Degree Program Documentation
Master's Program Neuroengineering

Part A

Department of Electrical and Computer Engineering
Technical University of Munich

General Information:

- Administrative responsibility: Department of Electrical and Computer Engineering
- Name of degree program: Neuroengineering
- Degree: Master of Science (M.Sc.)
- Standard duration of study and credits:
  4 semesters of enrollment and 120 credit points (CP)
- Form of study: Full time
- Admission: Aptitude assessment (EV – Master's)
- Start: WS 2016/17
- Language of instruction: English
- Additional information:
  Elite master's program with funding from Elitenetzwerk Bayern (ENB)

  Optional 30 CP Research Excellence Certificate

  Neuroengineering Associated Faculty members with affiliation at *Technical University of Munich (TUM)*, *Klinikum rechts der Isar der Technischen Universität München (MRI)*, Ludwig- Maximilians-Universität München (LMU), *Max Planck Institute of Neurobiology*, and *HelmholtzZentrum münchen*
- Academic administrator (program design):
  Prof. Dr. Gordon Cheng
- Contact for further questions (regarding this document):
  Person: Florian Rattei
  Email address: rattei@tum.de
  Phone number: +49 89 289 23559
- Status as of: 23.10.2020

Table of Contents

1 Degree Program Objectives

1.1 Purpose

Neuroengineering is an emerging interdisciplinary field that aims to translate findings in neuroscience to real-world practical engineering applications. The successful development of neuro-inspired technical approaches will lead to a new generation of smart systems that achieve complex functions in an efficient manner, and will simultaneously advance our understanding of neuroscience.

Advances in neurotechnology such as neuroprostheses, cochlear and retina implants, EEG-based therapy, brain-computer interfaces, and exoskeletons for neurorehabilitation are rapidly changing medical care for people with neurological diseases and disabilities. At the same time, there is a trend towards neuro-inspired principles for next-generation computing technologies and autonomous systems. Both directions of technological progress are based on the synergetic combination of engineering and neuroscience which has only recently given rise to the new research field called “neuroengineering”.

As an emergent research and technological field, neuroengineering requires a new kind of engineer who is firmly educated in fundamental neuroscience as well as engineering theory and is able to apply and combine the methods from both domains. The purpose of the neuroengineering master program at TUM is to educate such a new generation of interdisciplinary engineers and to equip them with the ethical sensitivity to integrate societal values and stakeholders into their future work.

The ENB Elite Master Program in Neuroengineering (MSNE) at TUM fills the gap in bridging engineering and neuroscience. The program aims to attract national and international talents and to create graduates opting for a career in academia or in research-oriented industry.

1.2 Strategic Significance

TUM’s mission statement[1] is the anchor point for all strategic plans and decisions, pointing out values and focus areas on a high-level perspective. It is the main guideline for the strategy, design, implementation, and innovation of TUM’s study programs.

Innovating and serving society, TUM is specially committed to progress in 22 profile-forming areas[2]. Among those, TUM has identified bioengineering, artificial machine intelligence and robotics, tumor research, and neurosciences as important research fields. All these areas have strong links to the neuroengineering domain, driving TUM’s ambition to educate graduates in a

[1] https://www.tum.de/en/about-tum/our-university/mission-statement/
[2] Excellence Strategy of the Federal and State Governments – Universities of Excellence Funding Line, *TUM. The entrepreneurial University*, Commencement of funding, Nov. 1st 2019

highly international Elite Graduate Program, creating focal points for Excellence Clusters and Integrative Research Centers and thereby building a perfect environment for excellent students to drive interdisciplinary innovations. The *Munich Cluster for Systems Neurology* (SyNergy, TUM/LMU) promotes integrative research into a broad range of neurological diseases. In the *German Center for Neurodegenerative Diseases* [3] (DZNE), TUM is investigating the causes of neurodegenerative diseases and developing strategies for prevention, treatment, and care. Recently, the *Central Institute for Translational Cancer Research* [4] (TranslaTUM) has been founded as a unique research platform that brings together biological discoveries and principles of technology, physics, and chemistry under one roof. TUM established the *Munich School of BioEngineering* [5] (MSB) as an Integrative Research Center comprising engineers, natural scientists, and medical scientists. TUM founded the *Munich School of Robotics and Machine Intelligence* [6] (MSRM) as an Integrative Research Center in the field of robotics and machine intelligence to develop innovative and sustainable technologies and solutions for central challenges of our time.

