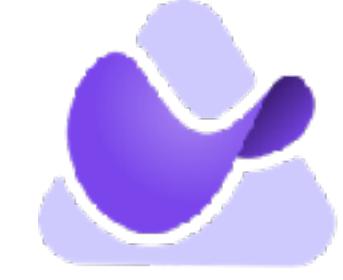


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Centre for  
Cognitive  
Science



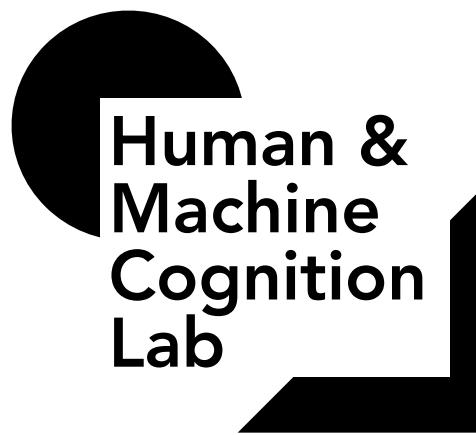
**hessian.AI**

# Human and Machine Cognition Lab



Thesis topics  
  
Prof. Dr. Charley Wu  
Computational Cognitive Science  
[hmc-lab.com](http://hmc-lab.com)  
Landwehrstr. 50A  
[charley.wu@tu-darmstadt.de](mailto:charley.wu@tu-darmstadt.de)

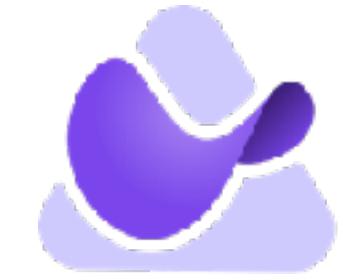




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Science

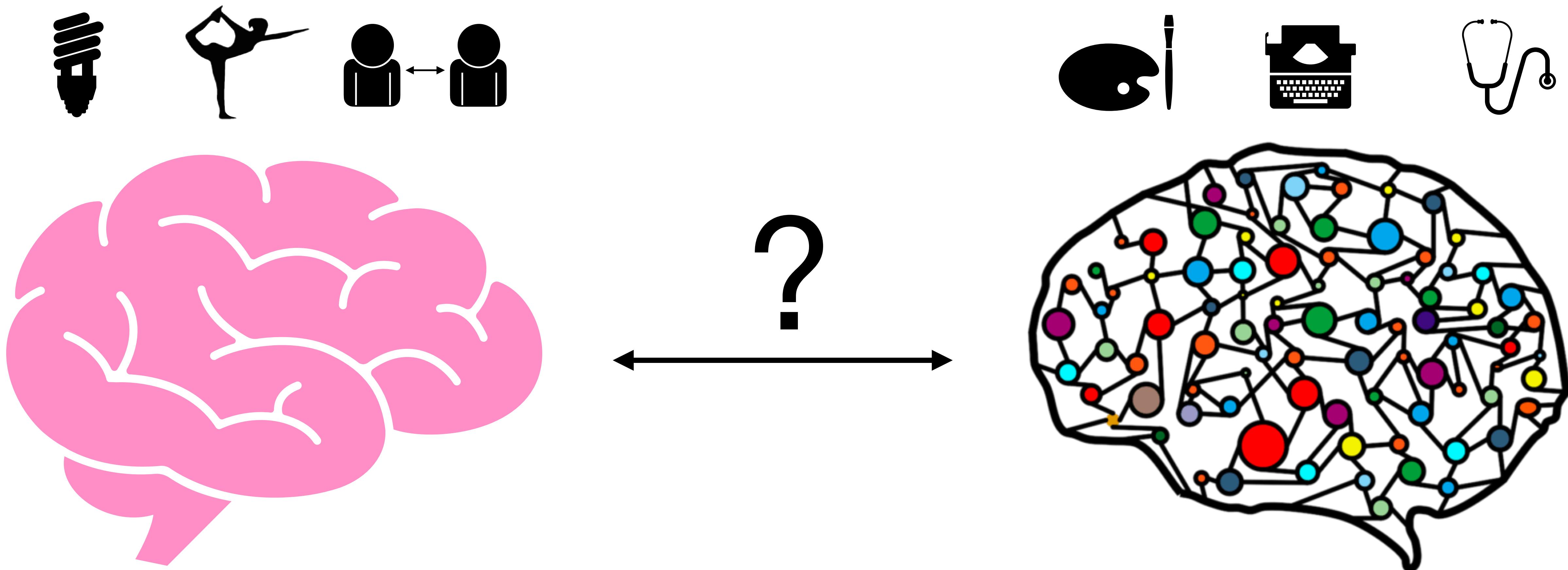


hessian.AI

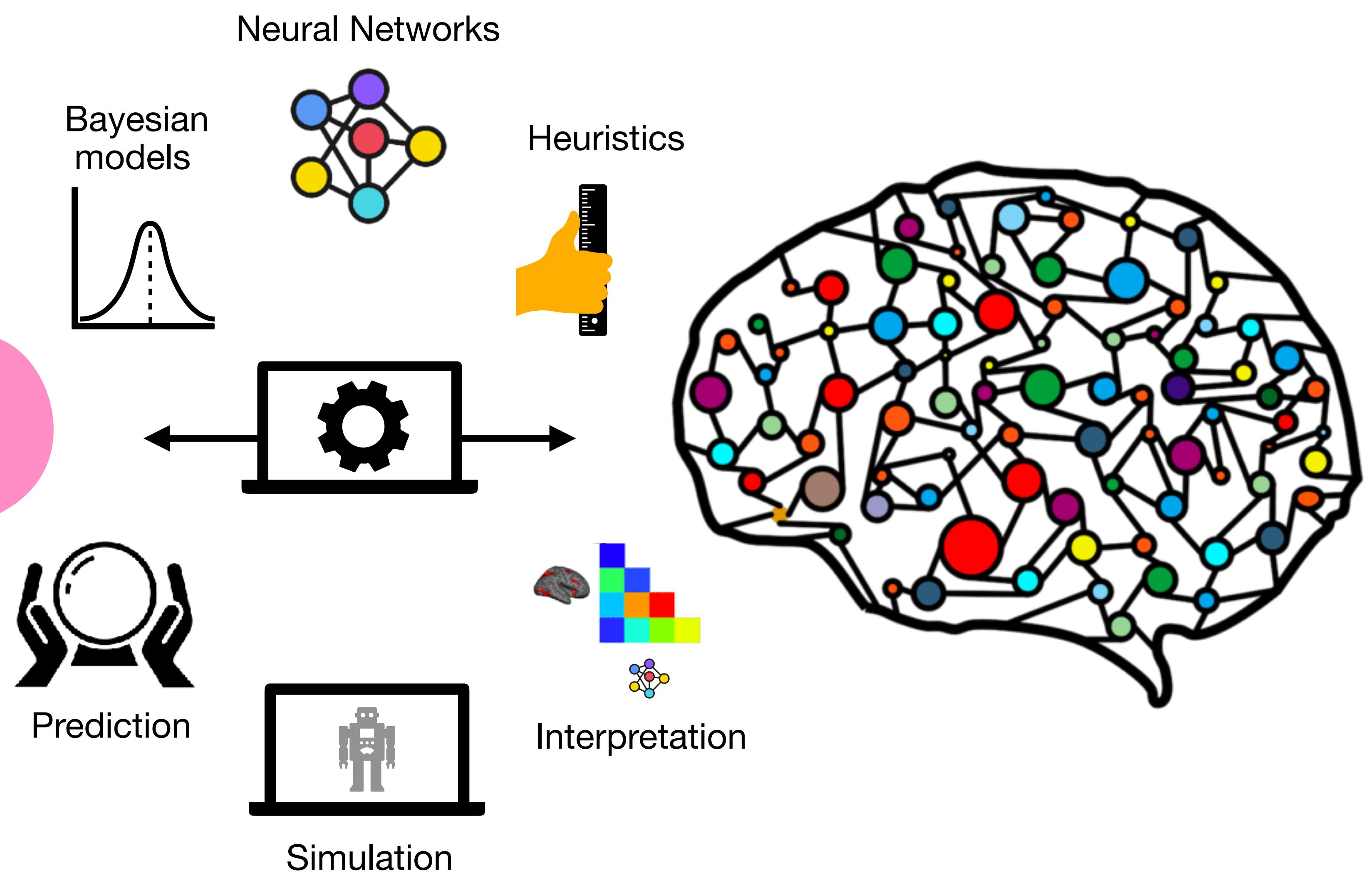


# Human and Machine Cognition Lab

# 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

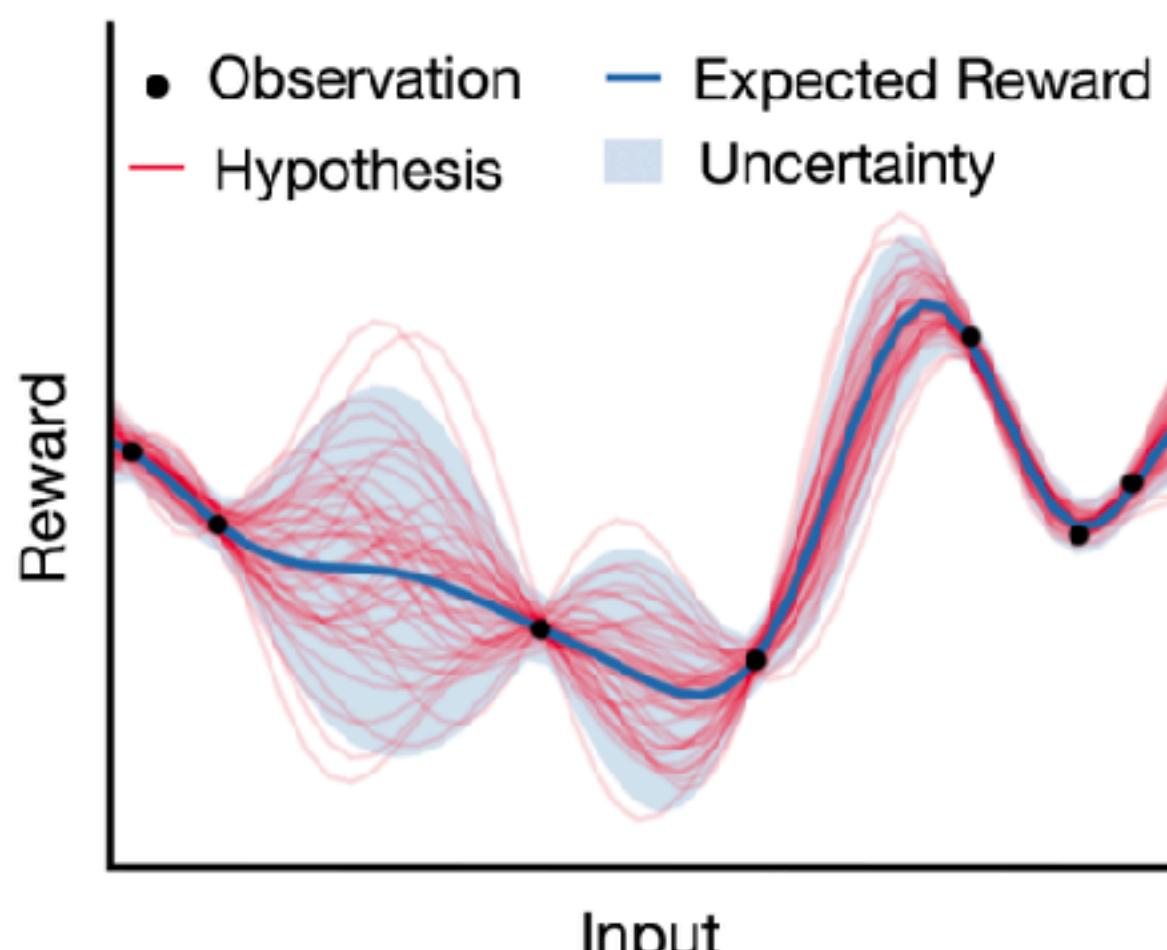
- Wu, Meder, & Schulz (*AnnRevPsych* 2025)
- Wu et al., (*NatHumBehav* 2018; *PlosCompBio* 2020)

# Guiding questions

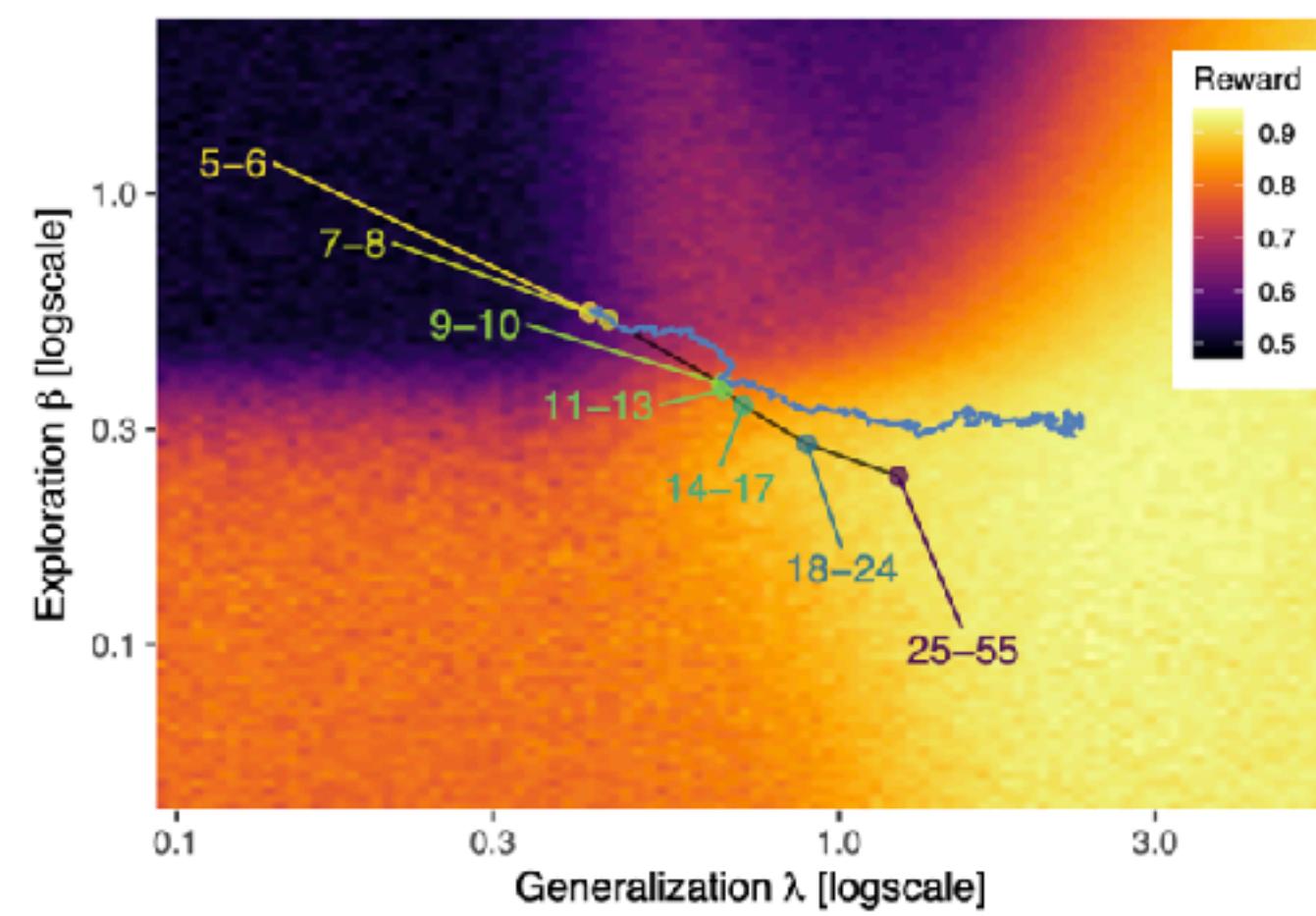
1. How do we **generalize** in novel environments?
2. How does intelligence **develop** over the lifespan?
3. How do we learn from each other in **social** and **cultural** settings?



