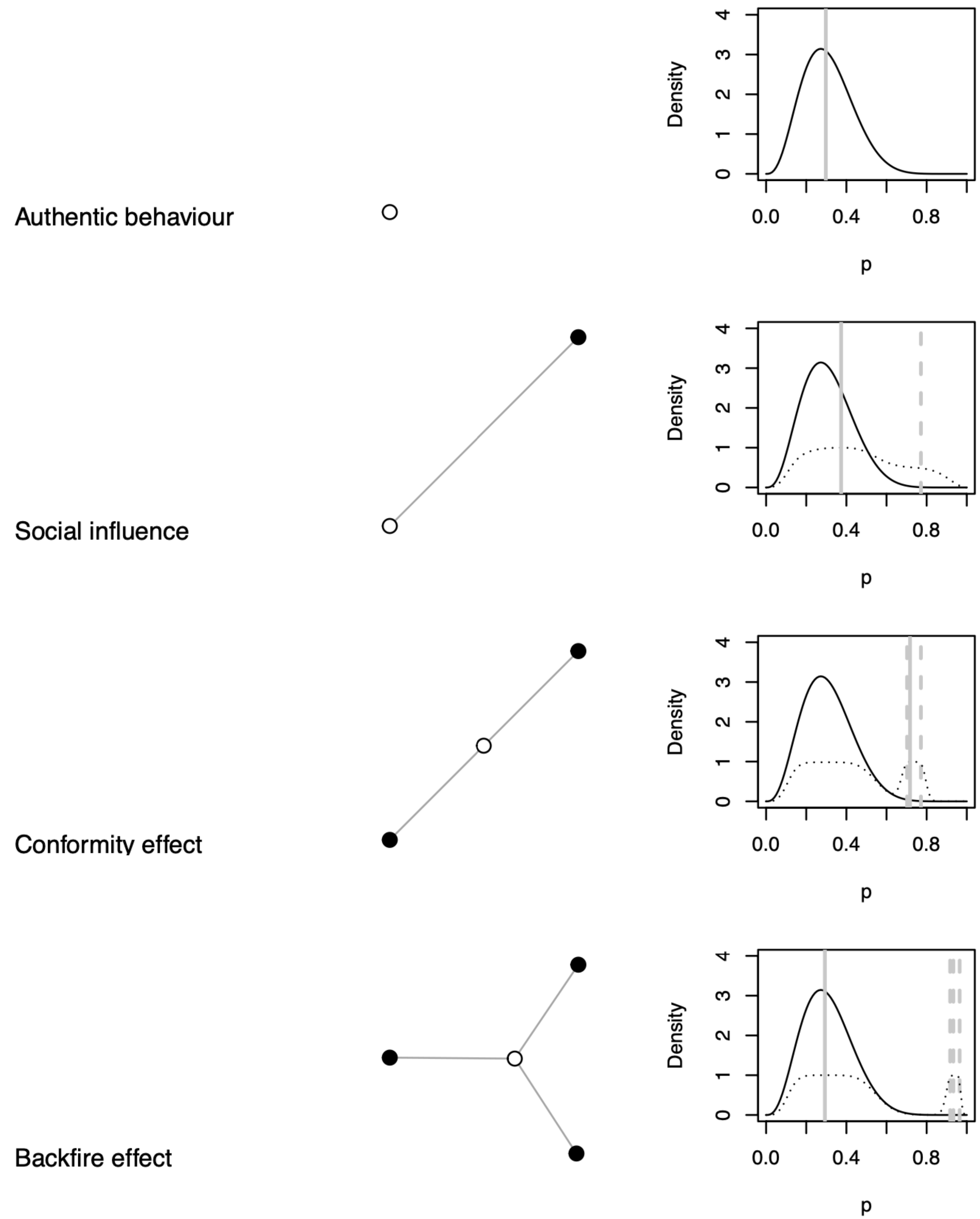
Behaviors are a function of authentic beliefs and social environment

