EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

# Module Handbook

## Neural Information Processing
## Master of Science

Academic Year 2021-22

Faculty of Science and Medical Faculty
Graduate School of Neural Information Processing

# Content

# 1. Qualification goals of the master course 'Neural Information Processing'

This research oriented course of study aims at German and international students with a first academic degree (BSc) in physics, mathematics, computer science, cognitive science or engineering or in another relevant field of natural sciences. The theoretical and practical education comprises topics of computational neuroscience, machine learning, systems neuroscience, neurophysiology, psychophysics and statistics. Moreover, an emphasis is set on scientific writing and communication skills.

The overall goal of the course is to impart solid knowledge and competences to qualify students to independently plan and carry out complex analyses and develop sophisticated models of neuroscientific data, to choose appropriate methodological approaches, and to critically evaluate their findings in comparison with published data. The interdisciplinary nature of the program qualifies the students to also interact closely with experimental researchers. The qualification goals in more detail:

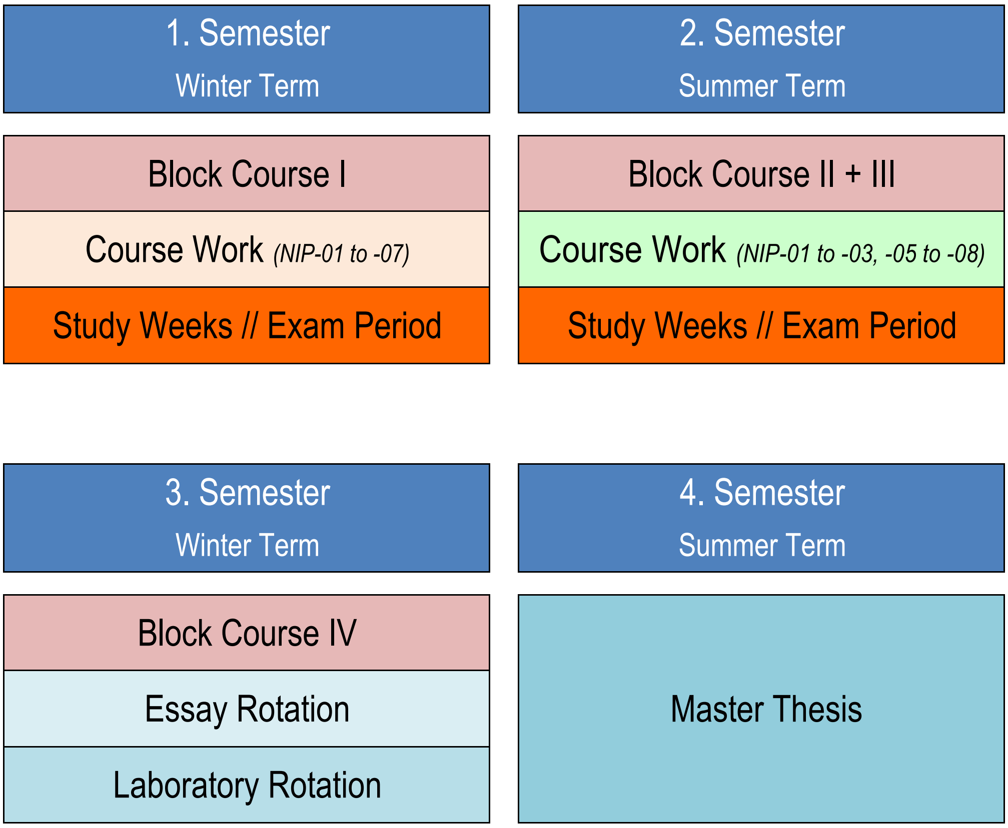
- Our graduates have a sound standing in the interdisciplinary field of computational neuroscience and machine learning, and broad knowledge of systems neuroscience.
- They have profound skills in mathematics and theoretical neuroscience, which allows them to theoretically dissect modeling questions in neuroscience.
- The students are able to implement basic and advanced algorithms for neuroscientific data analysis and modeling and to apply them to real data.
- Graduates have a solid theoretical and – to some extend – hands-on expertise in a range of state-of-the-art neuroscientific methods, including psychophysics, neurophysiology and imaging techniques and motor control.
- They are capable of critically scrutinizing the suitability of specific experimental approaches for studying various neuroscientific questions (*can I answer my scientific questions with the method at hand?*). Also, they will be able to combine techniques in a meaningful way to also make rather complex scientific problems accessible.
- Graduates have required English language competency at least equivalent to C1-level. They can present scientific findings of their research orally and in writing. Moreover, in discussions they are skilled to answer scientific questions in a proficient manner. At scientific meetings, they can communicate – in English – with experts in the field and contribute to discussions on current neuroscientific topics.
- During their studies and laboratory rotations, graduates have also gained general competencies such as time and conflict management, coping with stressful situations, as well as social skills and the capacity for teamwork. Furthermore, as members of an international course of study and by working in internationally composed research groups they also gain cross-cultural competence to some extent.

In conclusion, after successful graduation from the master course students are well prepared to engage, eventually, in a demanding doctoral research project and pursue a career in science.

