Human & Machine Cognition Lab

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

machine learning new perspectives for science

Tübingen AI Center

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](hmc-lab.com)

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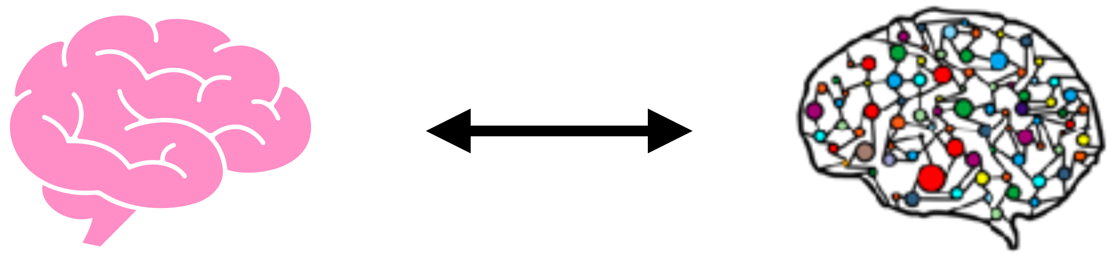
About the HMC Lab

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

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

Project 1: Episodic and model based control

Research question

Humans construct internal models to predict the consequences of possible actions. However in a newly encountered environment, limited experience can make it unfeasible to fit a parametric model. Therefore in the early stages of learning, relying on experiences directly may be more efficient (Lengyel & Dayan, 2009). It has been hypothesised that this constitutes a normative rationale for two complementary learning systems, one that constructs a parametric model (typically associated with the neocortex) and a non-parametric one (typically associated with episodic memory and hippocampal regions; Kumaran et al, 2016, Nagy & Orban, 2006). We are interested in how the brain arbitrates between these two controllers as well as better understanding the computational trade-offs that they make ([Nagy et al., in press]).

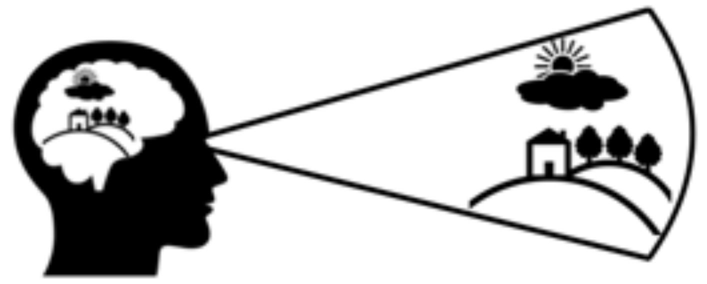
Approach

- Explore the interaction between parametric and non-parametric learning systems in a behavioural experiment, building on the setting of Xiong, Moneta, Banyai, & Wu, 2023
- Investigate how the contents of episodic memory are selected, specifically whether they are optimised to support the construction of the model
- We use a reinforcement learning framework and bayesian methods for computational modelling

Scope

- Implement an online experiment (experience with Javascript/HTML/PHP will be required)
- Option to construct computational models and analyse data (Python knowledge useful)
- Project in collaboration with MPI for Biological Cybernetics