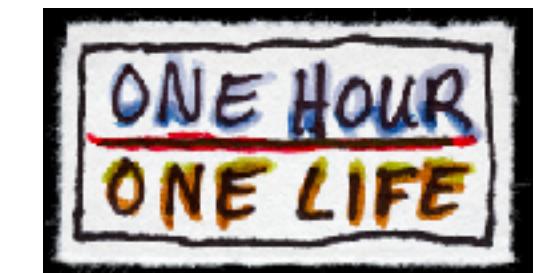
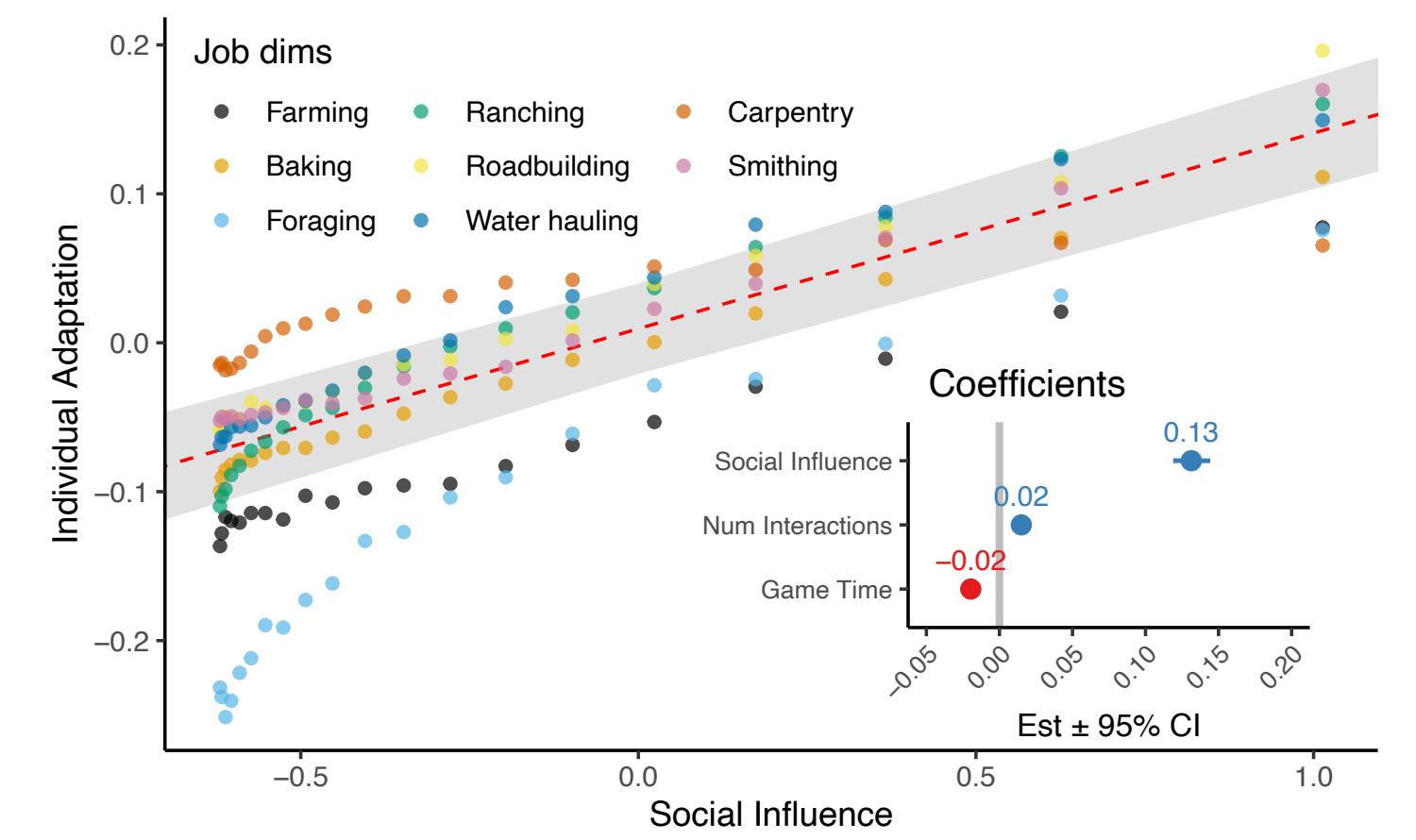
**Human generalization as Bayesian function learning**



**Developmental change as stochastic optimization**



**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



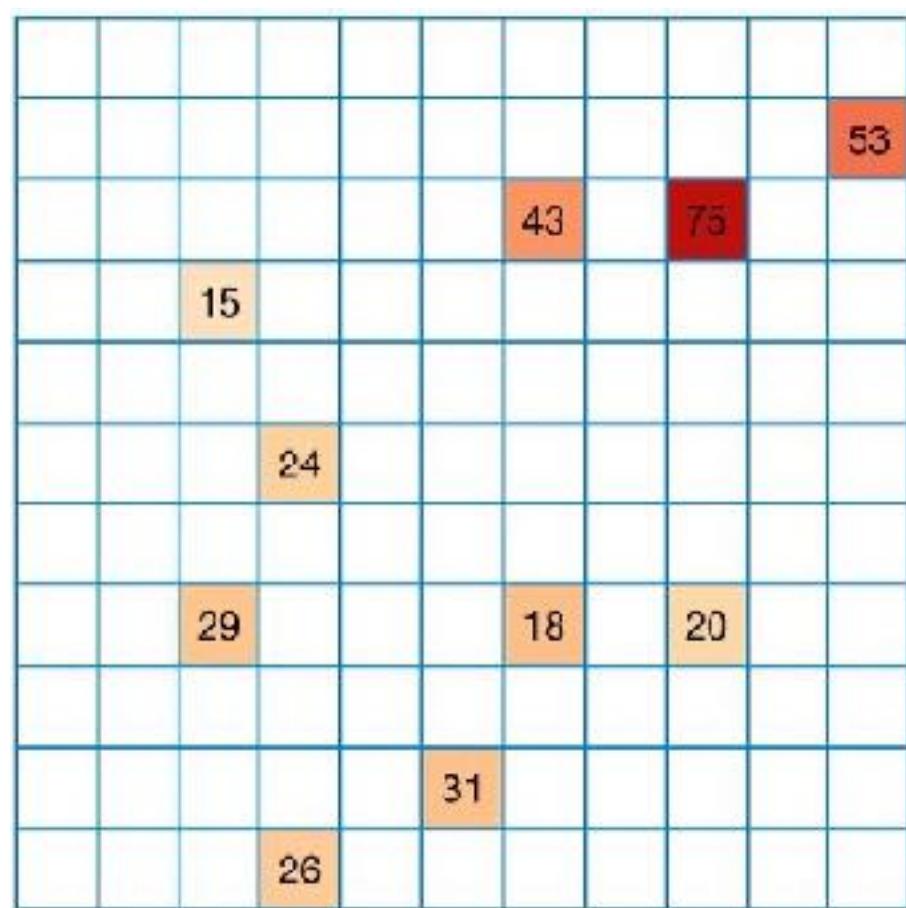
Reward expectations are spatially correlated



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

# Generalization as function approximation

Observations



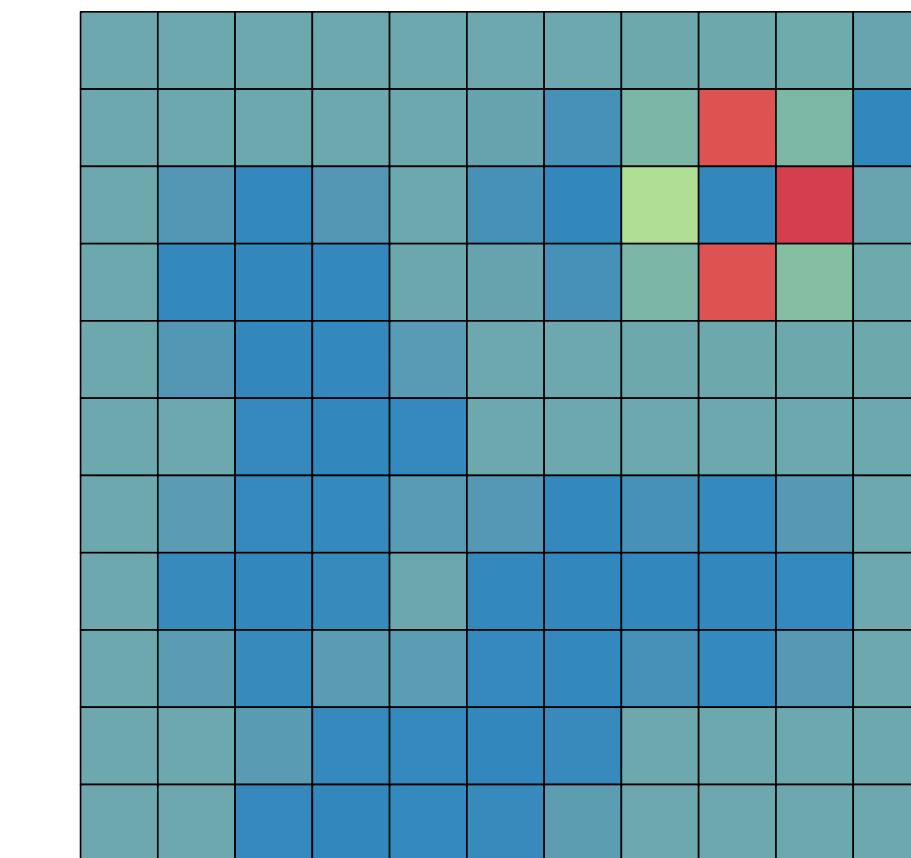
Gaussian Process model of generalization

- Observation
- Hypothesis
- Expected Reward
- Uncertainty

Reward

Input

Softmax Choice Rule



$P(x)$

0.1

0.0

0.0

0.0

# Framework and models replicated across a variety of tasks and contexts

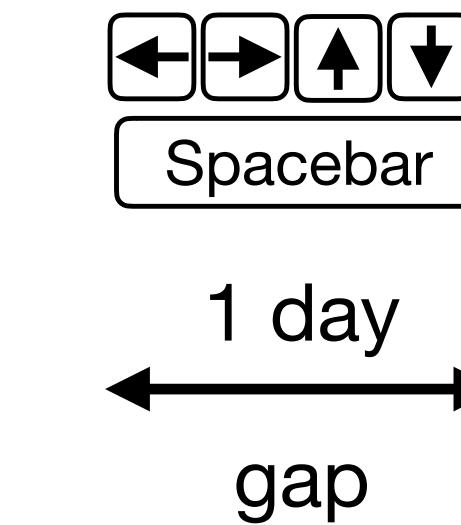
## Safe search with risky outcomes



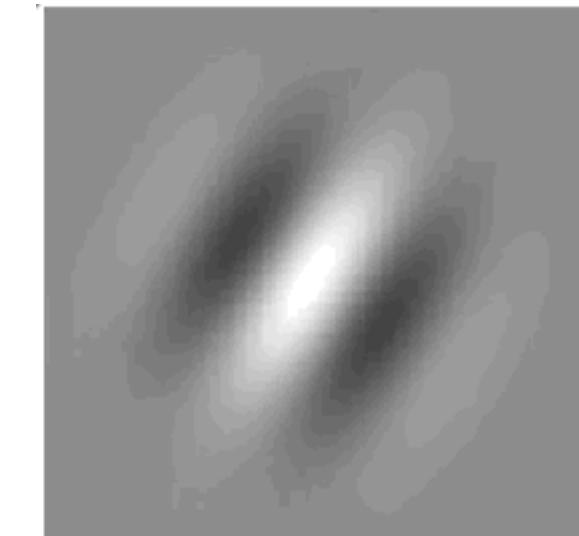
Schulz, Wu, Huys, Krause & Speekenbrink (*Cognitive Science* 2018)