# 2. Modules overview

| Module Code | Module Title | Semester | Credits |
|---|---|---|---|
| NIP-01 | Theoretical Neuroscience | 1st and 2nd | 10 |
| NIP-02 | Machine Learning | 1st and 2nd | 10 |
| NIP-03 | Data Processing | 1st and 2nd | 9 |
| NIP-04 | The Neuron and Experimental Methods | 1st | 6 |
| NIP-05 | Sensory Systems | 1st and 2nd | 10 |
| NIP-06 | Motor Systems | 1st and 2nd | 6 |
| NIP-07 | Introduction to Current Research | 1st and 2nd | 5 |
| NIP-08 | Electives | 1st and 2nd | 9 |
| NIP-09 | Essay Rotation / Laboratory Rotation | 3rd | 25 |
| NIP-10 | Masters Thesis | 4th | 30 |
| | | | **Sum 120** |

# 3. Timeline of the master course



# 4. Semester / Courses / Credits

| 1. Semester // Winter Semester | Credits | |
|---|---|---|
| Functional Neuroanatomy *(1 week block)* | 2 | |
| Neural Dynamics | 5 | |
| Machine Learning I | 5 | |
| Mathematical Basis for Computational Neuroscience | 2 | |
| Neurophysiology | 3 | |
| Neural Experimental Techniques | 3 | |
| Sensory Systems – The Auditory system | 3 | |
| Sensory Systems – The Visual System | 2 | |
| Motor Systems *(2 week block)* | 3 | |
| Electives | 3 | |
| NeuroColloquium | 0,5 | **Σ 31,5** |

| 2. Semester // Summer Term | Credits | |
|---|---|---|
| Neural Coding | 5 | |
| Machine Learning II | 5 | |
| Neural Data Science | 4 | |
| Signal Processing | 3 | |
| Computational Motor Control | 3 | |
| Psychophysics and Non-Invasive Methods | 3 | |
| Retreat | 2 | |
| NeuroColloquium | 0,5 | |
| Electives | 6 | **Σ 31,5** |

| 3. Semester // Winter Semester | Credits | |
|---|---|---|
| Introduction to Scholarly Research and Writing | 2 | |
| Essay Rotation / Laboratory Rotation (incl. Seminars) | 25 | **Σ 27** |

| 4. Semester // Summer Term | Credits | | |
|---|---|---|---|
| Masters Thesis | 30 | **Σ 30** | |
| | | | **Σ 120** |

# 5. Modules and examinations

| Module | Module Element // Course | Course Requirements | Exam Period | | |
|---|---|---|---|---|---|
| | | | Midterm WS/SS | Ex. Per. Spring | Ex. Per. Summer |
| NIP-01 | Neural Dynamics | Written exam (2 h) | | X | |
| | Neural Coding | Written exam (2 h) | | | X |
| NIP-02 | Machine Learning I | Written exam (2 h) | | X | |
| | Machine Learning II | Written exam (2 h) | | | X |
| NIP-03 | Signal Processing | Written exam (2 h) | | | X |
| NIP-04 | Neurophysiology | Written exam (4 h) | | X | |
| | Neural Experimental Techniques | | | | |
| NIP-05 | Functional Neuroanatomy | Written exam (1,5 h) | X | | |
| | Sensory Systems | Written exam (4 h) | | X | |
| | Psychophysics and Non-Invasive Methods | Written (online) exam (2 h) | | | X |
| NIP-06 | Motor Systems | Written mini-exams | X | | |
| | Computational Motor Control | Written exam (2 h) | | | X |
| NIP-07 | Retreat | Oral presentation | X | | |

**This examinations overview shows:**

- all examinations in the first year of study (1st and 2nd semester),
- the modules / module elements that are concluded with an examination,
- the type and the duration of an examination,
- the time points of the examinations (midterm, spring or summer examination period),
- and the number of exams in a given exam period (*please note the colour coding*).

# 6. Modules and courses

| Code | Module | Coordinator | ECTS | Module Elements |
|---|---|---|---|---|
| NIP-01 | **Theoretical Neuroscience** | Giese | **10** | • Neural Dynamics<br>• Neural Coding |
| NIP-02 | **Machine Learning** | Giese | **10** | • Machine Learning I<br>• Machine Learning II |
| NIP-03 | **Data Processing** | Berens | **9** | • Mathematical Basis for Computational Neuroscience<br>• Neural Data Science<br>• Signal Processing |
| NIP-04 | **The Neuron and Experimental Methods** | Euler | **6** | • Neurophysiology<br>• Neural Experimental Techniques |
| NIP-05 | **Sensory Systems** | Wichmann | **10** | • Functional Neuroanatomy<br>• Sensory Systems<br>• Psychophysics and Non-Invasive Methods |
| NIP-06 | **Motor Systems** | Schwarz | **6** | • Motor Systems (Block)<br>• Computational Motor Control |
| NIP-07 | **Introduction to Current Research** | Himmelbach | **5** | • Introduction to Scholarly Research and Writing<br>• NeuroColloquium<br>• Retreat |
| NIP-08 | **Electives** | Himmelbach | **9** | • Elective Courses I – III |
| NIP-09 | **Essay Rotation / Laboratory Rotation** | Himmelbach | **25** | • Essay Rotation + Report + Seminar<br>• Laboratory Rotation + Report + Seminar |
| NIP-10 | **Master Thesis** | Himmelbach | **30** | • Laboratory Work + Thesis |
| | | | $\sum 120$ | |

# 7. Descriptions of individual modules (NIP-01 to NIP-10)

| Module **Theoretical Neuroscience** | Code: NIP-01 | ECTS Credit points **10** |
|---|---|---|

| Module coordinator | Contact |
|---|---|
| Prof. Dr. Martin **Giese** | Centre for Integrative Neuroscience / Hertie Institute for Clinical Brain Research<br>Computational Sensomotorics<br>martin.giese@uni-tuebingen.de<br>phone 07071-29 **89124** |
| **Duration of module** | **Cycle** |
| 2 Semesters | Annually |

| Module elements | | |
|---|---|---|
| **Course title** | **Course type** | **Semester*** |
| Neural Dynamics | Lecture | WS |
| Neural Dynamics – Assignments | Assignments / Exercise Sessions | |
| Neural Coding | Lecture | SS |
| Neural Coding – Assignments | Assignments / Exercise Sessions | |

* WS = winter semester / SS = summer semester

**Module content**

This module provides an introduction to the main research topics of theoretical neuroscience. There are two major lectures, *Neural Dynamics* and *Neural Coding* which are combined with homework assignments. The two lectures discuss selected biophysical neuron models (e.g. Hodgkin-Huxley), and some more abstract models (e.g. integrate-and-fire). It further includes an basic introduction to network dynamics and some basic phenomena in recurrent neural network models, and of nonlinear phenomena in neurons. Information theoretic tools and estimation theory is provided for the analysis of neural codes and sensory decision-making. Basic models of neural population codes and probabilistic population codes are introduced as well as a characterization of natural stimuli.