TUM aims for the highest international standards, building global networks and alliances with leading teaching and research institutions. MSNE is embedded internationally, such as in the Neuroengineering Research Alliance with Georgetown University/USA (2018) and the Network of European Neuroscience Schools (NENS). TUM / MSNE are providing student exchange opportunities or cooperating in other forms with international Neuroscience and Neuroengineering benchmarking universities such as Harvard, Stanford; UC London, ETH Zurich, and University of Zurich. Identifying such benchmarks and competing with highest international standards, scientific challenges such as the Cybathlon Competition [7](ETH Zurich) and TUM / MSNE student teams attendance are an ideal environment pushing talented students to achieve internationally visible research experience in an early phase of career.

Connecting our home with the world is TUM's strategy to welcome talents from all over the globe, fostering an open and culturally diverse mindset. MSNE is heading to become a more international and more female Master program, with respect to student body and associated faculty likewise, supporting TUMs gender policy. While there is still a significant underrepresentation of women in engineering, the MSNE qualification profile is designed to accelerate a trend for more female students in engineering, while lowering concerns and decision thresholds of prospective female applicants, seeing more and more MSNE Alumnae and female neuroengineering researchers as a role model. With MSNE, TUM has designed a curriculum that has already proven to be capable of educating interdisciplinary student cohorts, training electrical/computer engineering or information technology students jointly with students of psychology, biomedical engineering, neuroscience, and cognitive science background. Empirically, the latter fields have a more balanced or an even female-biased gender ratio, compared with "traditional" engineering domains. As an indicator of success, five years after starting the program, MSNE is trending towards a more and more

[3] https://www.dzne.de
[4] https://www.translatum.tum.de
[5] https://www.bioengineering.tum.de
[6] https://www.msrm.tum.de
[7] https://cybathlon.ethz.ch/

balanced gender ratio. On average, in the five cohorts 2016-2021, 43% of all MSNE students have been female.

Within TUM Department of Electrical and Computer Engineering, MSNE is complementing the existing training portfolio consisting of i) fundamentals and methods-oriented training in the *Electrical Engineering and Information Technology* bachelor study program, hereby preparing for a possible master-level bioengineering or master-level neuroengineering continuation with focussed 5th and 6th semester modules, ii) the master-level program in *Electrical Engineering and Information Technology*, including a core area mainly driven by the *Center of Competence BIO-X Electronics for Life-Sciences*, iii) two international master programs with thematic focus on communications engineering and power engineering iv) the structured training program for doctoral candidates under the guidance of the *Faculty Graduate Center Electrical Engineering* and Information *Technology* (FGZ-EI) and with a strong link to the thematic *Graduate Center BioEngineering*.

The experience with existing lectures and seminars that are part of the established master program *Electrical Engineering and Information Technology* and the “master track” of the *Graduate School of Systemic Neurosciences* (GSN, former ENB, currently DFG Excellence Initiative) showed a clear need for research-oriented, highly-intensive training in Neuroengineering with a strong focus on the engineering part. Propelled by superior Elite Network of Bavaria study program characteristics and funding, MSNE is capable of attracting outstanding international and national talents and mainly students who are committed towards a career in academia or in research-oriented industry, from early on. Exactly this group of students is of high interest for the departmental Center of Competence in Neuroengineering and for the MSNE associated faculty with members from six departments of TUM.TUM/LMU have across board the ranges of disciplines to take on this highly interdisciplinary field, from biology, psychology, neuroscience and strong engineering. A substantial commitment from the host faculty and across the universities has been shown to this new field.

Table 1 Available degree programs of the TUM Department of Electrical and Computer Engineering

Dr.-Ing.	Doctorate			
Master	Electrical Engineering and Information Technology	Neuroengineering	Communications Engineering	Power Engineering
Bachelor	Electrical Engineering and Information Technology			

2 Qualification Profile

After successful completion of this Master's program, the graduates will not only enhance their professional and methodological skills, but also their personal and social (self-) competencies. The qualification profile in this section is structured according to the *Qualifications Framework for German Higher Education Qualifications* (HQR, Feb 02, 2017) in the categories i) knowledge and understanding, ii) use, application and generation of knowledge, iii) communication and cooperation, and iv) scientific self-image and professionalism.

