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A Primer on Agent-Based Modeling & Simulation

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Outline

- What is ABM?
- Why ABM?
- A few examples

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What?

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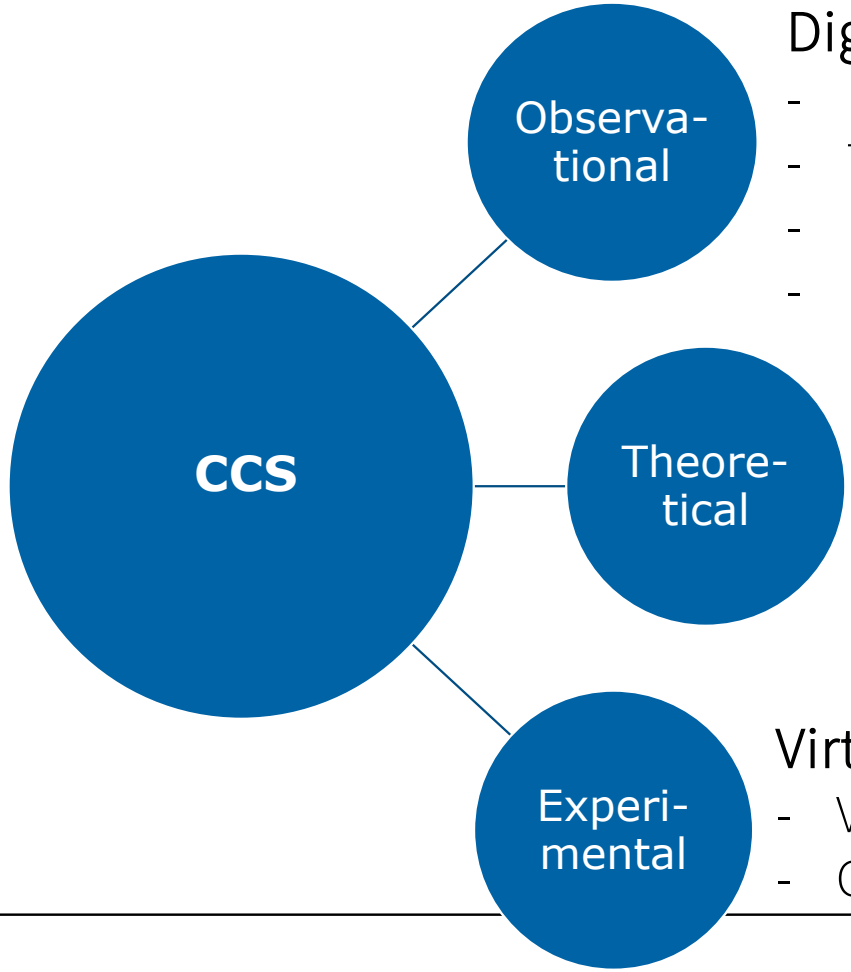
Computational Communication Science (CCS)



Digital traces

- Data scraping
- Text as data, text mining
- Images as data
- Network analysis

Computational modeling

- Simulation in the social sciences
- Agent-based modeling

Virtual experiments

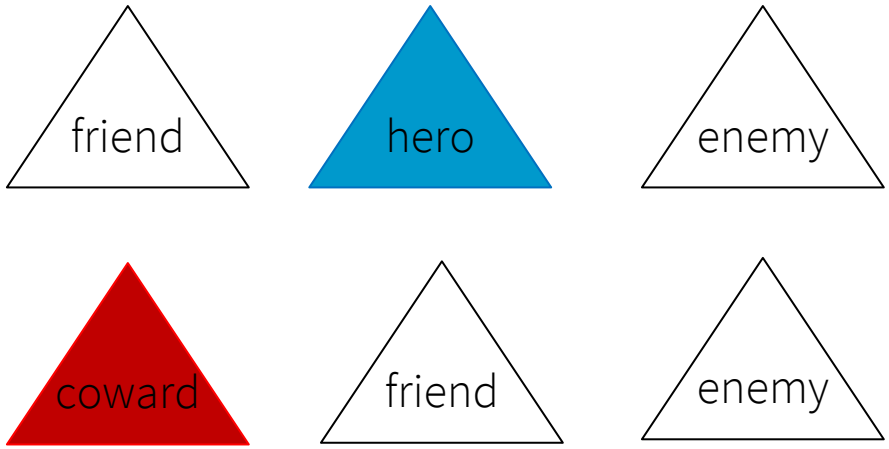
- Virtual field and lab experiments
- Citizen science & crowd computing

„Heroes and Cowards“ (Wilensky & Rand, 2015)

Each person randomly selects two other persons (friend and enemy).

Heroes: move between friend and enemy.

Cowards: moves in such a way that the friend stands between them and the enemy.



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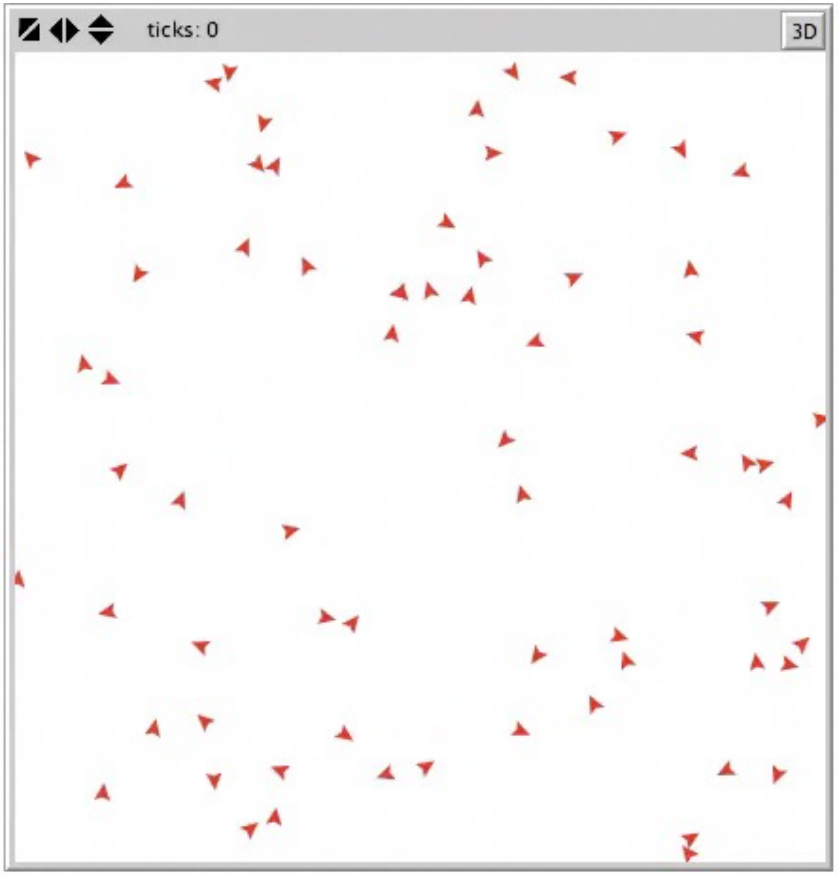
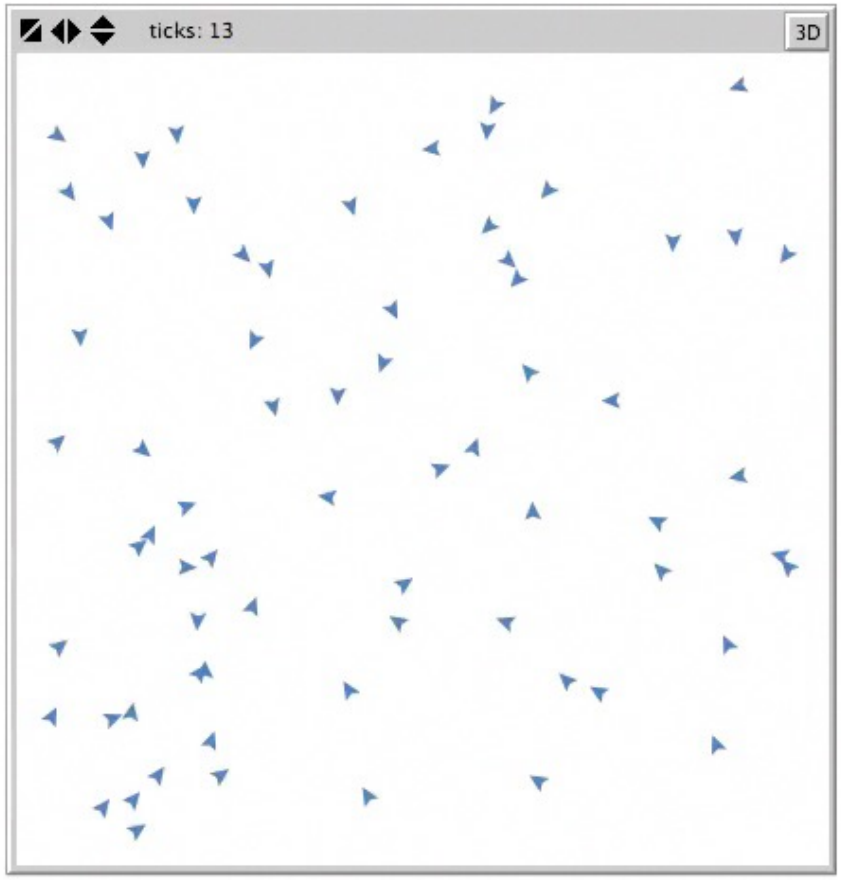
Only Cowards

