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Centre for
Cognitive
Science



Human and Machine Cognition Lab



Thesis topics

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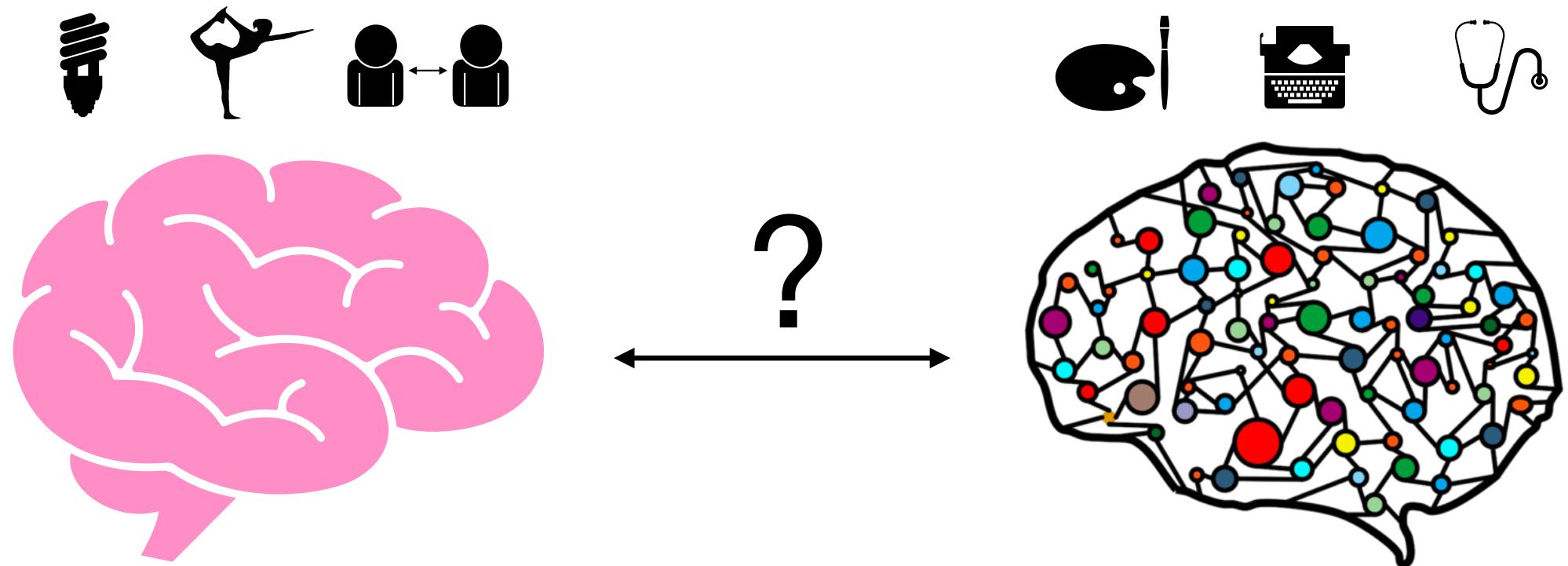


