# 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?*

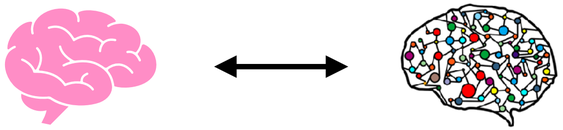
## Lab Rotations and BSc/MSc Thesis Projects

hmc-lab.com

Dr. Charley Wu
Group Leader
charley.wu@uni-tuebingen.de

# 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: 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)

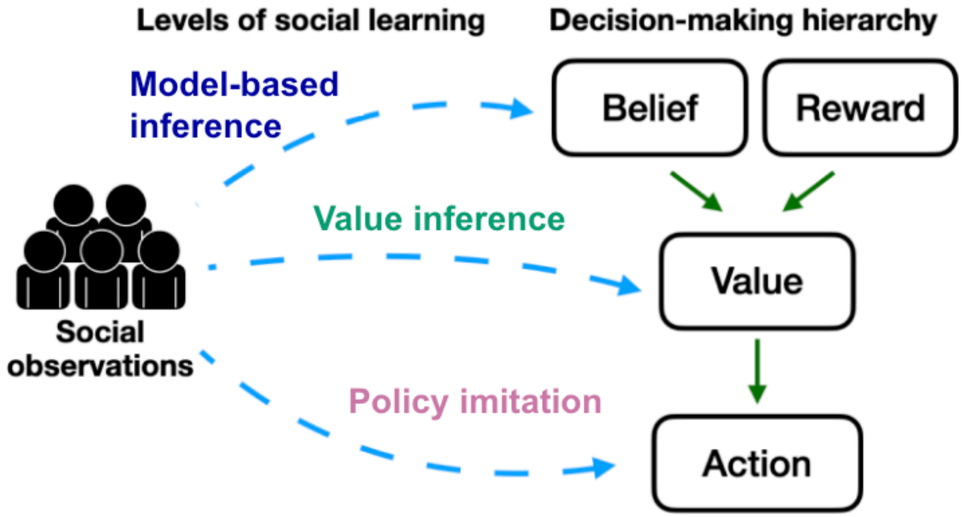
But how do we decide which of these strategies to use in a given situation?

**Approach**:

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

**Scope**:

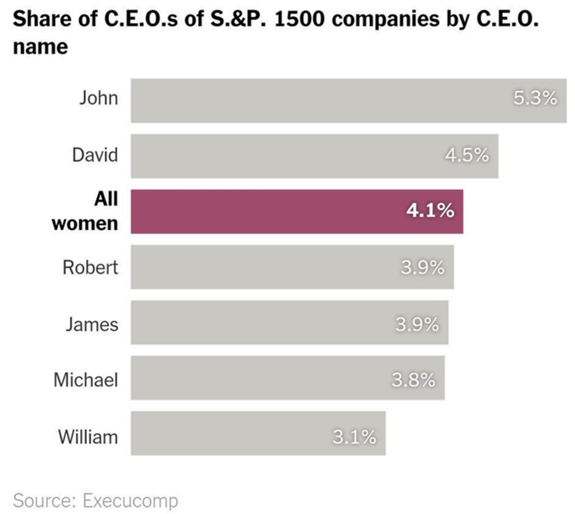
- Design and implement an online web-based experiment (HTML, Javascript, PHP)
- Simulate data using computational models of behaviour
- Analyze participant data and contrast with computational models




adapted from Wu et al., 2022

# Project 2: Leader Emergence and Intersectional Identities

**In the USA there are more CEOs named John or David, than female CEOs**




**Background**:

Recent economic, technological, and societal changes require organizations to adapt to the transforming nature of work by challenging assumptions, changing corporate cultures, and altering the way work is performed. In order to understand why and how people emerge as leaders in teams and organizations, we need to have a deeper understanding of human behavior.

This project investigates how computational models can be effectively used to develop and test theories from leadership and organizational behavior. The research is highly interdisciplinary and combines theory, agent-based simulations, and human behavioral experiments. Specifically, we aim to investigate how diverse leaders can benefit organizations, and which organizational principles can select the best leaders and avoid marginalizing persons from underrepresented backgrounds with intersectional identities (i.e., looking beyond one diversity dimension).

**In this project, you will:**

1. Work on agent-based simulations of collective behavior (strong programming skills in R are required)

2. Learn how to work with real world data and implement computational modeling to study organizational behavior

3. Have the possibility to work on human behavioral experiments


Gardenswartz & Rowe (2nd Edition, SHRM, 2003)

This project is in collaboration with the Organizational Leadership & Diversity research group at Max Planck Institute for Intelligent Systems.

# Project 3: Pedagogy and Tool Discovery

**Research Question**

Tool use is a key signature of human intelligence (Rawlings & Legare, TICS 2020),
yet the cognitive mechanisms underlying how we develop and innovate upon tools is not well understood.

