Human and Machine Cognition Lab

What makes humans so uniquely intelligent?
How do people make the best use of limited cognitive resources?
What are the unique algorithms we use to learn from other people?

Lab Rotations and BSc/MSc Thesis Projects

hmc-lab.com

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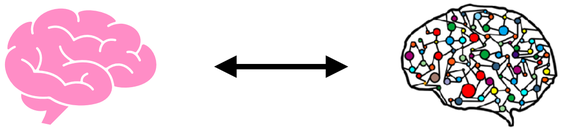
About the HMC Lab

The HMC Lab is an Independent Research Group led by Dr. Charley Wu, with the goal of understanding the gap between human and machine learning.



Our research methods include:

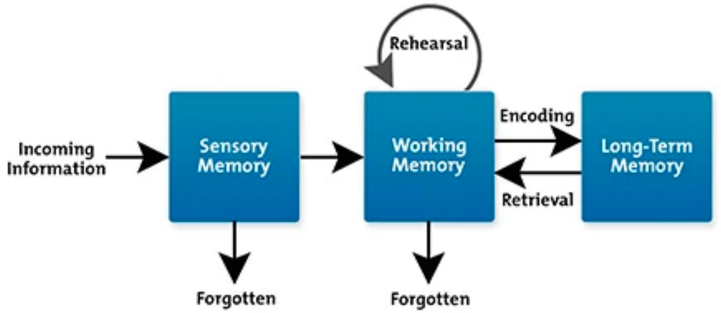
- online experiments (commonly in the form of interactive games)
- lab-based virtual reality experiments
- computational modeling of behavior (e.g., decisions, search trajectories, and reaction times)
- evolutionary models and simulations
- developmental studies (comparing children and adults)
- neuroimaging using fMRI/EEG
- analyzing large scale real-world datasets

We also have a rich collaboration network of researchers from Harvard, Princeton, UCL, and multiple Max Planck Institutes around Germany. To find out more, visit the lab website at **www.hmc-lab.com**

Project 1: Understanding human memory and forgetting using computational modeling

Research question

It was generally assumed that freshly acquired memories are initially in a dynamic, fluid state for a short period of time, after which the memory is consolidated or removed. Yet there are many current debates in the field about the exact mechanisms that govern the temporal dynamics of memories.

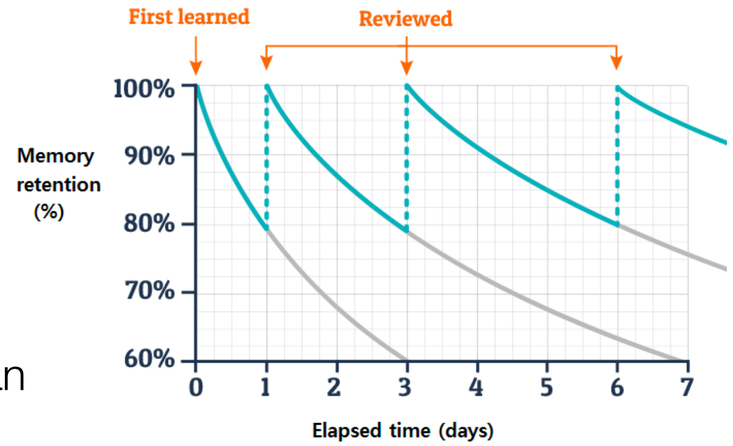


In this project, you will

1. **Develop a deeper understanding of the mechanism of human memory**. What empirical support is there for different memory systems (e.g., working memory, long-term memory, etc…)? What are the theoretical implications of these distinctions?

2. **Conceptualize the link between memory and forgetting**. What causes forgetting, and how is it different for distinct different memory systems? How does repetition help avoid forgetting?

3. **Develop computational models and experiments**. How to design models of human memory that combine rehearsal and retrieval?



This project is in collaboration with the ML Collab

Project 2: Arbitration between social learning strategies

Research question:

Humans are remarkably effective social learners. Social learning can be split into three levels differing in computational complexity and flexibility (Wu et al., 2022):

- **policy imitation** (copying the demonstrator's action; low complexity, low flexibility)
- **value inference** (inferring the demonstrator's value function from their behaviour and adopting it as your own; medium complexity, medium flexibility)
- **model-based inference** (inferring knowledge about the world from the demonstrator's behaviour and adapting your behaviour accordingly; high complexity, high flexibility)

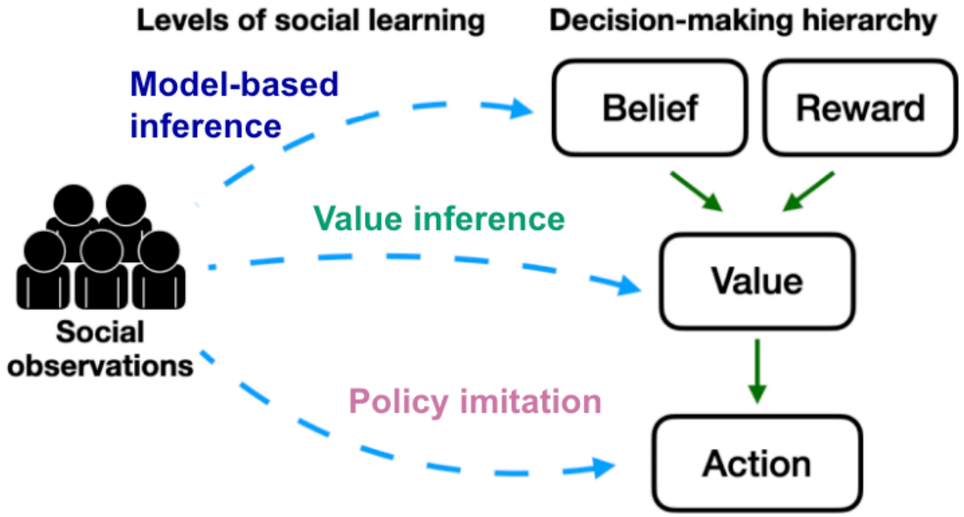
But how do we decide which of these strategies to use in a given situation?