Authenticity preferences plus social extremeness aversion

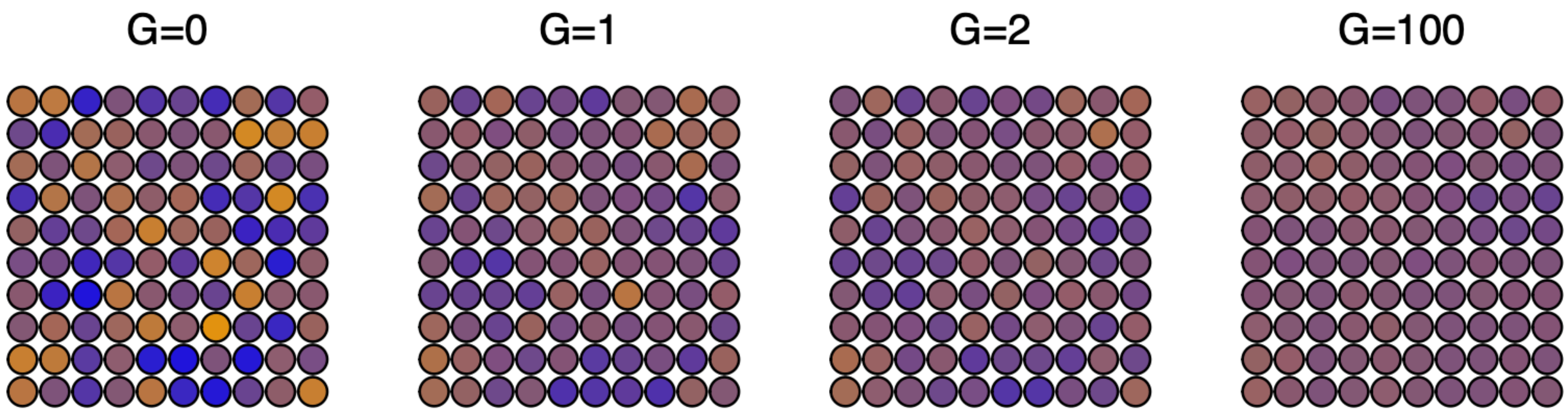


Social Sampling Theory

An individual's expressed behavior is a trade-off between authentic behavior and social influence.