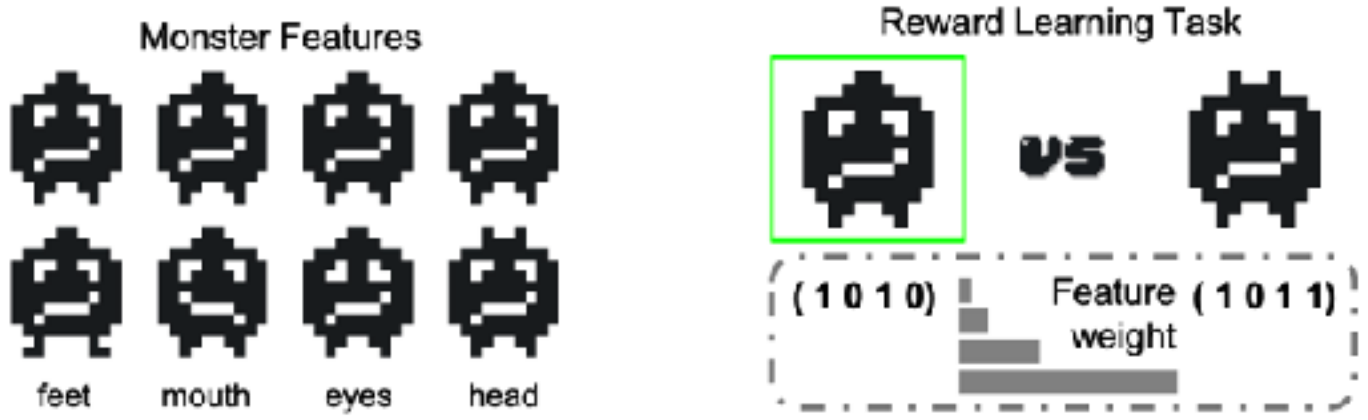
semantic model



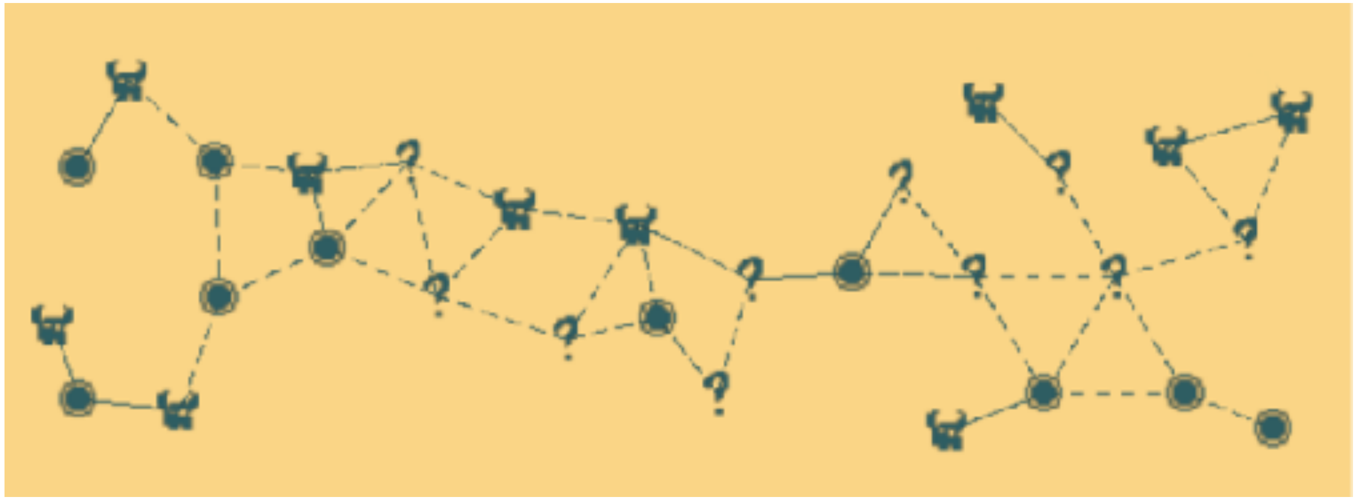
$$p(x, z, \theta \,|\, \mathcal{D})$$