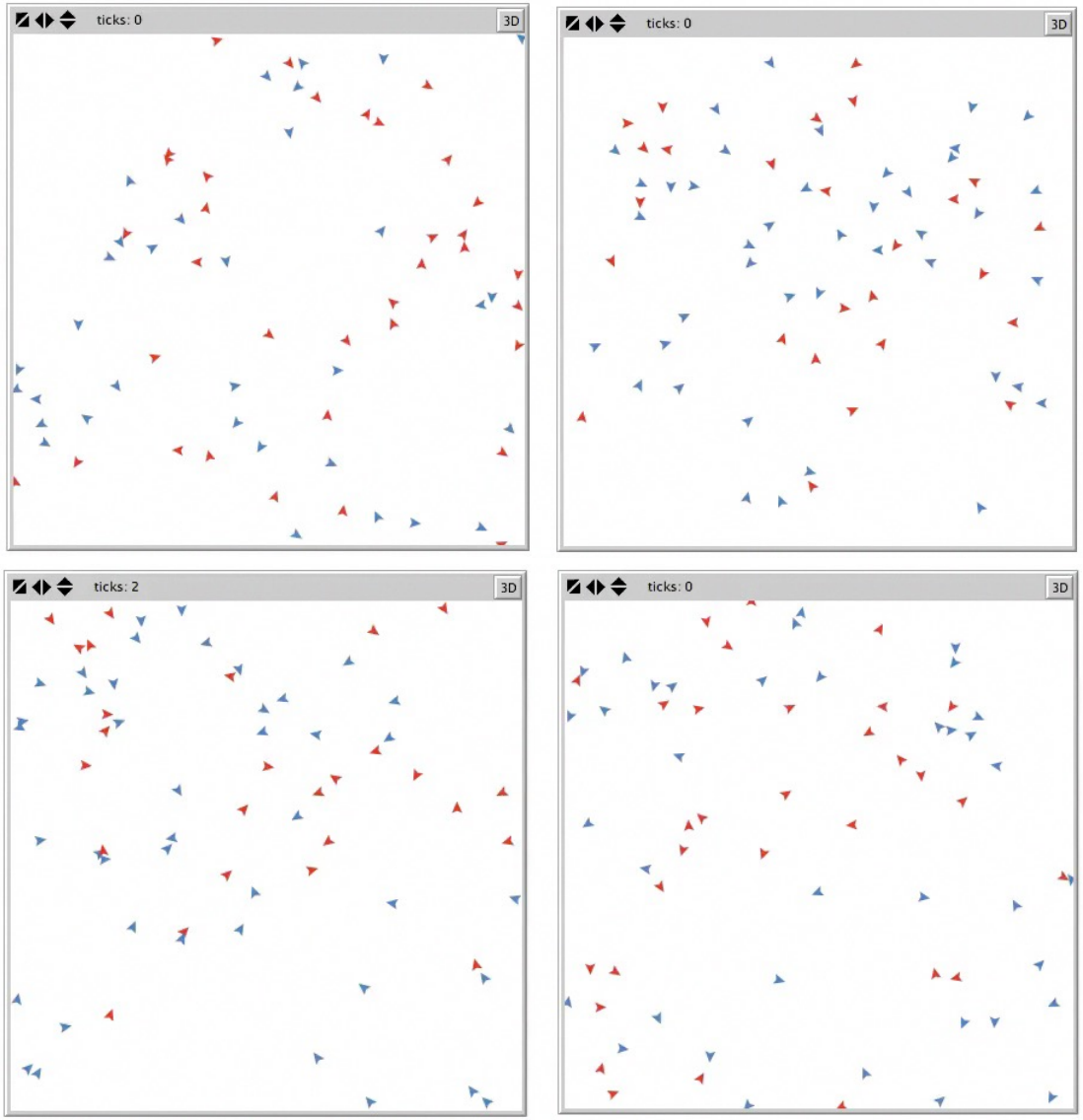


Only Heroes



Heroes and Cowards (at random)

- Networks
- Heterogeneity
- Self organization
- Nonlinearity
- Emergence



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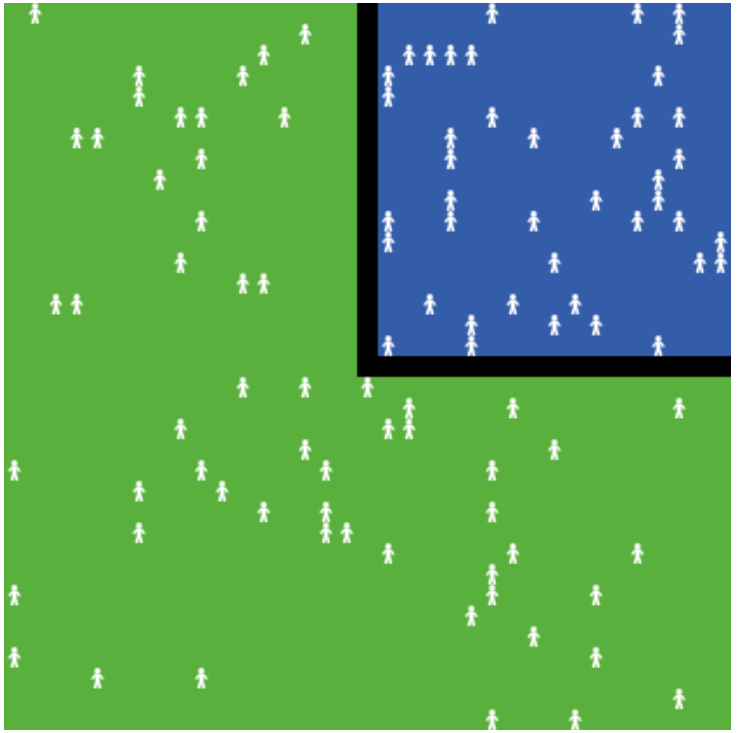
What are agent-based models (ABMs)?

Object-oriented computer models consisting of...

Agents: autonomous software objects with properties and objectives that receive, process and act on information.

Environment: virtual environment in which the agents move (e.g., topography, network, abstract space).

Rules: define what the agents do under what conditions.



"El Farol" NetLogo model
(Rand & Wilensky 2007)

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What is agent-based simulation?

„Given some macroeconomic explanandum – a regularity to be explained – the canonical agent-based experiment is as follows: Situate an initial population of autonomous heterogeneous agents in a relevant spatial environment; allow them to interact according to simple local rules, and thereby **generate – or ‚grow' – the macroscopic regularity from the bottom up**."

(Epstein 2006, S. 7)

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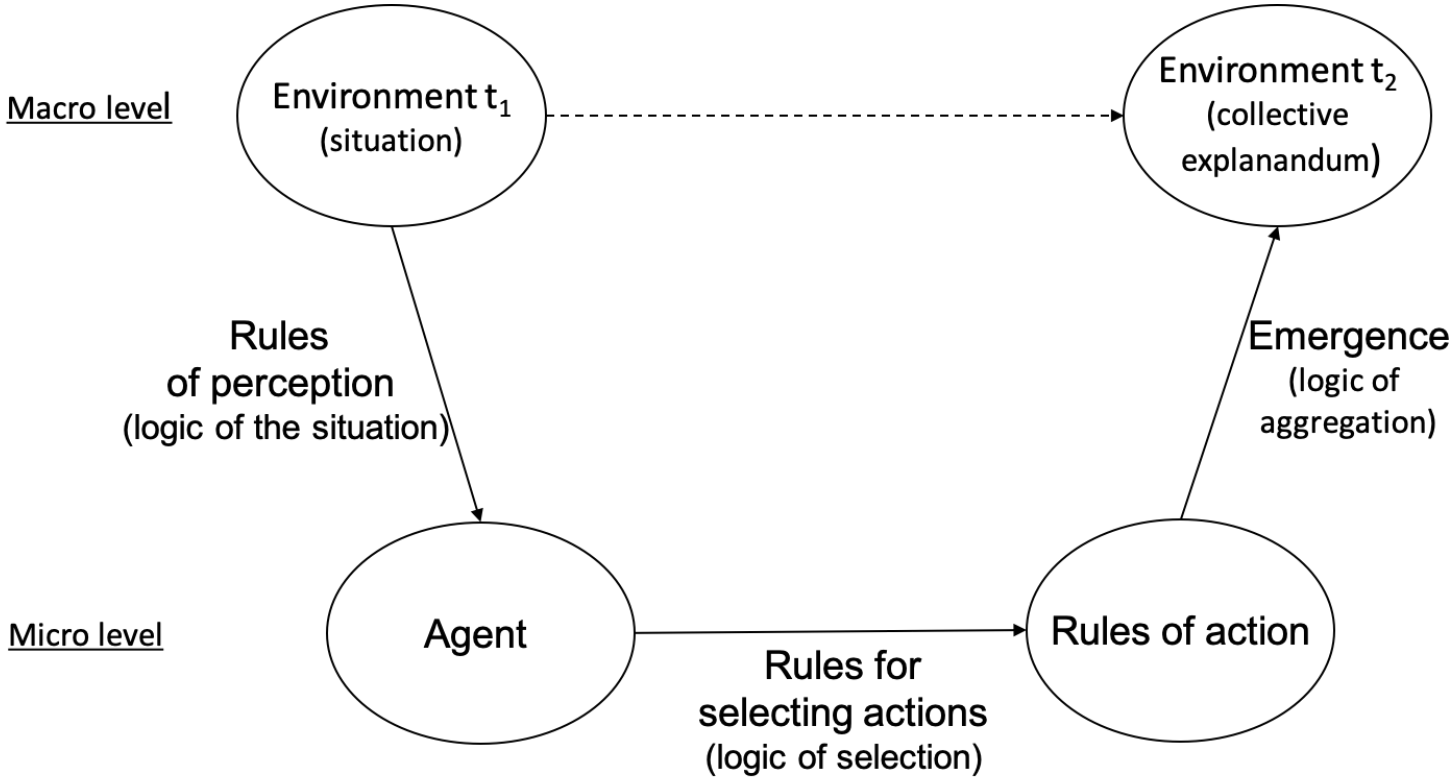
What is agent-based simulation?



