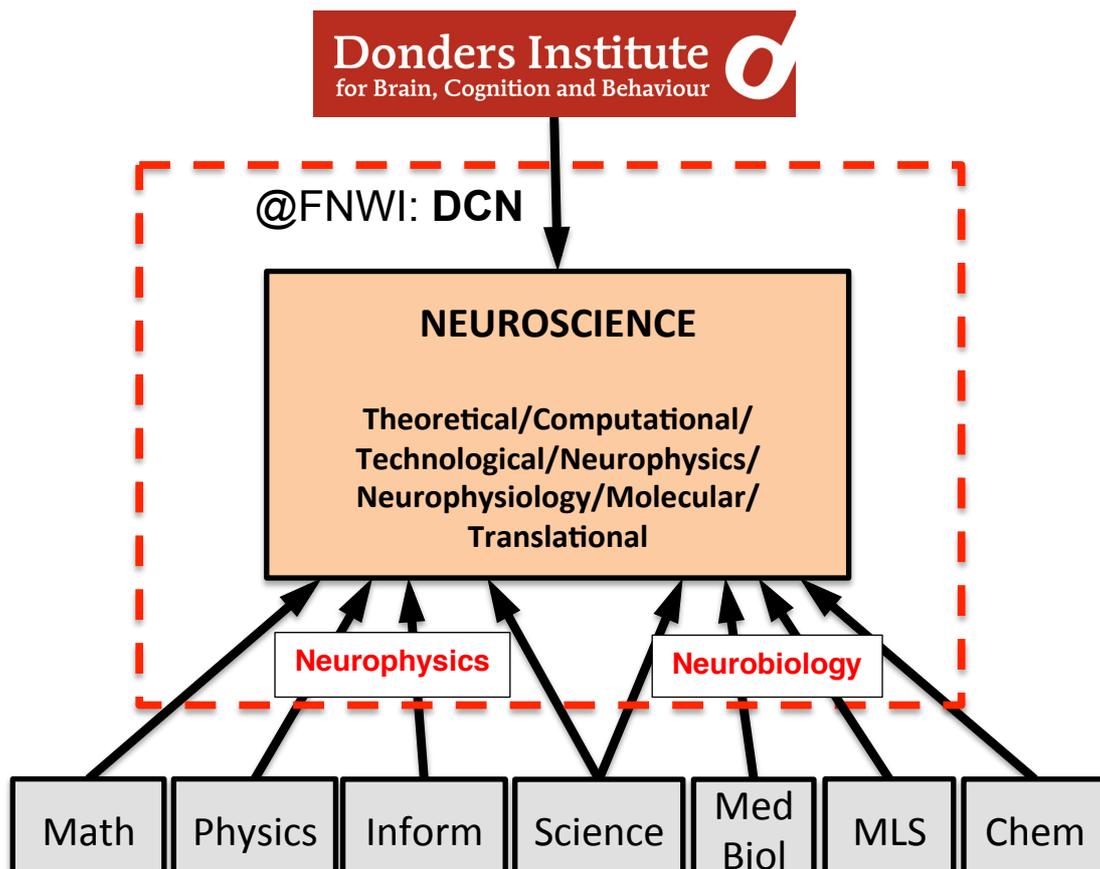
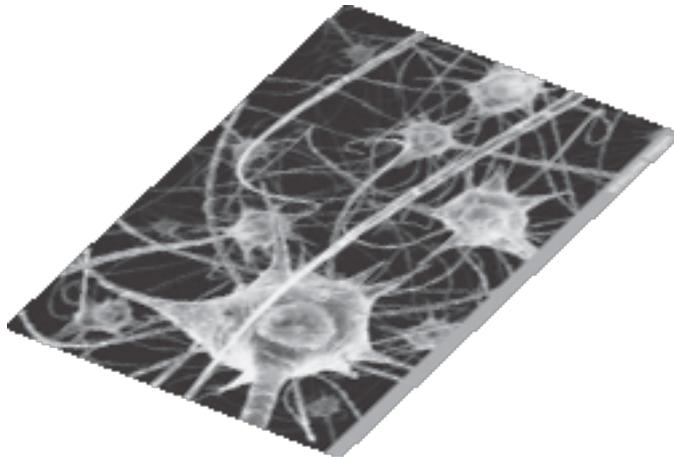


