The projects are thematically sorted by their main focus on:

- Machine learning
- Electrical engineering
- Theoretical neuroscience
- Data analysis
- Human experiments

However, most projects span several methods and areas of research, so you are advised to read through all projects and their specific requirements.

### Machine Learning

**Project: Incorporating physical prior knowledge in learning algorithms**

**Project ID: ML-01**

Lab: Learning and Dynamical Systems (MPI for Intelligent Systems)

Website: [https://lds.is.mpg.de/](https://lds.is.mpg.de/)

Machine learning algorithms, which aim at extracting and recognizing patterns from observed data, will play a central role for enabling robotic systems that efficiently and seamlessly adapt to changing environments. While current supervised learning techniques have been very successful at tasks such as image recognition, speech recognition, or personalized recommendations, their extension to cyber-physical and robotic systems leads to many challenges. A promising approach to deal with these challenges is to incorporate the wealth of a-priori known structure that many robotic and cyber-physical systems have, such as approximate models based on first principles, symmetries, and invariants. This could improve the sample complexity, ensure that the predictions generalize to unseen situations, and could also facilitate down-stream tasks.

The internship combines fundamental and/or practical aspects of machine learning in connection to cyber-physical systems. As an intern you will learn about one or a combination of the following machine learning aspects: reinforcement learning, adaptive decision-making, control algorithms (PID, LQR, etc.), feedback systems, iterative learning control, dynamical systems (stability, limit-sets, robustness), conducting experiments with real-world systems (such as a 7-DOF robot arm or a 4-DOF soft-robotic arm).

**Required skills:**

- strong analytical skills and programming experience (Python, C/C++, MATLAB or similar)

**Project: Using artificial neural networks as generative models to predict future behavior**

**Project ID: ML-02**

Lab: Systems Neuroscience & Neuroengineering (MPI for Biological Cybernetics)

Website: [https://www.kyb.tuebingen.mpg.de/systems-neuroscience-neuroengineering](https://www.kyb.tuebingen.mpg.de/systems-neuroscience-neuroengineering)

Motor patterns of animals vary in flexibility and complexity. While some motor sequences are stereotyped and highly predictable, other are flexibly controlled and dynamically adjustable. For small animals such as larval zebrafish, it’s possible to observe, annotate, and analyze its every movement. Larval zebrafish move in discrete bouts with widely varying kinematics, such as velocity and turning angle as a function of time.

In this computational project, we will use artificial neural networks (ANNs) to determine how soon, after the initiation of a new bout, we can predict the full kinematic trajectory of the entire bout. Using a short observation sequence as seed, we will train a generative model to predict the rest of the bout. Achieving
this goal will improve the performance of technologies for behavioral tracking and prediction, while revealing insights into the dynamics and bifurcation structure of zebrafish locomotion. As an intern, you will work with zebrafish behavioral data, learn to train ANNs, and potentially contribute to models of zebrafish locomotion. The project will provide an introduction to behavioral analysis and artificial neural networks.

**Required skills**
- Familiarity with Python, Julia, or C/C++

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**Electrical Engineering**

**Project: High performance MRI image reconstruction**

**Project ID: EE-01**

Lab: High-Field Magnetic Resonance (MPI for Biological Cybernetics)

Website: [https://www.kyb.tuebingen.mpg.de/high-field-magnetic-resonance](https://www.kyb.tuebingen.mpg.de/high-field-magnetic-resonance)

The process to generate images of the human brain from signals induced in receiver coils during an MRI sequence requires complex and computational demanding operations. In our department, we develop new sequences to visualize functional and anatomical brain microstructure, which, of course also require specific post-processing steps. To simplify this development, we recently set up an open-source reconstruction framework on a high-performance computer, where reconstruction steps can be developed in different programming languages, e.g. C++ or python. We now aim to establish cutting-edge signal processing algorithms for our sequences on this platform, to further improve our methods and additionally ensure reproducibility for larger studies.

As an intern, you will implement signal-processing steps, i.e. MR image processing for ultra high-field datasets. This can include e.g. massive parallelization of computational processes or calculation of quantitative brain tissue parameters, which can be potentially used in neuroscientific studies.

**Required skills:**
- Familiarity with Python, and ideally C++ basics
- Digital signal processing basics

**Project: Radio-frequency MRI coil construction**

**Project ID: EE-02**

Lab: High-Field Magnetic Resonance (MPI for Biological Cybernetics)

Website: [https://www.kyb.tuebingen.mpg.de/high-field-magnetic-resonance](https://www.kyb.tuebingen.mpg.de/high-field-magnetic-resonance)

MRI signals are detected by radiofrequency coils, and the quality of MR images thus critically depends on the performance of these coils. In addition, an array of such coils with spatially confined detection area can be used to parallelize and speed-up the imaging process. We recently proposed to develop receive coils with dynamic receive profiles that can be changed during the MR receive process. We now aim to test novel dynamic coil designs based on switched capacitors and optimized spatial layout.

As an intern, you will design novel radio-frequency coils with dynamic tuning and matching. This includes high-frequency electronic design and electromagnetic wave simulations.