## Spatial and conceptual search

### Spatial

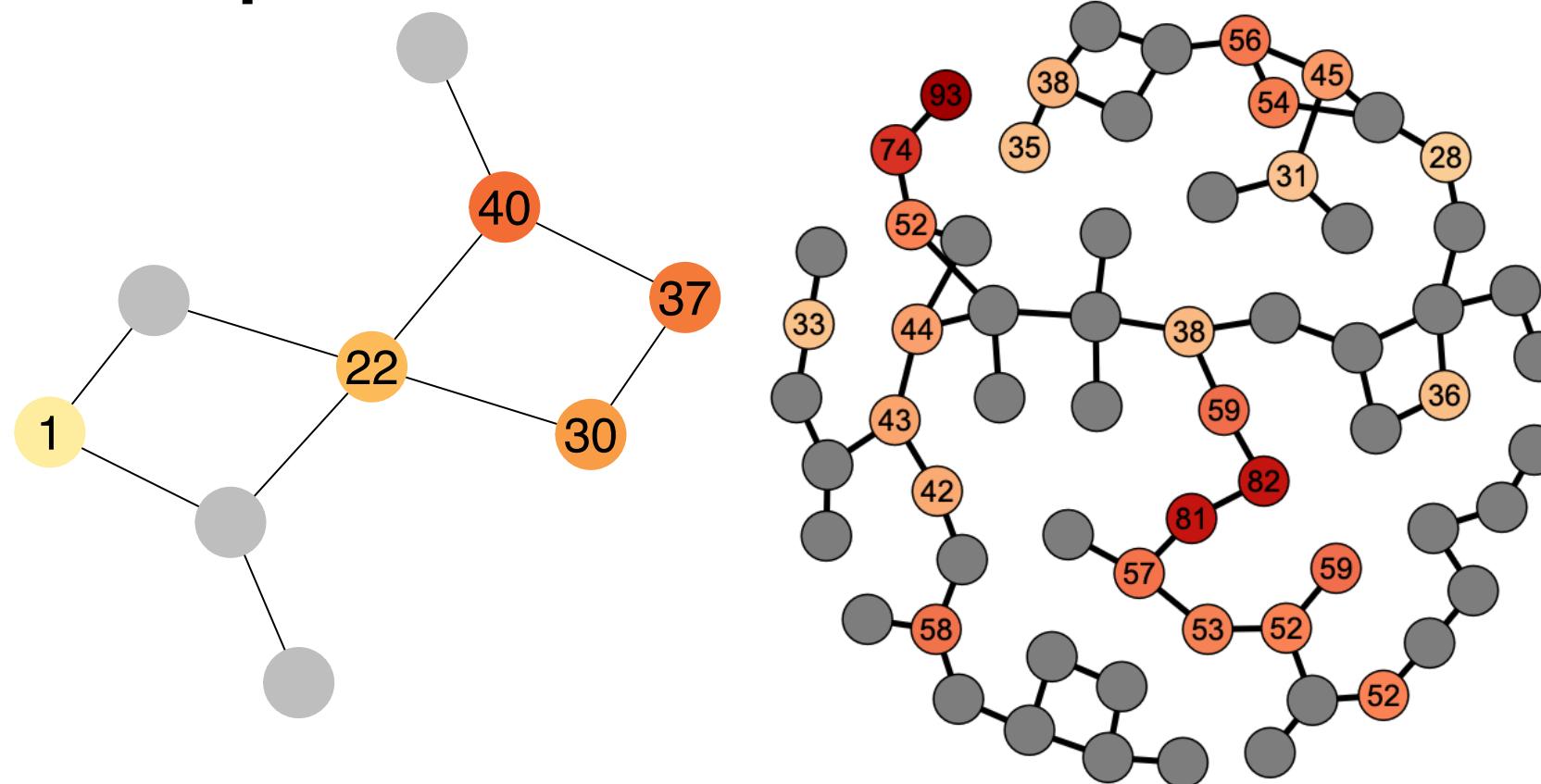


### Conceptual



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

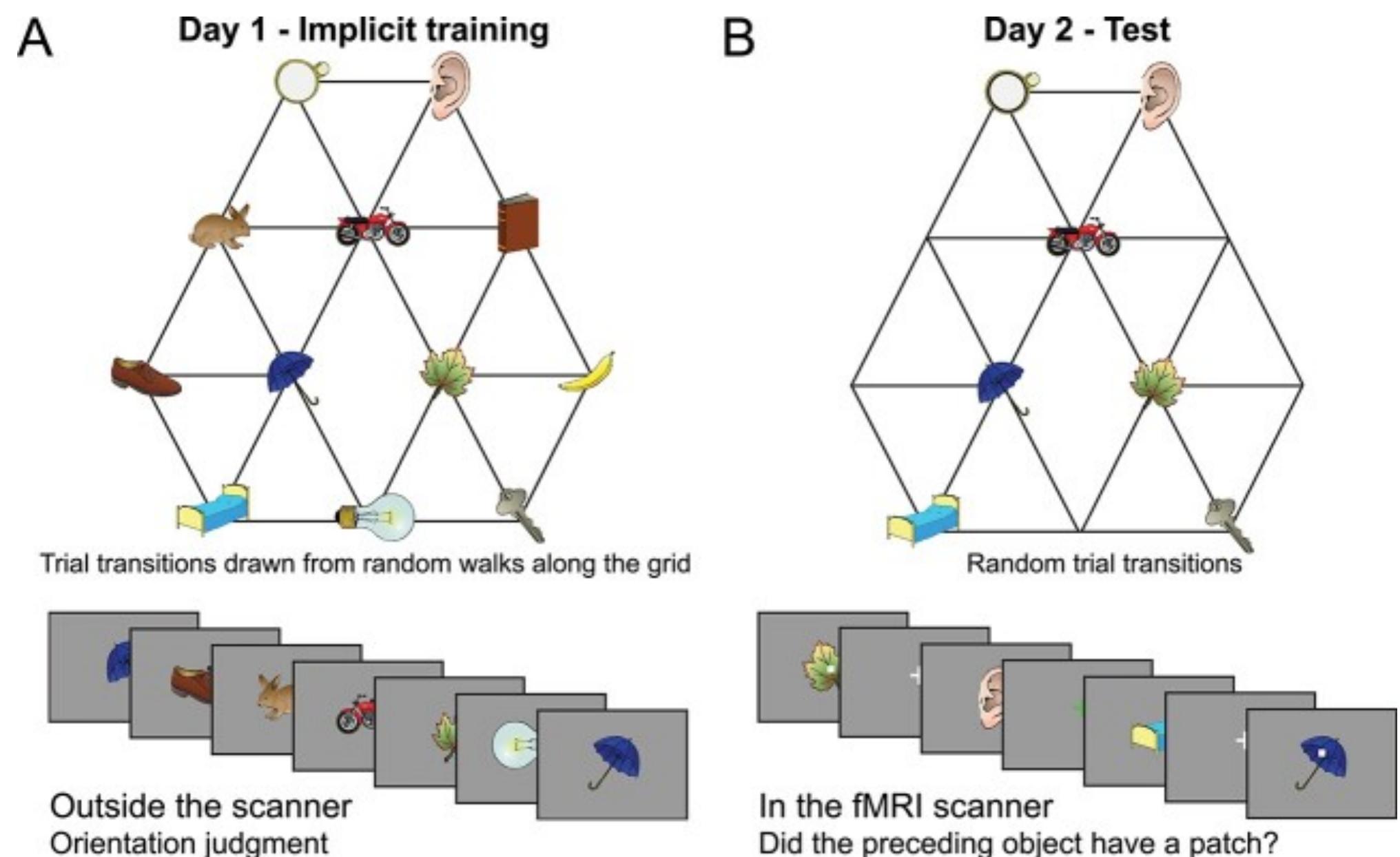
- Read Wu et al., (*AnnRevPsych* 2025) for an overview (any other relevant papers)
- Identify open questions and identify hypotheses

# Current Masters Thesis Example

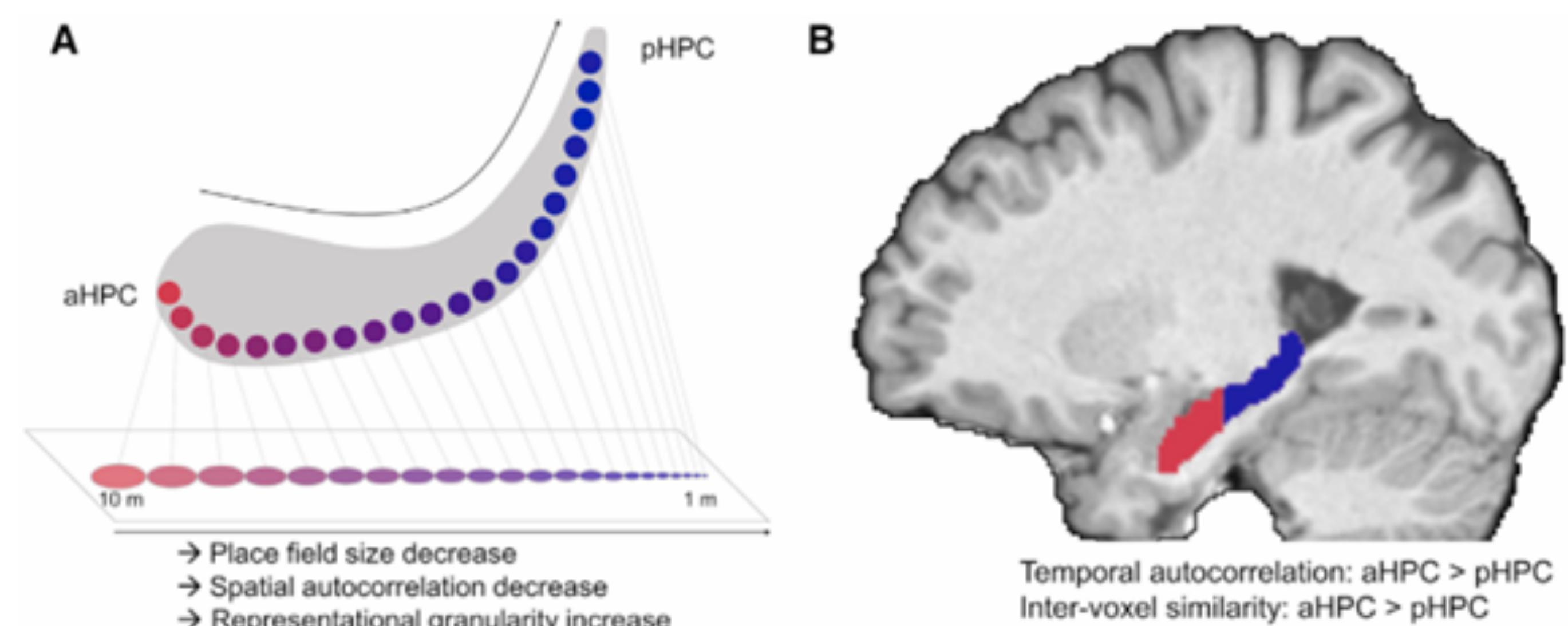
Multiscale Representations in the Human Hippocampus



Anna-Lea Beyer



Garvert et al., (2017)



Brunec & Momennejad (2022)

# Development as Stochastic Optimization



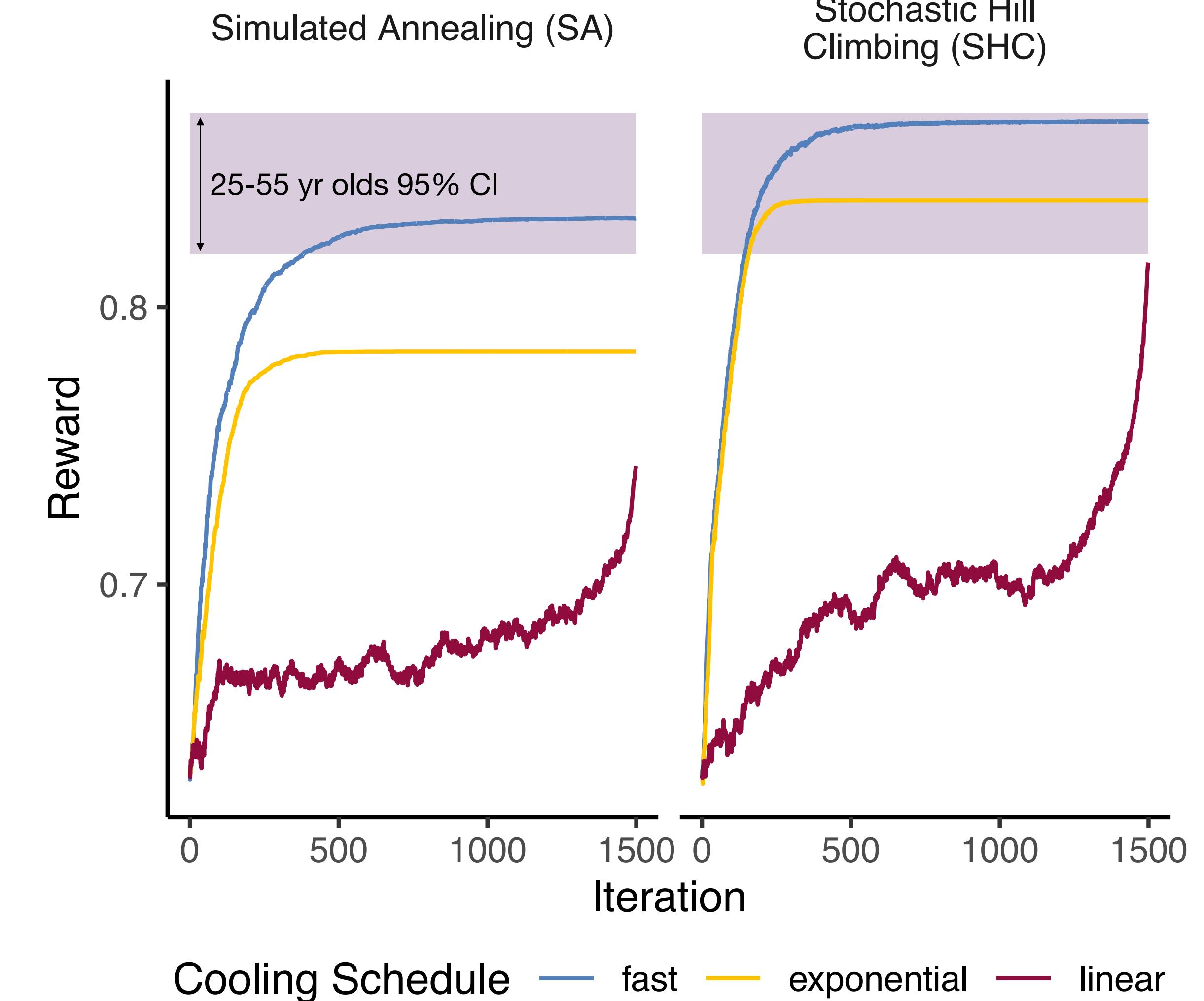
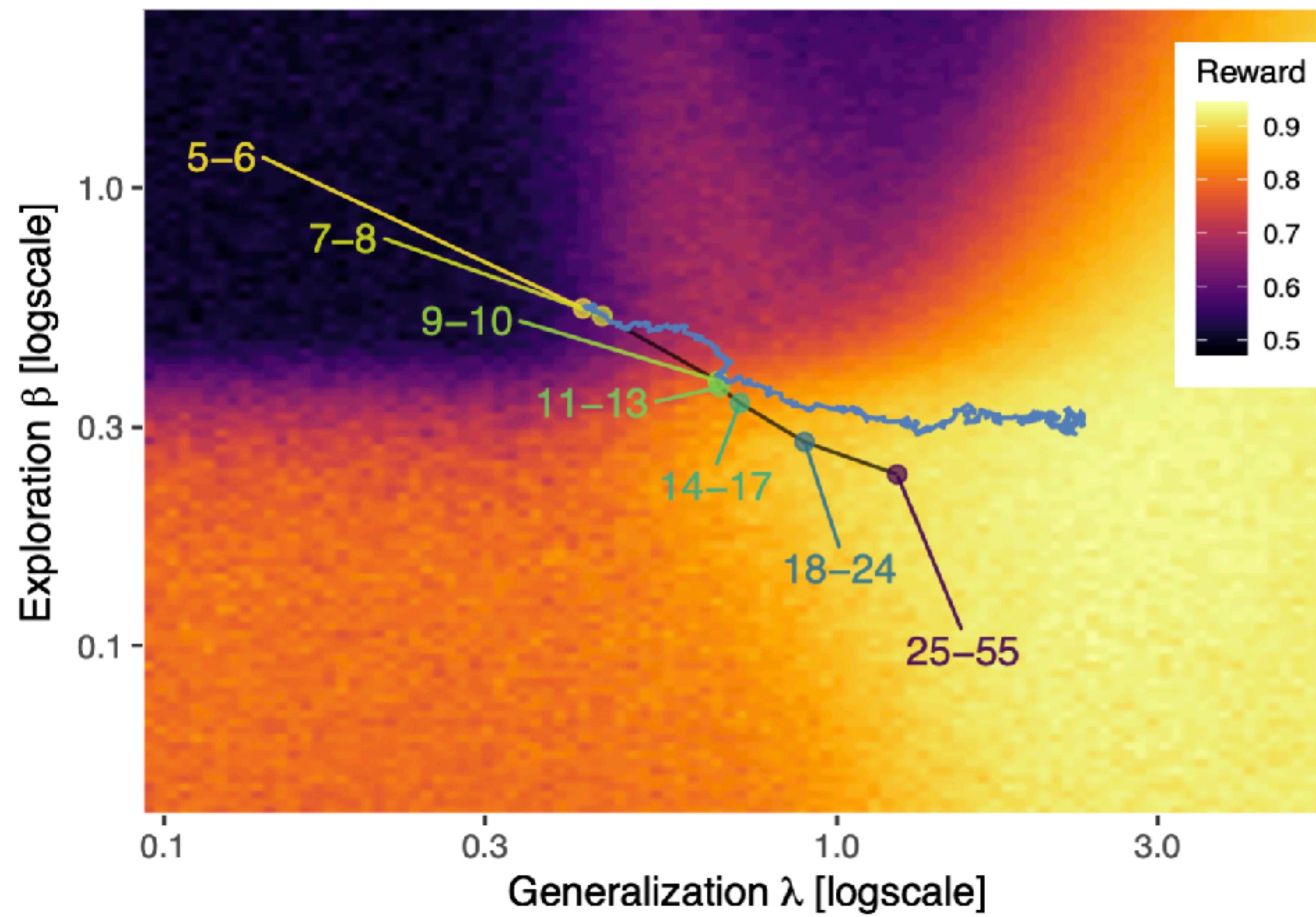
- Children initially perform high-temperature search, which gradually “cool offs” as they grow older
- The cooling schedule induces a gradual shift from exploration —> exploitation, preventing the algorithm from getting stuck in a local optimum