Knowledge and Understanding

Beyond the skillsets of only one or two disciplines, MSNE graduates acquire a broad understanding in a unique combination of neuroscience and engineering with a focus on engineering, e.g. an expert who is capable of transferring neuroscientific research outcomes into applications that can have a societal impact. Students are experienced in a more societal and ethical approach to engineering and can face challenges like opening up exploratory solution spaces for previously unformulated questions and evolving classical engineer's paradigm towards a human-centered engineering perspective.

Graduates are able to apply state-of-the-art neuroimaging, neurophysiology and electrophysiology techniques and are able to use the techniques to conduct Brain-Computer-Interface research. They understand the functional gross anatomy and the function of neurons as to design the research method for the specific applications. They are able to analyze current limitations and to estimate future trends and limitations in the field, likewise in scientific, in technological, and in socio-ethical dimension. Upon graduation they are profound in current hot-spots of research in the field of Neuroengineering and can name strengths and weaknesses of their chosen individual topic based on recent publications and own research projects. They understand the functionality of neuro-inspired systems

Graduates are able to handle a research project independently, to analyse the topic, to find out the challenges, to apply knowledge and methodologies acquired during coursework, and to solve the problem.

Use, Application and Generation of Knowledge

By using computational methods to abstract neural systems and their behaviors as well as modelling such behaviors in software and hardware (both with analog and digital systems), graduates are able to investigate brain functions to conduct research and participate in ongoing research projects. Graduates are able to derive results from such data with appropriate statistical methods and large-scale data analysis. They are able to engineer aspects of such systems during research projects such as their thesis. This involves the ability to consider the impact of such systems to the brain.

Communication and Cooperation

Students are practiced in communication skills and able to express themselves using a domain-specific terminology. They are able to interact with project teams while doing research project(s) or hands-on labs. Students are familiar with research in a global perspective and with diverse teams, hereby able to adapt to worldwide standards of research community. Beyond scientific presentation skills, students have developed debating skills, helping them for the scientific

discourse. In a societal and ethical perspective, graduates are able to reflect discussions and to identify crucial questions. Moreover, students are interacting with boards and stakeholders providing orientation for society and politics, such as German Ethics Counsil.

Scientific Self-image and Professionalism

Graduates are able to balance the possibilities of engineering and their responsibility towards society regarding the influence their research can have to humankind. Furthermore, graduates are able to use inter-disciplinary methods between the fields combined with extra-disciplinary fundamentals training (e.g. science-communication, entrepreneurship, leadership, training in safeguarding good scientific research), so that they can better serve the growing academic, economical and societal demand in neuroengineering topics.

Students opting to take the REC are encouraged going beyond the ability to conduct research with the ability to identify a first personal research field, allowing a smoother transition into doctoral studies. With the REC, students are even more accustomed to transform solutions within their individual research field into publications, present and to defend them during a research conference setup.

Graduates are able to estimate and to evaluate their own personal competencies, supported by intensive mentoring and supervision in all phases, helping them to identify future career paths.

3 Target Groups

3.1 Target Audience

The MSNE is applicable to candidates who hold a Bachelor of Science or Bachelor of Engineering or an equivalent degree from areas including electronics and computer engineering, biomedical engineering, computer science, neuroscience, and physics. Candidates holding a degree in psychology may also apply, given their minor is within the before-mentioned areas.
Candidates are opting for a career in academia or in research-oriented industry, preferring an early integration in the research community. Furthermore, ideal candidates favor an ambitious teaching program and they would like to actively contribute to outstanding study conditions, e.g. initiating student projects and scientific events, linking and interacting with outstanding academic talents at TUM and students worldwide, and transcending conventional study program structures. The MSNE program is entirely taught and managed in English language, attracting international and national candidates likewise.