MASTER SPECIALISATION NEUROPHYSICS

FACULTY OF SCIENCE (FNWI)

RADBOD UNIVERSITY NIJMEGEN





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1. The Donders Institute for Brain, Cognition, and Behaviour

The Donders Institute for Brain, Cognition and Behaviour is the largest interfaculty research institute at the Radboud University, with over 200 fte tenured research staff. Founded on September 1, 2008, it brought together, under one organisational umbrella, all Neuroscience research taking place at the RU. For more detailed information about the Donders Institute, its latest activities, and its current four major research themes, see <http://www.ru.nl/donders>

The Donders Institute operates at the forefront of Neuroscience research with worldwide-acknowledged experts in the fields of Cognitive Neuroscience and Neuroimaging, Systems Neuroscience, Translational and Clinical Neuroscience, Neurophysiology, Computational Neuroscience, Machine Learning and applications.

Neuroscience is a prime example of an interdisciplinary research field, in which scientists from backgrounds as diverse as biology, physics, mathematics, chemistry, computer science and informatics, psychology and the clinical sciences all work together to unravel functional and cognitive brain mechanisms in health and disease.

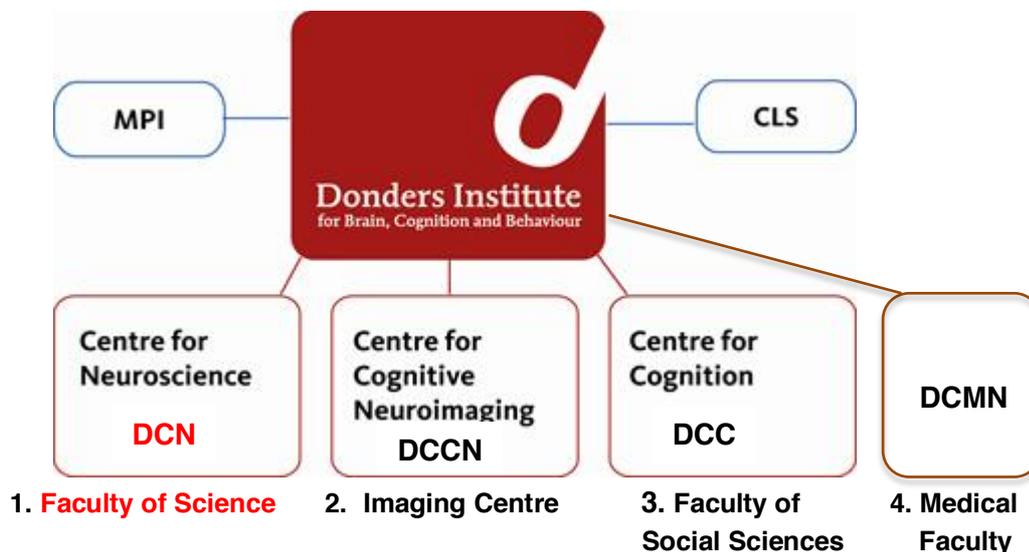


Figure 1: The Donders Institute with its four research centres: DCN (at FNWI), DCCN, DCC (at FSW), and DCMN at RadboudUmc. The Max Planck Institute (MPI; psycholinguistics) and the Centre for Language Studies (CLS) are affiliated institutes.

Research at the DI is performed at four research centres on the University Campus. It includes three faculties (Science, Medicine, and the Humanities) and the Donders Neuroimaging facility. For on-line information of DCN at the Science Faculty, please visit the faculty's website at: <https://www.ru.nl/science/dcn/>

Research at the DI is organised along four major themes (called 'tracks' at the Donders Graduate school), out of which themes 2-4 are also studied at DCN:

1. Language and Communication
2. Perception, Action, and Control
3. Plasticity and Memory
4. Neural computation and Neurotechnology

2. Master Specialisation *Neurophysics* at FNWI

“To understand any information-processing system, it should be studied at three complementary levels, all equally necessary” (David Marr, in ‘Vision’, 1982):

- Level 1: What is the *function* of the system? Why does it do what it does? What benefit does it acquire? Which problem (usually, for survival) does it solve? How does it solve it? In Neuroscience, this is the research topic of *Psychophysics* (which deals with the goals and algorithms of behaviour).
- Level 2: What are the optimal *computational principles*, that underly the observed behavior? And, importantly, how can the system acquire such behavior through *unsupervised learning*? This is where *Computational neuroscience and Machine Learning* enter the scene (the software...).
- Level 3: How are the algorithm(s) and behaviour(s) *implemented* in the system? This is the main topic of *Neurophysiology* (which deals with the hardware ...).