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Cognitive
Science

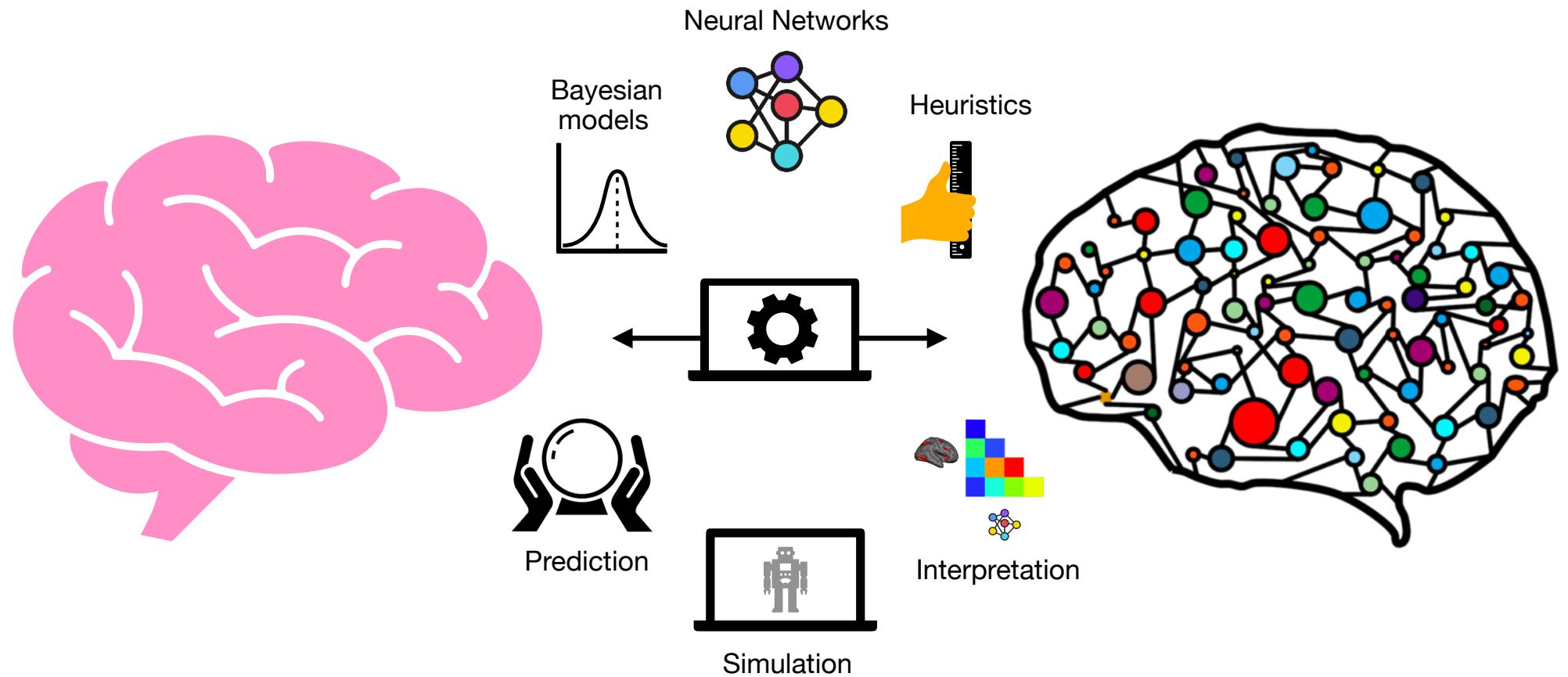


Human and Machine Cognition Lab

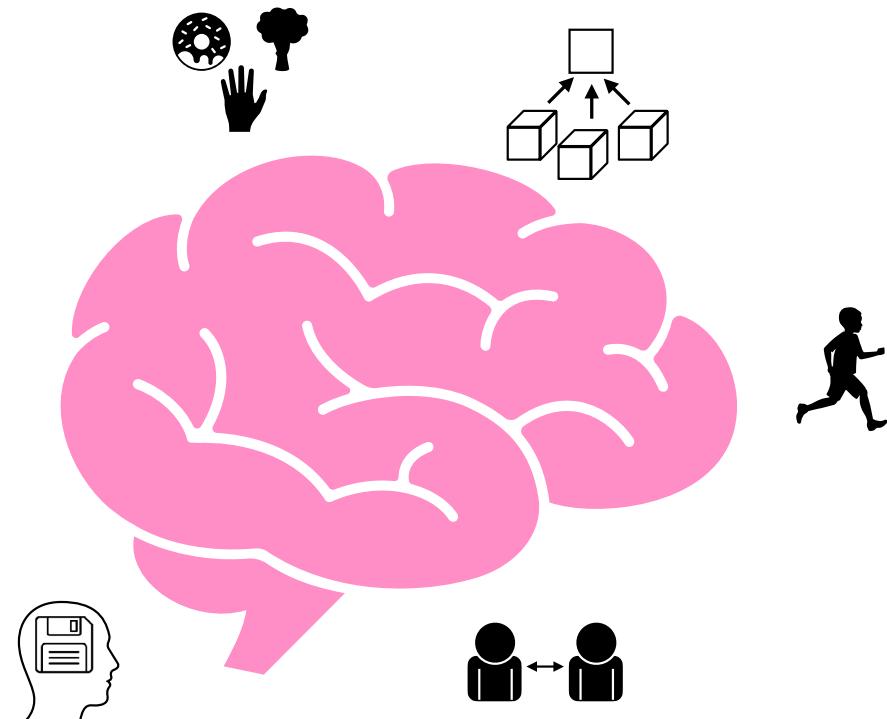
What makes humans uniquely intelligent?



Computational models as a common language



Research areas



- Memory

- Nagy, Orban, & Wu (*NatRevPsych* 2025)
- Zhou, Bamler, Wu* & Tejero-Cantero* (*ICLR* 2024)

- Decision-Making Under Constraints

- Rubino, Dayan, & Wu (in prep)
- Wu, Schulz, Pleskac, & Speekenbrink (*SciReps* 2022)

- Development

- Giron*, Ciranka*, & Wu (*NatHumBehav* 2023)
- Meder, Wu, Schulz, & Ruggeri (*DevSci* 2021)

- Collective Behavior

- Wu, Deffner, Kahl, Meder, Ho & Kurvers (*NatComms* 2025)
- Witt, Toyokawa, Lala, Gaissmaier & Wu (*PNAS* 2024)

- Generalization

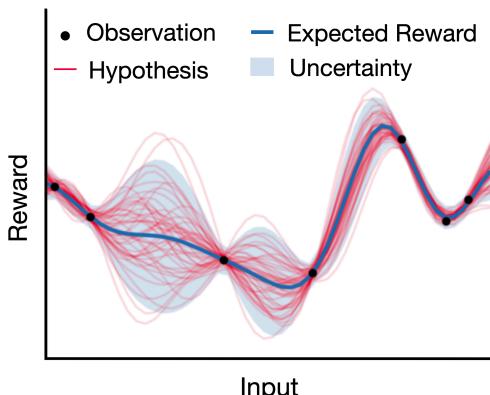
- Wu, Meder, & Schulz (*AnnRevPsych* 2025)
- Wu et al., (*NatHumBehav* 2018; *PlosCompBio* 2020)

Guiding questions

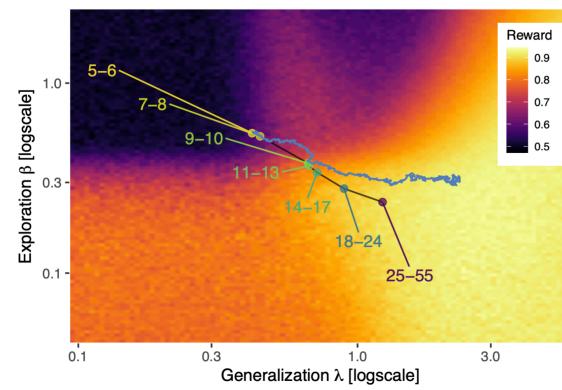
1. How do we **generalize** in novel environments?
2. How does intelligence **develop** over the lifespan?
3. How do we learn from each other in **social** and **cultural** settings?



Human generalization as Bayesian function learning

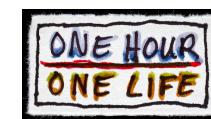
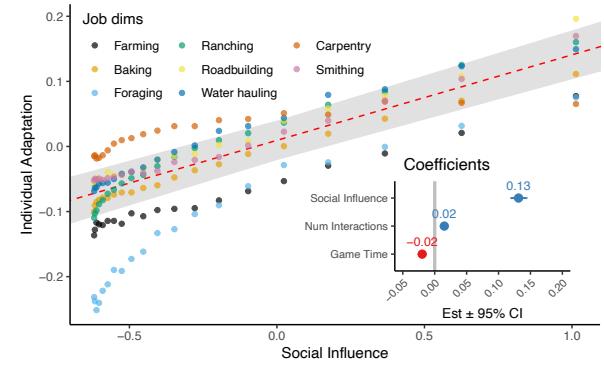


Developmental change as stochastic optimization



Human ↔ vs. Algorithm —

Cultural transmission through social interactions



Spatially Correlated Bandit

7	5	10	22	32	32	28	24	22	26	33
6	11	19	29	38	41	42	40	37	36	40
22	27	30	35	43	50	53	53	51	49	46
45	44	38	36	40	46	47	49	54	55	48
61	55	46	40	37	32	27	31	44	52	44
62	59	57	54	44	27	14	17	33	46	45
53	59	68	71	59	36	17	15	28	45	51
46	57	71	77	67	47	26	18	27	45	56
45	56	65	67	60	46	29	20	27	42	55
51	57	58	53	47	40	30	23	28	40	49
60	62	58	47	39	38	35	31	35	41	46