3.2 Prerequisites

Prospective students need to demonstrate i) self-initiated prior activity in the interdisciplinary area between neurosciences or bio-medicine and engineering, ideally in combination with a first exposure to research ii) a fast and focused study progress in the qualifying bachelor's program in combination with excellent grades, supplemented by additional modules or extra-curricular activities, pointing towards a continuation in a research-oriented career. The subject-specific qualification has to be proven by candidates' transcript of records, showing a focus on mathematics, fundamentals in science (such as physics, biochemistry, neuroscience, cognition and human-factor research) and on fundamentals in engineering (in the fields of bioengineering and medical engineering) or alternatively in psychology. For candidates with a native language other than English or for candidates with a medium of instruction in previous studies other than English, a proof of appropriate language skills is required, according to European Reference Guidelines level C1, such as the „Test of English as a Foreign Language "(TOEFL), „International English Language Testing System" (IELTS) or the „Cambridge Main Suite of English Examinations".

3.3 Target Numbers

Due to the specific boundaries of an Elite program funded by the ENB, the MSNE is designed as a program for a limited number of students to ensure a high student-teacher ratio and continuous interaction. The target figure is 25-30 students per academic year and class. The target figure is set to assure that during all labs and lectures, the capacities of the facilities are not exceeded and the student teacher ratio does not hinder close interaction between the students and lecturers, especially during the strong practical elements. A challenging aptitude assessment and mandatory admission interviews help to identify the best talents for the program. After a ramp-up phase jumpstarting the program in winter semester 2016/17, stable or slightly growing application numbers during the following four years allowed for a very focused program advertisement. On average, 21 highly talented and motivated students per intake. Practical parts in all mandatory modules are MSNE-exclusive. Lecturers may accept a small number (usually 1-3) of additional

students, mainly master's students of other ENB study programs, exchange students, and doctoral candidates, to attend in some of the MSNE mandatory modules, on a per-module or even per-class basis.

4 Analysis of Need

"*Neurotechnology holds the key to a healthy ageing population in 2050*" [8]. Neurodegenerative diseases urgently require a better understanding of the brain and better technology interfacing with the brain. More than 10 million people worldwide are diagnosed with Parkinson's disease [9].The demand for trained engineers with dual qualifications between the areas of engineering and neuroscience/medicine is rapidly growing. Salem-Press' seminal report on "Applied Science" [10] states:

"*Neural engineering is a fast-developing bioengineering specialty that is expected to grow tremendously. The increasing societal burden of neurological disorders, and the demand for more sophisticated medical devices, will drive an increase in new careers and employment. A global industry, with cutting-edge research under way in the United States, Europe, and Asia, neural engineering concentrates talent and capital in a network of neuro-technological innovation*."

With the promise of new treatments and new technology for billions of people suffering from nervous-system disorders (perception and motor-action), neuroengineering is quickly becoming the leading recipient of life science venture capital worldwide. The neuroengineering industry includes firms that manufacture neuro-modulation devices, neural prostheses, rehabilitation systems and intelligent information processing systems for customized applications. According to the *NeuroTech Industry Landscape Overview 2020* [11], around 200 companies, 200 investors and 30 technology hubs are currently building the Neurotech Industry.

Key private sector players: Bosch/Siemens/GE Healthcare; Otto Bock Prosthetics; Brain Products, Brainlab (Munich), more and more neurotech startups such as Neurable, Neuralink, Cognixion, Paradromics, Emotiv, just to name a few; Computing Hardware and Software Industry such as Amazon, Apple, Facebook, Google, Huawai, IBM, Intel, Microsoft, Qualcomm.

Key academic projects: large-scale long-duration (10+ years) international initiatives such as the "Human Brain Project" (EU), the "BRAIN Initiative" (USA), "Brain Mapping Initiative" (Australia); "Brain Mapping by Integrated Neurotechnologies for Disease Studies" (Japan); multiple EU research calls in Horizon2020 on ICT and Health-Care.