Modification of the bathtub model according to Esser (1993)

Waldherr & Wettstein, 2019, p. 3979)

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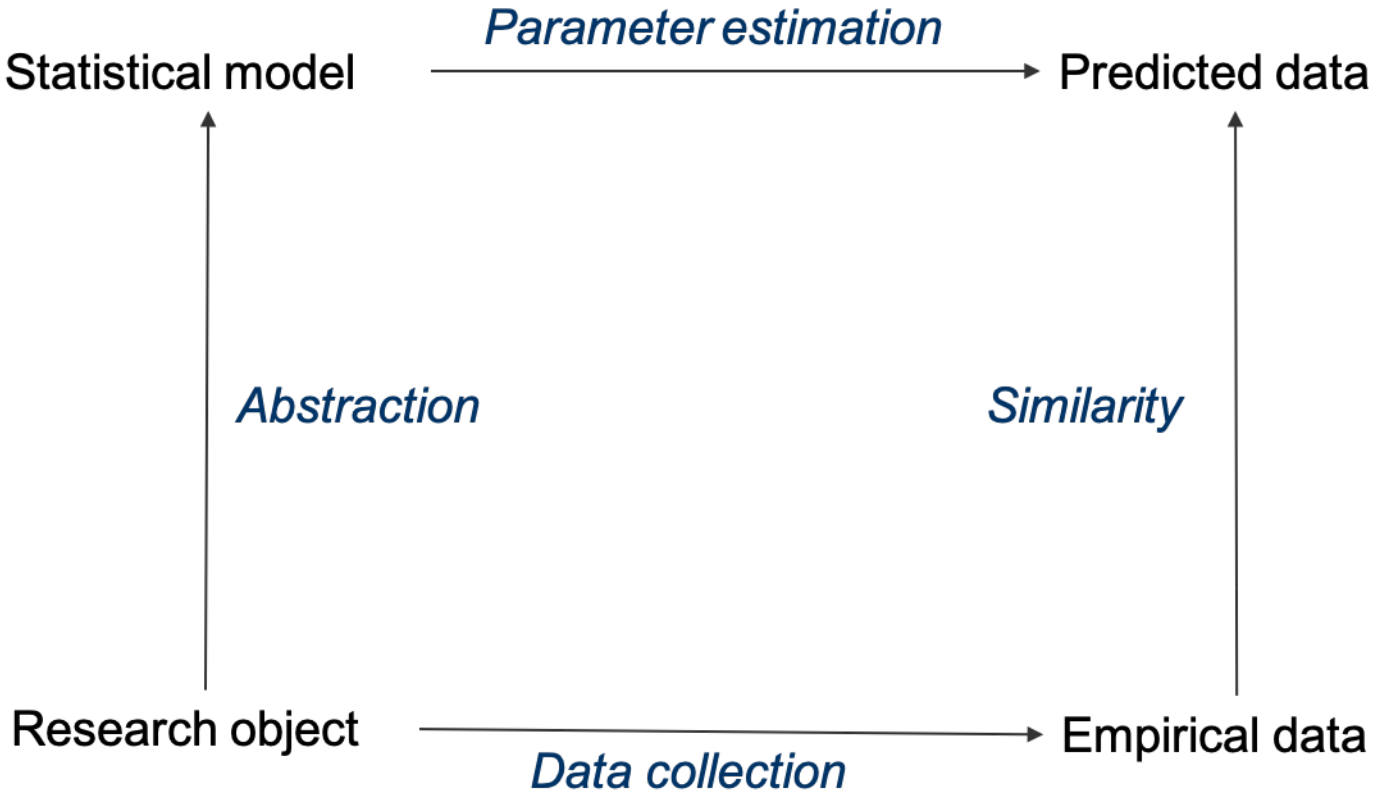
The logic of statistical modeling



Source: Gilbert & Troitzsch 2005, p. 16

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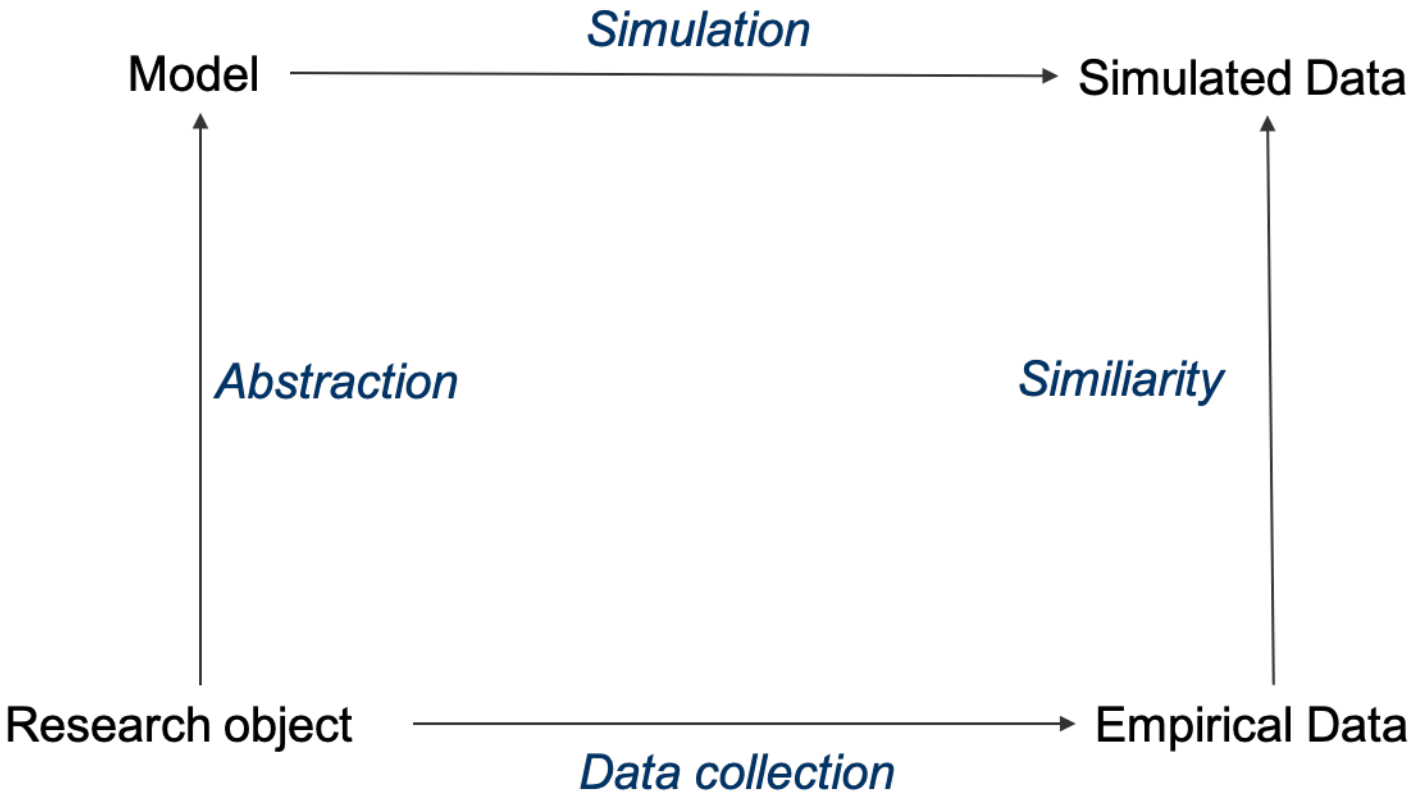
The logic of social simulation



Source: Gilbert & Troitzsch 2005, p. 17

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Why?