Click tiles on the grid to maximize rewards



Each tile is an arm of the bandit, giving noisy rewards

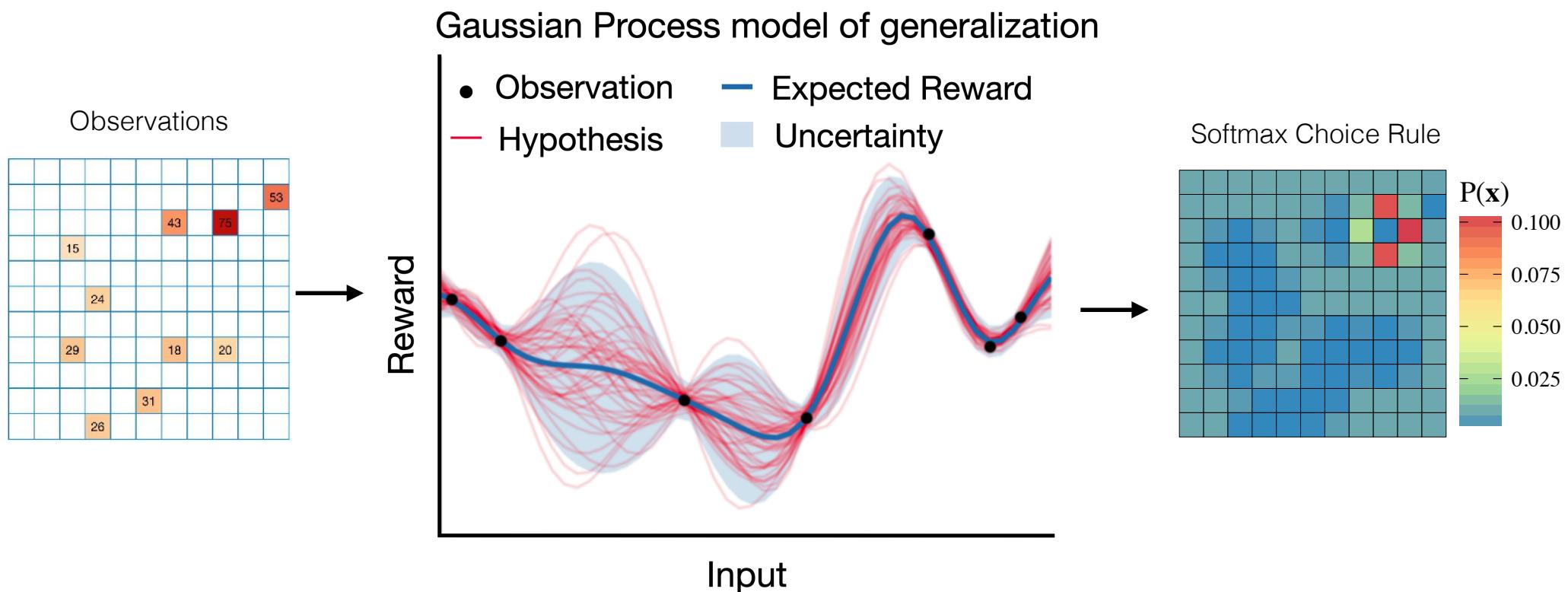


Reward expectations are spatially correlated



Limited search horizon (20-40 clicks) requires balancing explore-exploit

Generalization as function approximation



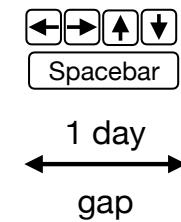
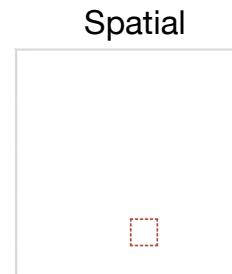
Framework and models replicated across a variety of tasks and contexts

Safe search with risky outcomes

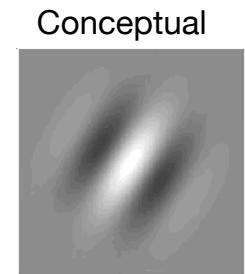


Schulz, Wu, Huys, Krause & Speekenbrink (*Cognitive Science* 2018)

Spatial and conceptual search



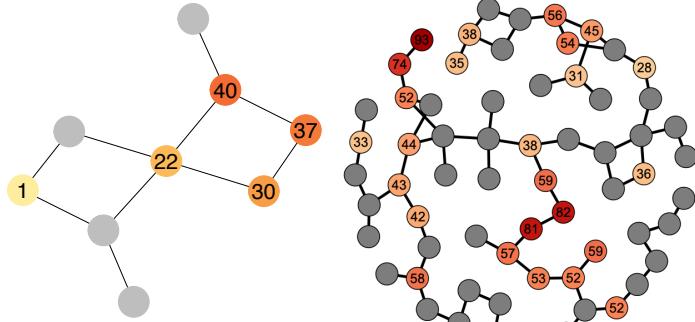
Current Score: 260
Trials Remaining: 12
Rounds Remaining: 10



Current Score: 141
Trials Remaining: 14
Rounds Remaining: 10

Wu, Schulz, Garvert, Meder & Schuck (*PLOS Comp Bio* 2020)

Graph-structured rewards



Wu, Schulz & Gershman (*CBB* 2021)

Potential thesis topics

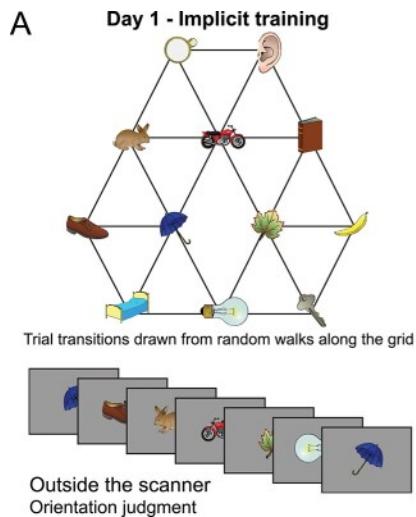
- Reanalyze published data to answer open questions
- Implement your own experiment and conduct new analyses

How to get started

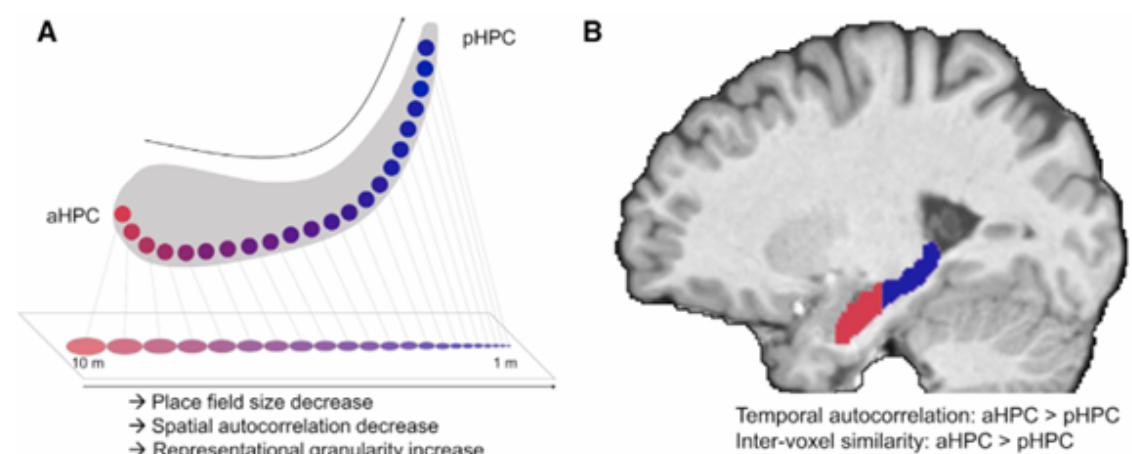
- Read Wu et al., (*AnnRevPsych* 2025) for an overview (any other relevant papers)
- Identify open questions and identify hypotheses