# Humans vs. Optimization algorithms

Anna Giron  
Uni Tübingen

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



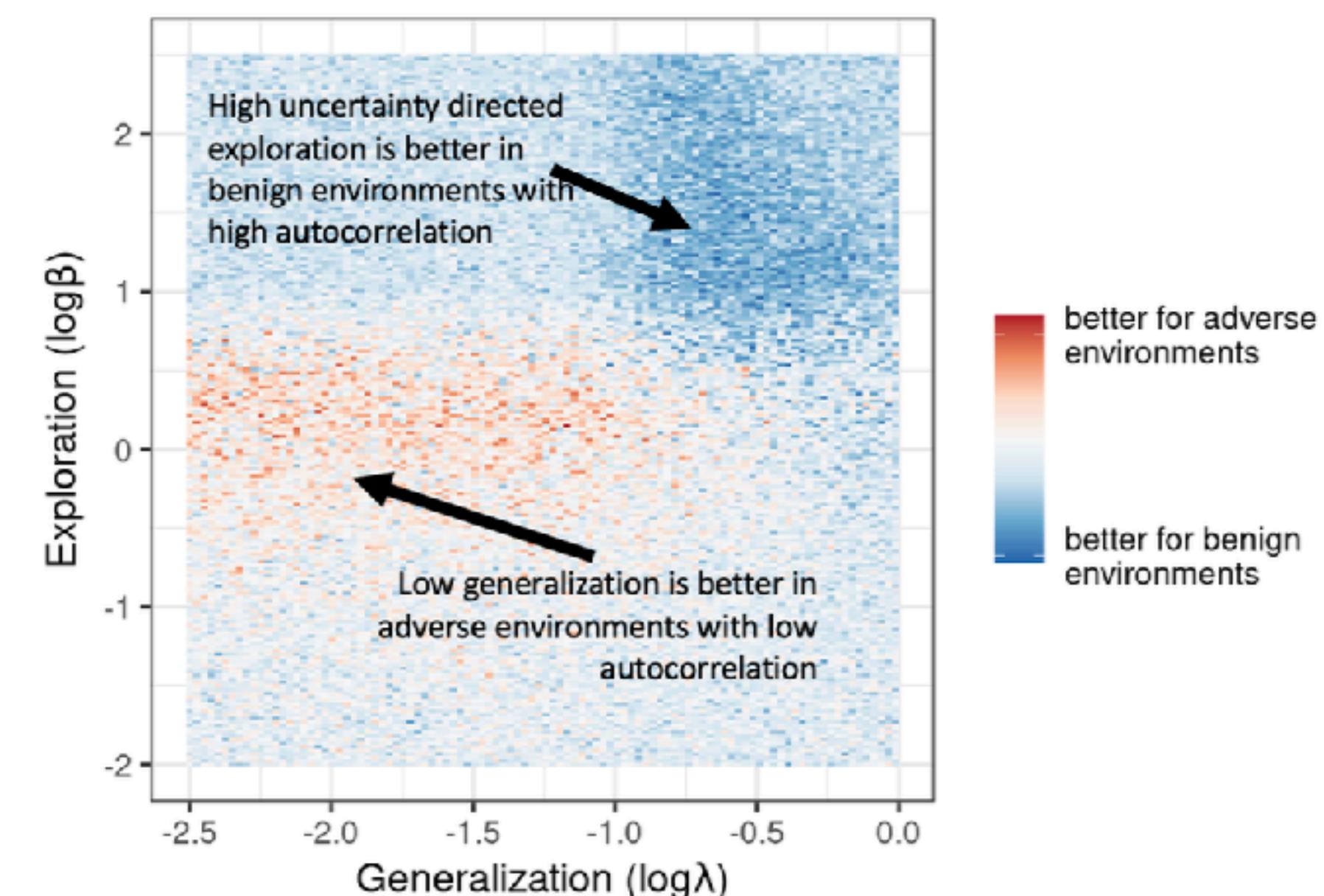
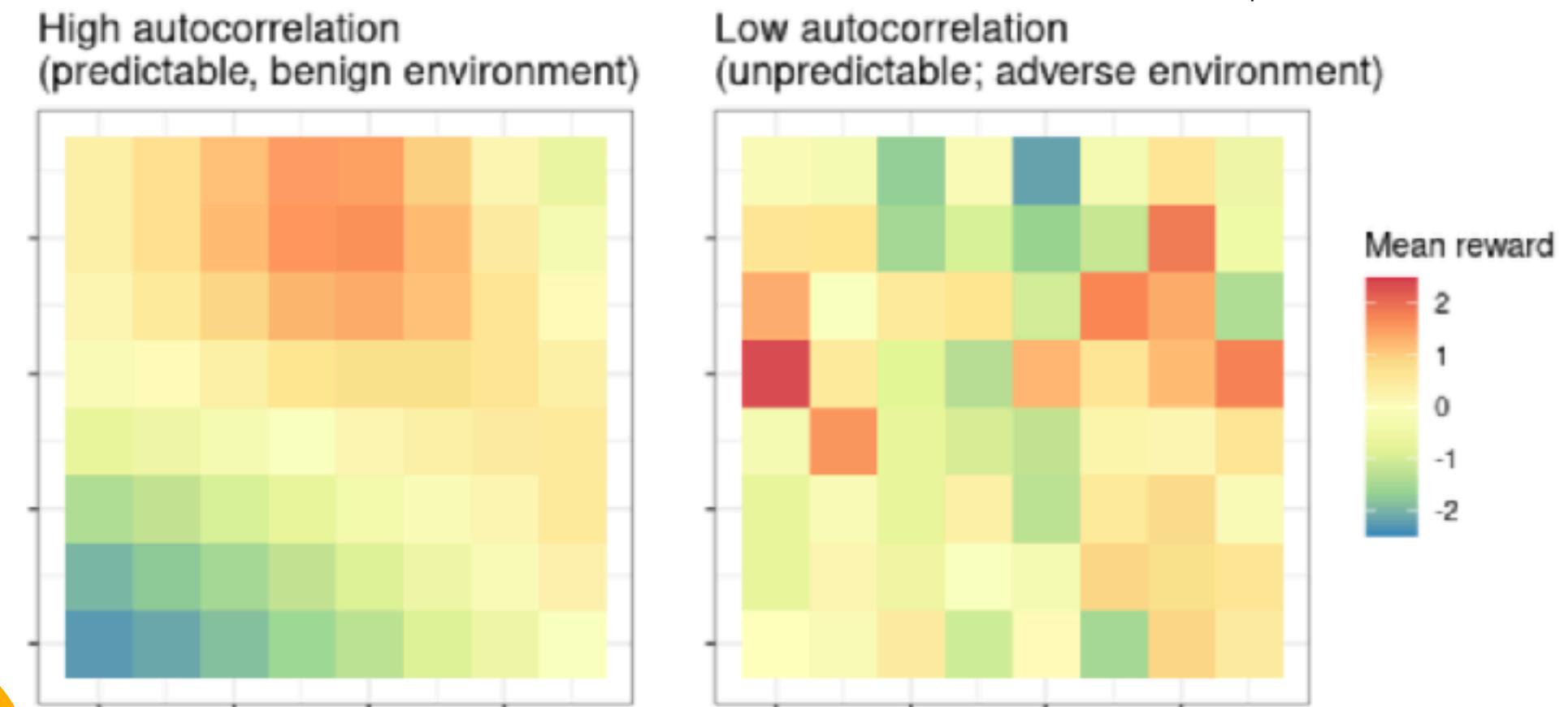
Dr. Simon Ciranka

MPI Berlin



Dr. Anna Thoma

MPI Berlin / Uni Frankfurt

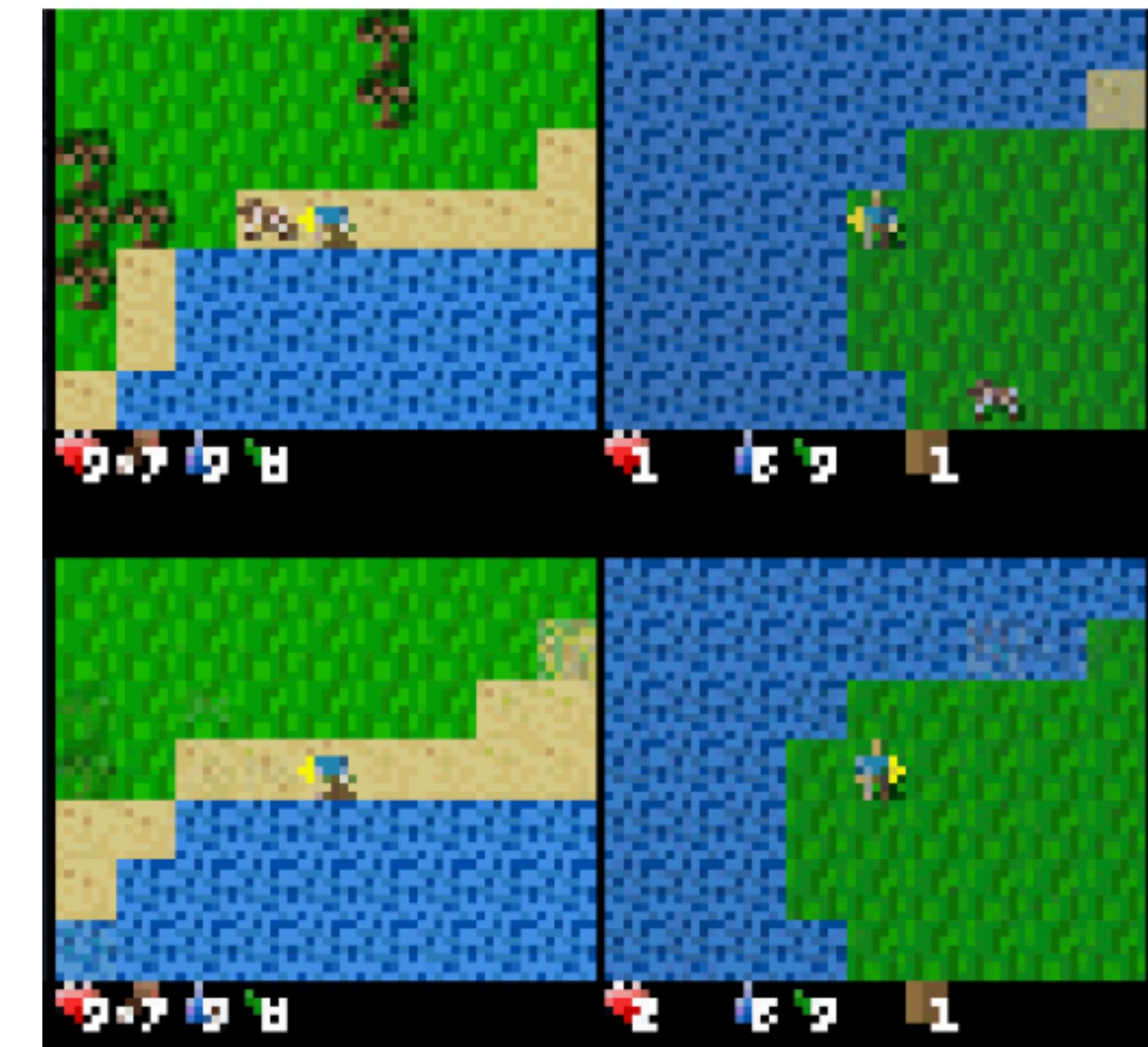
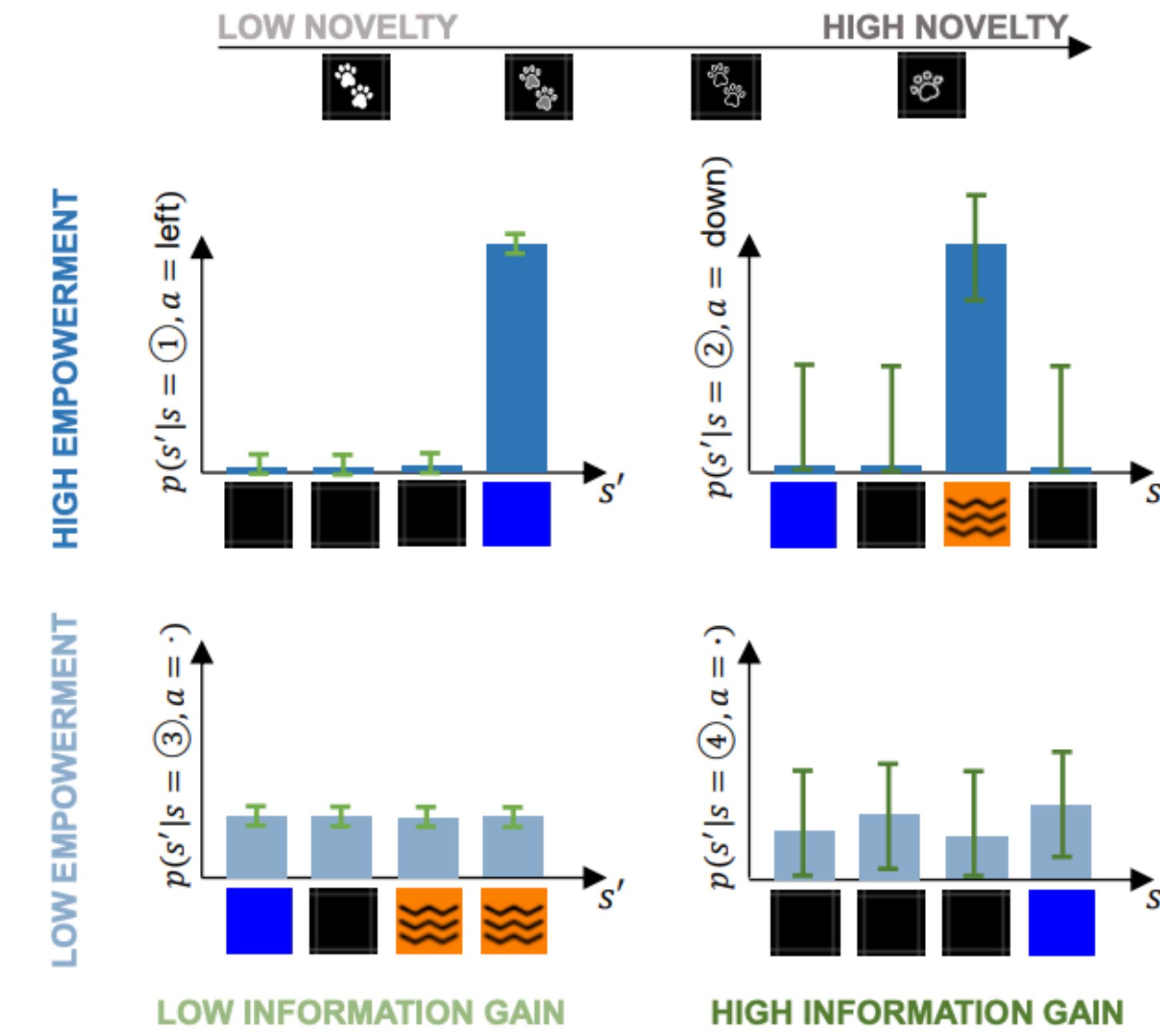
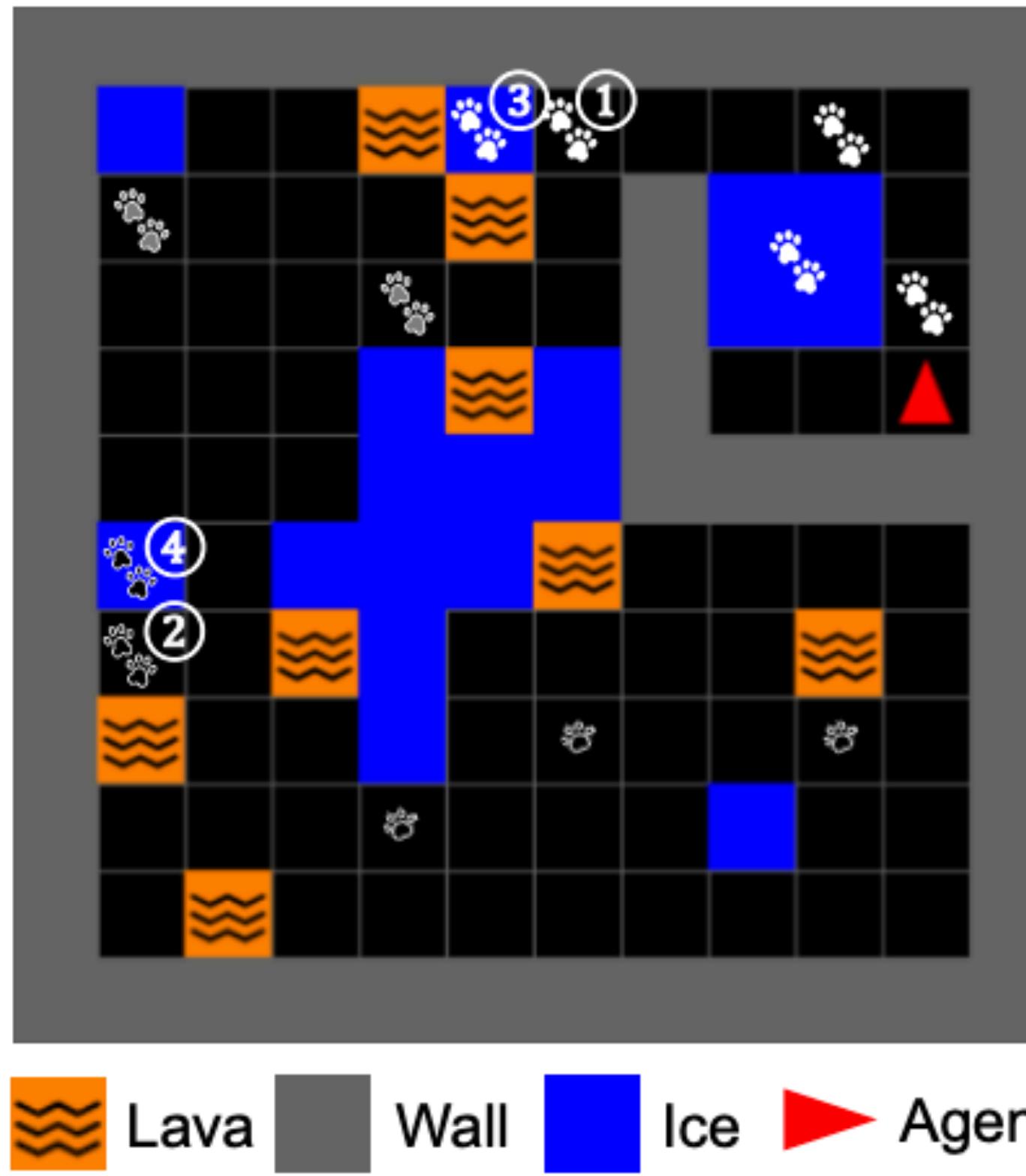