[8] https://www.ft.com/content/9792bb60-b794-11e9-8a88-aa6628ac896c, Clive Cookson, Science Editor of Financial Times, September 12, 2019
[9] https://www.parkinson.org/Understanding-Parkinsons/Statistics
[10] ISBN 978-1-58765-781-8; Edition May 2012
[11] https://www.neurotech.com/landscape-overview-2020

5 Competition Analysis

5.1 External Competition Analysis

As the master's program "Neuroengineering" is an interdisciplinary program, there is a certain overlap with several other programs. In a regional perspective, curricular similarities are with the Master "Neuroscience" offered by Ludwig-Maximilians-Universität München, which was also formerly under the framework of the Elitenetzwerk Bayern (now DFG funded). This program focuses on foundations on cellular level and therefore has a strong focus on biology. The second similar master's program offered by LMU, Neurocognitive psychology, also formerly part of the Elitenetzwerk Bayern, focusses on the intersection of experimental psychology and the cognitive neurosciences. Certain aspects of these master's programs are also relevant for the engineering point of view covered in the Master "Neuroengineering". In consequence and in accordance with the guidelines set by the ENB, some modules are available for students of all of the aforementioned master's programs to specialise. In a national perspective, as of October 2020, there exist 25 graduate schools and programs all with focus or strong links to neuroscience. All programs are taught in English and focussing on national and international students likewise. Mapping those programs [12], there are regional clusters in Munich and in Berlin, however, beside of MSNE, none of the German neuroscientific programs has such a strong focus on the Engineering part.

The Federation of European Neuroscience Societies (FENS) has established a Network of European Neuroscience Schools [13](NENS), fostering program interaction on a European level and providing a good overview on European graduate training, spanning approximately 200 programs in Europe. In this European context, mainly ETH Zürich/UZH Zurich offers a master's program with a Neuroengineering focus, namely *Neural Systems and Computation,* with a predominantly informatics-oriented profile. The EPFL master program *Life sciences engineering* offers a specialization track in neuroscience and neuroengineering, with similarities to the MSNE program. The Universities and TUM compete for a similar pool of excellent students, and existing links among associated faculties enable student exchange, e.g. for internships and theses. Imperial College London (ICL) is offering a master *Human and Biological Robotics*, overlapping with neuroengineering sub-domains such as neuromechanics, biomimetics, and robotics in health. Furthermore, ICL is offering a master of research training in *Neurotechnology*, interfacing between neuroscience and engineering similar to MSNE. The Universitat Politècnica de Catalunya (UPC) started a *Neuroengineering and Rehabilitation* master program, focussing on the health field and on rehabilitation. The Université Paris-Saclay is offering a *Computational Neuroscience and Neuroengineering* master program with a similar focus as MSNE.

US universities like Georgia Tech, University of Illinois, and Drexel University already offer competing master's programs. Programs with similarities to a lesser extent exist e.g. at

[12] https://www.neuroschools-germany.com/
[13] https://www.fens.org/Training/NENS/NENS-Programme-Directory/

Birmingham University, USC and University of Wisconsin, Johns Hopkins University in Baltimore, and Georgetown University in Washington, DC.

5.2 Internal Competition Analysis

The MSNE as an interdisciplinary program has certain overlaps with other disciplines at TUM as well. As an engineering program, the most similarities can be found with the Master *Elektrotechnik und Informationstechnik* where a core area named *Bioengineering/Neuroengineering* is part of the curriculum. As the Master *Elektrotechnik und Informationstechnik* is a program covering the whole area of Electrical and Computer Engineering, the core area *Bioengineering/ Neuroengineering* has a broader scope and only covers the engineering aspects of Neuroengineering, while the MSNE as an interdisciplinary program involves more than just the engineering point of view. Still, in accordance with the guidelines set by the ENB, some modules are available for students of both Master programs. Therefore, the qualification profile of graduates therefore is clearly different between “Neuroengineering” and “Elektrotechnik und Informationstechnik”.

To a lesser extent, this holds true for Masters in the field of biology and informatics, where certain content, specifically anatomy and computational methods, is also included. As foundation methods, they are used similarly, but for a different purpose and qualification profile.

The ENB Elite Graduate Program *Biomedical Neuroscience* (TUM) is an interdisciplinary program executed by lecturers from natural science institutes as well as from clinicians and clinical scientists. Aim of this program is an intensive education in the field of basic neuroscience and neuro-psychiatric diseases, therefore more focussing on students with a biology, molecular medicine, physics, and biochemistry background, while Neuroengineering has set a strong focus on engineering and mathematical skills.