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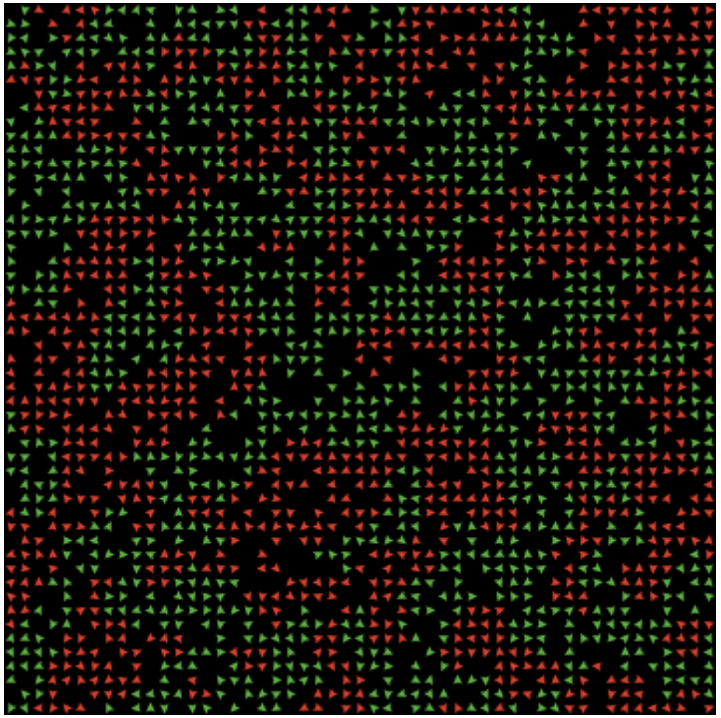
Why agent-based modeling (ABM)?



Example: Schellings (1978) Segregation Model
NetLogo model by Wilensky (1997)

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Why agent-based modeling (ABM)?

ABMs are particularly suitable for the analysis of complex systems:

- Emergent macro phenomena
- Heterogeneous agents
- Local and potentially complex interactions of agents
- Adaptive agents
- Medium numbers
- Rich and dynamic environment
- Dynamic processes

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Why agent-based modeling (ABM)?

Potential solution to long-standing research problems of the social sciences:

- Micro-macro link
- Causality
- Networking and adaptation
- Nonlinear dynamics
- Unobservable processes
- Fuzzy theories

Purposes of ABMs

COMMUNICATION METHODS AND MEASURES
https://doi.org/10.1080/19312458.2021.1986478

Routledge
Taylor & Francis Group

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Worlds of Agents: Prospects of Agent-Based Modeling for Communication Research

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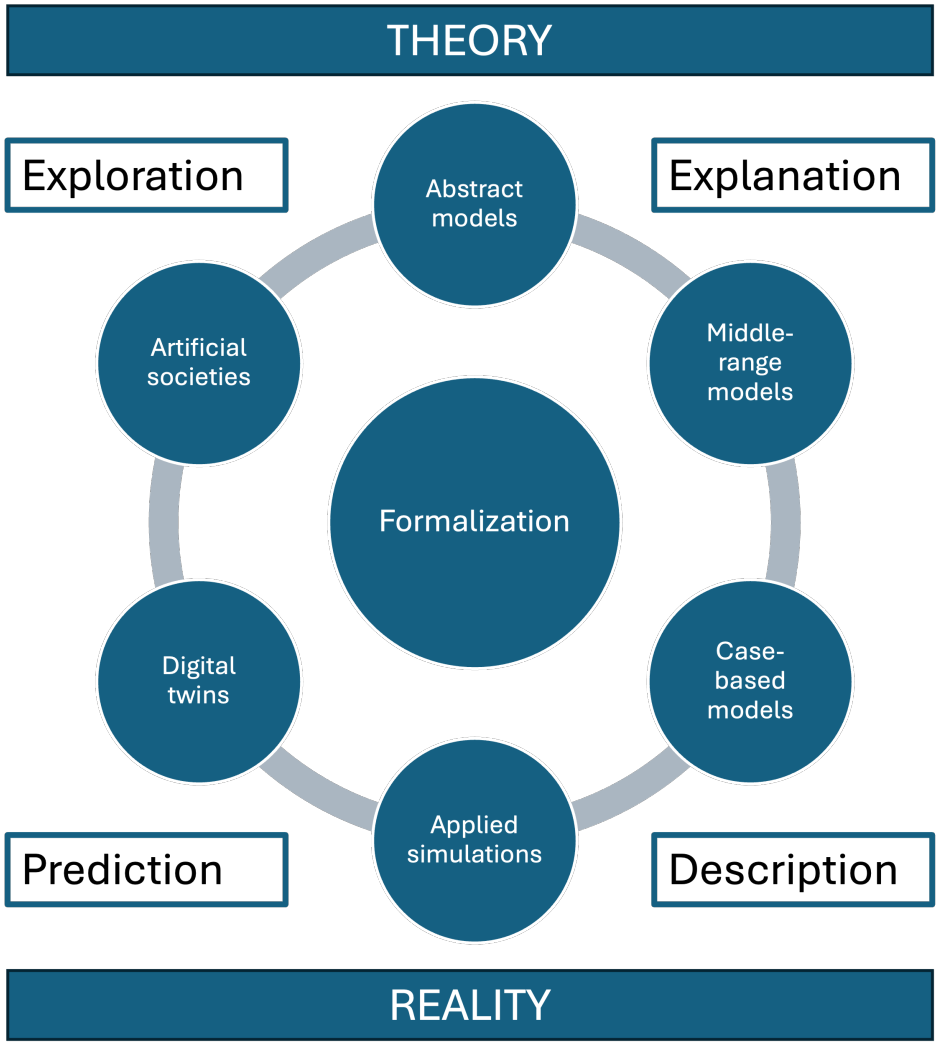
ABSTRACT

Agent-based computational models create virtual laboratories in which to formalize and simulate dynamic, multi-level theories of communication. They allow the systematic development of thought experiments, and they improve our understanding of the generative mechanisms that underlie patterns observed in empirical data. Simulation models help explore hypothetical and unprecedented scenarios, serving as powerful hypothesis generators for future theoretical and empirical research. This Special Issue showcases a collection of studies that demonstrate the analytical potential and methodological contribution of agent-based modeling (ABM) for media and communication research. In this introduction, we highlight five major benefits of this modeling approach to communication scholarship: (1) formalization, (2) understanding, (3) explanation, (4) prediction, and (5) exploration. We then present the four studies of this special issue, which contribute methodologically and theoretically to diverse key areas of communication: the emergence of meanings; political deliberation; information diffusion; and media use and social influence. We conclude with outlining future perspectives of ABM in communication research.

- Formalization
- Understanding
- Explanation
- Prediction
- Exploration

Waldherr, A., Hilbert, M., & González-Bailón, S. (2021). Worlds of agents: Prospects of agent-based modeling for communication research. Communication Methods and Measures, 15(4), 243-254. https://doi.org/10.1080/19312458.2021.1986478

Types of ABMs



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Limitations and criticism

- Methodological individualism and reductionism
- Dangers of lack of theory and lack of reality
- Conflicting goals between empirical calibration and generalization
- ABM cannot replace empirical data!

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A few examples

Agent-Based Model of the Media Arena (AMMA)

JOURNAL OF COMMUNICATION

Journal of Communication ISSN 0021-9916

ORIGINAL ARTICLE

Emergence of News Waves: A Social Simulation Approach

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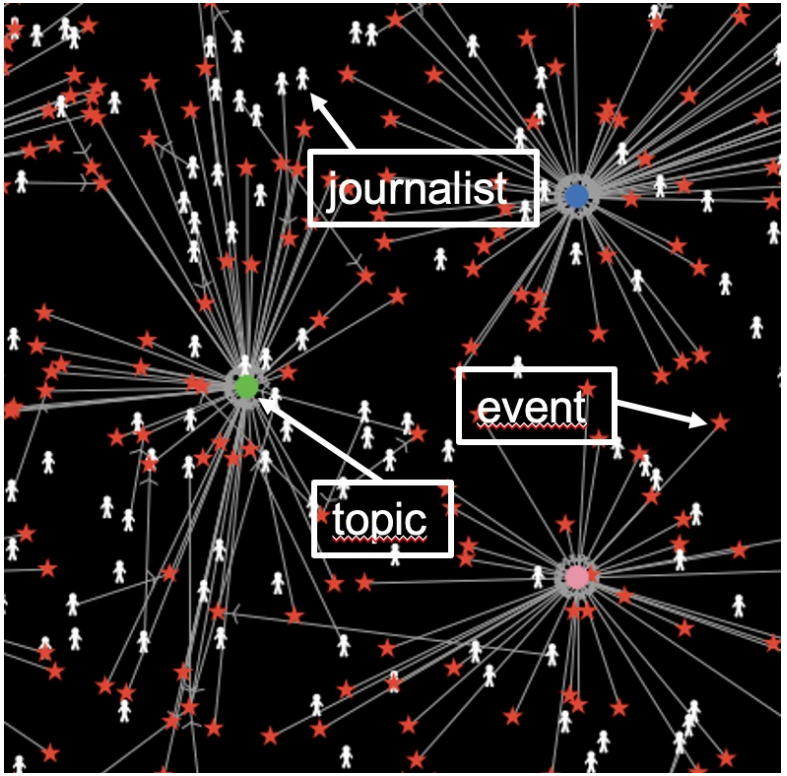
The study investigates fundamental mechanisms generating issue-attention cycles in news coverage with a social simulation approach. An agent-based computer model is developed, which integrates the main drivers of news waves as identified by empirical research. By simulating the model many times under varying conditions, the interaction of the factors to generate the typical issue-attention cycle can be observed. Results suggest that the momentum of news waves is mainly driven by the adaptive reporting behavior of journalists. Sponsors actively supporting issues by initiating events are not necessary to generate issue-attention cycles, but change their typical dynamics. Comparing simulated time series to two empirical cases yields that the model produces more realistic patterns of media attention when issue sponsors are introduced.