# Recent Masters Thesis Example



Fryderyk Mantiuk

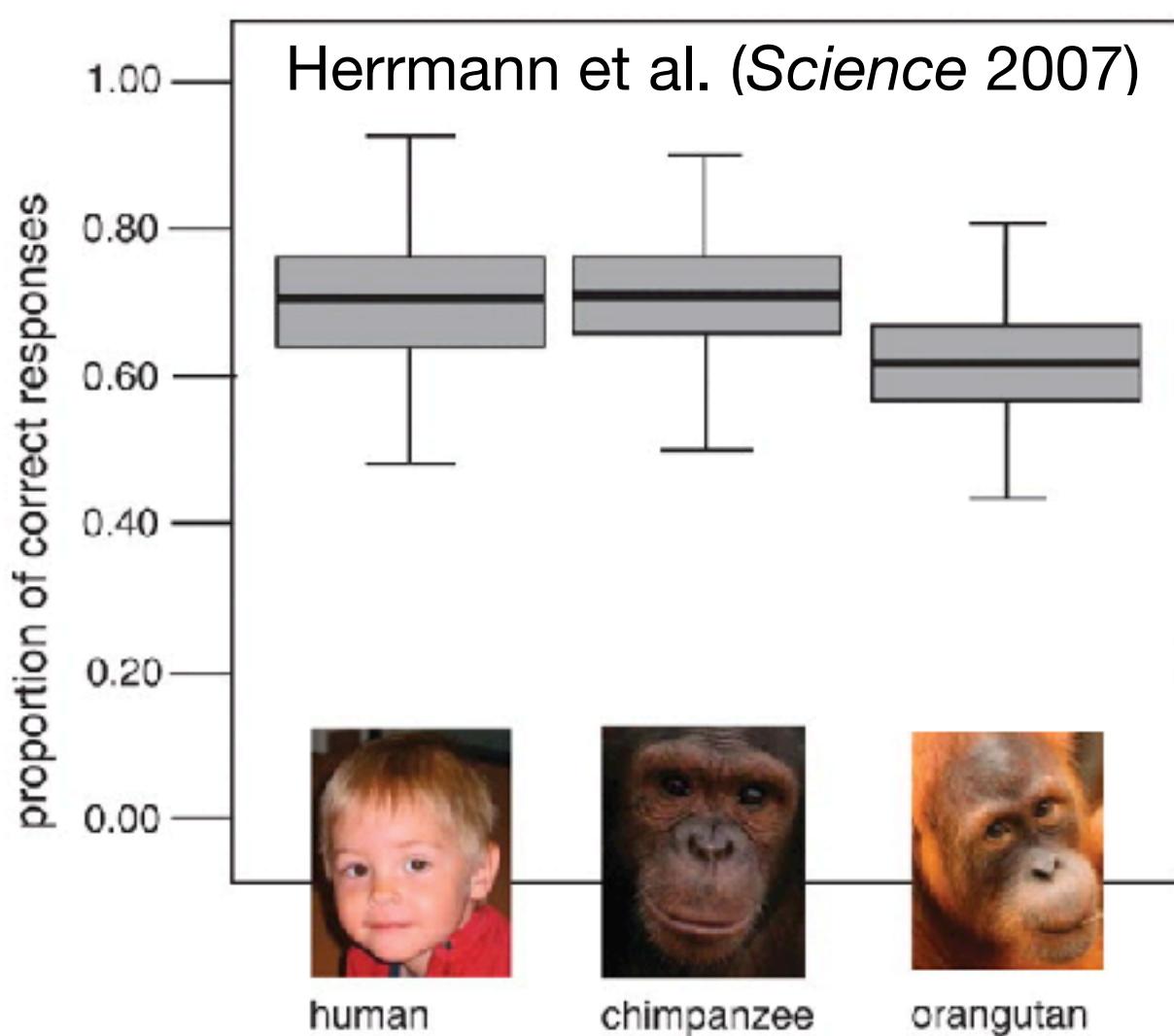
Intrinsically Motivated Learning in Open-Ended Environments:  
Understanding the Interplay of Empowerment and Information Gain



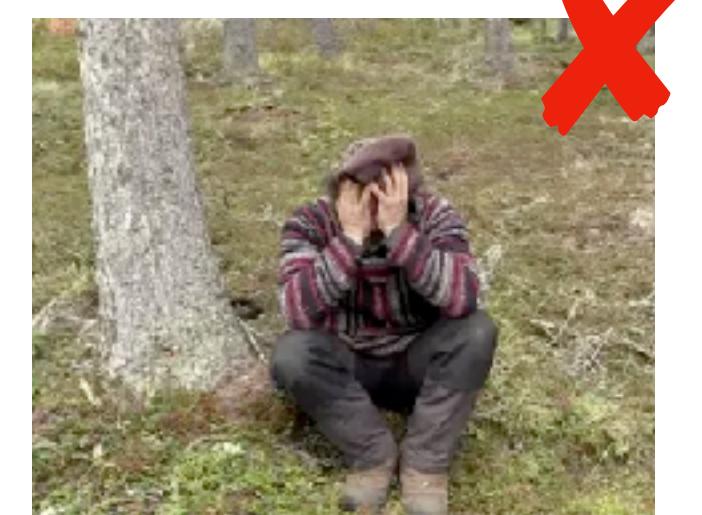
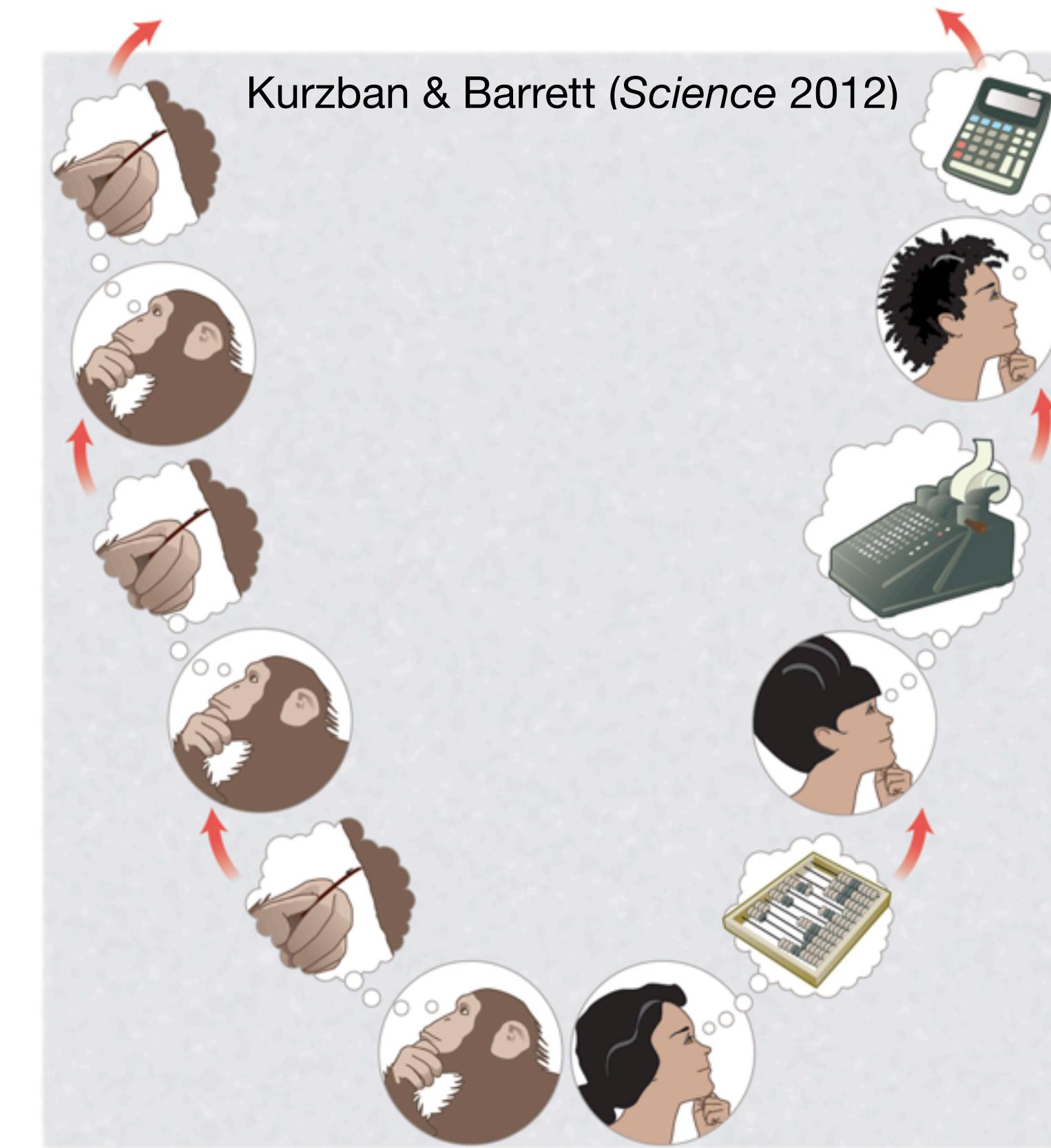
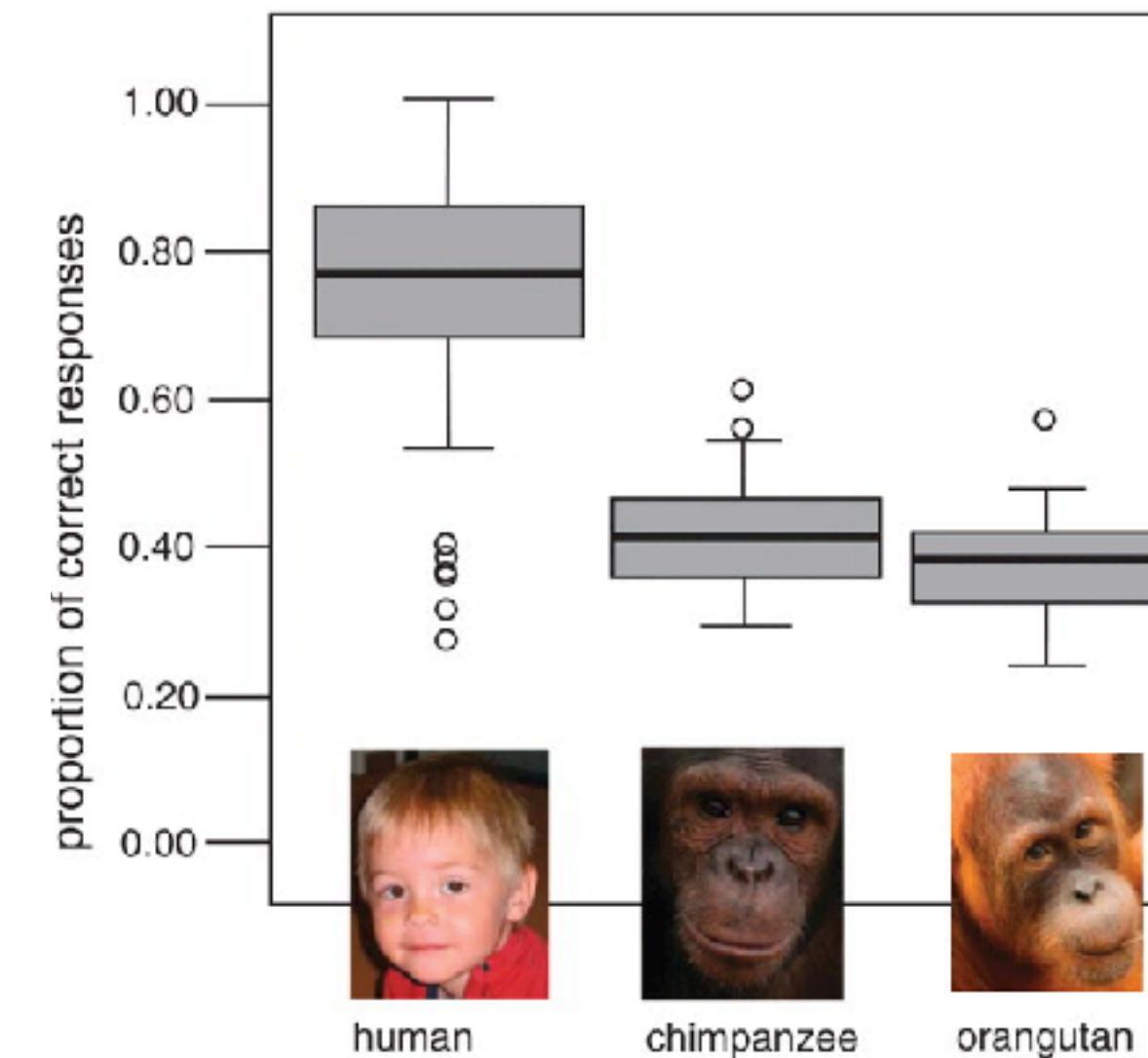
# Human intelligence is defined by our capacity for social learning and cumulative culture