**Qualification goals / learning targets**

After successful completion of this module students will be able to describe main research questions in theoretical neuroscience and will have some basic knowledge about relevant mathematical models to address them. By solving homework problems, students will gather hands-on experience in carrying out basic mathematical modelling and simple analyses by themselves, which also includes computer simulations.

**Teaching methods**

The two main courses in this module are taught as combined lectures (2h) and exercise sessions (2h), in which the homework assignments are discussed.

**Prerequisites for participation**

Calculus, linear algebra, basic analysis, basic probability theory and familiarity with a programming language (e.g. Matlab, Python).

**Usability of the module**

Compulsory module in the 1st and 2nd semester of the master program Neural Information Processing.

**Module requirements, exams and grading scheme**

Students are required to solve 50% of the exercise problem sheets as a prerequisite for participation in the final exams and present the solutions of at least one exercise problem to the class during an exercise session. The module will be concluded with two written exams (graded), one of which takes place in the spring and one in the summer examination period. The module grade will be calculated from the two exams, which are weighted according to their assigned credit points (5:5).

**Workload assessment and credit points**

| Module element | Workload* | CPs** |
|---|---|---|
| Neural Dynamics | Co: 30h + Re: 40h + Ex: 20h = 90h | 3 |
| Neural Dynamics – Assignments | Co: 15h + As: 45h = 60h | 2 |
| Neural Coding | Co: 30h + Re: 40h + Ex: 20h = 90h | 3 |
| Neural Coding – Assignments | Co: 15h + As: 45h = 60h | 2 |
| | | Total **10** |

* **Co**=contact time in class, **Re**=review after class, **As**=assignments/homework, **Ex**=exam preparation/exam

****** 30 hours workload = 1 ECTS credit point

| Module<br>**Machine Learning** | Code: NIP-02 | ECTS credit points<br>**10** |
|---|---|---|

| Module coordinator | Contact |
|---|---|
| Prof. Dr. Martin **Giese** | **Contact**<br>Centre for Integrative Neuroscience / Hertie Institute for Clinical Brain Research<br>Computational Sensomotorics<br>martin.giese@uni-tuebingen.de<br>phone 07071-29 **89124** |
| **Duration of module**<br>2 Semesters | **Cycle**<br>Annually |

| Module elements | | |
|---|---|---|
| **Course title** | **Course type** | **Semester*** |
| Machine Learning I | Lecture | WS |
| Machine Learning I – Assignments | Assignments / Exercise Sessions | |
| Machine Learning II | Lecture | SS |
| Machine Learning II – Assignments | Assignments / Exercise Sessions | |

* WS = winter semester / SS = summer semester

**Module content**

We provide a comprehensive overview of contemporary approaches in Machine Learning. Topics include (but are not limited to) probability theory, frequentist and Bayesian statistics, basic methods for classification and regression, elementary methods for unsupervised learning and dimension reduction, statistical learning theory, kernel methods, support vector machines, Bayesian inference and model selection, stochastic processes, graphical models, Hidden Markov Models, and approximation methods for learning and inference. We will exemplify the applicability of these approaches to various problem domains, e.g. neural data analysis and computer vision. Relevant software packages will be discussed. In addition, open problems in machine learning research will be discussed.

**Qualification goals / learning targets**

Students will learn the theoretical basis of fundamental methods in machine learning. They will learn to establish and prove simple relationships in probabilistic modeling and inference. They will be enabled to choose the appropriate machine learning tools for given problems in data analysis and modeling. As a consequence of the homework exercises, students will also be familiarized with the implementation and application of methods of machine learning research and relevant software tools. By working on concrete problems students will be familiarized with the practical realization of machine learning algorithms and the related implementation issues.

**Teaching methods**

The two main courses in this module are taught as combined lectures (2h) and exercise sessions (1h), in which the homework assignments are discussed. Solutions to exercise problems will be presented by students to the class in the exercise sessions.

**Prerequisites for participation**

Calculus, linear algebra, basic analysis, and familiarity with a programming language (e.g. MatLab, Python).

**Usability of the module**

Compulsory module in the 1st and 2nd semester of the master program Neural Information Processing.

**Module requirements, exams and grading scheme**

ML I: Students are require to submit 3 practical tasks on ILIAS which are graded and this practical part will count 40% towards the final grade. ML I will will be concluded with a written exam, which will count 60% towards the final degree.

ML II: Students are required to solve 50% of the exercise problem sheets as a prerequisite to participation in the final exam and present the solutions of at least one exercise problem to the class during an exercise session. The module will be concluded with a written exam.

The module grade will be calculated from the two final results, which are weighted according to their assigned credit points (5:5).