6 Program Structure

The program is designed as 2-year full time (120 ECTS) Master-of-Science training, in line with “standard” master studies, with an optional Research Excellence Certificate (additional 30 ECTS). To generate graduates with a strong focus on engineering, all mandatory modules include hands-on implementation of acquired knowledge in small-team projects with close supervision, challenging students to immediately apply the relevant methods and techniques. Due to the interdisciplinary character, the curriculum includes 58 ECTS of mandatory modules. This strong focus on a common skillset determines that all aspects of the qualification profile (neuroscience, engineering, mathematics, and informatics) are covered and that all students achieve the same qualification level, while still leaving students the choice of the preferred form of implementation during tutorials and labs. The mentor-assigned make-up course (1e) in the first semester allows students to fill-in possibly underrepresented knowledge depending on their earlier education program. Students without required make-up course can already select a first elective module.

The two *Literature Seminar, Scientific Debating, Colloquium* modules (2d, 3c) enable students to gain a substantial knowledge background on related literature in different topics, thereby being up-to-date in state of the art in Neuroengineering related topics. Students are learning how to build a framework for their individual choice of subject and related research papers, strengthening their ability to identify relevant research, analyze it, and convert it to their own contribution.

Furthermore, the program includes up to two individual research projects (of 8 and 12 ECTS, respectively), mainly performed during the semester breaks. Students get the opportunity to apply their obtained theoretical and practical expertise in independent research projects, working closely together with (post)doctoral students and in typical academic settings, thereby preparing for the final master thesis and a follow-up role in academia or the industry. All associated faculty and international partners agreed to offer small, tightly supervised research projects during the semester breaks, by that allowing students an exploration of their interests and an early specialization. Results of these research projects can potentially be published as small papers and shall be presented in the Neuroengineering Summit (after semester 3).

The MSNE study program offers a mandatory set of core courses covering all basic aspects of Neuroengineering. The module *Statistics and Probability Theory* (1b) in the first semester is offered exclusively for Neuroengineering students, teaching a specialized subset of mathematical tools, necessary for the module *Computational Neuroscience* (1a, synchronized with 1b syllabus) and *Large-Scale Modelling and Data Analysis* (2a) in second semester*. Neuroanatomy and Neurophysiology* (1c) along with *Mixed Signal Electronics in Neuroengineering (1d)* provide the necessary background for capturing signals, which is the main focus of *Neuro-Recording Methods* module (1c). Recording requires signal processing skills, taught in the first half of the second semester in the module *Signal Processing and Dynamic System Modelling* (2b). The modelling part completes the mandatory skillset of students, preparing for the more project-oriented *Neuro-inspired Systems Engineering* module (3a) in the third semester. In line with the TUM mission statement - fostering ethical awareness and human-centered engineering - Societal Impact and Ethics (3b) is a mandatory part in the curriculum. The study program encourages graduates to drive research and development of neuroengineering technology in a responsible and self-reflecting manner.

All courses offered at TUM/LMU at master level (LMU instructor permission required; granted by all associated faculty) are eligible as elective courses, subject to approval in the learning agreement between student and mentor. All MSNE students can individually adjust / specialize their curriculum by selecting at least three elective courses. Students opting to take the additional "Research Excellence Certificate" choose additional four elective courses and perform an additional research project, thereby allowing for a substantially stronger individual specialization and acquisition of competencies beyond a regular Master's graduate profile, geared towards a transition to doctoral studies. Furthermore, the implementation of REC stimulates early contributions to research, such as posters, conference papers or journal contributions, summer/winter school performances, or active participation in scientific conferences. Such performances may become part of REC based on a recognition of external performances. The Neuroengineering Summit is a mandatory part within the optional REC, challenging students to present their research projects or master's thesis to a larger scientific audience.

The students' intended mobility option is the nine-week research project after the second semester. At this point, they will have gained the necessary basic expertise in Neuroengineering to integrate well into different research groups. In addition to that, they may acquire valuable communication and professional skills in the international research community. Students opting for the Research Excellence Certificate may also decide to do the six-week research project after the third semester in an international environment, instead of after the first semester at TUM. After the third semester, MSNE students are well-prepared to adapt quickly to an international research community. Research projects must be started in full-time fashion; however, students may complete the projects in a part-time fashion, if this better fits the individual curriculum. Moreover, the master's thesis may be done at TUM or abroad, utilizing the worldwide professional network of MSNE program and MSNE associated faculty. TUM is preparing a more focused student exchange for master and doctoral students in a structured program with Georgetown University in Washington DC.