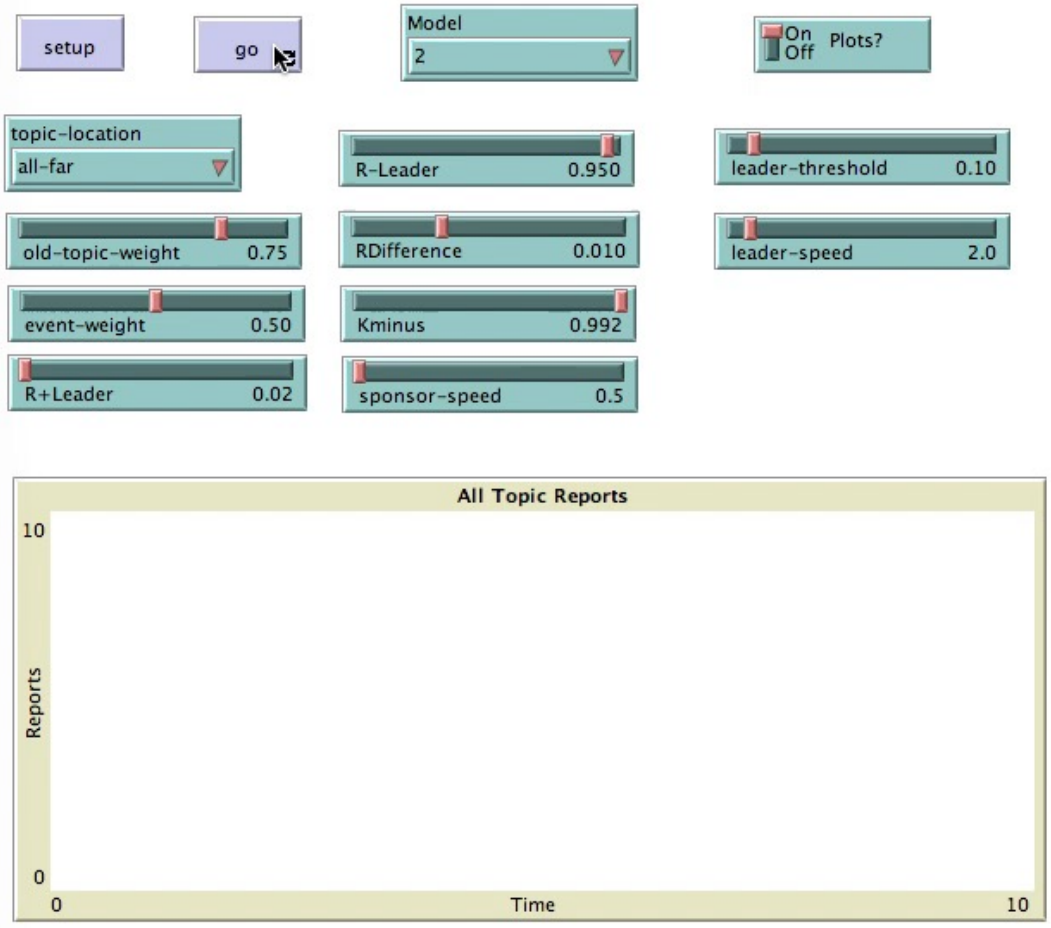
Keywords: News Wave, Issue-Attention Cycle, Media Attention, Media Arena, Simulation, Agent-Based Model, Time Series.

doi:10.1111/jcom.12117



Waldherr, A. (2012). *Die Dynamik der Medienaufmerksamkeit.* Baden-Baden: Nomos

Waldherr, A. (2014). Emergence of news waves: A social simulation approach. *Journal of Communication* 64(5), 852-873.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2
On
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Plots?
topic-location
all-far
R-Leader 0.950
leader-threshold 0.10
old-topic-weight 0.75
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leader-speed 2.0
event-weight 0.50
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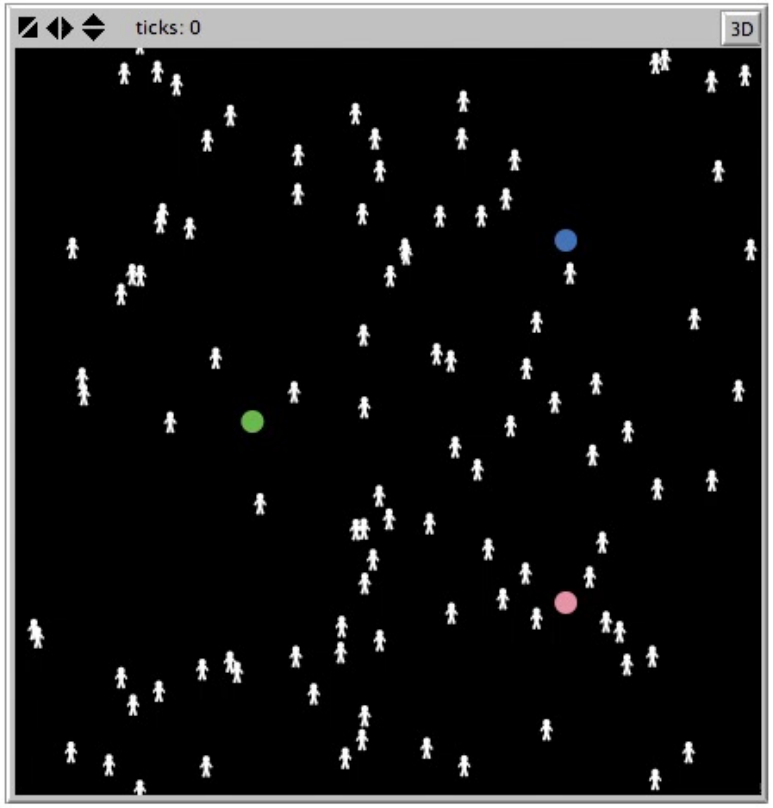
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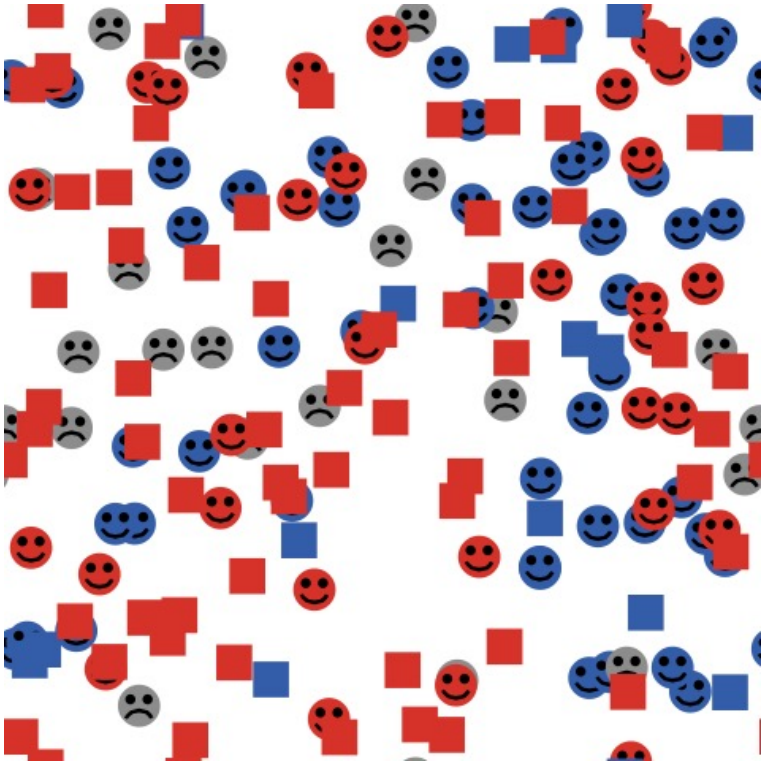
The Spiral of Silence (Waldherr & Bachl, 2011)



Individuals

- are of opinion or ,
- are willing to speak out, or not
- have a threshold of fear of isolation normally distributed with M=50%.

Mass media

- report opinion or
- do not fear isolation and are always willing to speak out.