**Workload assessment and credit points**

| **Module element** | **Workload*** | **CPs**** |
|---|---|---|
| Machine Learning I | Co: 30h + Re: 40h + Ex: 20h = 90h | 3 |
| Machine Learning I – Assignments | Co: 15h + As: 45h = 60h | 2 |
| Machine Learning II | Co: 30h + Re: 40h + Ex: 20h = 90h | 3 |
| Machine Learning II – Assignments | Co: 15h + As: 45h = 60h | 2 |
| | | Total **10** |

* **Co**=contact time in class, **Re**=review after class, **As**=assignments/homework, **Ex**=exam preparation/exam

** 30 hours workload = 1 ECTS credit point

| Module<br>**Data Processing** | Code: NIP-03 | ECTS credit points<br>**9** |
|---|---|---|

| Module coordinator | Contact |
|---|---|
| Prof. Dr. Philipp **Berens** | Institute for Ophthalmic Research<br>Neural Data Science for Vision Research<br>philipp.berens@uni-tuebingen.de<br>phone 07071-29 **88833** |
| **Duration of module**<br>2 Semesters | **Cycle**<br>Annually |

**Module elements**

| Course title | Course type | Semester* |
|---|---|---|
| Mathematical Basis for Computational Neuroscience | Lecture + Exercises + Tutorial | WS |
| Neural Data Science | Lecture with homework assignments | SS |
| Signal Processing | Lecture | SS |

* WS = winter semester / SS = summer semester

**Module content**

Modern neuroscience is full of large and complex datasets acquired with ever more sophisticated experimental methods. In this module we will cover essential techniques for neural data sciences and modelling various types of data (electrophysiology, optical imaging, transcriptomics, anatomy). This module contains courses covering the mathematical basics for the description of data, signal processing and neural data science. In many ways, it will make practical use of machine learning algorithms and models discussed in other modules. Topics include but are not limited to spectral analysis, filter design, Kalman filters, time series analysis, spike triggered average/covariance, spike sorting and dimensionality reduction techniques.

**Qualification goals / learning targets**

The students must be able to name and explain essential techniques in signal processing and neural data science. The students should be able to analyse multidimensional data from neural systems, including spike trains, voltage/calcium signals, LFP, EEG, transcriptomes and morphologies. The students should be aware of the difficulties of applying signal processing and data analysis techniques to real data.

**Teaching methods**

The courses in this module are taught in lecture-style with computer exercises. Students are expected to review topics after class and complete homework assignments. Homework assignments mostly consist of practical programming exercises.

**Prerequisites for participation**

Calculus, linear algebra and analysis (series, integrals, derivatives); basics of machine learning and neural coding; familiarity with a programming language.

**Usability of the module**

Compulsory module in the 1st year of the master program Neural Information Processing.

| **Module requirements, exams and grading scheme** |
|---|
| MBC: Students are required to attend the class and participate.<br>NDA: Students are expected to obtain 60% of the points for the exercise sheet to pass the class and present the solutions of the exercise problems weekly. The grade is determined from the weekly assessment of exercise solutions.<br>SP: The module element will be concluded by two home assignments and one exam. The final grade will be calculated from the two performances, which are equally weighted.<br>The module grade is obtained by a weighted average from the NDA and SP grades based on the CPs. |

| **Workload assessment and credit points** | | |
|---|---|---|
| **Module element** | **Workload*** | **CPs**** |
| Mathematical Basis for Computational Neuroscience (pre-course) | Co: 20h + Re: 40h = 60h | 2 |
| Neural Data Science | Co: 60h + Re: 15h + As: 45h = 120h | 4 |
| Signal Processing | Co: 30h + Re: 40h + As: 20h = 90h | 3 |
| | | Total **9** |

* **Co**=contact time in class, **Re**=review after class, **As**=assignments/homework

** 30 hours workload = 1 ECTS credit point

| Module<br>**The Neuron and Experimental Methods** | Code: NIP-04 | ECTS credit points<br>**6** |
|---|---|---|

| Module coordinator | Contact |
|---|---|
| Prof. Dr. Thomas **Euler** | Centre for Integrative Neuroscience<br>Ophthalmic Research<br>thomas.euler@cin.uni-tuebingen.de<br>07071-29 **58028** |
| **Duration of module**<br>1 Semester | **Cycle**<br>Annually |

**Module elements**

| Course title | Course type | Semester* |
|---|---|---|
| Neurophysiology | Lecture | WS |
| Neural Experimental Techniques | Lecture | WS |

* WS = winter semester / SS = summer semester

**Module content**

Information processing in neurons occurs on all levels of organization, genes, molecules, electrochemical activity of single neurons, neuronal networks and neuronal systems. This module will focus on neuronal function on a higher level, starting from the neuron's ability to generate electrical and chemical signals to network interaction and finally the generation of behaviour. Lecture 1 focuses on neuronal signals, their nature, their mechanisms of generation, and their transmission and processing at the intra- and intercellular levels. Basic concepts, key experiments and methodological tools to study these issues are presented. The topics covered include basic electro-chemical properties (resting, action and synaptic potentials), as well as basic characteristics of neural coding using spikes and computation using dendritic potentials. An overview on state of the art electrophysiological tools (intracellular current and voltage recordings of soma and dendrites; extracellular spike and local field potential recordings; micro stimulation) as well as novel experimental techniques probing neural function using light rather than electricity (calcium/voltage imaging, and optogenetic stimulation) will be given. The overview on different electrophysiological methods will be provided in more depth in Lecture 2 including of a discussion of their relative advantages and disadvantages for the study of neural systems. Lecture 3 will provide an overview of non-invasive methods such as electrophysiological (EEG/MEG) as well as imaging methods (fMRI, PET, etc.) covering both, their physical basis as well as their potential use and limitations. Finally psychophysical methods that assess the individual's behaviour generated by neuronal activity will be discussed.

**Qualification goals / learning targets**

The aim of the module is to provide students with profound knowledge and basic competences on the physiology of neurons at the cellular and network level, and the methods used for its study. By the end of the module, students will have a solid understanding of electrical signal generation, processing and integration in neurons, transmission of the neuronal signal at the chemical synapse. They will also be familiar with the techniques used to study neuronal processing at the single cell, neuronal network, and neuronal systems level. Furthermore, they will have insight into psychophysical methods to study behavioural outcome of neuronal processing.