Current Masters Thesis Example

Multiscale Representations in the Human Hippocampus

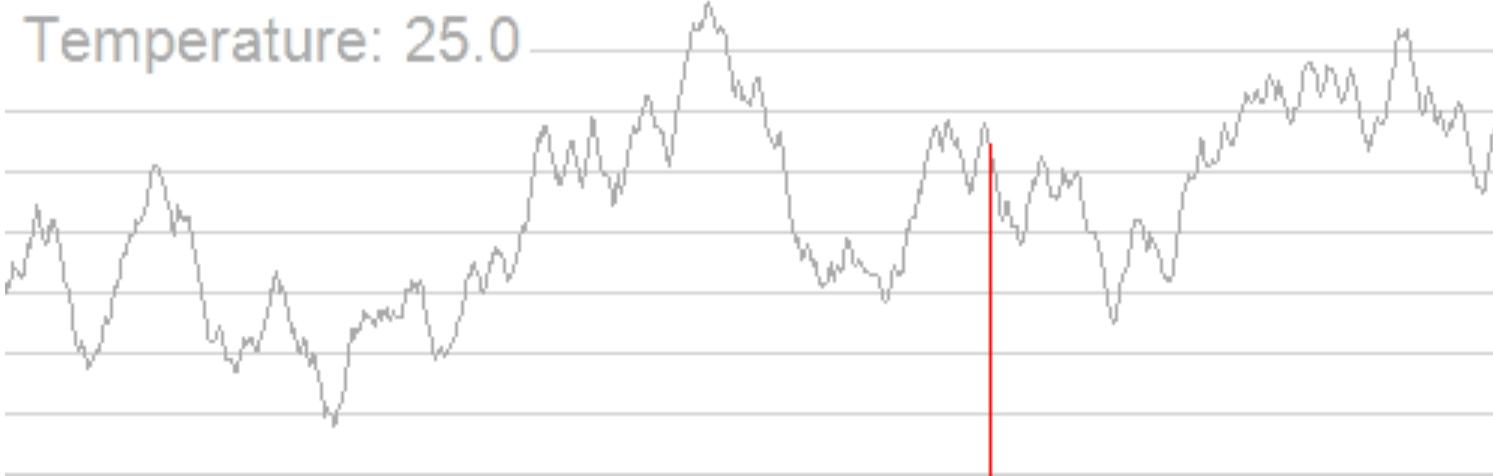


Garvert et al., (2017)



Brunec & Momennejad (2022)

Development as Stochastic Optimization



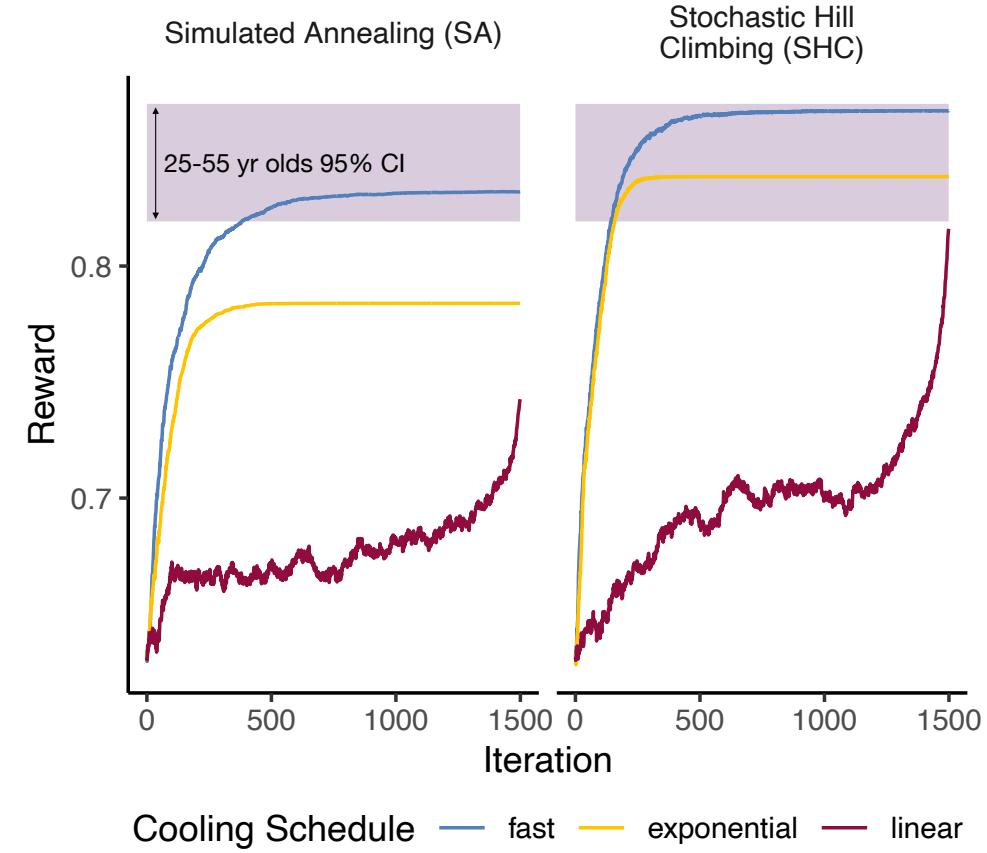
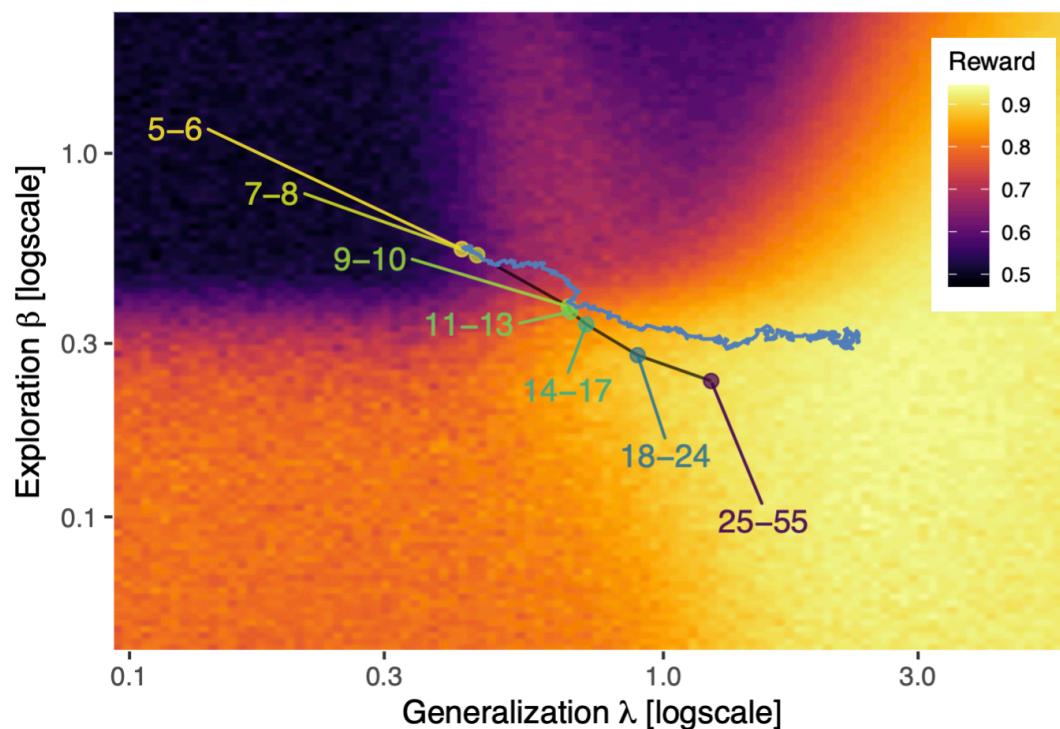
- Children initially perform high-temperature search, which gradually “cool offs” as they grow older
- The cooling schedule induces a gradual shift from exploration → exploitation, preventing the algorithm from getting stuck in a local optimum