In addition to MSNE-internal quality management, the ENB is tracking international phases of students in the annual surveys. Based on these surveys, MSNE students frequently use the opportunity to perform international phases at high-ranked universities worldwide.

Course List

All fundamental / methodological courses **in bold** are designed for the MSNE program and contain a theoretical introduction part combined with a practical hands-on component. Courses in blue are required for the optional Research Excellence Certificate (+30 ECTS).

1. Semester (30(+8) ECTS)

- (a) **Computational Neuroscience**	5 ECTS
- (b) **Statistics and Probability Theory**	5 ECTS
- (c) **Neuro-Anatomy and Neuro-Physiology**[14]	5 ECTS
- (d) **Mixed Signal Electronics in Neuroengineering**	5 ECTS
- (e) Mentor-Assigned Make-Up-Course or Elective Course	5 ECTS
- (f) Elective Course	5 ECTS

Followed by a **6 Weeks Research Project**[15] 8 ECTS
typically at one of the participating groups in Munich

2. Semester (31+10 ECTS)

- (a) **Large-Scale Modeling and Data Analysis**	5 ECTS
- (b) **Signal Processing and Dynamic System Modeling**	5 ECTS
- (c) **Neuro-Recording Methods**[16]	5 ECTS
- (d) **Literature Seminar, Scientific Debating, Colloquium 1**	6 ECTS
- (e) Elective Course	5 ECTS
- (f) Elective Course	5 ECTS
- (g) Elective Course	5 ECTS
- (h) Elective Course	5 ECTS

Followed by a **9 Weeks Research Project**[17] 12 ECTS
possibly outside Munich at one of the partner institutions

3. Semester (29+7 ECTS)

- (a) **Neuro-inspired Systems Engineering**	6 ECTS
- (b) **Societal Impact, Ethics**	5 ECTS
- (c) **Literature Seminar, Scientific Debating, Colloquium 2**	6 ECTS
- (d) Elective Course	5 ECTS

Offered every semester, a one-day **Symposium ("Neuroengineering Summit")**, presentation of research results (poster and talk) 2 ECTS

4. Semester (30+5 ECTS)

- (a) **Master Thesis**	30 ECTS
- (b) Elective Course	5 ECTS

Total 120 ECTS (+ 30 ECTS)

.

[14] As a follow-up, students can apply for a limited number of MSNE stipends to attend the "Munich BrainAnatomy Course" (3-day optional block course, offered annually in Feb/Mar).
[15] May be completed in part-time fashion during lecture period
[16] Includes clinical studies with TUM hospital patients, attended by MSNE students in small groups.
[17] May be completed in part-time fashion during lecture period

Table 6.1 shows an exemplary study plan.[18]

	1.Semester	2.Semester	3.Semester	4.Semester
120 ECTS Master Program	Computational Neuroscience 5 CP, ET-W	Large-Scale Modeling and Data Analysis 5 CP, ET-W	Neuro-inspired Systems Engineering 6 CP, ET-E	Master's thesis 30 CP
	Statistics and Probability Theory 5 CP, ET-W	Signal Processing and Dynamic System Modeling 5 CP, ET-W	Societal Impact, Ethics 5 CP, ET-R	
	Neuro-Anatomy and Neuro-Physiology 5 CP, ET-W	Neuro-Recording Methods 5 CP, ET-W	Literature Seminar, Scientific Debating, Colloquium 2 6 CP, ET-P	
	Mixed Signal Electronics in Neuroengineering 5 CP, ET-W	Literature Seminar, Scientific Debating, Colloquium 1 6 CP, ET-P	Research Project 12 CP, ET-R	
	Mentor-Assigned Make-Up Course or Elective Course, (e.g. Information Theory 5 CP, ET-W)	Pattern Recognition 5 CP, ET-W		
	Brain, Mind, and Cognition 5 CP, ET-W	Machine Learning in Robotics 5 CP, ET-W		
	30 CP	**31 CP**	**29 CP**	**30 CP**
30 ECTS REC (optional)	Research Project (REC) 8 CP, ET-R	Humanoid Sensors and Actuators (REC) 5 CP, ET-EL	BioMEMS and Microfluidics (REC) 5 CP, ET-W	Sensory and Behavioral Neurogenetics (REC) 5 CP, ET-W
		Making Neuro-Technologies for Society (REC) 5 CP, ET-R	Neuroengineering Summit (REC) 2 CP, ET-P	
	8 CP	**10 CP**	**7 CP**	**5 CP**