**Teaching methods**

The courses in this module are taught in lecture-style with interposed tutorials. Students are expected to review topics after class by using their class notes, the hand-outs provided and recommended additional readings, such as textbooks and articles. The required textbooks are present in the Graduate Schools library. For the tutorials, short assignments have to be prepared and presented in class.

**Prerequisites for participation**

All lectures are self-contained, however, basic notions of cell biology, physiology, and mathematics are needed.

**Usability of the module**

Compulsory module in the 1st semester of the master program Neural Information Processing.

**Module requirements, exams and grading scheme**

The module will be concluded with a written exam (graded) by the end of the winter term.

**Workload assessment and credit points**

| Module element | Workload* | CPs** |
|---|---|---|
| Neurophysiology | Co: 30h + Re: 30h + As: 10h + Ex: 20h = 90h | 3 |
| Neural Experimental Techniques | Co: 30h + Re: 30h + As: 10h + Ex: 20h = 90h | 3 |
| | | Total **6** |

* **Co**=contact time in class, **Re**=review after class, **As**=assignments/homework, **Ex**=exam preparation/exam

** 30 hours workload = 1 ECTS credit point

| Module<br>**Sensory Systems** | Code: NIP-05 | ECTS credit points<br>**10** |
|---|---|---|

| Module coordinator | Contact |
|---|---|
| Prof. Dr. Felix **Wichmann** | Department of Computer Science<br>Neural Information Processing Group<br>felix.wichmann@uni-tuebingen.de<br>phone 07071 - 29 70420 |
| **Duration of module**<br>1 Semester | **Cycle**<br>Annually |

**Module elements**

| Course title | Course type | Semester* |
|---|---|---|
| Functional Neuroanatomy *(1 week block course)* | Lecture + Practical + Tutorial | WS |
| Sensory Systems – The Auditory System | Lecture | WS |
| Sensory Systems – The Visual System | Lecture | WS |
| Psychophysics and Non-Invasive Methods | Lecture | SS |

* WS = winter semester, SS = summer semester

**Module content**

In this module, we first provide an introduction to the functional organisation of the components of the central nervous system, from the spinal cord to the neocortex. This will build the basis for the students to follow the subsequent, more detailed courses. Thereafter, the anatomy and physiology of two model sensory systems – visual and auditory – will be covered from signal transduction at the sensory receptors to higher order processing and psychophysics. Common principles of neural coding and information processing will be emphasized.

Finally, psychophysical methods that assess the individual's behaviour generated by neuronal activity will be discussed. Analysing and designing experiments, for example in the vision sciences, requires knowledge straddling the typical boundaries of many disciplines. In this course, we will therefore, cover some physics (light), electrical engineering (display devices), mathematical psychology (signal detection theory) and statistics (psychometric function estimation) in sufficient detail, to allow the students to both analyse and critically assess psychophysical experiments.

**Qualification goals / learning targets**

The aim of the course is to provide students - coming from diverse, in general non-biological backgrounds - with a common platform of theoretical and practical knowledge about the microscopic, macroscopic and functional organisation of the brain with an emphasis on mammals. After successful completion of the module, students will be able to name and identify the major brain nuclei and their connectivity comprising the different sensory systems pathways and circuits and their role in sensorimotor integration. They will be familiar with the different types of sensory receptor cells and their signal transduction cascades. Furthermore, students will be able to differentiate the basic features of information processing and coding of sensory information in the different systems.

In the psychophysics course, students will acquire the necessary knowledge and skills to critically assess experiments in the vision sciences and, most importantly, to design and analyse their own behavioural (psychophysical) experiments. Through homework assignments and computer exercises they will gain hands-on experience applying signal detection theory and psychometric function estimation to data, and avoid common pitfalls.

**Teaching methods**

The neuroanatomy course is a one-week block course consisting of lectures and tutorial-style, supervised practical parts. The two sensory systems courses are taught in lecture-style with interposed tutorials. For the tutorials, students are expected to come armed with questions based on the lecture material. Moreover, as an aid for preparing their tutorial questions and for exercise, the lecturers will provide a list of questions after the lectures. The psychophysics course is taught in lecture-style with homework assignments and computer exercises. For all courses, students are expected to review topics after class by using their class notes, the lecture slides and recommended additional readings, such as textbooks and journal articles.

**Prerequisites for participation**

Basic notions of cell biology, physiology and brain organisation are needed as well as basic mathematical (probability, theory, calculus) and programming skills (Matlab).

**Usability of the module**

Compulsory module in the 1st semester of the master program Neural Information Processing.

**Module requirements, exams and grading scheme**

The final module grade will be compiled from separate examinations. The written exam covering the functional neuroanatomy course will be held shortly after completion of the course (midterm exam) and makes up 20% of the module grade. The sensory systems – auditory system examination consists of a written, graded exam covering the topics of the lectures taught in this module (75%) and regular weekly homeworks covering topics of that week's lecture (25%).The examination for the sensory systems – visual system consists of a written and graded exam after the end of the lecture covering the topics of the lecture.  A fourth exam (online) in the summer examination period covers the psychophysics course and contributes 30% to the module grade.

| Workload assessment and credit points | | |
|---|---|---|
| **Module element** | **Workload*** | **CPs**** |
| Functional Neuroanatomy | Co: 20h + Re: 40h + As: 10h + Ex: 20h = 90h | 2 |
| Sensory Systems – The Auditory system | Co: 30h + Re: 30h + As: 10h + Ex: 20h = 90h | 3 |
| Sensory Systems – The Visual System | Co: 20h + Re: 20h + As: 5h + Ex: 15h = 60h | 2 |
| Psychophysics and Non-Invasive Methods | Co: 30h + Re: 30h + As: 10h + Ex: 20h = 90h | 3 |
| | Total | **10** |

