# CaCTüS Internship Projects 2026

The projects are thematically sorted by their main focus on:

- Machine Learning
- Theoretical Neuroscience
- Data Analysis
- Scientific Software Development
- Computational Modeling

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

## Machine Learning

**1. Project: Trotting Data: AI based 3D Dynamic Horse Models**
**Lab: Optics and Sensing**
**Main Supervisor: Senya Polikovsky**
**Co-Supervisor: Dennis Perrett**
**Area: Point cloud analysis, 3D model, 3D scanning, Animal anatomy, Deep learning**

The render of our 3D statistical horse model

In our lab we focus on the development of highly realistic human and animal avatars for use in research, film, virtual reality, biology and medicine using unique 3D & 4D capture facilities, machine learning, computer vision and advanced graphics. Our efforts in the previous years aimed at developing collaborative partnership and providing the veterinarian community with a 3D statistical model of quadrupedal large domestic animals with a focus on horses, which excels in anatomical accuracy. Within this project we can offer various different tasks.

As an intern, you will:
1. Develop computer vision systems for the 3D/4D reconstruction of horses from images/video
2. Predict horse body conformation score from 3D horse shape parameters
3. Develop optimization-based 3D model-to-image fitting pipelines
(These can be tailored to your interest / skill set.)

**Required technical skills:**
1. Experience in one of the following: Point-cloud libraries, OpenCV, 3D rendering pipelines, deep-learning frameworks, linear algebra, statistics
2. Strong academic performance in relevant bachelor's or master's courses
3. Good programming skills in Python or C++; PyTorch experience is a plus
4. Good oral and written communication skills in English

**2. Project: Equal Voices: Designing AI Co-Facilitators for Inclusive Team Meetings**
**Lab: COMPASS Research Group & Organizational Leadership & Diversity Group**
**Main Supervisor: Sahar Abdelnabi**
**Co-Supervisor: Ksenia Keplinger**
**Area: Machine learning, human experiments**

Across organizations, meetings consume an enormous amount of time yet often fail to achieve their purpose. Employees spend on average 20 hours per week in meetings, and managers even more. Yet, up to half of these meetings are rated as ineffective or unnecessary, leading to disengagement and lost productivity. Research also shows that in most meetings, only about one in three participants actively contributes, while others remain silent or overlooked. Ensuring inclusive, effective, and balanced meetings is even particularly challenging in hybrid settings where it could be harder for hybrid participants to feel included. For these reasons, organizations and companies are increasingly raising awareness about how to promote inclusive behaviors during meetings.

This project investigates how large language models (LLMs) can assist human leaders in facilitating more inclusive and effective team meetings. We will develop human-in-the-loop AI systems that enhance leaders' real-time awareness of group dynamics, such as speaking-time balance, acknowledgment of input, conversational tone, recognition of potential dismissive behaviors, proactively inviting contributions from less dominant participants, or suggesting probing questions and follow-up points to discuss accordingly. The project is a collaboration between the COMPASS Research Group at the ELLIS Institute Tübingen, which focuses on AI safety and cooperative AI, and the Organizational Leadership & Diversity Group at the Max Planck Institute for Intelligent Systems in Stuttgart, which focuses on human-AI interaction in the workplace and inclusive leadership.

The intern will contribute to the design and testing of an LLM-based meeting co-facilitator and learn about AI-mediated communication, inclusive leadership, and human-subject experiments. They will gain hands-on experience with LLM prototyping and conversational data analysis. The project will also evaluate how LLMs can efficiently detect exclusive behaviors and suggest inclusive ones.

**Required technical skills**

- Good programming skills in Python
- Good knowledge of machine learning, natural language processing, and data analysis
- Basic knowledge of LLMs
- Basic knowledge of LLM APIs and platforms (e.g., OpenAI, Hugging Face)
- Experience with text or conversational data analysis
- Experience in human–AI interaction and human-subject experiments

**3. Project: Model Organisms of Metacognition**
**Lab: Safety- and Efficiency-aligned Learning and Deep Models and Optimization**
**Main Supervisor: Jonas Geiping**
**Co-Supervisor: Antonio Orvieto**
**Area: Machine Learning**

Our labs are interested broadly in both efficiency considerations (DMO group, Antonio Orvieto) and safety considerations (SEAL group, Jonas Geiping) in modern machine learning, and we hence are interested not only in understanding and improving state-of-the art deep learning models, such as large language model, but also in methods to reduce harm arising from the use of these models.