episodic memory

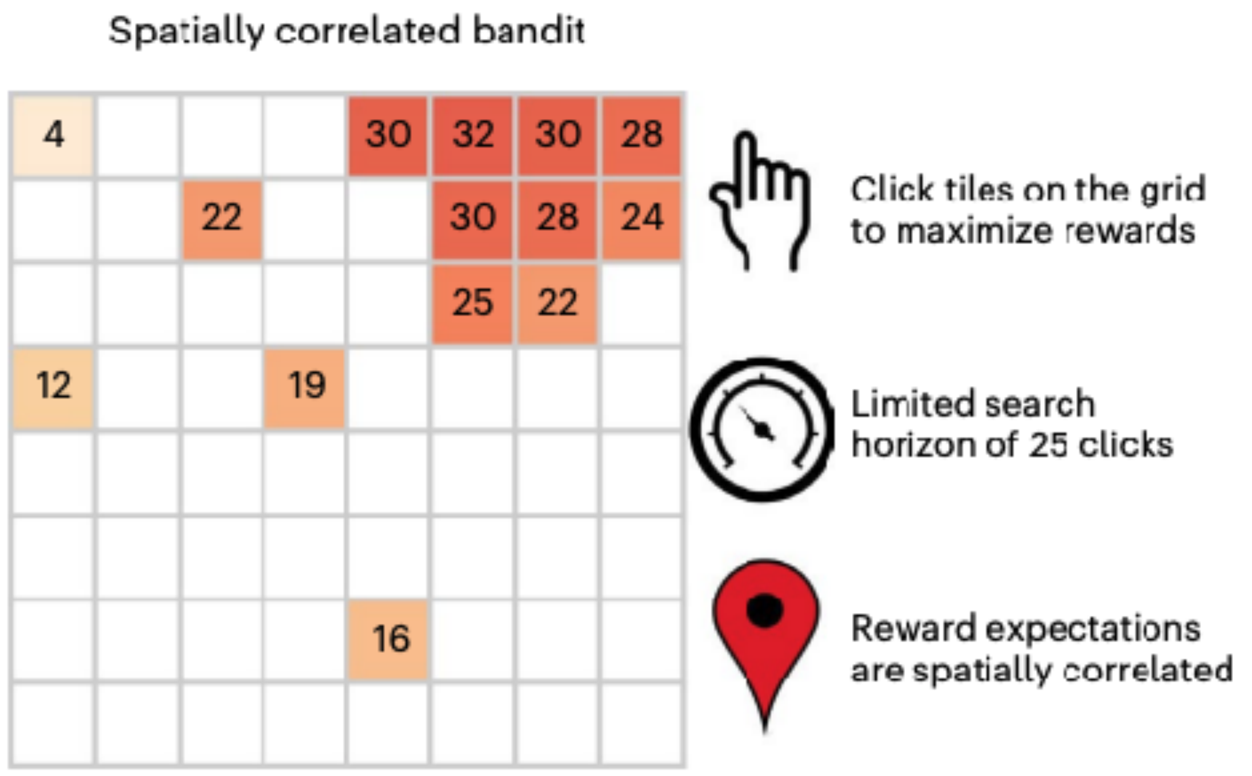
$$\{x_t\} \subset \mathcal{D}$$



Xiong, Moneta, Banyai, & Wu (CCN 2023)