The Neurophysics specialisation at DCN offers courses for **all three** levels.

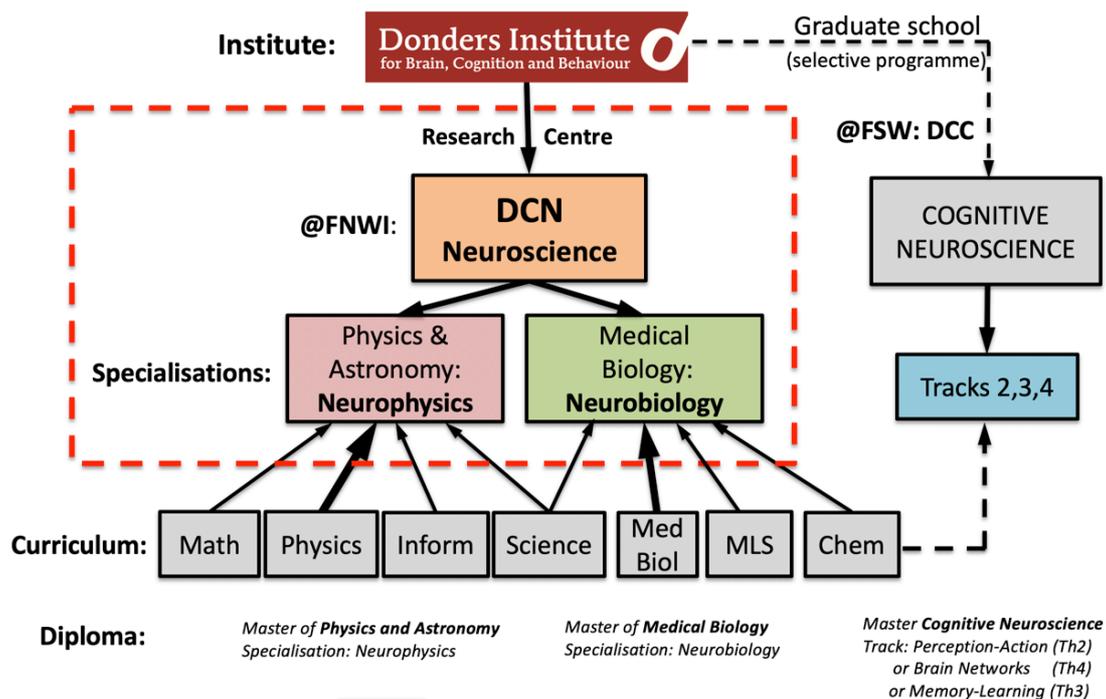


Figure 2: Position of the Neurophysics Master's specialisation at DCN within the University's Donders Institute for Brain, Cognition and Behaviour (DI), and in relation to FNWI's educational institutes. The Cognitive Neuroscience program at the Faculty of Social Sciences (DCC at FSW) is a selective international Research Master, into which FNWI students can enroll, provided they pass the selection. It is possible, however, (see Section 5) to obtain a double Master degree with a 180 ects curriculum.

The scheme in Figure 2 illustrates the top-down and bottom-up relations of the Neurophysics master's specialisation at FNWI with the Donders Institute, and with the faculty's bachelor programs of WiNSt, Informatics, and Science.

The Donders Centre for Neuroscience (DCN) consists of four research departments at FNWI (see section 7), which together offer a multitude of Neuroscience topics, ranging from theoretical, computational neuroscience, and psychophysics, on one end of the spectrum (Marr's Levels 1 and 2), to neurophysiology, molecular neuroscience, and translational neuroscience on the other end (Level 3). The **Neurophysics** (within the Physics and Astronomy master) and **Neurobiology** (within the Medical Biology master) specialisations each offer a series of dedicated courses that will appeal to students from a wide range of different backgrounds in the Natural Sciences. Top researchers at the four participating departments contribute advanced courses to these specialisations.