In this project, we are interested in studying the metacognition of large language models. Metacognition, or the ability to think about one's own thinking, is an aspect of intelligence linked to reflection, self-awareness, and higher-order reasoning. Aside from understanding and improving formalizations of this capability in a measurable way and developing new ways to measure it, we are especially interested in developing "model organisms", toy models, and small-scale tests that can be used to better how understand how this capability develops over the course of training and post-training stages of a large language model.

**Required technical skills**

- Good coding skills in Python
- Great command of the English language, necessary to improve and analyze text model outputs
- Basic Understanding of Nature Language Processing with Large Language Models

**4. Project: Structured Fine-tuning for LLMs**
**Lab: Methods of Machine Learning, Deep Models and Optimization and Safety- and Efficiency-aligned Learning**
**Main Supervisor: Antonio Orvieto**
**Co-Supervisor: Jonas Geiping**
**Co-Supervisor 2: Joanna Sliwa**
**Area: Machine Learning**

Our labs are broadly interested in statistical aspects (Methods of Machine Learning, Joanna Sliwa), optimization dynamics (DMO group, Antonio Orvieto), and efficiency (SEAL group, Jonas Geiping) in modern machine learning. We are therefore concerned not only with understanding and improving state-of-the-art deep learning models, but also with developing a strong theoretical foundation.

In this project, we are interested in studying structured approaches for adapting LLMs to perform new tasks. Beyond standard low-rank adaptation (LoRA), many options are possible – such as, for instance, Kronecker Adapters or Butterfly Transforms. The project at hand aims to benchmark which options are most efficient for fine-tuning large language models on standard reasoning tasks. It involves inspecting training dynamics, initialization, and generalization (e.g., how does the structure of the adapter relate to overfitting or minimizer qualities in the loss landscape?). The project requires good knowledge of PyTorch and an interest in mathematical aspects of deep learning. We (supervisors) will engage with the student and help develop a solid theoretical and experimental framework, with the objective to deliver solid answers to the community to pressing issues such as identification of the optimal adapter size and parametrization in finetuning.

**Required technical skills**

- Good coding skills in Python
- Knowledge of basic Linear Algebra (ranks, eigenvalues, etc.)
- Great command of the English language, necessary to analyze text model outputs
- Basic Understanding of Nature Language Processing with Large Language Models

**5. Project: Safety of LLMs as Diagnostic Tools in Psychiatry**
**Lab: COMPASS Research Group & Embodied Social Interaction Group**
**Main Supervisor: Philipp Müller**
**Co-Supervisor: Sahar Abdelnabi**
**Area: Machine Learning**

This is a collaborative project between the COMPASS (COoperative Machine intelligence for People-Aligned Safe Systems, ELLIS / MPI-IS Tübingen, headed by Sahar Abdelnabi) and the Embodied Social Interaction Group (MPI-IS Stuttgart, headed by Philipp Müller). The COMPASS research group focuses on developing safe, aligned, and steerable AI agents with emphasis on security, human aspects, and cooperative multi-agent systems. The Embodied Social Interaction group focuses on social interactions involving humans and machines. It follows an interdisciplinary approach that integrates perspectives from psychology with computer science.

Large Language Models (LLMs) are increasingly investigated in the context of psychiatric diagnoses. By analysing conversations between patient and therapist, LLMs might be able to support diagnostic decisions and increase their accuracy. It might even be possible to fully automatize the diagnostic process via conversation with an artificial agent. While such an approach has the potential to improve access to psychiatric services and reduce costs, previous research has shown that LLMs are prone to adversarial manipulation, which potentially compromises their clinical reliability. One example for such manipulation is prompt injection, a technique where instructions intended to maliciously steer the LLM output are placed in the data consumed by the LLM. Another attack technique is Retrieval Augmented Generation (RAG) poisoning where external data consumed by the LLM leads to false outcomes. In your internship, you will contribute to research that studies such LLM security attacks in the psychiatric domain. You will learn how to apply LLMs for psychiatric diagnoses, how to conceptualise and operationalise security attacks in this scenario, and how to evaluate their impact.