Anna Giron
Uni Tübingen

Humans vs. Optimization algorithms

Human ● vs. SHC-fast —



Current directions

- How do (adversive) childhood experiences influence learning strategies in adulthood?
- Would the predictability of your childhood environment influence how we generalize and explore as an adult?

Potential thesis topics

- Simulation-based study of how strategies optimized for one set of environments generalize to new environments
- Implement an experiment to relate childhood background to normative predictions

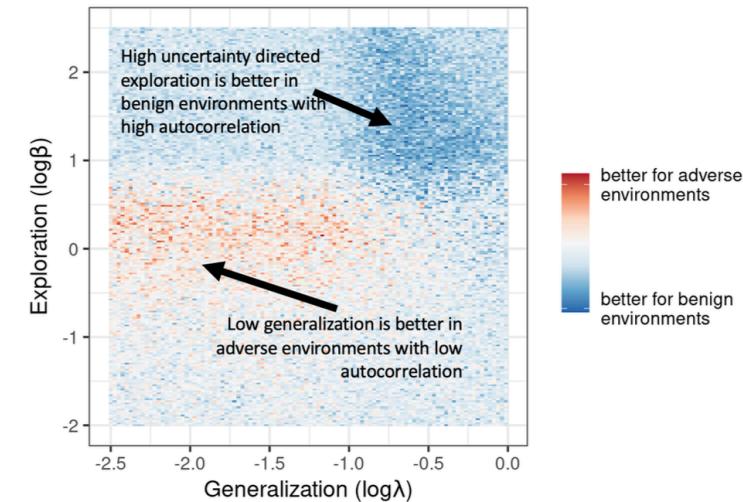
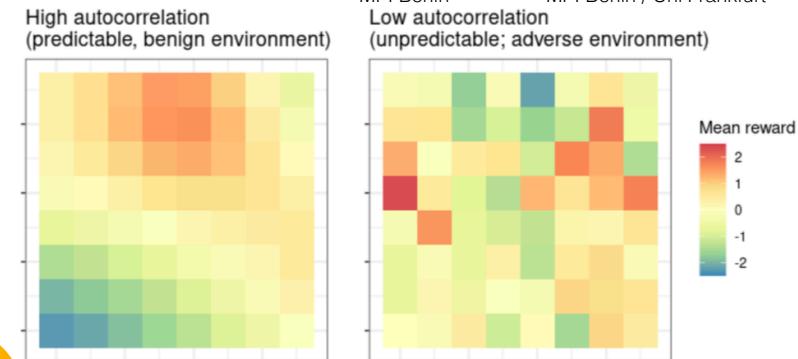
How to get started

- Read Giron et al., (*Nature Human Behavior* 2023) for an overview and recent papers (e.g., Schechtl, *NatComms* 2025; Vermeent et al., *JEP:G* 2025)
- Develop theory-driven predictions and propose a plan for how to map them to the model



Dr. Simon Ciranka
MPI Berlin
Low autocorrelation
(unpredictable; adverse environment)

Dr. Anna Thoma
MPI Berlin / Uni Frankfurt

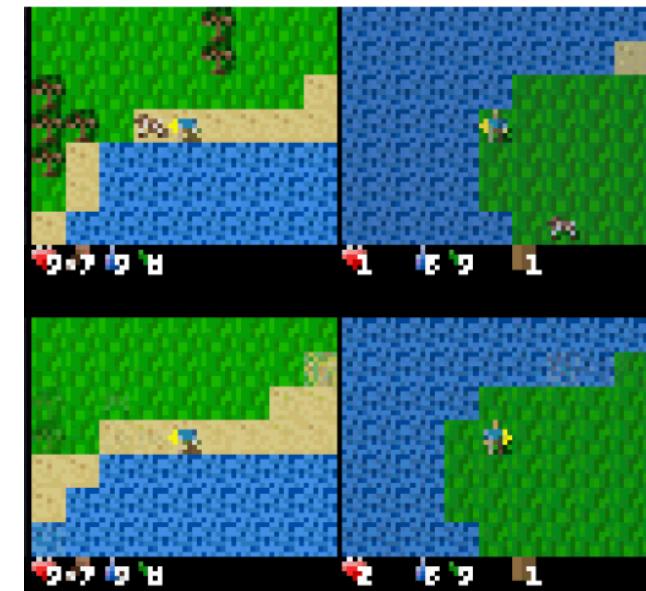
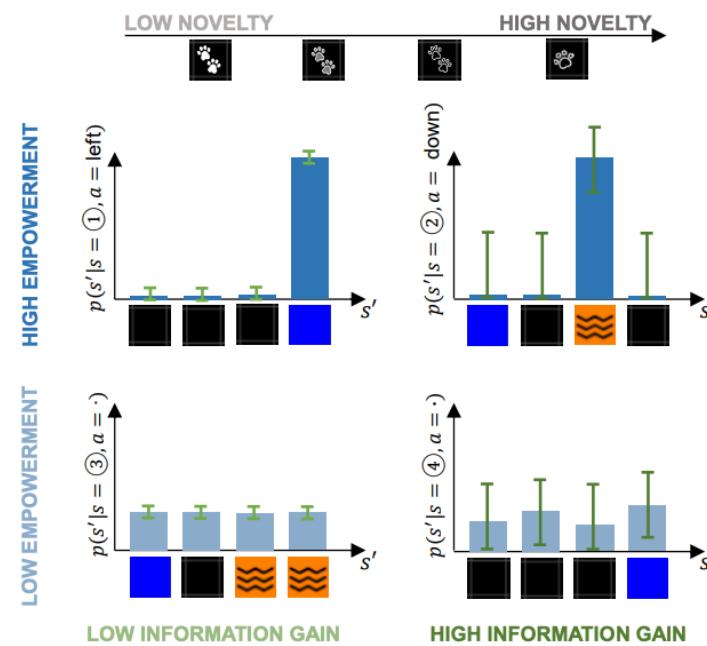
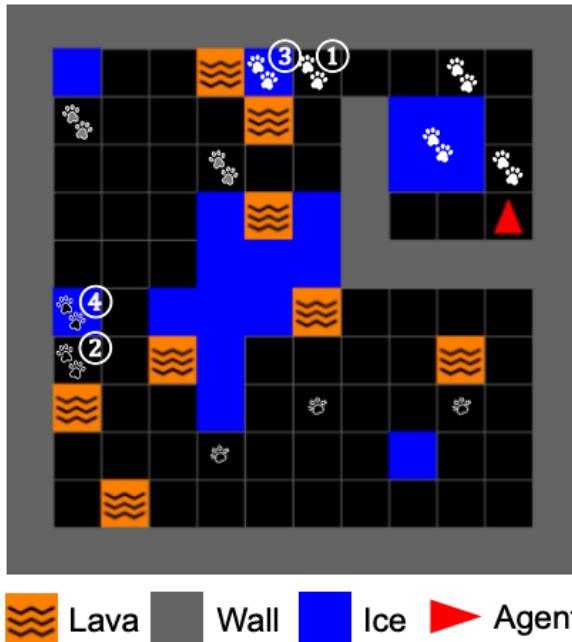