**Required skills:**
- Experience in high-frequency electronics
- Experience in electromagnetic simulations
Theoretical Neuroscience

Project: Replicating a neural circuit model of the primary visual cortex and apply it to visual images
Project ID: TN-01
Lab: Department of sensory and sensory motor systems (MPI for Biological Cybernetics)
Website: https://www.kyb.tuebingen.mpg.de/sensory-and-sensorimotor-systems

The department headed by Li Zhaoping performs neuroscience research with the aim to discover and understand how the brain receives and encodes sensory input (visual or olfactory) and processes this information to direct body movements as well as to make cognitive decisions. The research is highly interdisciplinary, and uses theoretical (or computational modeling) as well as experimental approaches (mainly human behavioral experiments) to answer questions for example about visual illusions, attention, object recognition and saliency. Some of our educational information can be found here.

As an intern, you will learn about a neural circuit model of the primary visual cortex from chapter 5 of the book "Understanding vision: theory, models, and data". This includes computer programming (e.g., in Matlab or another suitable language) to implement the model and apply the model to visual images. If the project goes well, you as the intern will then build a web-based interface allowing users to run the model simply by uploading images, using HTML, Javascript and any additional tools necessary.

Required skills
- Good computer programming skills in matlab and/or other suitable languages such as C# with Unity3D programming, Javascript, HTML
- Good communication and team work skills

Data Analysis

Project: Using learning algorithms to predict human behaviour
Project ID: DA-01
Lab: Computational Neuroscience (MPI for Biological Cybernetics)
Website: https://www.kyb.tuebingen.mpg.de/computational-neuroscience

The computational neuroscience lab is investigating the decision making mechanisms of humans and animals, both from the neural and behavioural point of view, using mathematical models and experiments. This internship falls in the area of representation learning, asking the question how humans learn to process sensory stimuli in a way that is helpful for their goals. To develop algorithms and experimental paradigms to address this question stand at the core of this field.

As an intern, you will work on the implementation of simple learning algorithms used in machine learning, and analyze data from behavioural experiments to assess whether the algorithms are able to predict statistical properties of the data. You will learn how to fit parameters of computational models to measurement data, and how the components of an algorithm interact to produce behaviour.

Required skills
- familiarity with Python
- basic knowledge of algebra and statistics
Project: The neural and algorithmic basis of learning generalisable knowledge
Project ID: DA-02
Lab: Computational Neuroscience (MPI for Biological Cybernetics)
Website: https://www.kyb.tuebingen.mpg.de/computational-neuroscience
Solving complex real-world tasks requires biological and artificial agents to form efficient representations of their sensory input that can be generalised to novel circumstances. This is one key competence that computational neuroscience seeks to understand better. In this project, the aim is to investigate the formation of such representations in a Tangram/Tetris-like task in which human subjects learn how to build artificial objects using an inventory of basic building blocks and relations (rotations, ‘ontopness’, ‘besideness’, etc). Empirical data and computational modelling are being used to investigate the mechanisms underlying the cognitive processes in this task.

As an intern, you will be able to work with human behavioural and possibly neural data from our experiment to investigate different questions by analyzing e.g. behavioural changes over the course of learning in reaction times or actions that subjects take. You will also be able to work on models of this task, such as models based on reward learning (reinforcement learning) or models of perception. This project will provide you with a basic introduction into data analysis and computational neuroscience.

Required skills

- Interest in behavioural experiments and/or computational modelling
- Some experience with coding, ideally Python or R

Project: Exploring human eye movement data
Project ID: DA-03
Lab: Computational Neuroscience (MPI for Biological Cybernetics)
Website: https://www.kyb.tuebingen.mpg.de/computational-neuroscience
Eye movements are not random actions. They are actually very structured actions that humans make almost every moment, and they follow some characteristic patterns. For example, the distribution of saccade magnitudes follows a power-law distribution (e.g. see this). Interestingly, eye movement patterns seem to be optimal for scanning a scene.

As an intern, you will try to characterize eye movement patterns as optimal behaviour, and [if time allows] their relationship to other exploratory behavior. We will use open eye movement datasets (like this one) and explore different aspects of eye movements by analyzing quantities like saccade durations and magnitudes with different categories of images (e.g. natural vs. artificial images).

Required skills

- some programming knowledge (preferably Matlab or Python)
- familiarity with basic mathematics (e.g. what is a probability distribution, what is the derivative of a function). Such basics are usually part of the first-year curriculum of natural sciences and engineering, but sometimes also part of the psychology curriculum or similar
- interest in exploratory data analysis

Human Experiments
Project: Learning to Trust
Project ID: HE-01
Lab: Computational Neuroscience (MPI for Biological Cybernetics)
Website: https://www.kyb.tuebingen.mpg.de/computational-neuroscience
The main focus of my research is the study of the sequential effects of social information sampling for impression formation in interactive, social environments. Thereby, I employ different experimental practices from the psychological tradition and statistical methods borrowed from the Bayesian and computer science literature.