**Required technical skills**

- Good coding skills in Python
- Experience with machine-learning methods

## 6. Project: In-Training Compression of Oscillatory State-Space Models

**Lab:** Computational Applied Mathematics & AI Lab (CAMAIL)

**Main Supervisor: Konstantin Rusch**

**Area: Machine Learning**

This project builds on recent work [1], which introduced CompreSSM — a control-theoretic framework for in-training compression of State-Space Models (SSMs) that are based on first-order Linear Time-Invariant (LTI) systems via balanced truncation. The goal of this project is to extend this approach from first-order SSMs to second-order SSM formulations making it applicable to Oscillatory State-Space Models (LinOSS) [2].
Balanced truncation can be formulated for second-order systems, by preserving the special structure of the state matrix. The student will investigate these formulations and develop an in-training balanced truncation algorithm for LinOSS, leveraging classical results from model order reduction for second-order LTI systems.

**Tasks.**

- Review literature on balanced truncation for second-order LTI systems (e.g., [3]).
- Derive controllability and observability Gramians for the LinOSS formulation.
- Extend CompreSSM to second-order dynamics.
- Evaluate the approach on synthetic and real sequence-modeling benchmarks (e.g., on the Long-Range Arena benchmark).

**Expected Outcomes.**

- A validated in-training compression method for oscillatory SSMs.
- Quantitative analysis of performance vs. compression trade-offs.
- Integration into the open-source CompreSSM and LinOSS repositories.

**Prerequisites.**

- Background in control theory, numerical linear algebra, and deep learning.
- Familiarity with deep learning frameworks (in particular JAX).
- Interest in dynamical systems and physics-inspired machine learning.

References

[1] Makram Chahine, Philipp Nazari, Daniela Rus, and T Konstantin Rusch. The curious case of in-training compression of state space models. arXiv preprint arXiv:2510.02823, 2025.
[2] T Konstantin Rusch and Daniela Rus. Oscillatory state-space models. In International Conference on Learning Representations, 2025.
[3] Peter Benner, Patrick KÅNurschner, and Jens Saak. Improved second-order balanced truncation for symmetric systems. IFAC Proceedings Volumes, 45(2):758–762, 2012.

## Theoretical Neuroscience

### 7. Project: Decision-making algorithms underlying different foraging paradigms

**Lab:** Computational Neuroscience
**Main Supervisor: Roxana Zeraati**
**Co-Supervisor: Shervin Safavi**
**Area: Theoretical Neuroscience and Data analysis**

Our lab focuses on developing and testing theories and computational models of neural processing across cognitive tasks such as decision-making and learning. One of the directions we are interested in is neural reinforcement learning, which allows us to gain a deeper understanding of how humans and animals learn to perform adaptive behavior (e.g., decision-making, foraging, etc.) in dynamic and complex environments and uncover the underlying neural machinery.

As an intern, you will be working on a large-scale behavioral dataset to investigate decision-making mechanisms across various foraging paradigms. Foraging is a natural decision process shared among species. To study the mechanisms underlying foraging, different task paradigms are used in neuroscience. However, it is unknown whether animals use the same decision-making algorithms to solve these different paradigms. In this project, first, you will learn about handling and curating large-scale behavioral data. Then, you will use reinforcement learning models to extract relevant decision-making algorithms from these data.

**Required technical skills**

- Proficiency in programming in Python
- Good familiarity with reinforcement learning models
- Experience with modeling behavioral data is advantageous

## Data Analysis

### 8. Project: Sex differences in non-visual effects of light

**Lab: Translational & Circadian Neuroscience**

**Main Supervisor: Carolina Guidolin**

**Co-Supervisor: Manuel Spitschan**

**Area: Data Analysis**

In our lab we study the effects of light on human physiology and behaviour. We aim to understand how light is processed by non-visual pathways in the brain and how this impacts the human circadian clock. Sex differences in non-visual effects of light have been reported, but the mechanisms behind these differences are unknown.