Recent Masters Thesis Example

Intrinsically Motivated Learning in Open-Ended Environments:
Understanding the Interplay of Empowerment and Information Gain



Fryderyk Mantiuk



Mantiuk et al., (Cogsci 2025)¹⁴

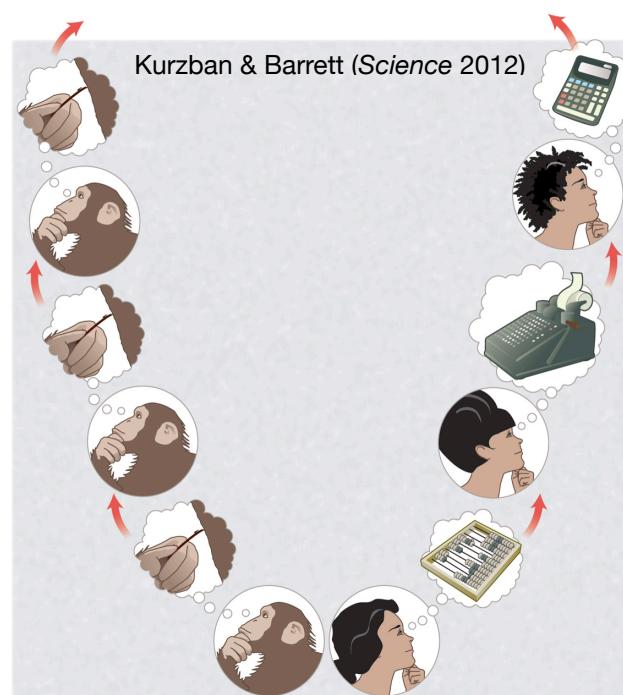
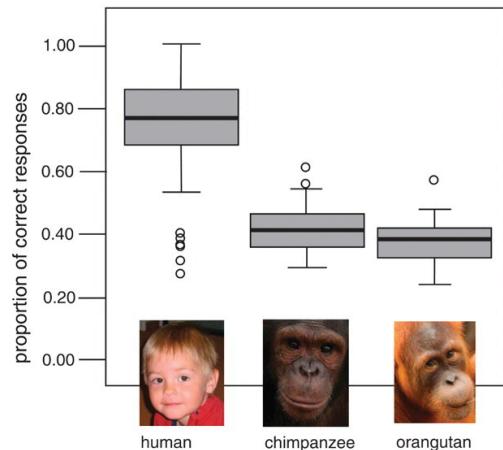
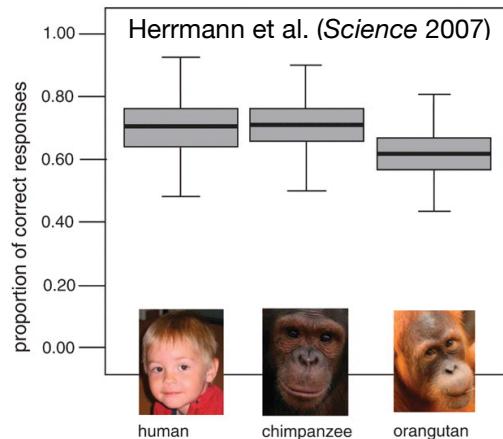
Human intelligence is defined by our capacity for social learning and cumulative culture



Physical

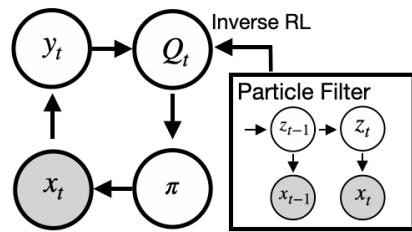
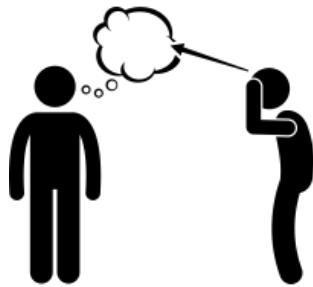


Social



Hierarchy of Social Learning

Theory of Mind (ToM)

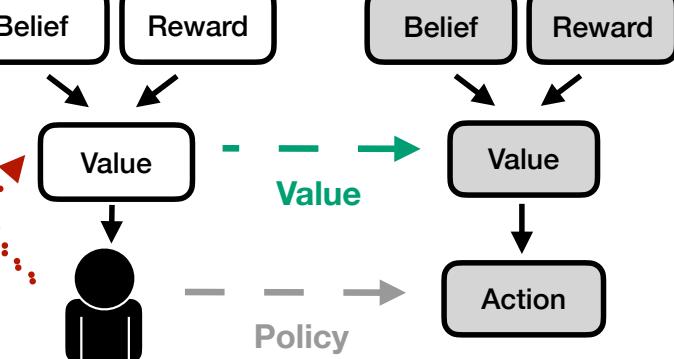


Wu, Dale & Hawkins (2024)

Flexible &
Compositional
↑
Computationally
Cheap
↓

Model-based

Self



Wu, Veléz & Cushman (2022)

Cost-based arbitration

Social transitive inference task



Value hierarchy

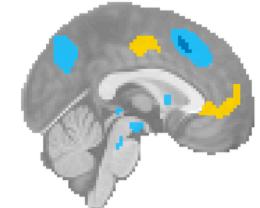
Demonstrator



Participant



Witt et al., (2023; *in prep*)