Approach:

- Observational task where the different strategies predict different behaviour
- Computational modelling

Scope:

- Design and implement an online web-based experiment (HTML, Javascript, PHP)
- Simulate data using computational models of behaviour
- Analyze participant data and contrast with computational models



adapted from Wu et al., 2022

Project 3: Neural correlates of reward generalization and exploration

Research Question

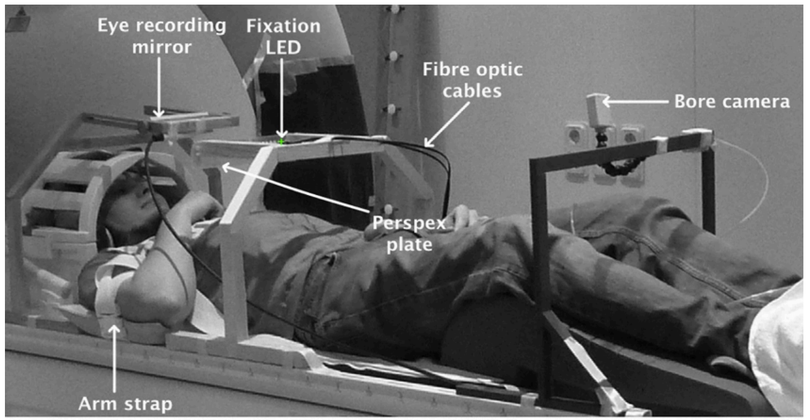
How do people integrate observations of reward when they also generalize to similar options?

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

Approach

- Simultaneous fMRI and eye-tracking study planned for late 2022, using a modified version of the Spatially correlated bandit task
- Use eye-tracking to improve our process-level understanding of previous computational models (**Wu et al., 2018**; **Wu et al., 2020**)
- Relate model predictions and parameters to understand the neural mechanism underlying reward generalization and exploration



Scope

- Learn to design and implement an fMRI experiment based on previous online experiment code (Javascript/HTML)
- Learn to work with the analysis of eye-tracking data
- Collaboration with University Hospital Tübingen and MPI Berlin

Project 4: Propose your own project!

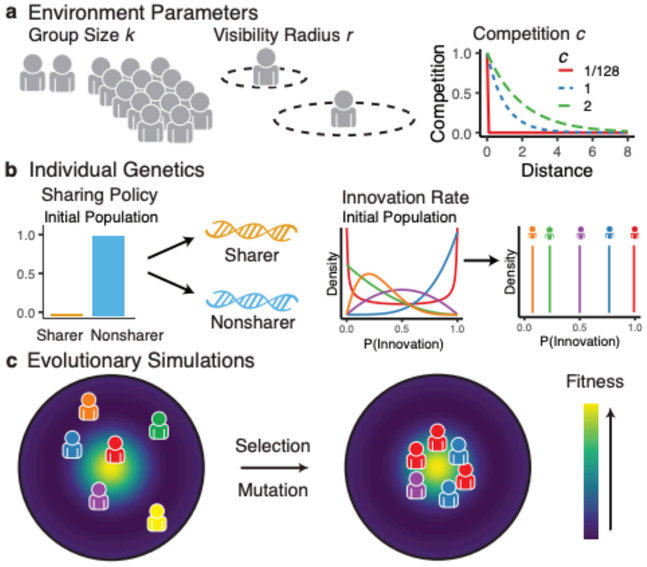
- Take the reigns and propose your own research project! To make things feasible within the rotation period or for a thesis, here are some suggestions of projects with existing data/code that could be built upon:

- **How does cooperation arise in competitive environments?** Through a series of agent-based and evolutionary simulations, we found that unconditional sharing of information can be beneficial, even in the absence of traditional reciprocity or reputation-based mechanisms. Many open questions, new environments, and learning mechanisms that can be tested

- **Why do people systematically under-generalize? Why are people systematically biased towards performing local search?** These are unexplained questions from a series of previous papers studying the search for rewards in spatially structured (Wu et al., 2018) and conceptually structured (Wu et al., 2020), and graph-structured environments (Wu et al., 2021). All the code and data are publicly available (1, 2, 3)

- **Note**: proposing your own project requires a high level of independent thinking and ability to craft an interesting and obtainable research question

Evolutionary simulations



Spatial

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
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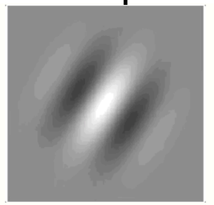
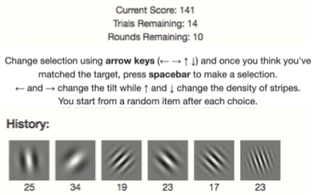
Conceptual





Graph-structured