Physical

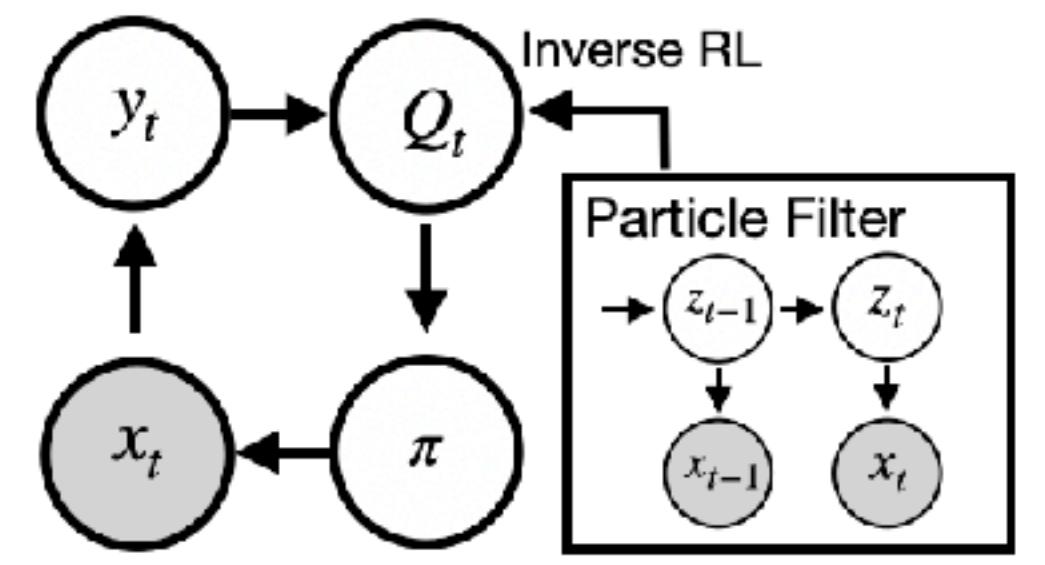
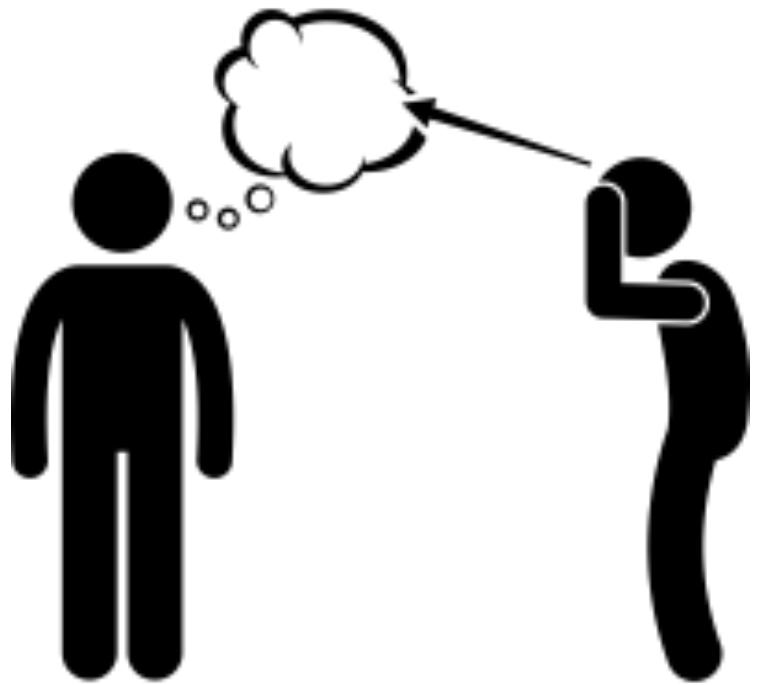


Social



# Hierarchy of Social Learning

Theory of Mind (ToM)



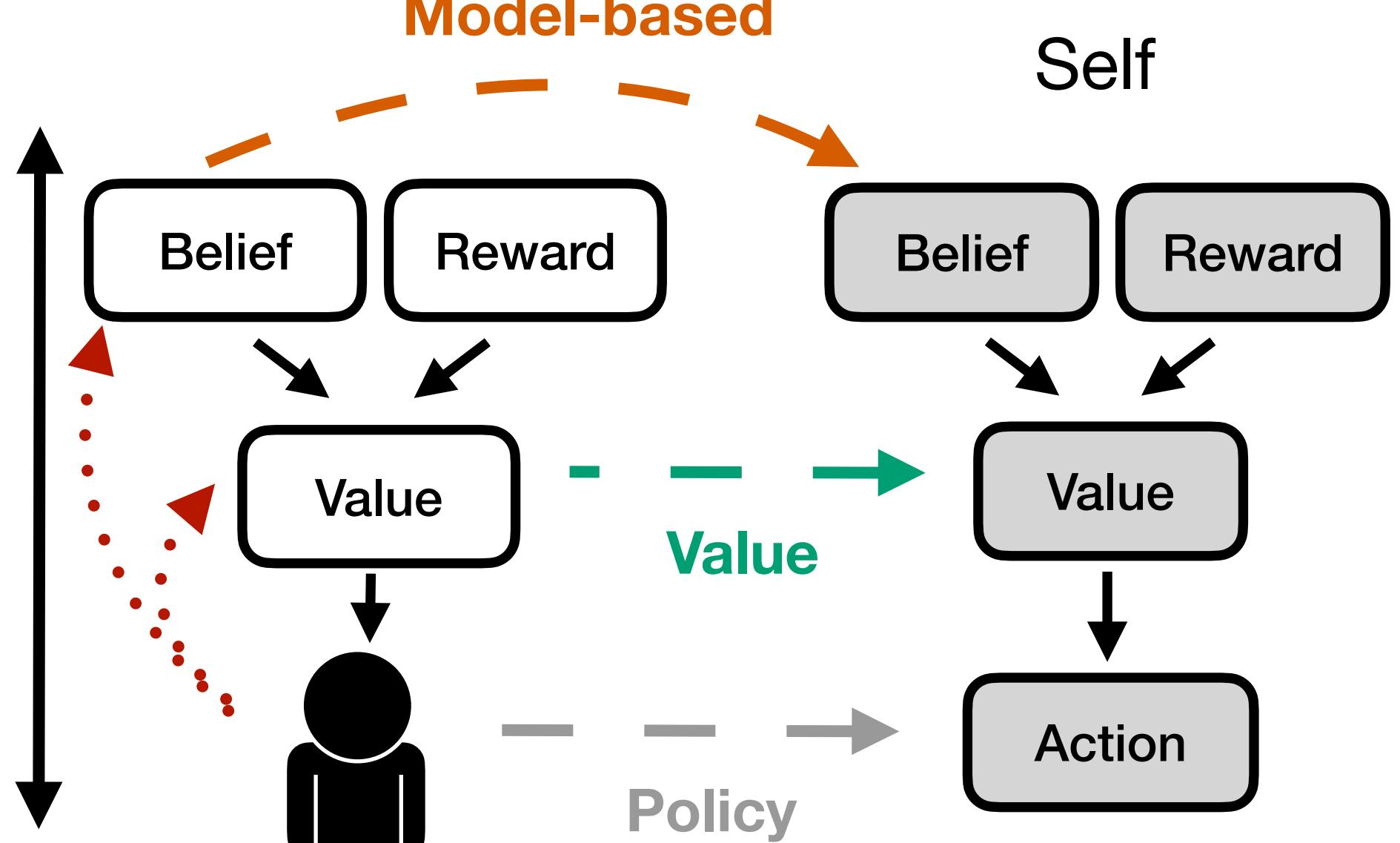
Wu, Dale & Hawkins (2024)

Flexible

&  
Compositional

**Model-based**

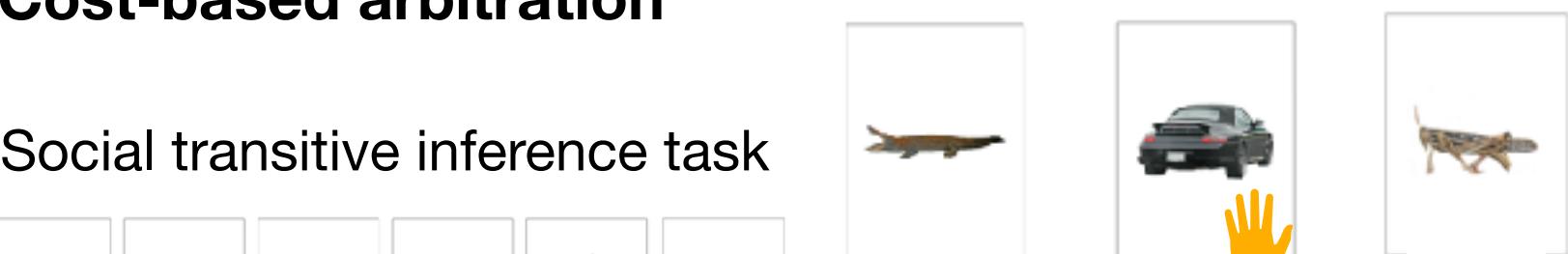
Computationally  
Cheap



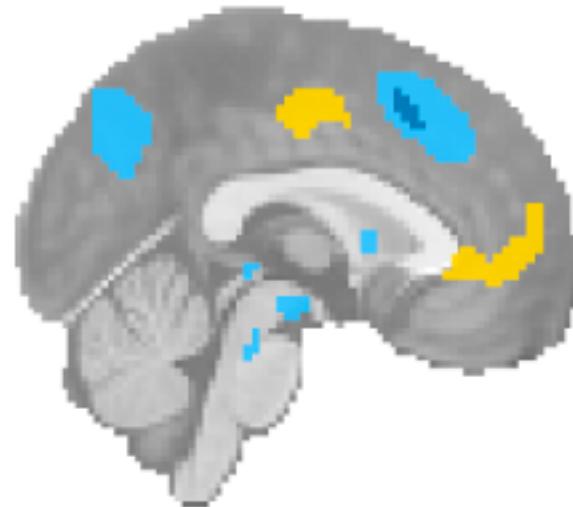
Wu, Veléz & Cushman (2022)

## Cost-based arbitration

Demonstrator

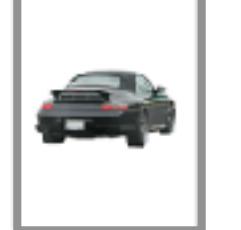


Witt et al., (2023; *in prep*)

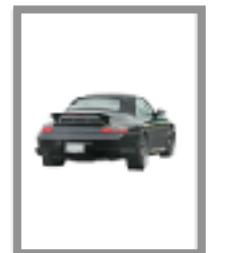


Value hierarchy

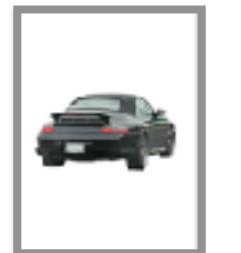
Participant



Imitation



Value Inference



Model-based Inference

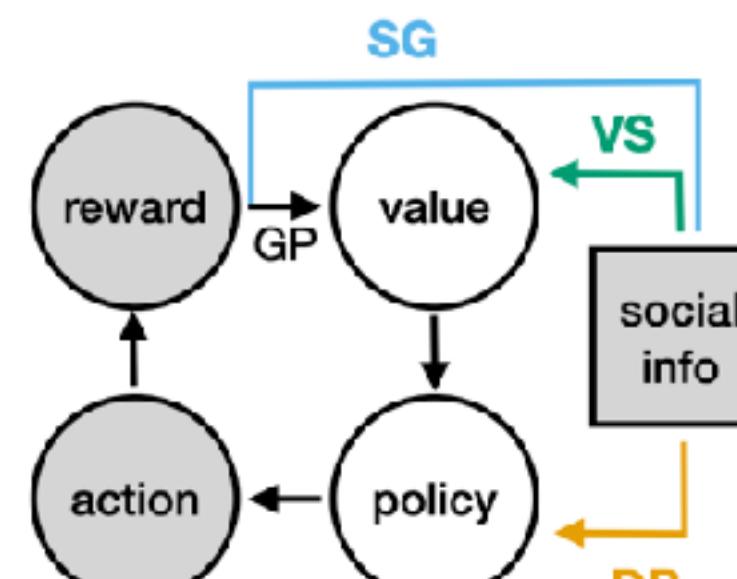


## Flexible social learning despite individual differences

**PNAS**



Witt et al., (2024)

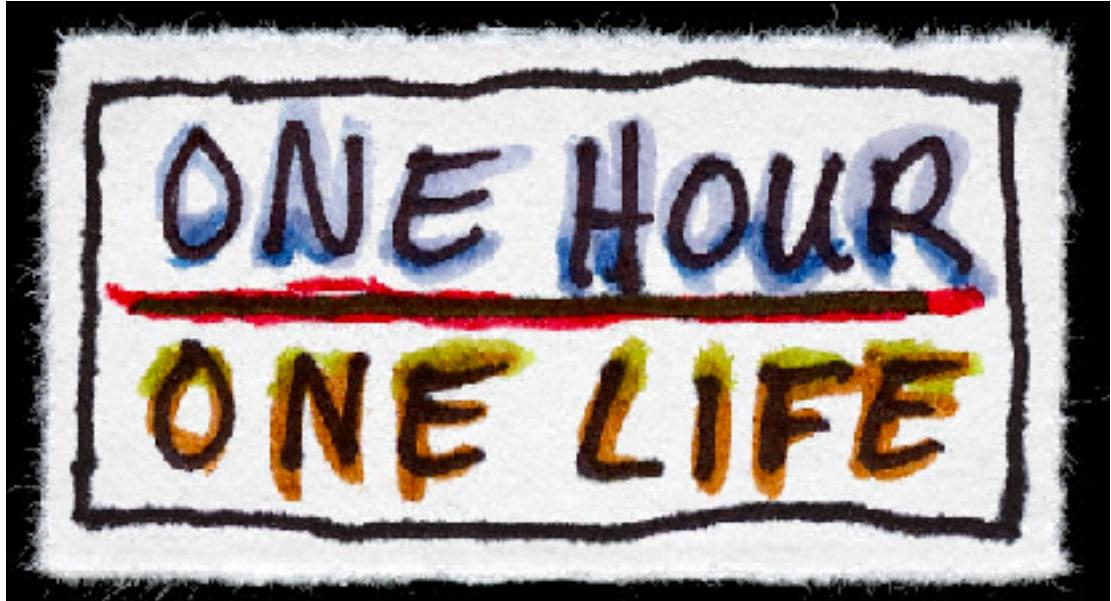


Wu et al., (2025)