The aim of this project is to analyse preliminary data from a human experiment looking at sex differences in melatonin suppression by light exposure in the evening. As an intern, you will be working on pre-processing, analysing and comparing melatonin data collected in naturally cycling individuals, individuals taking the oral contraceptive pill, and healthy male participants. You will learn statistical methods to analyse circadian markers and have the opportunity to assist the ongoing data collection, which will give you insight into how human circadian experiments are performed.

**Required technical skills**

- Basic knowledge in data wrangling and analysis (e.g. R and/or Python)
- Proactive, solution-oriented communication and reporting skills
- Basic knowledge of neuroscience and interest in chronobiology

**9. Project: Thermoregulatory control in response to endogenous pacemaker and ambient conditions**
**Lab: Translational & Circadian Neuroscience**
**Main Supervisor: Manuel Spitschan**
**Co-Supervisor: Salma Thalji**
**Co-Supervisor 2: Hannah Sophie Heinrichs**
**Area: Data Analysis**

In our lab, we investigate the interactions between endogenous circadian rhythms and exogenous environmental factors in shaping human physiology and behavior. We employ longitudinal monitoring, controlled in-lab protocols, and ecological field studies to capture physiological dynamics across timescales and contexts. One of our focuses is understanding how the circadian system orchestrates physiological regulation across multiple domains, including thermoregulation, cardiovascular function, and endocrine activity. Using forced desynchrony protocols that disentangle internal circadian timing from sleep-wake and environmental cycles, we analyze continuous multimodal data streams to isolate intrinsic rhythmic influences on body temperature, heart rate, blood pressure, and hormone secretion. Our goal is to elucidate how circadian timing regulates physiological rhythms and contributes to the maintenance of homeostatic balance across systems.
As an intern, you will work on analyzing high-resolution thermoregulatory data collected under controlled experimental conditions. You will learn to clean, process, and align multimodal body temperature signals (core and peripheral) from a 53-hour nap protocol, and to explore and visualize how temperature dynamics relate to sleep-wake behavior and circadian phase using reproducible, version-controlled analytical workflows.

**Required technical skills**

- Strong background in signal processing, time-series analysis, and data visualization (e.g. using Python libraries such as NumPy, pandas, SciPy, matplotlib, or similar)
- Familiarity with Git for version control and collaborative coding workflows

**10. Project: Circadian modulation of physiological signals during forced desynchrony**
**Lab: Translational & Circadian Neuroscience**
**Main Supervisor: Manuel Spitschan**
**Co-Supervisor: Hannah Sophie Heinrichs**
**Co-Supervisor 2: Salma Thalji**
**Area: Data Analysis**

In our lab, we investigate the interactions between endogenous circadian rhythms and exogenous environmental factors in shaping human physiology and behavior. We employ longitudinal monitoring, controlled in-lab protocols, and ecological field studies to capture physiological dynamics across timescales and contexts. One of our focuses is understanding how the circadian system orchestrates physiological regulation across multiple domains, including thermoregulation, cardiovascular function, and endocrine activity. Using forced desynchrony protocols that disentangle internal circadian timing from sleep-wake and environmental cycles, we analyze continuous multimodal data streams to isolate intrinsic rhythmic influences on body temperature, heart rate, blood pressure, and hormone secretion. Our goal is to elucidate how circadian timing regulates physiological rhythms and contributes to the maintenance of homeostatic balance across systems.

As an intern, you will work on analyzing cardiovascular and endocrine data collected during controlled experimental conditions. You will learn to process, visualize, and interpret physiological signals such as heart rate, blood pressure, and cortisol across circadian and behavioral cycles within a 53-hour nap protocol. Through this work, you will gain experience identifying intrinsic circadian patterns, exploring their coordination across physiological systems, and applying reproducible, version-controlled analytical workflows.