An example of a Neurophysics program, is described in more detail in section 4.

Neurophysicists study the computational mechanisms of the brain, and focus on topics from biophysics, computational neuroscience, psychophysics, theoretical neuroscience, machine learning, artificial intelligence, neurotechnology, and robotics. It is primarily directed at students with a bachelor's degree in physics and astronomy, but also students from the bachelor programme Science (biophysics), Mathematics, Informatics, Biomedical Engineering, or related diploma's, can apply for this specialisation. Note that the program leads to master's diploma in Physics and Astronomy

3. Obligatory courses for Neurophysics

The departments Neuroinformatics and Biophysics of DCN (at HG00.800) offer the Master's Specialisation Neurophysics for students with a bachelor diploma in Physics and Astronomy, Mathematics, or Science (biophysics), or with a related diploma (e.g., Biomedical Engineering; Medical Technology; see Figure 2). Students can tailor their individual preferences (theoretical, experimental, computational, etc.) to a high degree, by selecting from a wide variety of elective courses. However, *all students* embarking on the Neurophysics specialisation share a **22 ec common program** (in the first year of their master's curriculum) that consists of the following courses:

Obligatory courses and activities for all Neurophysics master students

From the Physics curriculum: **7 ec**

Electrodynamics 1	(3 ec, Q1)
Professional preparation	(1 ec, Q1,2,3,4)
Physics and Philosophy	(3 ec, Q3)

Neuroscience courses: **15 ec**

Neurobiophysics	(3 ec, Q1)
Machine learning	(3 ec, Q1)
Computational Neuroscience	(3 ec, Q2)
Neuroscience Review	(6 ec, Q3,4)

Neuroscience seminars (no ec)

Students have considerable freedom in defining the contents of their Neurophysics specialisation through a dedicated selection of Neuroscience courses. Section 4 describes an example Neurophysics program.

Furthermore, the Neurophysics seminars are attended by all PI's, PhD's, postdocs and students who partake in Neuroscience research, and are organised on an ad-hoc basis by the DCN departments and the DI. These seminars offer students insight into the newest developments in the field of Neuroscience, often in a broad, international, context. Seminars are announced on the DCN website (www.ru.nl/science/dcn/).

For the specialisation electives and the free electives, the students can fill a total of **39 ec** with courses: 21 ec on neuroscience-specific electives, and 18 ec on free electives. In the second year, they do their specialisation-related internship (60 ec).

Diploma. As of 2019, students who follow and pass the Neurophysics specialisation will obtain their master's degree in Physics and Astronomy (see Figure 2).

As described in section 5, it is in principle possible for the best and highly motivated students to also enroll in the CNS Research Master, and obtain their second degree in Cognitive Neuroscience (double master) through an extended curriculum of 180 ec.

Year 1		
Mandatory courses (22 ec)		
Electrodynamics (3 ec)	Philosophy (3 ec)	Professional preparation (1 ec)
Neurobiophysics (3 ec)	CDS*: Machine Lrng (3 ec)	Computational Neuroscience (3 ec)
Neuroscience seminars		Neuroscience Review (6 ec)
Elective courses Neurophysics (21 ec)		
Methods Neurosci (3 ec)	Auditory system (3 ec)	Psychophysics 2 (6 ec)
CDS: Advanced Machine Learning (6 ec)	CDS: Advanced Comput. Neuroscience (6 ec)	Neuro-analysis (3 ec)
		Quantitative Brain Networks (6 ec)
CNS courses		
Free Electives (18 ec)		
CDS: Numerical methods (3 ec)	CDS: Advanced programming (3 ec)	CDS: Machine Learning Applications (6 ec)
CNS courses	FREE (approval Exam Committee)	CDS: Data analysis (3 ec)
Year 2		
Internship (60 ec)		Neuroscience seminars

*CDS: course from the Synergy track Computational Data Science

All Physics & Astronomy courses are described in the Master's study guide for Physics and Astronomy:

<https://www.ru.nl/courseguides/science/master/master-physics-astronomy/>

4. Neurophysics programme

Bachelor students from the following disciplines (at the RU, or elsewhere) may enroll in the Neurophysics specialisation:

- Physics and Astronomy
- Mathematics
- Science (biophysics)
- Informatics/Computer science
- or similar, like Electrical Engineering, Biomedical Engineering, etc.