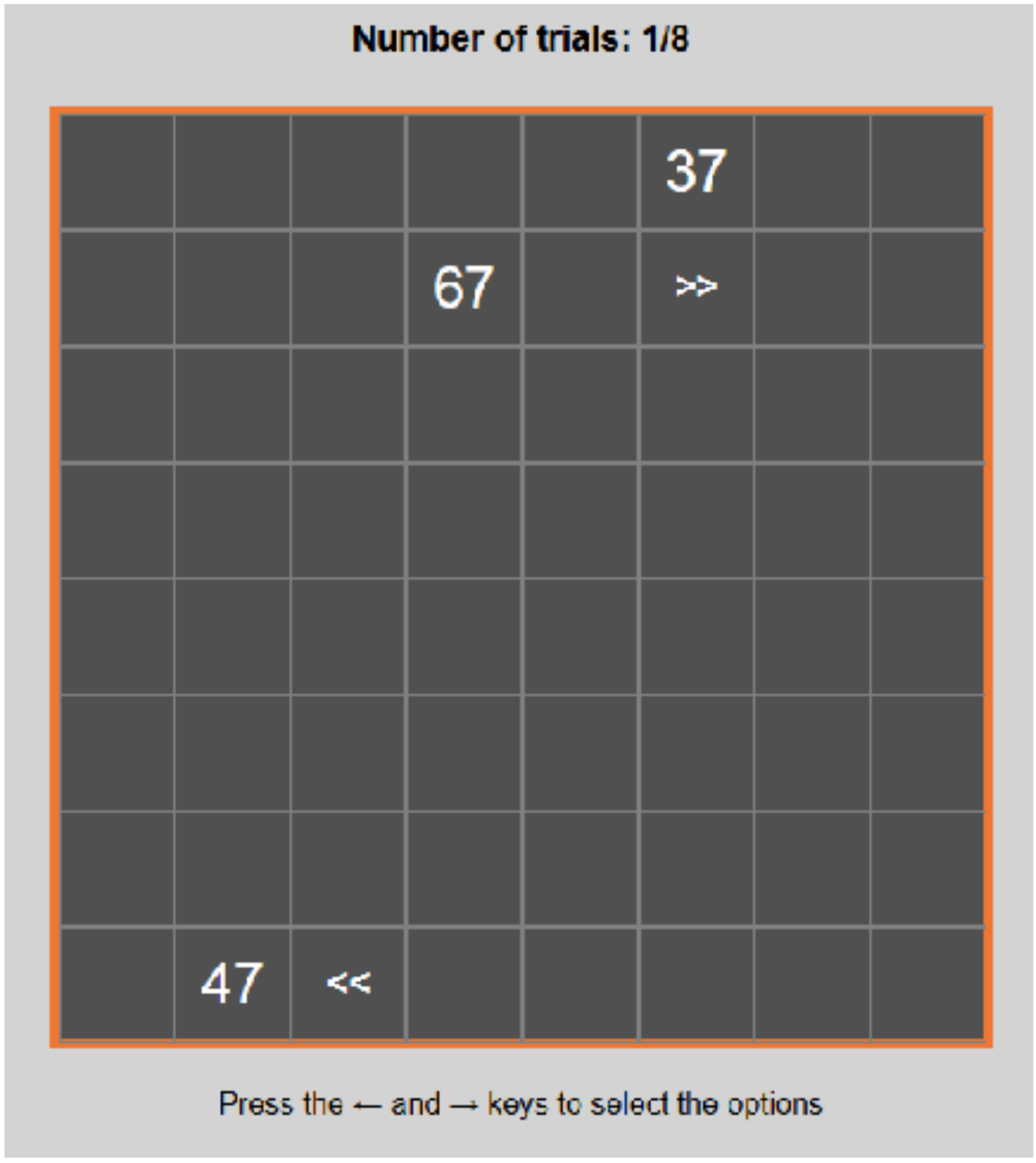


Project 2: Neural Correlates of Generalisation During Active Exploration



Research Question

Humans engage in a variety of efficient exploration strategies while navigating uncertain environments. However, much of what we know about these strategies come from simplified environments that do not fully capture the complexity of real-world exploration. When decision spaces are vast such that we cannot explore every possibility, how do exploratory strategies remain adaptive? Prior research have found that humans rely on generalisation, by drawing inferences about novel encounters from previous experiences. Our goal is to understand how this process is implemented in the brain. To this end, we have developed an fMRI-compatible version of the spatially correlated bandit task (e.g., Giron et al., 2023), a paradigm designed to probe generalisation and exploration mechanisms.



Approach

- Implement a modified spatially correlated bandit task for use in fMRI experiments
- Validate task performance and data quality in an online cohort
- Relate choice behaviour to brain activity using fMRI

Scope

- Computational modelling of human choice behaviour using Gaussian Process regression
- fMRI data collection and analysis
- Collaboration with MPI Berlin and University of Hamburg