[18] Light grey = required modules, dark grey = elective modules, light blue = optional Research Excellence Certificate (REC), dark blue = final thesis; Examination type (ET-) written (W), oral (O), report (R), presentation (P), practical credit requirement, e.g. exercises or lab performance (EL)

7 Organization and Coordination

The Master “Neuroengineering” is offered by the Department of Electrical and Computer Engineering of Technische Universität München with support of the Elitenetzwerk Bayern.

The following administrative tasks are performed by:

- Student Advising:
  General Student Advising (TUM CST)
  Student Advising and Prospective Student Programs
  Email: studium@tum.de
  Phone: +49 (0)89 289 22245
  Provides information and advising for prospective and current students (via hotline/service desk)
- Departmental Student Advising:
  Student Services Office (Department of Electrical and Computer Engineering)
  http://www.ei.tum.de/studium/studienberatung/
  studienberatung@ei.tum.de
- Academic Programs Office:
  Student Services Office (Department of Electrical and Computer Engineering)
  http://www.ei.tum.de/msne
  msne@ei.tum.de
- Study Abroad Advising/Internationalization:
  TUM-wide: TUM International Center, internationalcenter@tum.de

  Student Services Office (Department of Electrical and Computer Engineering)
  https://www.ei.tum.de/en/degree/exchange-students/
  abroad@ei.tum.de
- Gender Equality Officer:
  TUM-wide: Dr. Eva Sandmann
  sandmann@tum.de, Tel. +49 (0)89 289 22335

  Department of Electrical and Computer Engineering:
  diversity@ei.tum.de
- Advising – Barrier-Free Education:
  TUM-wide: TUM CST, Service Office for Disabled and Chronically Ill Students (and Prospective Students),
  Email: Handicap@zv.tum.de
  Phone: +49 (0)89 289 22737

Departmental:
https://www.ei.tum.de/en/degree/student-services-office/

- Admissions and Enrollment: TUM CST, Student Admission
  Email: studium@tum.de
  Phone: +49 (0)89 289 22245
  Admissions, enrollment,
  Student Card, leaves of absence,
  student fees payment, withdrawal
- Aptitude Assessment (EV): TUM-wide: TUM CST, Student Admission
  Departmental: MSNE Aptitude Assessment Commission
  http://www.ei.tum.de/msne
  msne@ei.tum.de
- Semester Fees and Scholarships:
  TUM CST, Semester Fees and Scholarships
  Email: beitragsmanagement@zv.tum.de
- Examination Office: TUM CST, Examination Office,
  Campus Munich/Garching/Weihenstephan/
  Klinikum rechts der Isar
  Graduation documents, notifications of
  examination results, preliminary degree certificates
- Departmental Examination Office:
  Student Services Office (Department of Electrical
  and Computer Engineering)
  https://www.ei.tum.de/en/degree/student-services-office/
  Master@ei.tum.de
- Examination Board: Registrar of the Examination Board (MSc)
  https://www.ei.tum.de/en/degree/student-services-office/
  Master@ei.tum.de

- Quality Management – Academic and Student Affairs:
  TUM-wide: Academic and Student Affairs Office,
  https://www.lehren.tum.de/startseite/team-hrsl/

  Departmental:
  https://www.ei.tum.de/en/degree/student-services-office/

8 Enhancement Measures

In the year 2020, based on almost four years of experience in the study program, discussions with MSNE associated faculty and student representatives, focus surveys among students, semester-wise quality meetings and course evaluations triggered a careful revision of the Neuroengineering curriculum. Aim of this revision is a more logical sequence of mandatory modules, allowing students with heterogeneous background to catch up easier during the first semester. This revision is bolstered by updated module descriptions, improving inter- and intra-module coherency.

In detail, shifting Neuro-Recording Methods from a first-semester module to a more advanced second-semester module improves synchronization with the Neuro-Anatomy and Neuro-Physiology module, providing required fundamentals. The shift of Mixed-Signal Electronics in Neuroengineering to the first semester offers further groundwork that is essential for Neuro-Recording Methods.