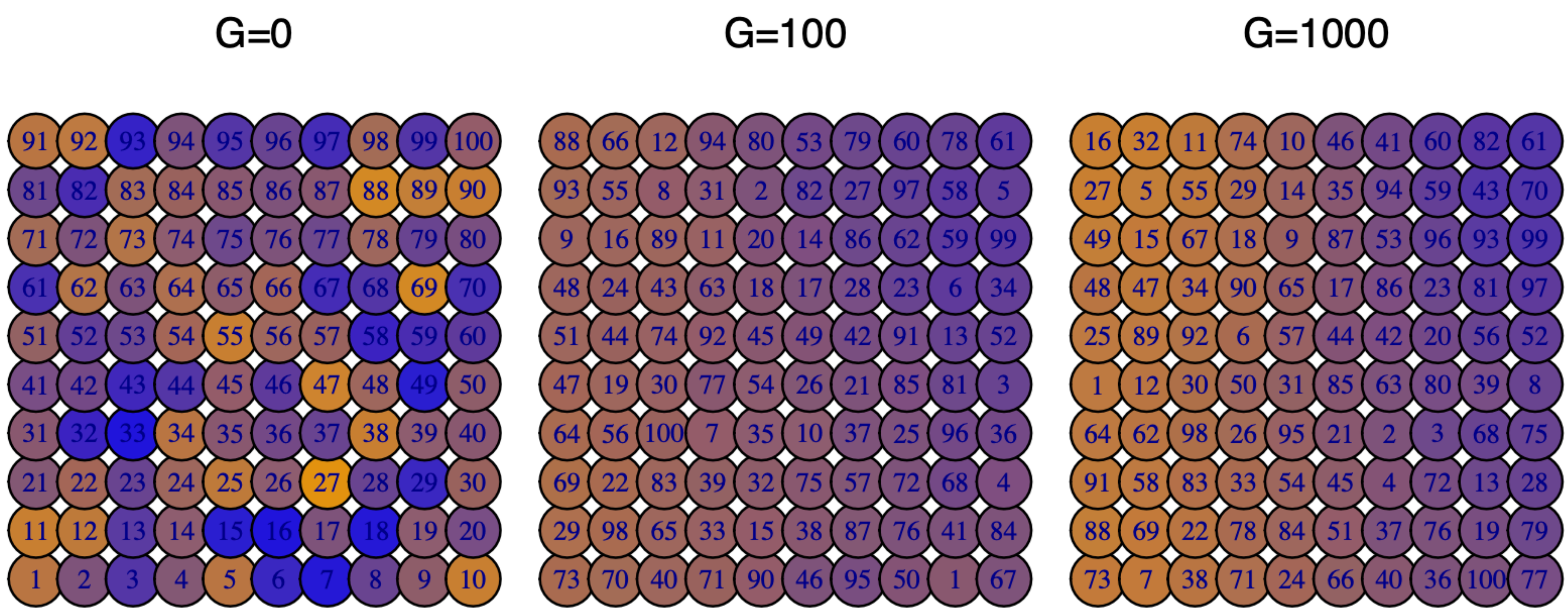


Social beliefs on a lattice

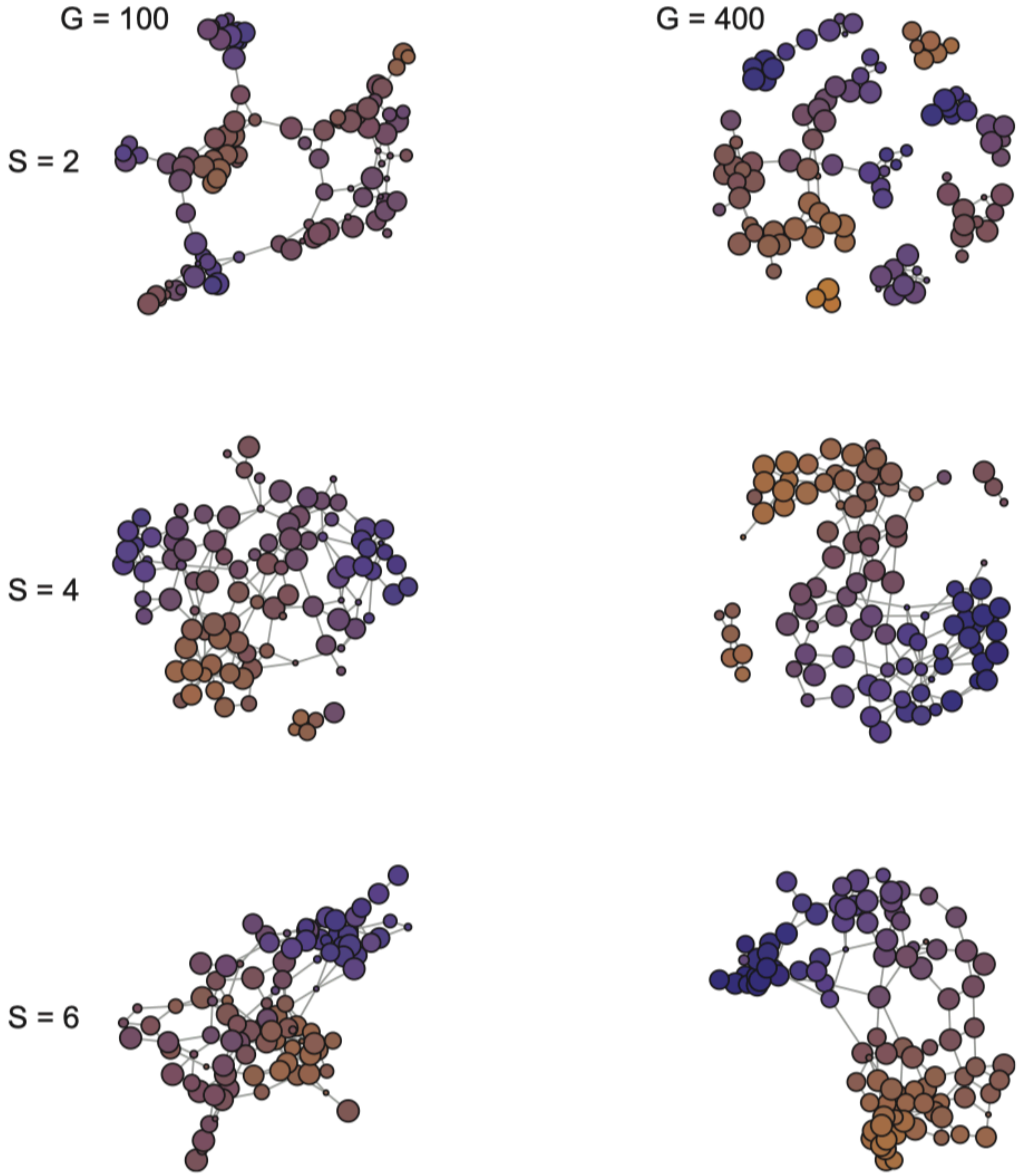


Without movement, people tend to approximate their environment, we lose polarity, and we get a kind of mush.

Social beliefs with Schelling Migration



With Schelling Migration, people can move and some find good homes (1), though some become stuck (7).



Letting people form and destroy edges leads to various structures depending on the depth of search (what is the path length to new nodes they could connect to).

Figure 7: Search and Social Sampling Theory. Starting with a 10 x 10 lattice, agents adjust expressed behaviour to their local neighbors and authentic attitude. Then agents search through local neighbors to identify the individual with the expressed behaviour that is the smallest distance from their authentic attitude. If this behaviour is closer to their authentic attitude than the most distance behaviour among their existing neighbors, they rewire the edge to ther existing neighbor, swapping it to the more authentic distance neighbor. Agents search to a path length, S, of 2,4,6, or 10 edges. Colors indicate the expressed behaviour and size indicates the relative utility.