* **Co**=contact time in class, **Re**=review after class, **As**=assignments/homework, **Ex**=exam preparation/exam

** 30 hours workload = 1 ECTS credit point

| Module Motor Systems | Code: NIP-06 | ECTS credit points 6 |
|---|---|---|

| Module coordinator | Contact |
|---|---|
| Prof. Dr. Cornelius **Schwarz** | Centre for Integrative Neuroscience<br>Systems Neurophysiology<br>cornelius.schwarz@uni-tuebingen.de<br>phone 07071-29 **80462** |
| **Duration of module** | **Cycle** |
| 2 Semesters | Annually |

**Module elements**

| Course title | Course type | Semester* |
|---|---|---|
| Motor Systems *(2 week block course)* | Lecture | WS |
| Computational Motor Control | Lecture | SS |

* WS = winter semester, SS = summer semester

**Module content**

The Motor Systems course will introduce students to motor behaviour and sensorimotor integration and will provide a coherent view of the hierarchical organization of the muscular and neuronal motor periphery, pattern generators in spinal cord/brainstem, motor- and premotor cortex, as well as intermediate control loops mediated by the cerebellum and the basal ganglia. The structure and function of these brain areas for planning, generating and guiding movements, and their interconnectivity with the other components, will be discussed in detail.

The course on Computational Motor Control completes the module and addresses motor behavior as an interaction of neural control, morphology and (changing) environments. Therefore, the lecture introduces methods for the development of models of biomechanics, motor control and motor learning processes. In the first part, the focus lay on the biomechanical modelling and the connection to neural control. The second part of the lecture will comprise the description and modelling of motor adaptation. Human adaptive motor behavior will be presented in various experimental setups. The effects of different learning strategies, impairments in motor adaptation in neurological patients and the use of motor learning principles in neuro-rehabilitation will be presented.

**Qualification goals / learning targets**

This module provides students with diverse technical and theoretical educational backgrounds with a common platform of theoretical and practical knowledge on structure and function of the mammalian motor system, with some references to vertebrate and invertebrate systems.

After successful completion of the module, students will be able to name and identify major brain nuclei involved in movement generation and sensorimotor integration. They will be able to describe the internal functional network organization and will be aware of major functional hypotheses in the field about the major sub-systems. They will have done first steps to successfully read, discuss and communicate the content of current journal publications on motor systems. They will be able to connect computational motor-neuroscience approaches with the actual hypothesized neuronal function of the different motor subsystems.

Moreover, students will be familiarised with methods for modelling the interaction between biomechanics and neural control as well as quantitatively describe motor learning processes. This will enable the student to identify the requirements and possibilities for modelling complex movement behaviour in order to understand underlying control principles. Thereafter, they will be able to apply these models to various fields, such as rehabilitation robotics and medical engineering.

**Teaching methods**

The courses in this module are taught in lecture-style with interposed tutorials. Students are expected to review topics after class by using their class notes, the hand-outs provided and recommended additional readings, such as textbooks and articles. The required textbooks are present in the Graduate Schools library. For the tutorials, short assignments have to be prepared and presented in class.

**Prerequisites for participation**

Basic notions of cell biology, physiology and brain organisation are needed.

**Usability of the module**

Compulsory module in the 1st and 2nd semester of the master program Neural Information Processing.

**Module requirements, exams and grading scheme**

The block course in winter term will not be graded (pass/fail). Criteria to pass the course are regular attendance, the successful passing of three mini-exams (30 min duration, 50% correct answers), and the successful preparation and presentation of a seminar talk in class.

The summer term lecture will be concluded with an oral exam (graded) by the end of the term.

**Workload assessment and credit points**

| **Module element** | **Workload*** | **CPs**** |
|---|---|---|
| Motor Systems | Co: 30h + Re: 30h + As: 10h + Ex: 20h = 90h | 3 |
| Computational Motor Control | Co: 30h + Re: 30h + As: 10h + Ex: 20h = 90h | 3 |
| | Total | **6** |

* **Co**=contact time in class, **Re**=review after class, **As**=assignments/homework, **Ex**=exam preparation/exam

** 30 hours workload = 1 ECTS credit point

| Module | Code: NIP-07 | ECTS Credit points |
|---|---|---|
| **Introduction to Current Research** | | **5** |

| Module coordinator | Contact |
|---|---|
| PD Dr. Marc **Himmelbach** | Graduate Training Centre of Neuroscience<br>marc.himmelbach@uni-tuebingen.de<br>phone 07071-29 **77177** |
| **Duration of module** | **Cycle** |
| 2 Semesters | Annually |

**Module elements**

| Course title | Course type | Semester* |
|---|---|---|
| NeuroColloquium | Talks *(invited speakers)* | WS + SS |
| Weekend Seminar / Retreat *(changing topics)* | Student Seminar | SS |
| Introduction to Scholarly Research and Writing | Lecture with homework assignments | SS |

* WS = winter semester / SS = summer semester

**Module content**

The aim of this module is to introduce the students not only to current research in the field of neuroscience but also initiate and foster discussions among students and with guests and lecturers about a broad range of topics at the interface between neuroscience and society. In addition, a one-week interactive course will offer the opportunity to learn about, discuss and practice scholarly writing and good scientific conduct.

The NeuroColloquium is a long-standing, fortnightly seminar series organized by the Tübingen neuroscience community. The seminar presents internationally renowned researchers from various fields of neuroscience. The talks have a review-like character providing an overview of state-of-the-art neuroscience topics, from genes to behaviour and new methodologies. Students will get the opportunity to choose speakers of their interest and meet with them before and after the talk.