## Visual-spatial dynamics of adaptive social learning



# Cultural evolution in virtual societies

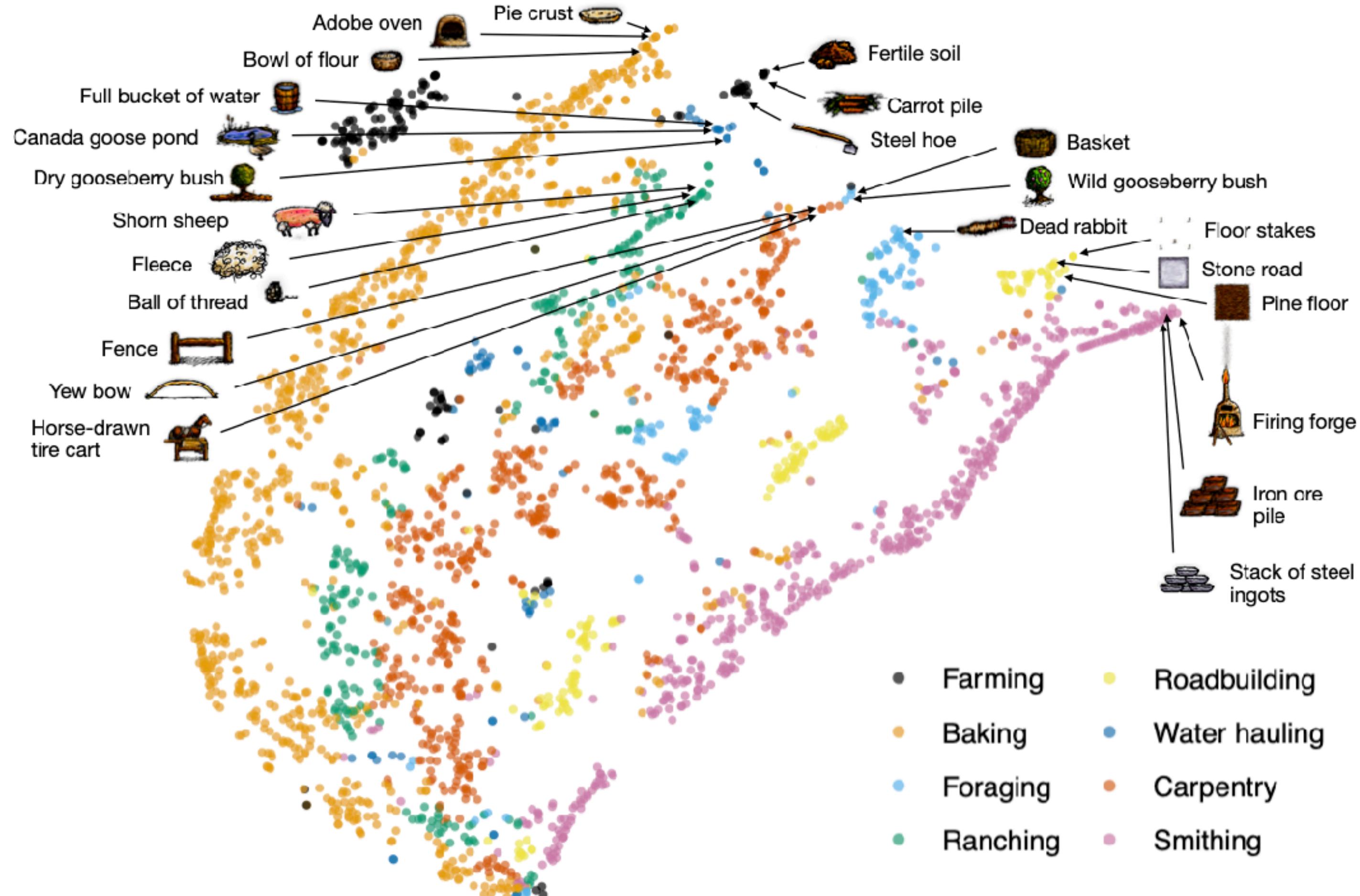
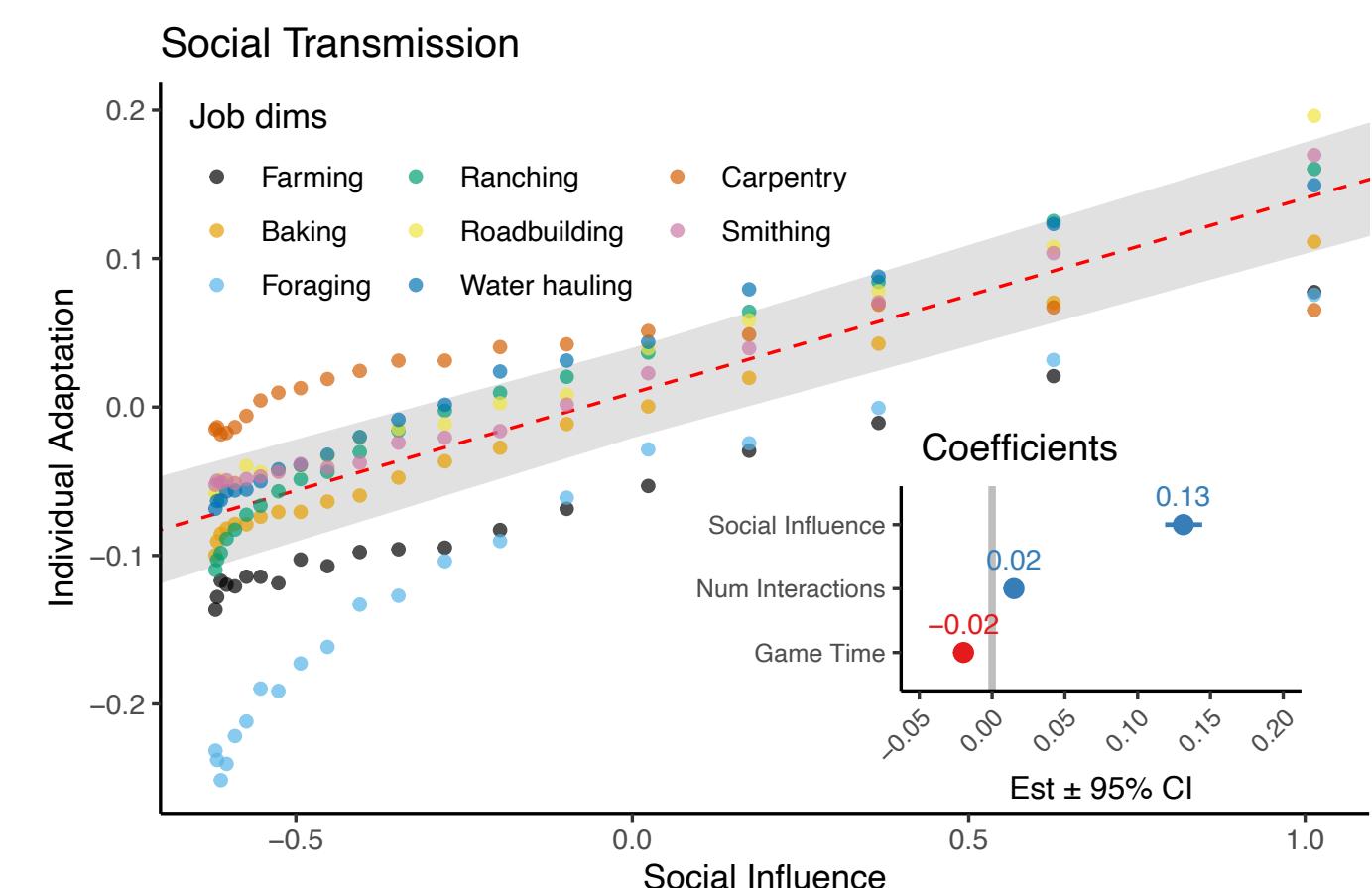
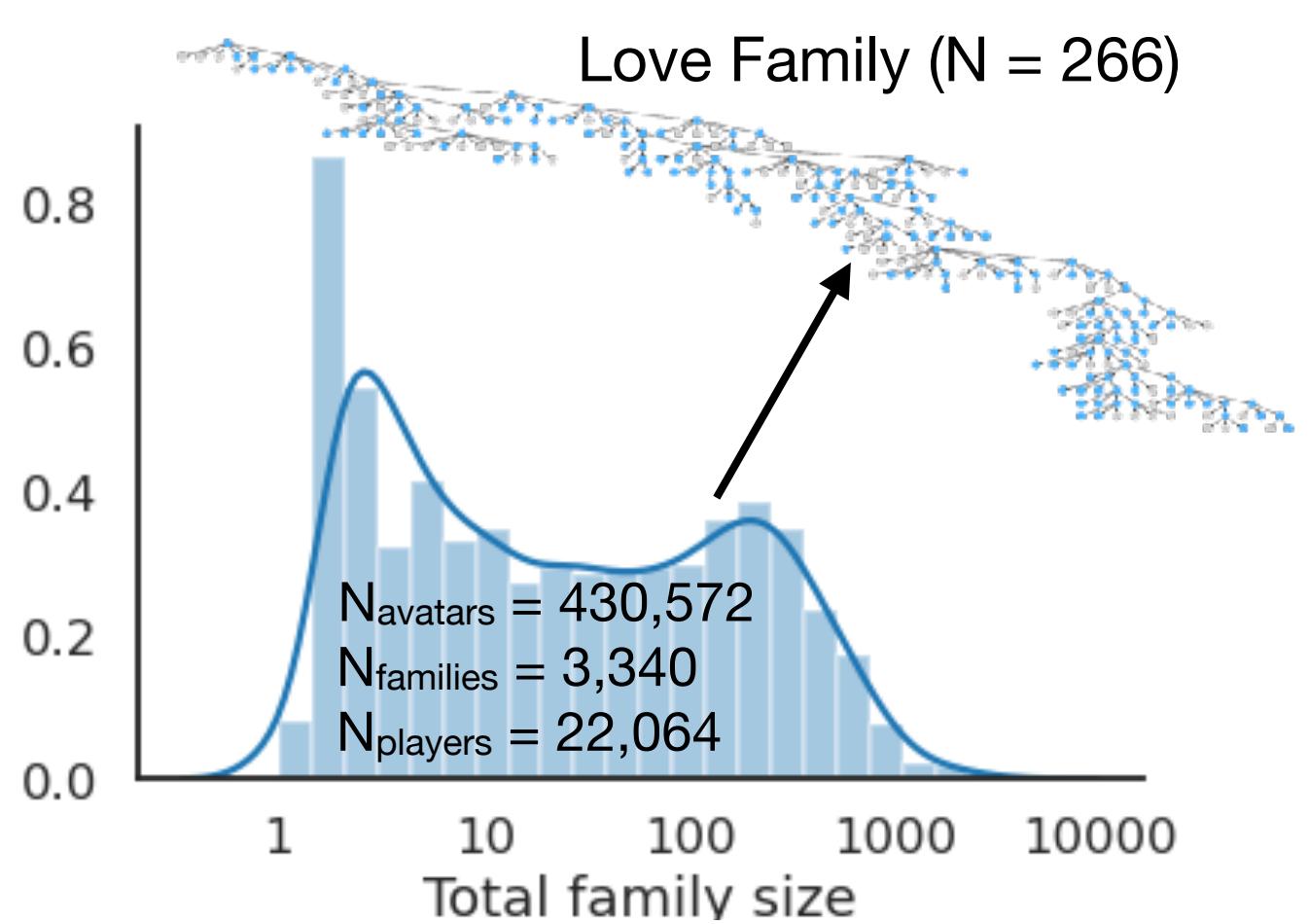


~ 60 minutes real time



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**

## Cultural Transmission

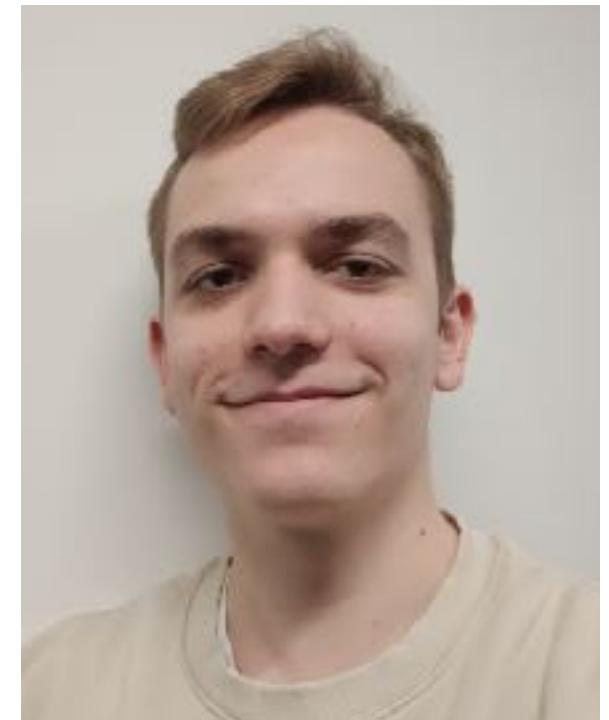
- **Agent-based simulations** to study the dynamics of social transmission over multiple generations
- [Infrastructure in progress]: **model cultural transmission using LLMs**
- [Infrastructure in progress]: **online transmission chain experiments**