As an intern, you will work on a branch of a current project, which will encompass the implementation of an experimental paradigm to investigate how humans sample information about someone else’s expertise and motives, and how these pieces of information are weighted in the decision-making process underlying trust decisions. The project will touch on different phases of a classic empirical study with the aim to familiarize the student with the different aspects of empirical investigations. First you will learn about study planning and designing, and will attempt to independently elaborate a small research question to test on your own. Second, you will have hands-on experience of the different steps of experiment implementation for data collection, from experimental programming and participant recruitment, to data collection and data management. Third, you will learn to implement experimental data visualization in accordance with standard scientific practices and state-of-the-art statistical methods for scientific hypothesis testing. Finally, you will practice advanced scientific writing, thereby learning how to report the research questions, procedures, and results of a scientific investigation according to high-quality scientific standards.

**Required skills**

- No prior experience (e.g. in programming) is required for this project; the intern will acquire the necessary know-how during the internship.

**Project: Human visual psychophysics experiment**

**Project ID: HE-02**

Lab: Department of sensory and sensory motor systems (MPI for Biological Cybernetics)

Website: [https://www.kyb.tuebingen.mpg.de/sensory-and-sensorimotor-systems](https://www.kyb.tuebingen.mpg.de/sensory-and-sensorimotor-systems)

The department headed by Li Zhaoping performs neuroscience research with the aim to discover and understand how the brain receives and encodes sensory input (visual or olfactory) and processes this information to direct body movements as well as to make cognitive decisions. The research is highly interdisciplinary, and uses theoretical (or computational modeling) as well as experimental approaches (mainly human behavioral experiments) to answer questions for example about visual illusions, attention, object recognition and saliency. Some of our educational information can be found [here](https://www.kyb.tuebingen.mpg.de/sensory-and-sensorimotor-systems).

As an intern, you will implement a visual psychophysics experiment using computer programming. This is mainly to program visual displays which will be viewed by human observers whose responses (e.g., visual recognition) are then recorded as experimental data. The internship is an adaptation and extension of this course [here](https://www.kyb.tuebingen.mpg.de/sensory-and-sensorimotor-systems) to a specific experiment, such as a stereo vision experiment. The experiment can either be programmed in (a) matlab or (b) C# with Unity3D programming.

**Required skills**

- Good computer programming skills in matlab and/or other suitable languages such as C# with Unity3D programming, Javascript, HTML
- Good communication and team work skills

**Project: Value Estimation: Comparing Online-Tracking vs. Memory-Based Theories**

**Project ID: HE-03**

Lab: Computational Principles of Intelligence Lab (MPI for Biological Cybernetics)

Website: [https://www.kyb.tuebingen.mpg.de/computational-principles-of-intelligence](https://www.kyb.tuebingen.mpg.de/computational-principles-of-intelligence)

This interdisciplinary research group of cognitive scientists, neuroscientists, and computer scientists develops computational models of human intelligence. The goal is to build formal theories of how people
learn, generalize, explore, and find approximate solutions in complex and richly-structured environments. This project as an investigation of the following question at its heart: How do people learn the value of objects repeatedly encountered over their lifetime? For example, how do we know and learn that ice cream is a good thing? The goal of the project is to derive diverging predictions from different theories and design a behavioral experiment that can discriminate between them.

As an intern, you are going to conduct a literature research and summarize their findings highlighting divergent theoretical claims. Based on that, you will design an experiment able to differentiate between the theoretical claims. In the following, you are going to implement the theories in R/python in order to derive predictions for the experiment. If there is time left, you can program the experiment in Javascript/python.

**Required skills**
- coding experience in R or python
- motivation to learn how to program experiments with human participants (e.g. in Javascript or python, depending on the Covid-19 situation)

**Project: Understanding human metacognitive learning**

**Project ID: HE-04**
Lab: Rationality Enhancement Group (MPI for Intelligent Systems)
Website: [https://re.is.mpg.de/](https://re.is.mpg.de/)

The scientific mission of this lab is to develop a scientific foundation for helping people make valuable contributions to society and improve themselves. One of our topics of interest is to understand human metacognitive learning through empirical measurements and computational models. In this project, we would like to test our hypothesis that metacognitive learning involves reinforcement learning mechanisms. For this, we will conduct a series of online experiments to reveal to which extent metacognitive learning relies on reinforcement learning mechanisms and what kinds of reinforcement learning mechanisms people might use.

We offer you an innovative and international environment to conduct pioneering research in a team comprising cognitive scientists, computer scientists, psychologists, and developers. As an intern you will design, program and conduct online experiments using HTML / Javascript and manage deployment as a Web Application. You will also perform scientific data analysis on the collected data (in Python or R) to test the hypothesis that metacognitive learning involves reinforcement learning mechanisms. This project will lead to a journal article. Depending on the quality and quantity of your contributions you can become the first or second author of that article. In addition, we offer to supervise and support you to complete your bachelor/master thesis on the aforementioned project. For this, you need to be enrolled at a university and might have to find an affiliated supervisor at the university on your own.

**Required skills**
- Strong HTML / JavaScript skills
- Intermediate data analytics (Python or R) skills
- Strong academic background in the field of cognitive science and machine learning
- solid knowledge in reinforcement learning