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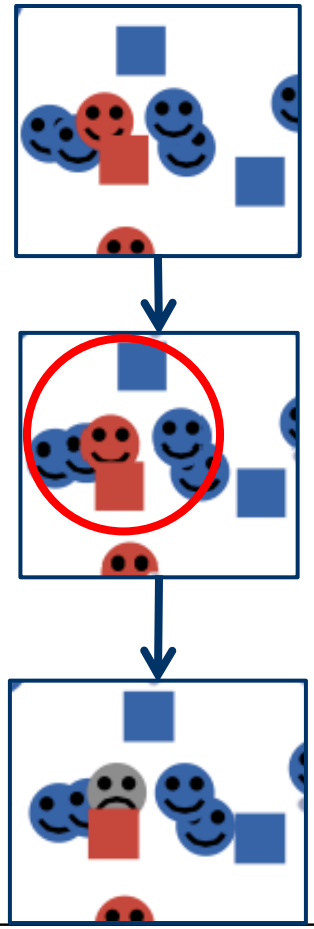
The Spiral of Silence (Waldherr & Bachl, 2011)



move-turtles:
Individuals move slowly and in random directions through space.

compute-public-opinion:
They compute the opinion climate as the share of their own opinion of the total of spoken out opinions in their neighborhood, weighted with past experiences.

compute-willingness-to-speak:
If the opinion climate supports their own opinion, the individuals speak out; if not, they choose to be silent.

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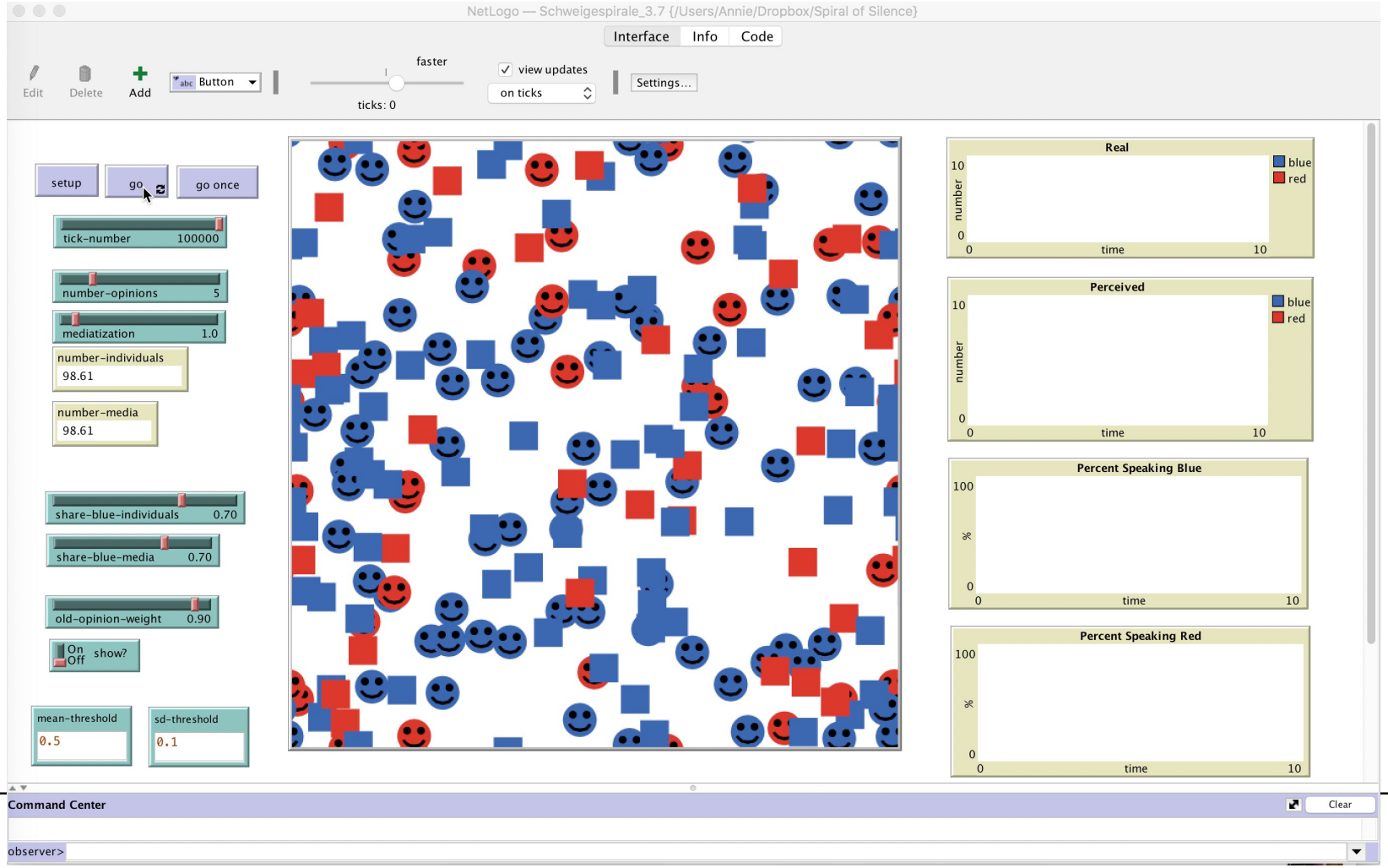
The Spiral of Silence (Waldherr & Bachl, 2011)



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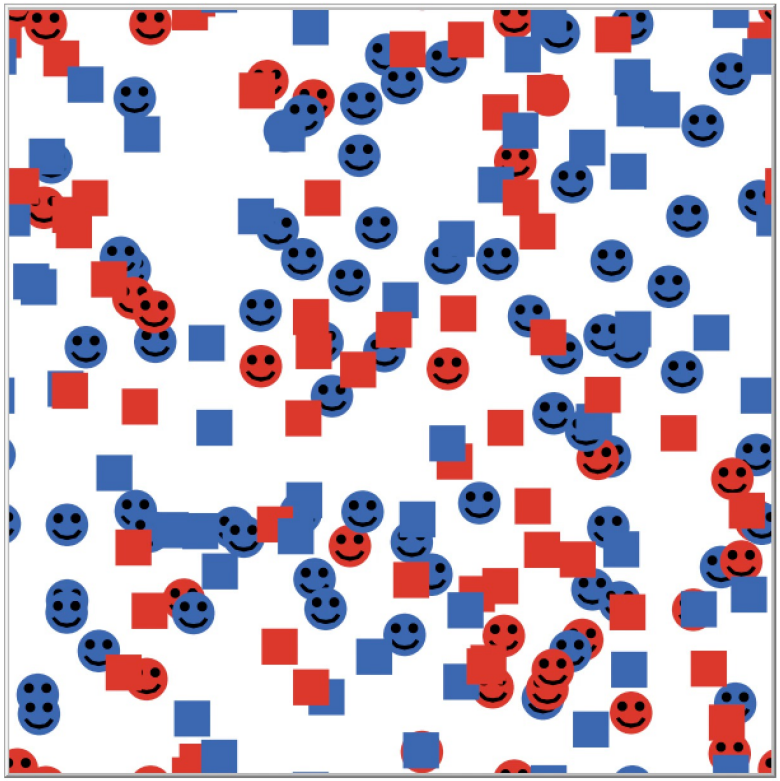
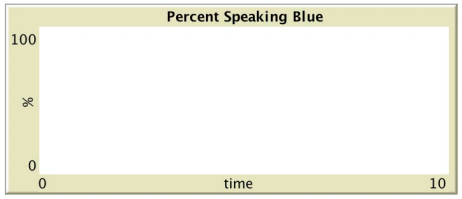
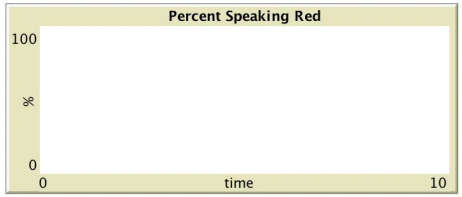
More Sample Runs (with mediatization = 1)