### How to get started

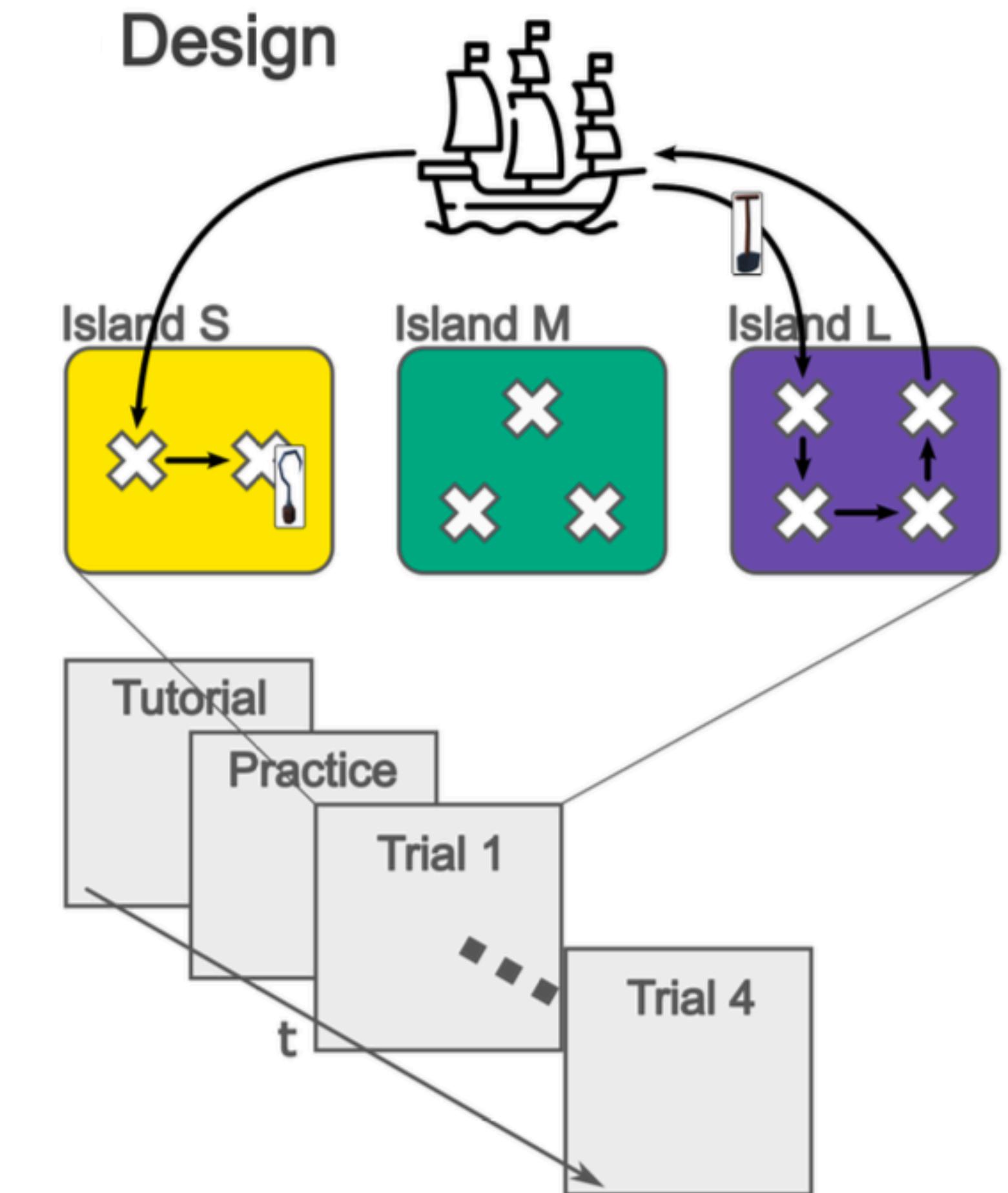
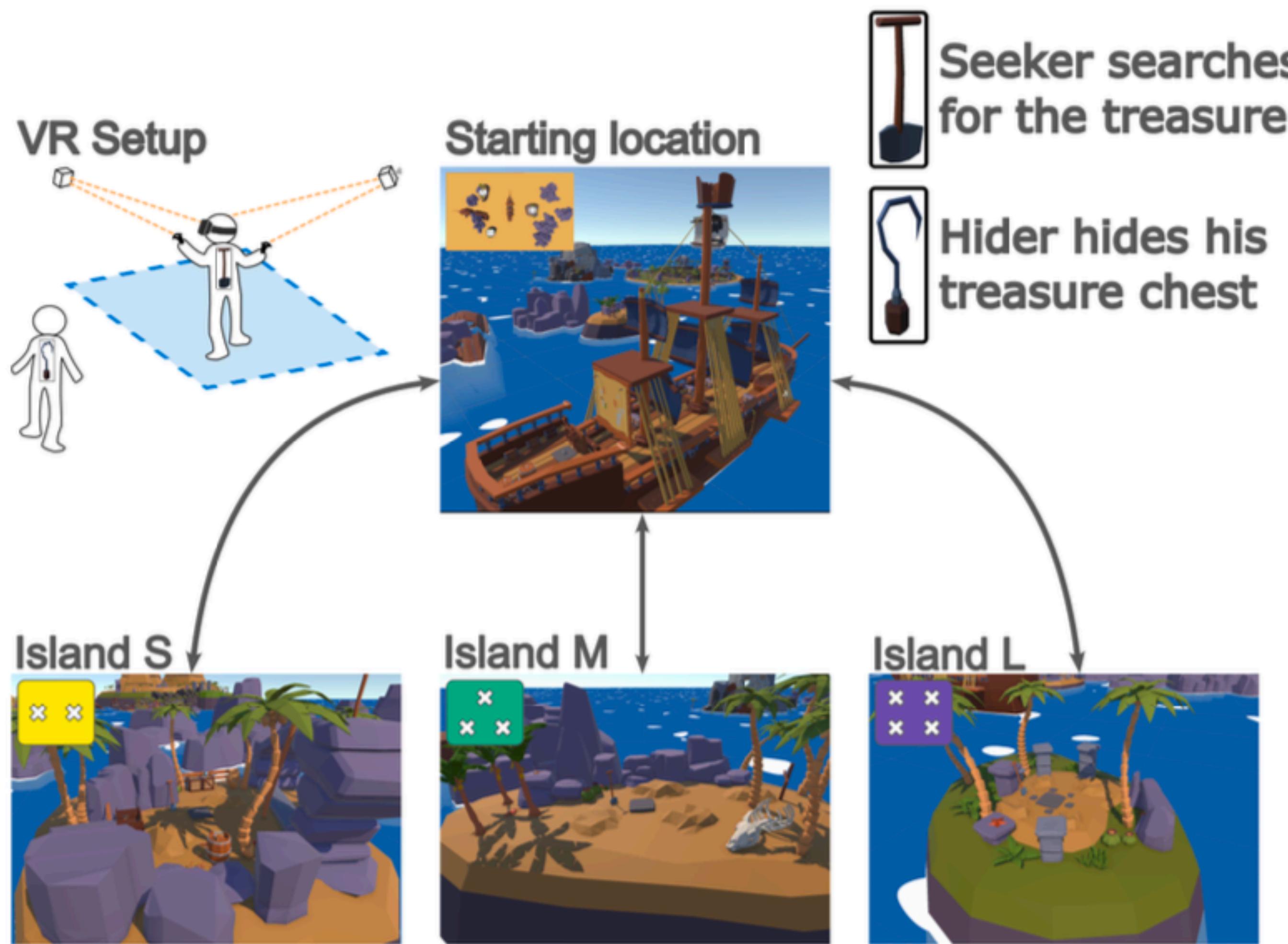
- Read Wu, Dale, & Hawkins (*Open Mind*, 2024) for an overview of some open questions
- Read related literature to identify current theoretical accounts and hypotheses
- Propose a plan for how to test them empirically

# Recent Bachelor's Thesis Example

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

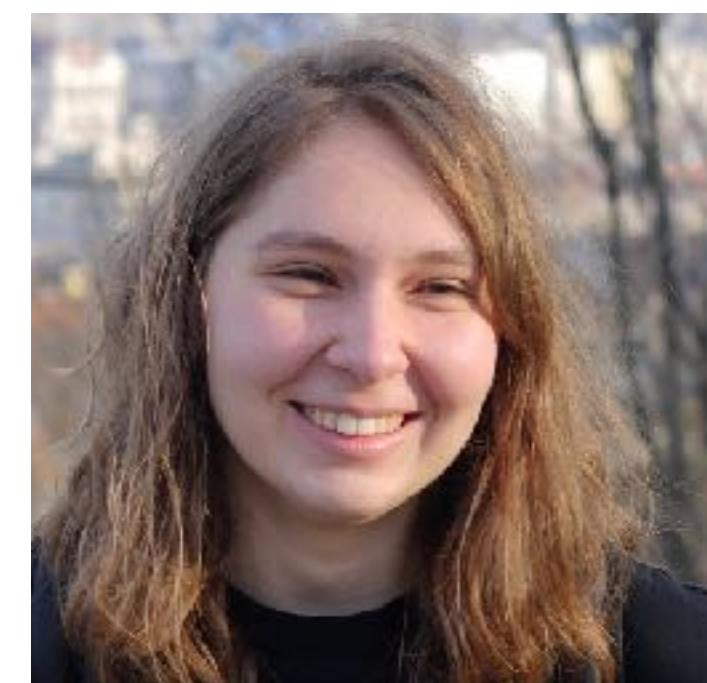


Stephen Taffner



# Recent Masters' Thesis Example

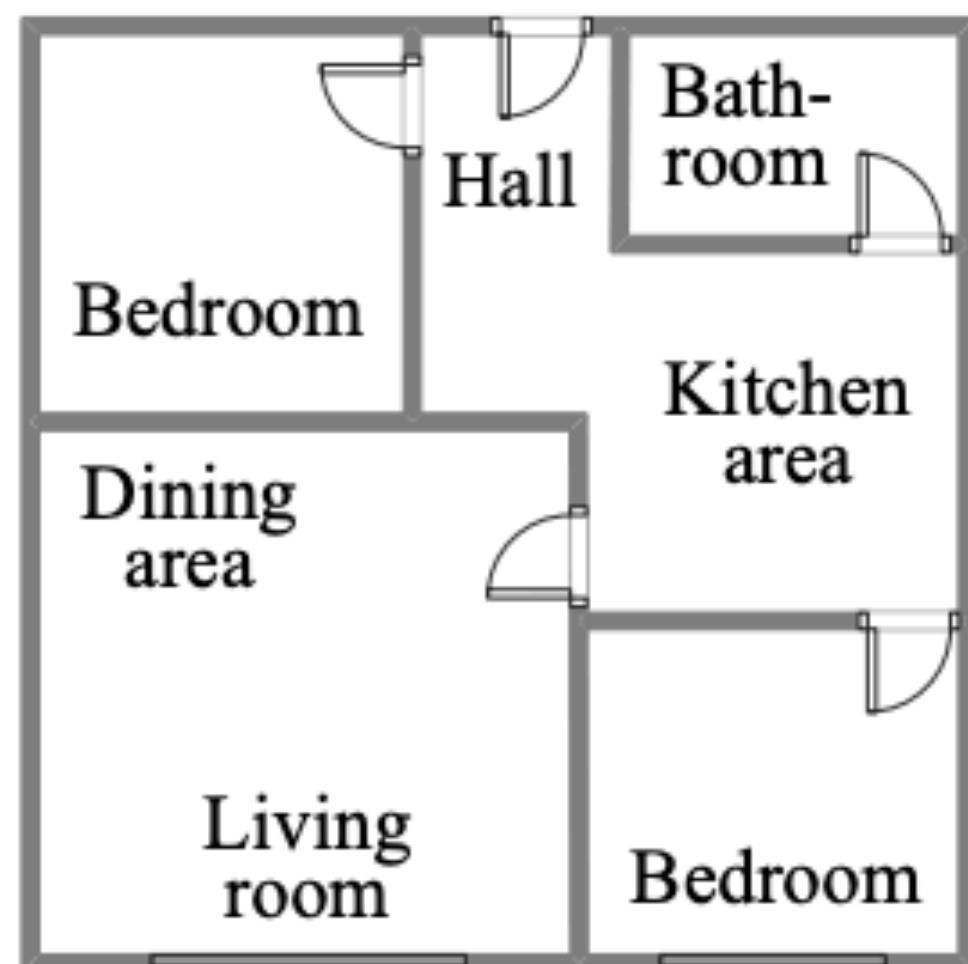
Comparing Global and Local Advice in Human-AI Interaction



Orsolya Szőcs

*Global vs. local AI assistance in home design*

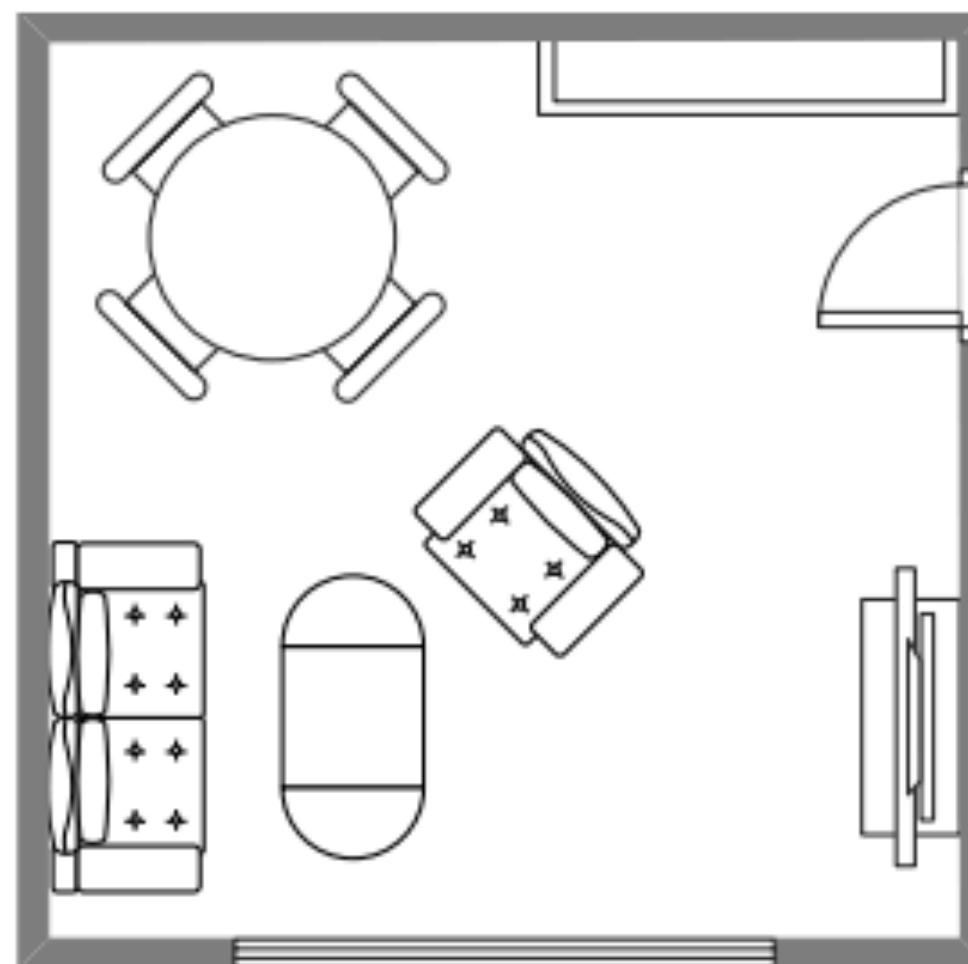
**Global AI:** assigns functional roles to rooms within a home



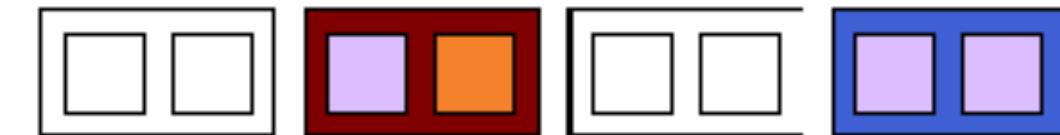
*Example for global advice*



**Local AI:** optimises furniture arrangements within a room



*Example for local advice*



*Experimental procedure overview*

Tutorial



Pre-AI



AI instructions



AI (global or local)



AI (global or local)

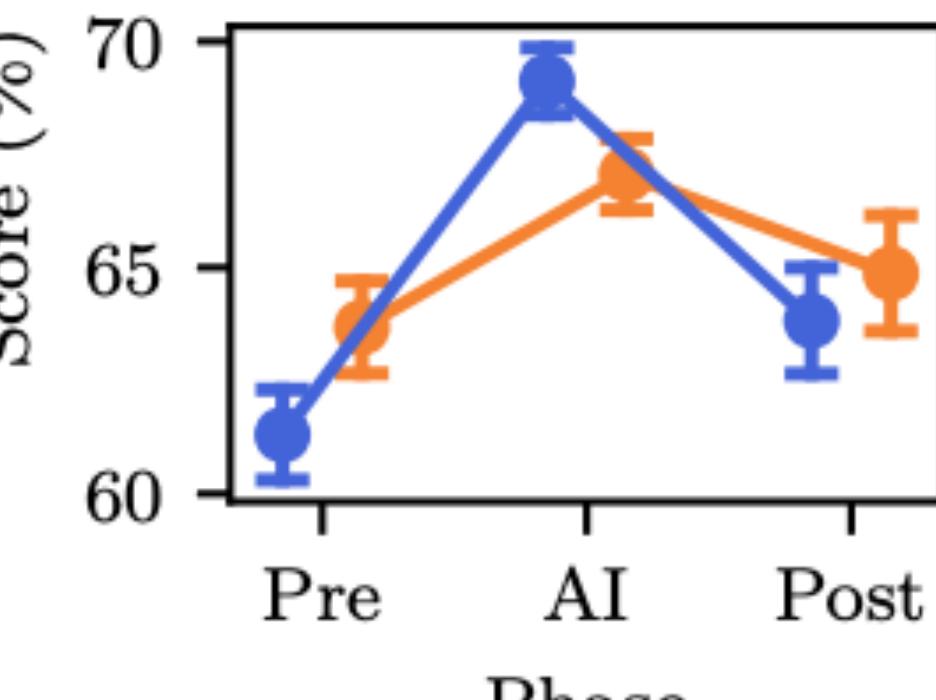


Post-AI



Questionnaire

Time



*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](http://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](mailto:charley.wu@tu-darmstadt.de)
  - Bluesky: [@thecharleywu.bsky.social](https://thecharleywu.bsky.social)