Here, we focus on the role of pedagogy in amplyifying individual innovations and unlocking cumulative cultural evolution

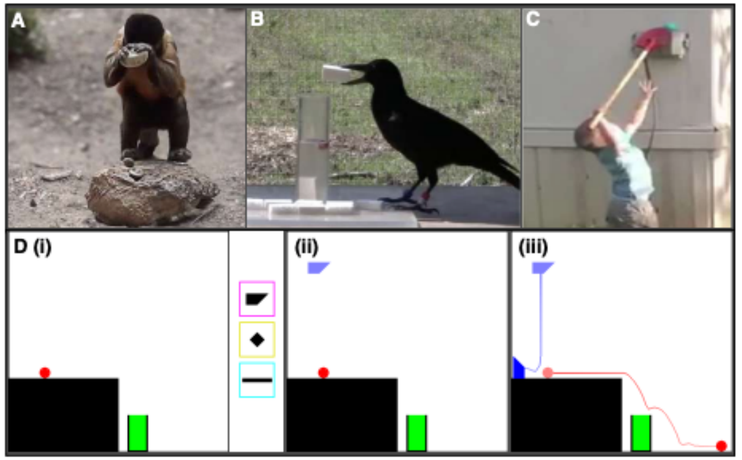
**Approach**

- Innovate upon a previous experiment (Allen*, Smith*, & Tenenbuam (PNAS 2020), where participants selected which tool they found most useful
- Here, we will allow people to develop their own tools and implement a transmission chain, where the solutions or instructions from one generation of participants will be passed along to the next
- Study the key ingredients for cumulative culture in tool use (e.g., observational learning vs. explicit pedagogy) and which task dimensions are most sensitive to pedagogy (e.g, opaque vs. transparent causal structure)

**Scope**

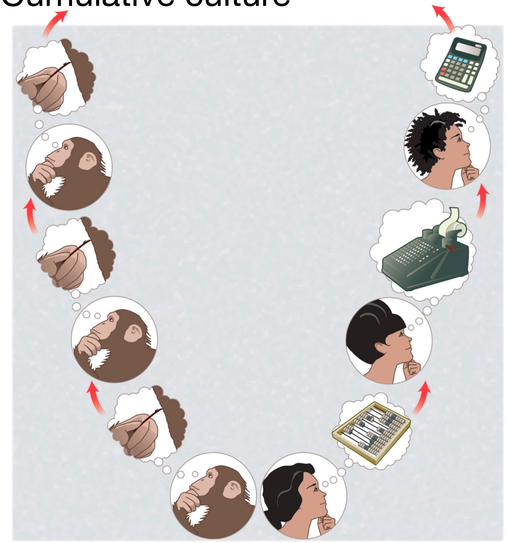
- Learn to design and implement an online experiment based on previous online experiment code (experience with Javascript/HTML/PHP highly recommended)
- Analyze data and perform statistical analyses (experience with Python/R encouraged)
- Collaboration with MIT and Deepmind

Tool use in animals and humans




Allen*, Smith*, & Tenenbuam (PNAS 2020)

Cumulative culture



Kurzban & Barrett (Sci, 2012)

# Project 4: Neural correlates of reward generalization and exploration

## Research Question

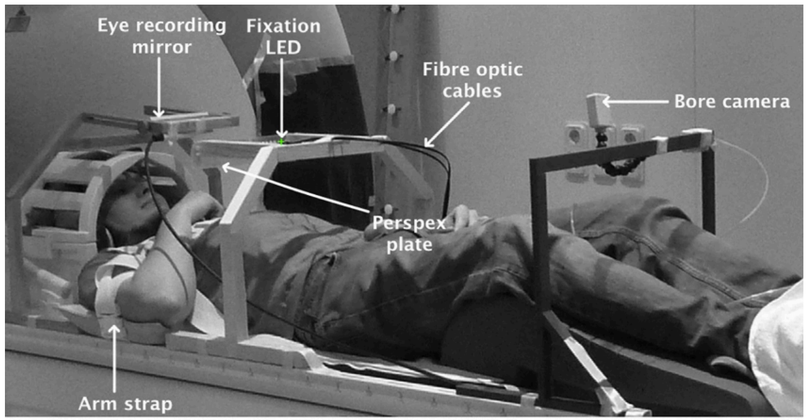
How do people integrate observations of reward when they also generalize to similar options?

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 early 2023, 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 5: Propose your own project!

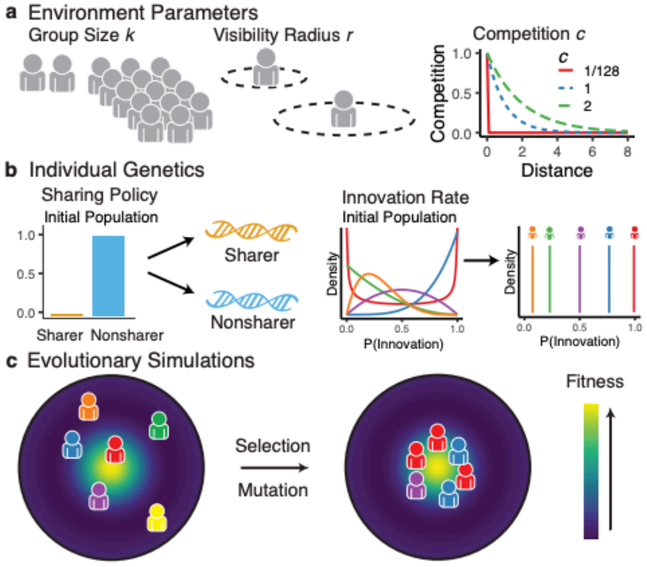
- Take the reigns and propose your own research project! To make things feasible within the rotation period or for a thesis, here are some suggestions of projects with existing data/code that could be built upon:

- **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

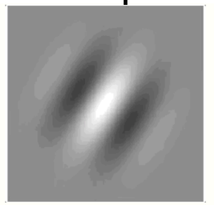
Evolutionary simulations




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 |
| 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 |

Conceptual




Graph-structured