Perceived Normality

(a structural explanation of false consensus)

$$\mathcal{N}_i = 1 - |1 - \frac{2(r_i - 1)}{k_i}|$$

rank-based measure to evaluate where people are relative to their neighbors.
If r_i = 1, then N = 0
If r_i = k+1, then N = 0
if r_i = (k/2+1), then N = 1

Table 1: Impact of search on social dynamics. Search depth and belief after 200 iterations, 50 network simulations each. Schelling migration picks two individuals at random as in Figure 6.

Depth	Utility	SD	Variance	SD.1	Components	SD.2	Normality	SD.3
No movement	0.778	0.000	0.034	0.000	1.00	0.000	0.448	0.000
Schelling migration	0.783	0.014	0.065	0.022	1.00	0.000	0.607	0.095
2	0.829	0.013	0.153	0.021	4.90	1.403	0.619	0.030
4	0.843	0.010	0.158	0.016	1.68	0.713	0.650	0.033
6	0.846	0.010	0.156	0.018	1.36	0.525	0.650	0.032

Summary of structural explanations for false beliefs

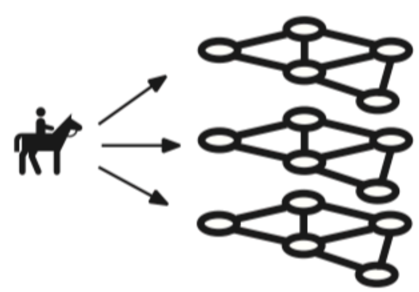
- People have beliefs
- But they interact with their social environment
- When that environment can change based on beliefs, false consensus arises (think filter bubbles and echo chambers)
- But movement also facilitates bridging connectivity