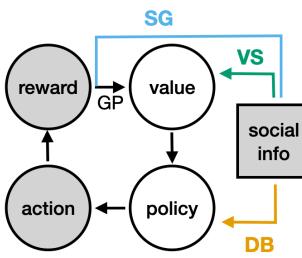


Flexible social learning despite individual differences

PNAS



Witt et al., (2024)

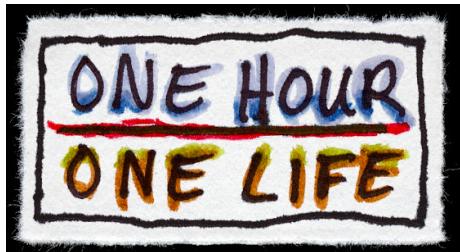


Wu et al., (2025)

Visual-spatial dynamics of adaptive social learning



Cultural evolution in virtual societies

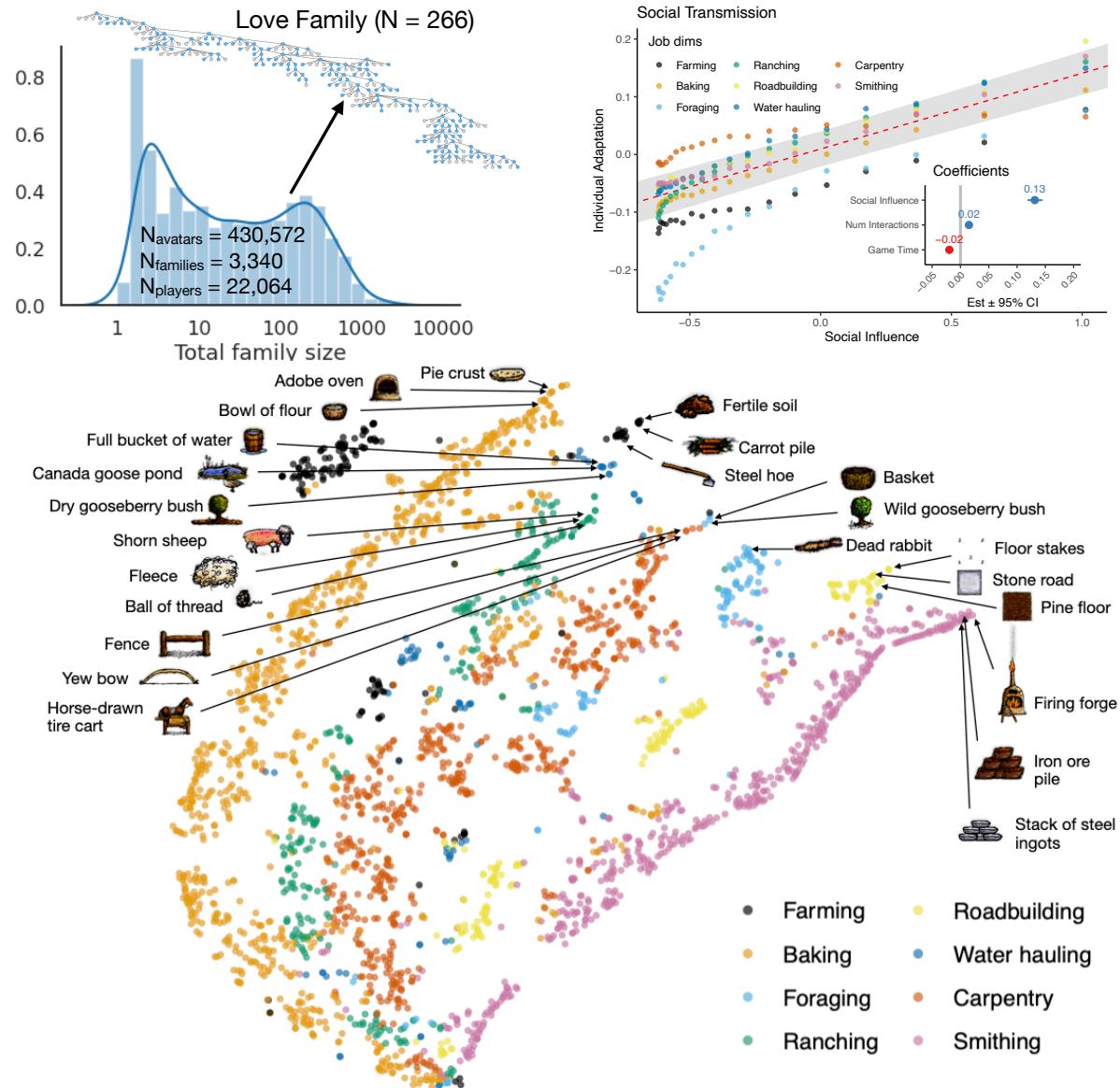


~ 60 minutes real time



Born to a random player Dependent on online player community to survive until adulthood

Incremental improvements lead to largescale technological progress over successive generations



Potential thesis projects

Social Learning

- **Agent-based simulations** to study which social learning strategies perform best in different environments (wisdom vs. madness of crowds)
- **Implement experiments** with AI-Human collaboration
- [Infrastructure in progress]: **online multiplayer experiments**

How to get started

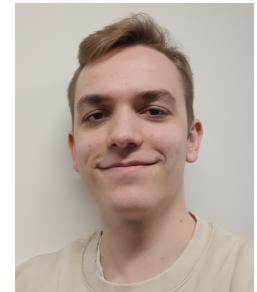
- Read Wu, Dale, & Hawkins (*Open Mind*, 2025) for an overview of some open questions
- Read related literature to identify current theoretical accounts and hypotheses
- Propose a plan for how to test them empirically