Once a year, the master students of the two Graduate Schools will jointly attend a Weekend Retreat where they present and discuss topics that are generally not part of their regular curricular course program such as: Sex Differences in the Brain, From Basic Science to Marketable Drugs, Neuroprosthetics, Executive Functions, Philosophy of Mind, Ethics in Neuroscience, and Animals in Neuroscience Research. The seminar topics are usually chosen cooperatively by students and Graduate School staff and do change every year.

Furthermore, the module offers an one-week introduction into Scholarly Research and Scientific Writing. Here the motivation is that being a successful scientist requires more than great experimental skills and a deep understanding of methods; scientists have to be able to present their work convincingly to various audiences, including their fellow scientists, students and colleagues, the agencies who fund their work, but also the critical public that finances research with from taxes. In addition, successful science builds on a network of mutual trust and rules of conduct (good scientific practice) that every scientist is to adhere to. Learning about these aspects should be an integral part of becoming a scientist, nevertheless this still tends to be neglected in favour of the 'actual' research work.

**Qualification goals / learning targets**

The NeuroColloquium introduces students to a wide range of neuroscience research and make them 'look beyond their own noses'. Of the 8 speakers visiting per semester, 2 speakers will be selected, invited and hosted by students of the Graduate Schools. By doing so, students actively participate in organizing a seminar series and will thereby gain organizational skills and social competence.

After successful accomplishment of the retreat, students will have achieved skills that are required for scientific work in general, including literature search and preparation and presentation of a seminar talk on an unfamiliar topic. In addition to discussing scientific topics, these retreats are also meant as social events where students from the two master programs meet with scientists and lecturer in a beautiful setting and a relaxed ambiance to get to know each other and to potentially initiate local co-operations.

After passing the one-week scholarly writing course, the students will have acquired a good sense of the ethical standards in science and of the necessary skills to write scientific papers. They will have learned and practiced summarizing and assessing scientific reports and papers, graphical presentation of data, structuring talks and preparing effective slices and posters, presenting findings to a scientific audience, and preparing a CV and a statement of purpose. In addition, the students have learned about the principles and practice of good scholarship, and discussed research ethics, with the focus on animal experimentation.

**Teaching methods**

The NeuroColloquium is a seminar series with invited speakers. The retreat requires students to deal with unfamiliar neuroscience topics in more depth. The students present talks on selected topics. The core findings and conclusions of the presentation will be discussed after the talk. The one-week course is a hands-on mixture of presentations, discussions and practical exercises. The course work (9:00 – 13:00) is complete by homework for the afternoons, which will help preparing or introducing the next day's topics.

**Prerequisites for participation**

None.

**Usability of the module**

Compulsory module in the 1st and 2nd semester of the master program Neural Information Processing.

**Module requirements, exams and grading scheme**

For the NeuroColloquium, regular attendance is required. For the Weekend Seminar, successful participation requires, in addition to attendance of all talks of the seminar session, a presentation of a 30-minute talk on a selected topic including hand-out. For the Scholarly Writing course, attendance of the morning session and completion of the homework is required. This module is not graded (pass/fail).

**Workload assessment and credit points**

| Module element | Workload* | CPs** |
|---|---|---|
| NeuroColloquium (14 talks in total in WS and SS) | Co: 21h + As: 9h = 30h | 1 |
| Weekend Seminar / Retreat (2 days) | Co: 30h + Se: 30h = 60h | 2 |
| Introduction to Scholarly Research and Writing | Co: 20h + Re: 10h + As: 30h = 60h | 2 |
| | | Total **5** |

* **Co**=contact time in class, **Re**=review after class, **As**=assignments/homework, **Se**=preparation of seminar presentation

** 30 hours workload = 1 ECTS credit point

| Module<br>**Electives** | Code: NIP-08 | ECTS Credit points<br>**9** |
|---|---|---|

| Module coordinator | Contact |
|---|---|
| PD Dr. Marc Himmelbach | Graduate Training Centre of Neuroscience<br>marc.himmelbach@uni-tuebingen.de<br>phone 07071-29 **77177** |
| **Duration of module**<br>2 Semesters | **Cycle**<br>Annually |

**Module elements**

| Course title | Course type | Semester* |
|---|---|---|
| Elective Courses | n.a. | WS / SS |

* WS = winter semester, SS = summer semester

**Module content**

Depending on the subjects of their previous training and/or their particular interests, students are free to choose courses from the masters programs Neural and Behavioural Sciences or Neural Information Processing or from any other masters program offered at Tübingen University. The electives may comprise advanced neuroscience or neuroscience methods courses, statistics or programming courses as well as courses on ethical, philosophical or related issues. Before the start of the term, students will be provided with a list of selected courses to choose from. Courses selected by a student have to be approved beforehand by the module coordinator.

**Qualification goals / learning targets**

The electives will impart students with specific knowledge and competencies in subject areas of their choice and may either deepen their knowledge in fields of their specialization or complement the training already provided with the compulsory curricular courses. By doing so, students can pursue their broad interest and can under- stand contexts and co-relations beyond the limits of their major discipline and, depending of the topics chosen, students will be imparted to discuss research topics interdisciplinary.

**Teaching methods**

Depends on the type of course selected.

**Prerequisites for participation**

Depending on the type of course selected. The course coordinator must approve the subjects of choice.

**Usability of the module**

Compulsory module in the 1st year of the master program Neural Information Processing.

**Module requirements, exams and grading scheme**

According to the specifications provided in the module description of the respective masters program.