A few caveats

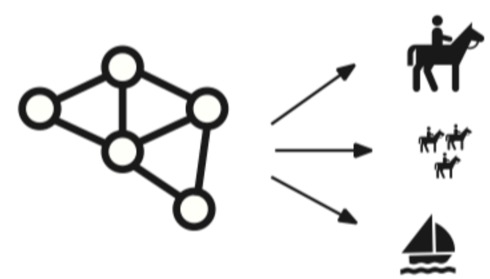
Map and Vehicle

Structure and Process

One process to rule them all



One network to rule them all

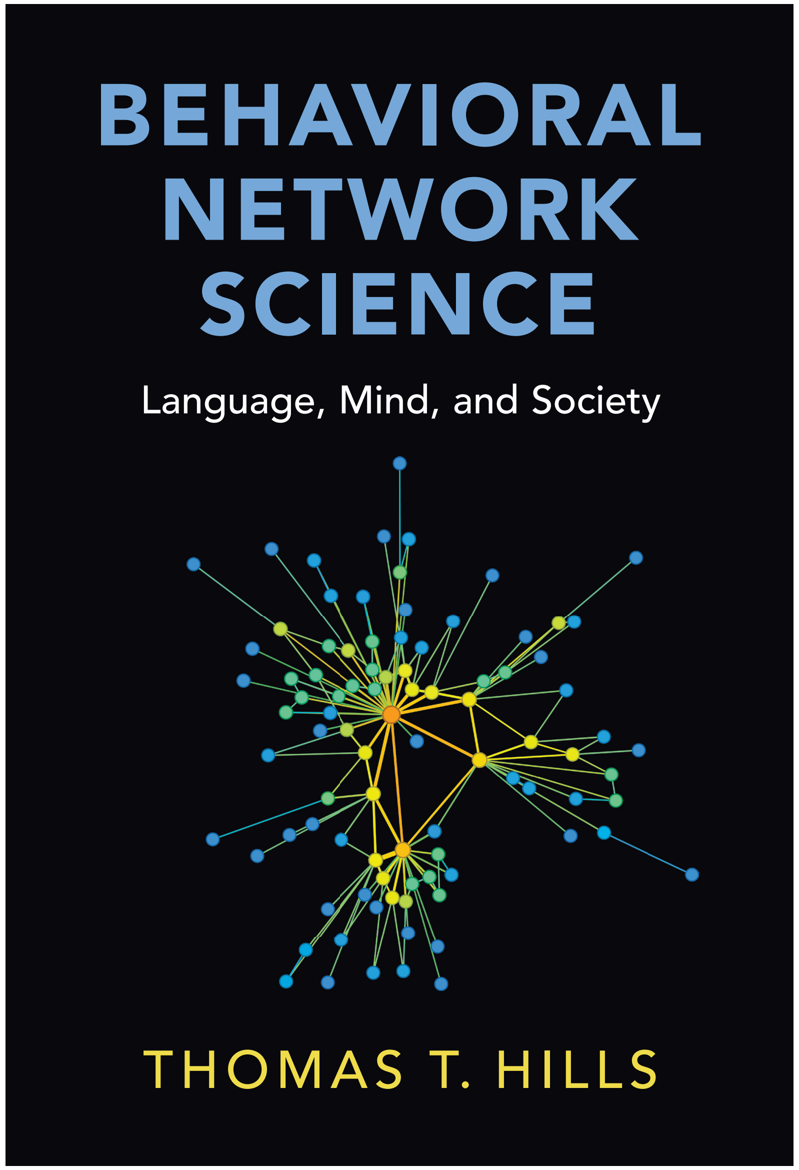


What you assume will influence what you find.

If you find structural differences, ask yourself how processes might have generated that structure. Alternatively, if you find process differences (e.g., inhibition), ask how structure might facilitate that difference.

Hills & Kenett, 2021, Is the mind a network? *TopiCS.*

Thank you



BEHAVIORAL NETWORK SCIENCE
Language, Mind, and Society
THOMAS T. HILLS