„False balance“ scenario







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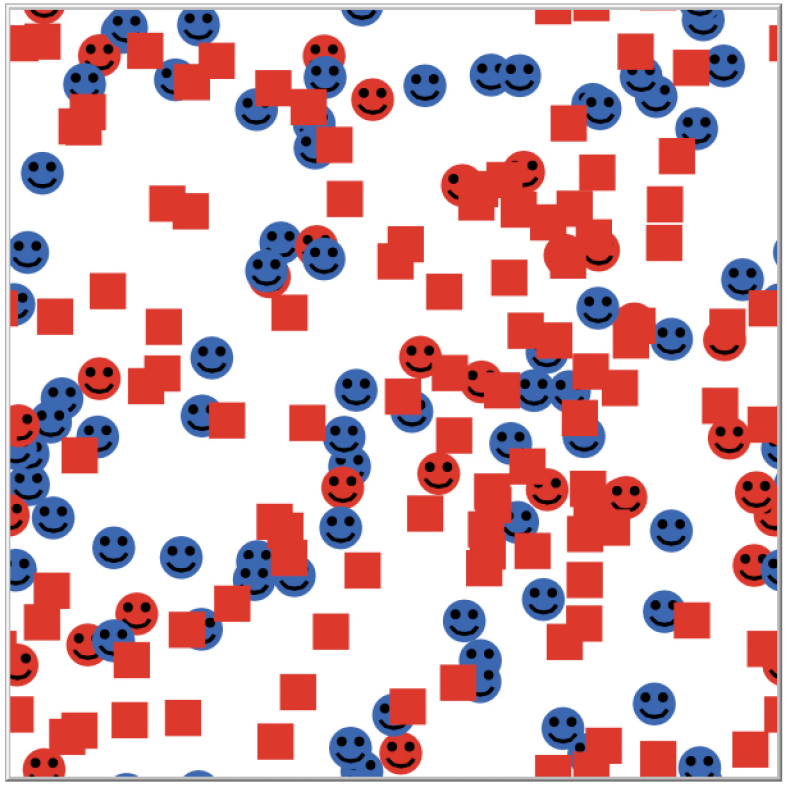
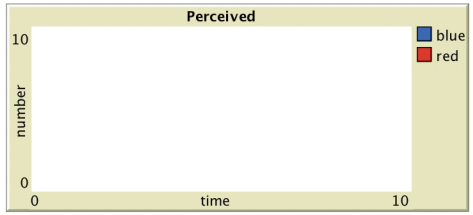
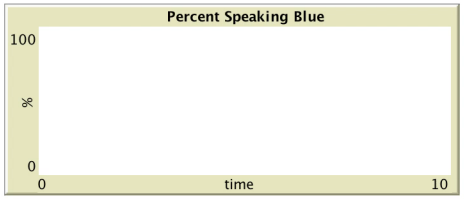
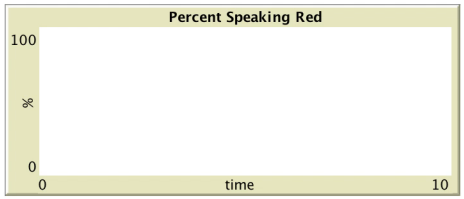
More Sample Runs (with mediatization = 1)

„Double opinion climate“ scenario









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3-Factorial Simulation Design

- *mediatization* (relative importance of perceived opinions from individuals and mass media, ratio media / individuals):
  - 0, 1/2, 1/1, 2/1
- *share-blue-individuals* (share of individuals with blue opinions):
  - 50% to 90% in 10%-steps
- *share-blue-media* (share of mass media information with blue opinions):
  - 0% to 100% in 10%-steps

- Overall: 200 conditions, 50 replication runs per condition

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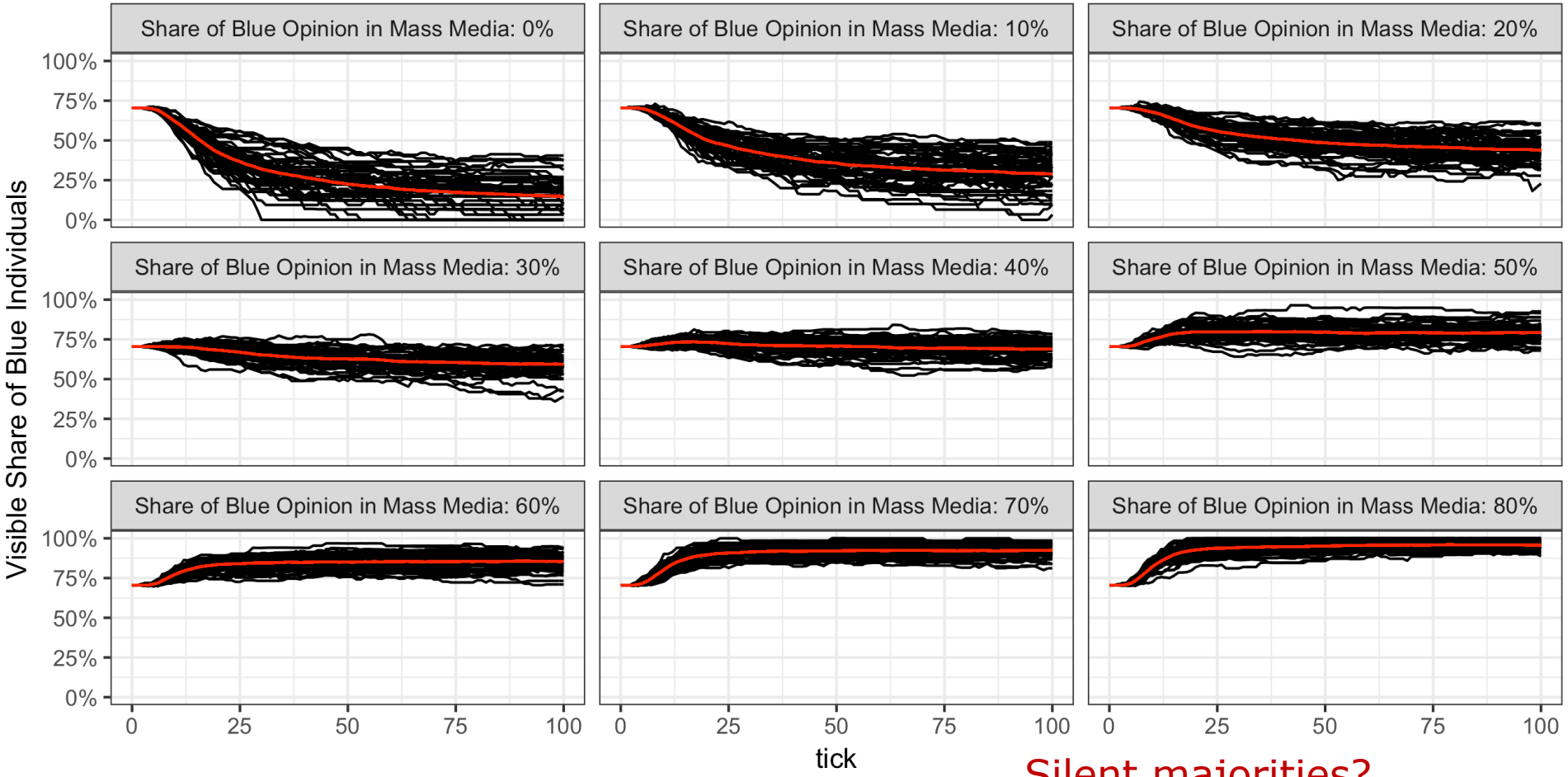
Simulation Results

for share-blue-individuals = 70%, mediatization = 1, and varying share-blue-media



Silent majorities?

Integrating ABMs with LLMs

Generative Agents: Interactive Simulacra of Human Behavior

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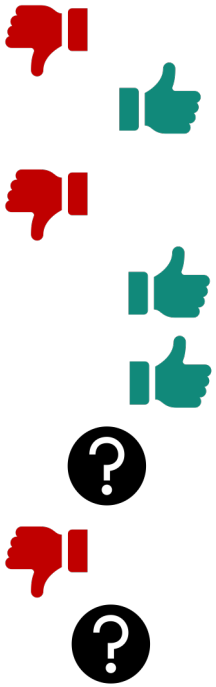
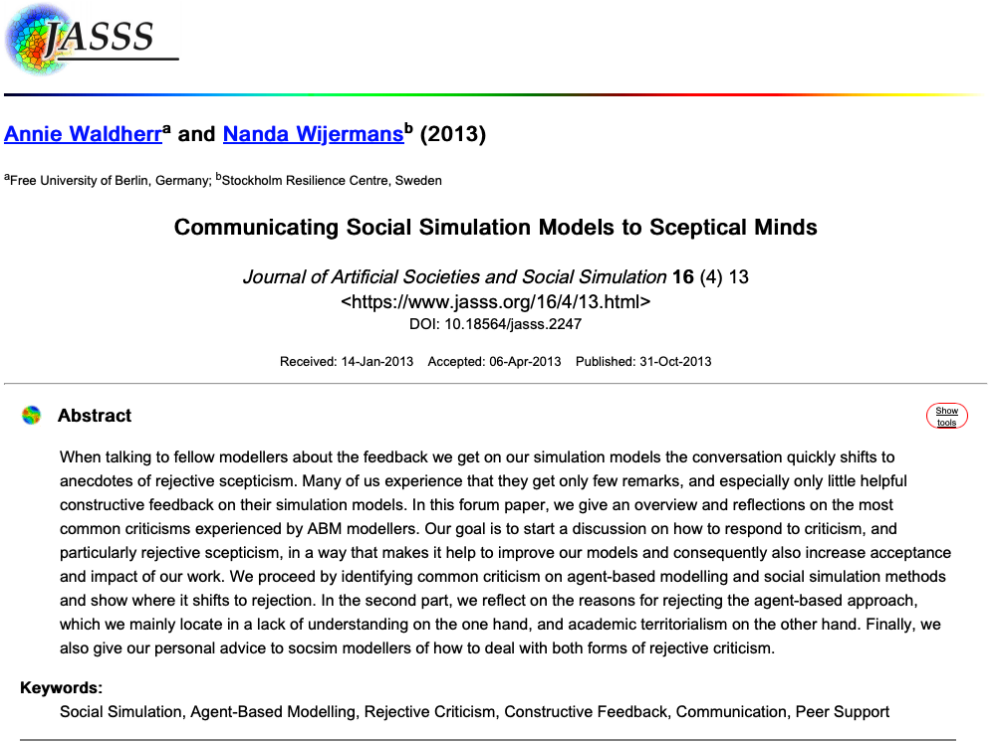
Figure 1: Generative agents are believable simulacra of human behavior for interactive applications. In this work, we demonstrate generative agents by populating a sandbox environment, reminiscent of The Sims, with twenty-five agents. Users can observe and intervene as agents plan their days, share news, form relationships, and coordinate group activities.