Cultural Transmission

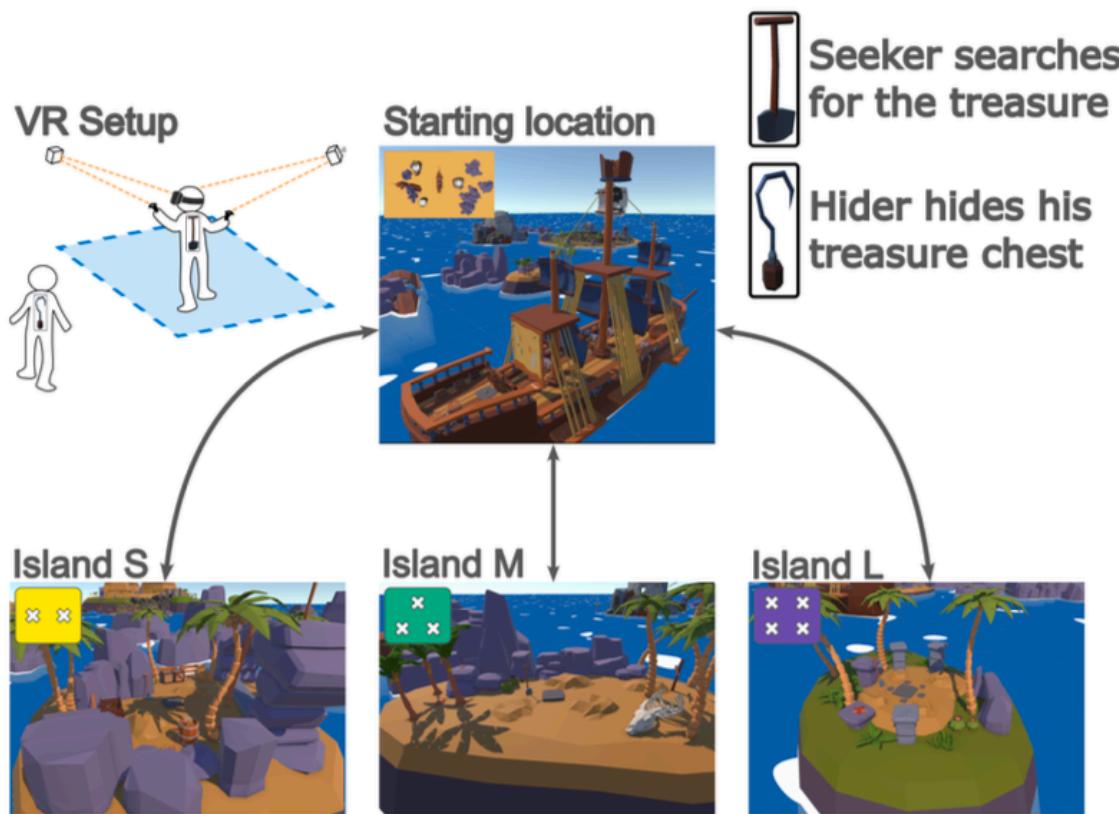
- **Agent-based simulations** to study the dynamics of social transmission over multiple generations
- [Infrastructure in progress]: **model cultural transmission using LLMs**
- [Infrastructure in progress]: **online transmission chain experiments**

Recent Bachelor's Thesis Example

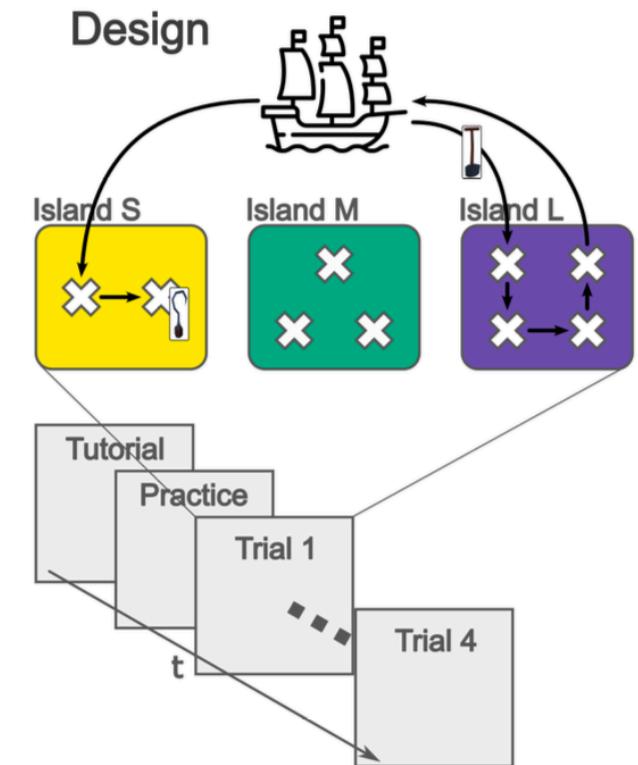
K-level reasoning in a repeated Hide-and-Seek VR Game



Stephen Taffner



- Seeker searches for the treasure
- Hider hides his treasure chest



Recent Masters' Thesis Example

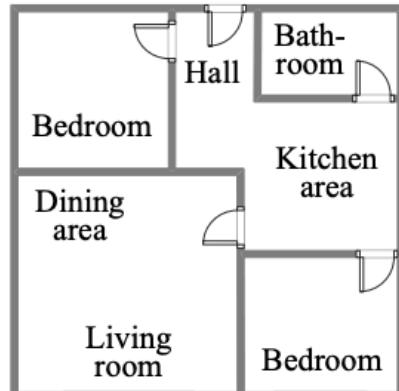
Comparing Global and Local Advice in Human-AI Interaction



Orsolya Szőcs

Global vs. local AI assistance in home design

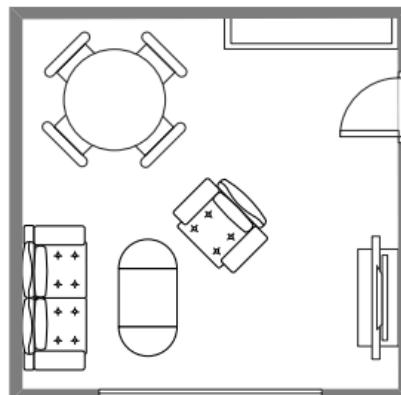
Global AI: assigns functional roles to rooms within a home



Example for global advice



Local AI: optimises furniture arrangements within a room



Example for local advice



Experimental procedure overview

Tutorial



Pre-AI



AI instructions



AI (global or local)



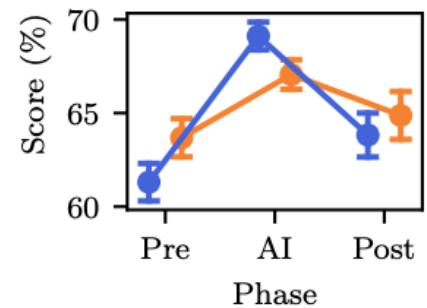
Post-AI



Questionnaire



Average performance across phases



General information

- Working language is English
- Strong computational skills are required for all lines of research
 - Please make sure to *include a link to public code repositories* when contacting me about a thesis project
- My lab members only start in Darmstadt between January - February 2026
 - Earliest start date of a thesis is in the Summer Semester
- You will be expected to take part in weekly lab events (lab meeting, journal club, and talks)
- A high-degree of independence and self-motivation is required, including willingness to learn new skills and read relevant papers on your own initiative

Thank you for your attention

- Lab website: hmc-lab.com
 -  PUBLICATIONS for open access pdfs of all papers & links to open code/data
 -  RESOURCES for these slides as a pdfs
- Offices: @ Hessian.AI, Landwehrstraße 50A
 - Flex office for Bachelor/Masters students
- Contact:
 - Email: charley.wu@tu-darmstadt.de
 - Bluesky: [@thecharleywu.bsky.social](https://thecharleywu.bsky.social)