**Workload assessment and credit points**

| Module element | Hours | CPs* |
|---|---|---|
| Elective Courses | 270h | 9 |
| | | Total **9** |

* 30 hours workload = 1 ECTS credit point

| Module Code: NIP-09 | ECTS Credit points |
|---|---|
| **Essay Rotation / Laboratory Rotation** | **25** |

| Module coordinator | Contact |
|---|---|
| PD Dr. Marc Himmelbach | Graduate Training Centre of Neuroscience<br>marc.himmelbach@uni-tuebingen.de<br>phone 07071-29 **77177** |
| **Duration of module** | **Cycle** |
| 1 Semester / 18 Weeks | Annually |

**Module elements**

| Course title | Course type | Semester* |
|---|---|---|
| 1st Rotation (*Essay* Rotation) | Practical | WS |
| + Presentation of Essay Projects | Student Seminar | |
| 2nd Rotation (*Laboratory* Rotation) | Practical | WS |
| + Presentation of Laboratory Projects | Student Seminar | |

* WS = winter semester

**Module content**

Students are required to perform two rotations (18 weeks total, all day) where they work on small projects in research groups of their choice. In general, the assigned study is in line with currently ongoing research in the respective laboratory and supervised by an advanced doctoral student or a postdoc. Both, essay and lab project have to be concluded with a written report (formatted like a scientific paper) and with an oral presentation in the course of a seminar which provides a platform for the students to present their research projects done during the rotations. The curriculum requires students to perform one theoretical (essay) and one experimental (laboratory) rotation, which- ideally - should be performed in different research groups with distinct scientific questions and different methods.

**Qualification goals / learning targets**

During the rotations, students will acquire a wide range of practical skills in state-of-the-art methods and they get to know current scientific questions and research approaches. The skills trained during lab rotations include literature survey, planning of research projects and design of experiments, documentation of data generated, critical evaluation and interpretation of results, compiling data for and writing of a report and, also, train social competences during collaboration with other members of the hosting research group. In the end, students have also learned to prepare and give an oral presentation on their research project and to defend their findings in discussions after the talk.

**Teaching methods**

Supervised practical training in laboratories, including reading of research papers, writing of a report formatted like a scientific paper, oral presentation and discussion of the research findings. The student's progress is monitored through weekly meetings with her/his supervisor.

**Prerequisites for participation**

Successful completion of the winter and summer (1st and 2nd) semester modules and project-specific knowledge gained in the winter and/or summer semester.

| Usability of the module |
|---|
| Compulsory module in the 3rd semester of the master program Neural Information Processing. |

| Module requirements, exams and grading scheme |
|---|
| The student's performance in the essay rotation will be assessed and graded by the supervisor according to the following criteria: Written report (80%), oral presentation of the project and discussion in the seminar (20%).The student's performance in the laboratory rotation will also be assessed and graded by the supervisor according to the following criteria: understanding of theoretical framework and literature overview (15%), practical work in the research group (30%), generation of own ideas (10%), oral presentation of the project and discussion in the seminar (15%), written lab report (30%). A relevant form will be provided. |

| Workload assessment and credit points | | |
|---|---|---|
| **Module element** | **Workload *** | **CPs**** |
| Essay Rotation | Co: 6w = 240h | 8 |
| Writing of essay, preparing presentation, seminar | LR/Se: 7d = 56h | 2 |
| Laboratory Rotation | Co: 10w = 400h | 13 |
| Writing of lab report, preparing presentation, seminar | LR/Se: 7d = 56h | 2 |
| | Total **752** h | **25** |

* **Co**=contact time in laboratory, **LR**=writing of laboratory report, **Se**=preparation of seminar presentation + seminar

** 30 hours workload = 1 ECTS credit point (**w**=weeks, **d**=days, **h**=hours)

| Module<br>**Master Thesis** | Code: NIP-10 | ECTS Credit points<br>**30** |
|---|---|---|
| **Module coordinator**<br>PD Dr. Marc Himmelbach | **Contact**<br>Graduate Training Centre of Neuroscience<br>marc.himmelbach@uni-tuebingen.de<br>phone 07071-29 **77177** | |
| **Duration of module** 1 Semester / 6 Months | **Cycle** n.a. | |

| Course title | Course type | Semester* |
|---|---|---|
| Experimental Master Thesis | Research project | SS |

*SS = summer semester

**Module content**

To complete their studies, students are required to prepare a master thesis in a research group of their choice. In general, the assigned study is in line with currently on-going research in the respective laboratory and super- vised by the group leader or at least by an advanced postdoc. The experimental master thesis will train students to perform research more or less independently within the given period of time. The master's project will be concluded with a written thesis formatted like a scientific paper.

**Qualification goals / learning targets**

After successful completion of the master thesis, students have acquired profound practical skills in state-of-the-art methods applied in neuroscience. They are acquainted with current neuroscientific questions and recent publications in this particular field. They are trained in generating and analysing scientific data and writing a scientific report. In addition to scientific expertise, students will acquire soft skills, such as time and project management, working in international, interdisciplinary teams, English communication and writing skills, and rules of responsible conduct of research. Overall, with successful completion of the master thesis, students proof their scientific competence and demonstrate that they are well prepared to tackle demanding research projects such as, for example, a doctoral thesis (see also qualification goals of module **NIP-09**).

**Teaching methods**

Supervised practical training in a research group, reading of research papers and writing of a master thesis.

**Prerequisites for participation**

Successful completion of all theoretical (1st and 2nd semester) and practical course requirements (3rd semester).

**Usability of the module**

Compulsory module in the 4th semester of the master course Neural Information Processing.

**Module requirements, exams and grading scheme**

Students are required to submit - after 6 months of work - 3 copies of their thesis to the office of the Graduate School. At the student's request and upon hearing the supervisor, the examination board may grant an extension of the submission deadline for up to 4 weeks at most. Two readers, one of which is the supervisor, will evaluate the thesis. The examination board will appoint the second reader.

| Workload assessment and credit points | | |
|---|---|---|
| **Module element** | **Workload** | **CPs*** |
| Master Thesis | 23w x 5d x 8h = 920 h | **30** |

* 30 hours workload = 1 ECTS credit point (**w**=weeks, **d**=days, **h**=hours)