**Required technical skills**

- Strong background in signal processing, time-series analysis, and data visualization (e.g. using Python libraries such as NumPy, pandas, SciPy, matplotlib, or similar)
- Familiarity with Git for version control and collaborative coding workflows

**11. Project: Characterization of human facial responses under bright light exposure**

**Lab: Translational & Circadian Neuroscience**

**Main Supervisor: Manuel Spitschan**

**Co-Supervisor: Lucien Bickerstaff**

**Area: Vision science, data analysis, neuroscience, facial recognition, visual discomfort**

Light plays a crucial role in regulating human physiology and behavior, however its impact on facial expressions and how they relate to sensitivity to light and visual discomfort outcomes has so far been poorly characterized. This internship aims to provide insights into the physiological manifestations and predictors of visual discomfort under bright lighting conditions.

As an intern, you will be working on a dataset of physiological (pupillometry, facial sEMG, facial video recording, subjective reporting) measures of visual discomfort and light sensitivity under bright light conditions. The dataset includes video recordings of participant faces, and the goal of the internship will be to extract facial expressions information (using the Facial Action Coding System) from the videos and relate them to the other physiological outcomes. You will learn about the physiology of the human visual system, improve your programming skills, learn how to use facial expression recognition software, analyze multi-modal physiological time series data, and model facial responses to light from these data.

**Required technical skills**

- Good programming skills (Python), for data processing, analysis and visualization
- Experience using version control systems (Git/GitHub or similar)
- Experience handling physiological time series data
- Experience with statistical modeling

## Scientific Software Development

### 12. Project: Developing robust libraries for Computational Neuroscience

**Lab: Computational Neuroscience**

**Main Supervisor: Andrew Webb**

**Co-Supervisor: Peter Dayan**

**Area: Scientific Software Development**

In the Computational Neuroscience lab, we focus on developing and testing computational models of neural processing, to understand and explain the cognitive process involved in decision-making, learning, and representation. In practice, this means that much of the work we do involves turning our clean and concise mathematical descriptions of models into rather less clean and concise code. Although this is unavoidable to some extent, we are often solving similar problems, and so reinventing the wheel is both time-consuming and prone to error.

As an intern you will help to develop a library (or libraries) in python that can be used as part of the computational modeling process. Depending on what is most needed, and where your interests lie, this may involve implementing reusable and extensible building blocks for modeling (*e.g.* for simple Markov Decision Processes (MDPs), or more exotic methods, such as POMDPs/BAMDPs), or more general-use data structures and algorithms (*e.g.*, for Monte Carlo Tree Search), or for running online experiments. You will learn the gory algorithmic details of a range of different computational modeling tools and techniques, extend your programming knowledge, and gain experience in the software development process.

**Required technical skills**

- Good coding skills in python (experience in C++/rust would be great, but is not required)
- An interest in the (underappreciated) programming aspects of modern science

## Computational Modeling

### 13. Project: Estimating decision biases via joint modeling of choices and reaction times

**Lab:** Developmental Computational Psychiatry

**Main Supervisor: Tobias Hauser**

**Co-Supervisor: Ben J. Wagner**

**Area: Theoretical Neuroscience, Computational Modeling, Decision-Making**

This project investigates human decision biases arising from action repetition. It is a follow-up to the paper *"Explaining decision biases through context-dependent repetition"* (Wagner et al., 2025). We will extend the framework presented in that paper by incorporating reaction time data and modeling the joint dynamics of evidence accumulation and reinforcement learning. The goal is to examine how action repetition influences decision thresholds, drift dynamics, and ultimately bias formation across multiple datasets.

The intern will learn to apply hierarchical Bayesian reinforcement learning-drift diffusion models (RL-DDMs) and gain hands-on experience in computational modeling, hierarchical Bayesian inference, and model comparison across datasets of varying complexity (ranging from two to over seventy choice contexts). The project will also include training in producing publication-ready figures and writing reproducible analysis code, providing a comprehensive introduction to computational psychiatry research on decision biases.

**Required technical skills**

- Basic coding skills in Python or R
- Some basic knowledge of Bayesian data analysis and/or reinforcement learning models
- Strong interest in cognitive modeling and decision neuroscience, and most important high motivation to learn