Enhancing ABMs with LLMs – Pros and Cons

- Too complex
- Too simple
- Not theory-based
- Not realistic
- Arbitrary parameters
- Built-in results
- Black box
- Not useful





JASSS

Annie Waldherr[a] and Nanda Wijermans[b] (2013)

[a]Free University of Berlin, Germany; [b]Stockholm Resilience Centre, Sweden

Communicating Social Simulation Models to Sceptical Minds

Journal of Artificial Societies and Social Simulation **16** (4) 13
<https://www.jasss.org/16/4/13.html>
DOI: 10.18564/jasss.2247

Received: 14-Jan-2013 Accepted: 06-Apr-2013 Published: 31-Oct-2013

Abstract

Show tools

When talking to fellow modellers about the feedback we get on our simulation models the conversation quickly shifts to anecdotes of rejective scepticism. Many of us experience that they get only few remarks, and especially only little helpful constructive feedback on their simulation models. In this forum paper, we give an overview and reflections on the most common criticisms experienced by ABM modellers. Our goal is to start a discussion on how to respond to criticism, and particularly rejective scepticism, in a way that makes it help to improve our models and consequently also increase acceptance and impact of our work. We proceed by identifying common criticism on agent-based modelling and social simulation methods and show where it shifts to rejection. In the second part, we reflect on the reasons for rejecting the agent-based approach, which we mainly locate in a lack of understanding on the one hand, and academic territorialism on the other hand. Finally, we also give our personal advice to socsim modellers of how to deal with both forms of rejective criticism.

Keywords:
Social Simulation, Agent-Based Modelling, Rejective Criticism, Constructive Feedback, Communication, Peer Support

Waldherr, A. & Wijermans, N. (2013). Communicating social simulation models to sceptical minds. Journal of Artificial Societies and Social Simulation, 16(4), 13. https://doi.org/10.18564/jasss.2247

WHat-if: Advanced Simulations for Testing the Effect of the Information Environment on the Functioning of Democracy

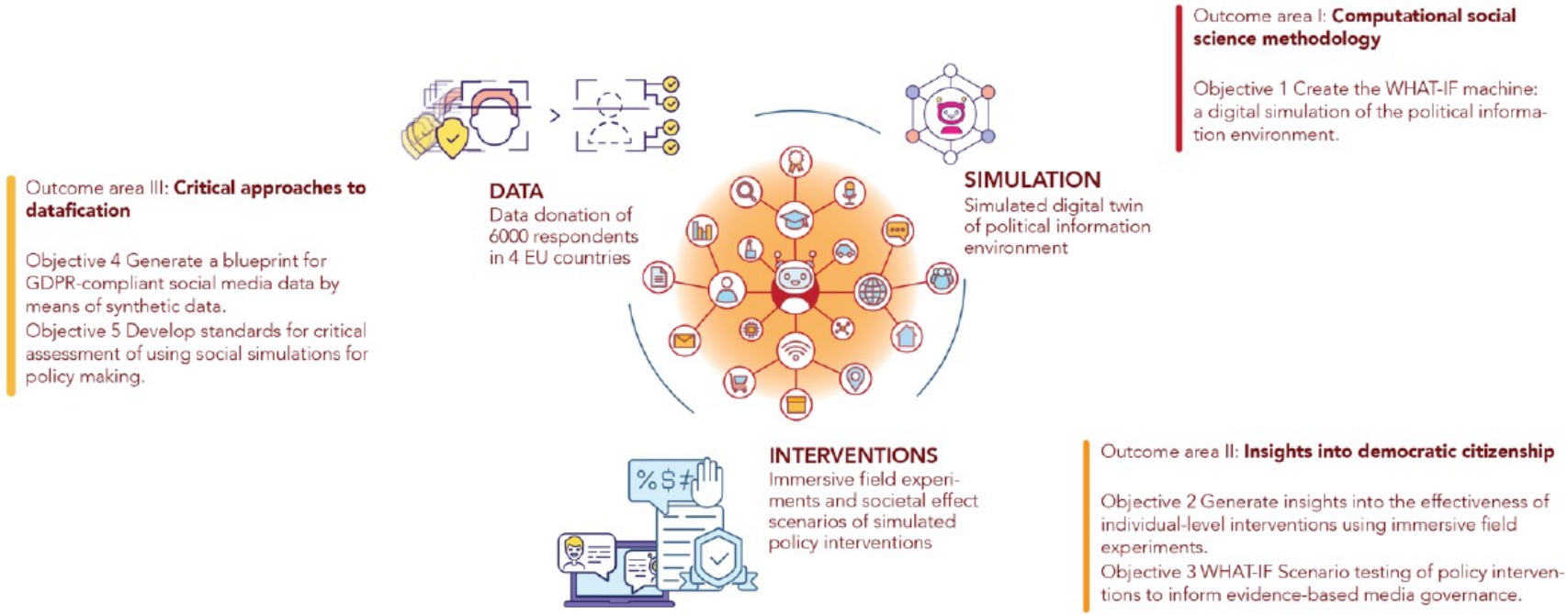


***Figure 2:** WHAT-IF approach and objectives*

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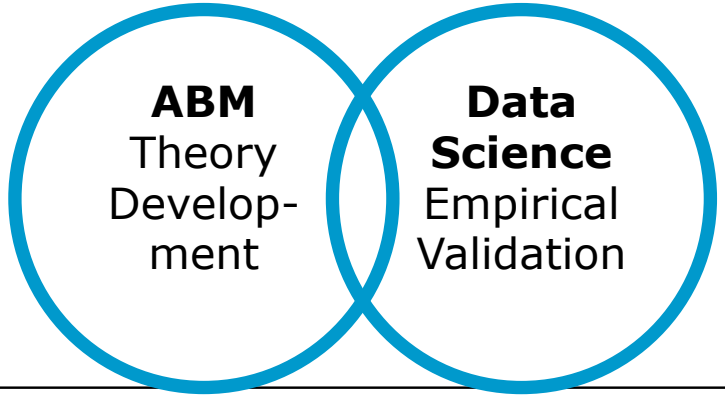
Potentials of ABM for the Social Sciences

Proof of concept: Test whether proposed micro assumptions lead to proposed macro effects.

Pattern-oriented modeling: Find underlying mechanisms which are able to generate the observed empirical patterns.

Possible futures: Explore macro consequences of varying micro assumptions.



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References

- Download NetLogo: http://ccl.northwestern.edu/netlogo
- Epstein, J. M. (Ed.). (2006). Generative social science: Studies in agent-based computational modeling. Princeton University Press.
- Gilbert, N. & Troitzsch, K. G. (2005). Simulation for the social scientist. Maidenhead, UK: Open University Press.
- Railsback, S. F. & Grimm, V. (2012). Agent-based and individual-based modeling: A practical introduction. Princeton, NJ: Princeton University Press.
- Park, J. S., O'Brien, J., Cai, C. J., Morris, M. R., Liang, P., & Bernstein, M. S. (2023). Generative Agents: Interactive Simulacra of Human Behavior Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology, San Francisco, CA, USA. https://doi.org/10.1145/3586183.3606763
- Schelling, T. (1971). Dynamic models of segregation. The Journal of Mathematical Sociology, 1(2), 143–186. https://doi.org/10.1080/0022250X.1971.9989794

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References

- Waldherr, A., & Bachl, M. (2011). Simulation gesellschaftlicher Medienwirkungsprozesse am Beispiel der Schweigespirale. In M. Suckfüll, H. Schramm, & C. Wünsch (Eds.), Rezeption und Wirkung in zeitlicher Perspektive (pp. 203-220). Nomos.
- Waldherr, A. (2012). Die Dynamik der Medienaufmerksamkeit: Ein Simulationsmodell. Nomos.
- Waldherr, A. (2014). Emergence of news waves: A social simulation approach. Journal of Communication, 64(5), 852-873. https://doi.org/10.1111/jcom.12117
- Waldherr, A. & Wettstein, M. (2019). Bridging the gaps: Using agent-based modeling to reconcile data and theory in computational communication science. International Journal of Communication, 13, 3976-3999. https://ijoc.org/index.php/ijoc/article/view/10588

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References

- Waldherr, A., & Wijermans, N. (2013). Communicating social simulation models to sceptical minds. Journal of Artificial Societies and Social Simulation, 16(4), 13. http://jasss.soc.surrey.ac.uk/16/4/13.html
- Waldherr, A., Hilbert, M., & González-Bailón, S. (2021). Worlds of agents: Prospects of agent-based modeling for communication research. Communication Methods and Measures, 15(4), 243-254. https://doi.org/10.1080/19312458.2021.1986478
- Wilensky, U., & Rand, W. (2015). An introduction to agent-based modeling: Modeling natural, social, and engineered complex systems with NetLogo. Cambridge, MA: MIT Press.