Entry level: *Students should have passed at least the following Neuroscience-related courses from the Physics & Astronomy bachelor program, e.g. through the Neuroscience Minor:*

Neurophysics 1 (3 ec, 2nd year, Q1)

Introduction Machine Learning (3 ec, 3rd year, Q1)

as well as **6 ec of Programming** courses (e.g. *Programming 1* and *2*)

(or courses with equivalent content and level; to be assessed by the study coordinator)

Textbook Neurophysics 1 (and 2):

Neuronal Dynamics: From single neurons to networks and models of cognition.

Eds.: Wulfram Gerstner, Werner M. Kistler, Richard Naud and Liam Paninski.

Online version: <http://neuronal Dynamics.epfl.ch/book.html>

ISBN-13: 978-1107-63519-7

Textbook Introduction Machine Learning:

Chr. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006

Chapters 1, 2, 3, parts of 5 (Neural networks) and 6 (Gaussian processes).

ISBN-13: 978-0387-31073-2

Other neuroscience courses from the Bachelor curriculum for Physics and Astronomy that are recommended as a prerequisite are

Neurophysics 2 (3 ec, 2nd year, Q2),

Psychophysics 1 (3 ec, 2nd year, Q3),

Nonlinear Dynamics, Chaos and Applications (3 ec, 3rd year, Q4).

Note 1: Students who wish to enroll in the Neurophysics specialisation, but have not completed the two required bachelor courses (or equivalents), can incorporate them in their Neuroscience elective programme. Introduction Machine Learning can be followed in the first quarter of the Master programme.

Note 2: *When Neurophysics 1 or 2 cannot be followed during the regular course hours, deficient students can acquire the material through self-study, for which a weekly feedback and response hour with the lecturer can be organised. Lectures have been video-taped.*

See the Bachelor study guides for Physics, Mathematics and Science, for more information (unfortunately, course description are only available in Dutch):

<https://www.ru.nl/studiegids/science/vm/bachelor-generiek/overzicht-cursussen/overzicht-cursussen/overzicht-cursussen-wiskunde-natuur-sterrenkunde/>

A. Recommended electives (21 ec from the following)

Courses may be selected after consulting potential PI('s) for the future internship, or based on the student's personal preferences:

Quantitative Brain Networks (6 ec; Q3+Q4)
Advanced Machine Learning (6 ec; Q2)
Advanced Computational Neuroscience (6 ec; Q3+Q4)
Psychophysics 2 (6 ec; Q3+Q4)
Auditory System (3 ec; Q1)
Methods in Neuroscience (3 ec; Q2)
Advanced neuroscience techniques (6 ec; Q1 – Q4)
Neuro-analysis (3 ec; Q4)
Up to 2 courses from the Cognitive Neuroscience research master¹.

B. Free elective courses.

Neurophysics students can further select up to **18 ec** from master's physics courses. See the study guide for more detailed information:

<https://www.ru.nl/courseguides/science/master/master-physics-astronomy/>

Or from elective courses at the selective Research Master Cognitive Neuroscience¹:

Perception (6 ec: *Visual Perception*, Q2-3)

Motor Control (6 ec, Q1-2)

Cognitive Control (6 ec, Q3-4)

Neuroimaging 1 (6 ec, Q1-2)

Neuroimaging 2: Electrophysiology (6 ec; Q3-4)

Neuroimaging 2: Haemodynamics (6 ec; Q3-4)

See the CNS study guide for more detailed information:

<https://www.ru.nl/opleidingen/master/cognitive-neuroscience/>

- Elective courses from the bachelor's Neuroscience minor (see above).
- Other free elective courses, according to personal preference.²

B2. Master's Synergy Track in Computational Data Science (CDS).

Within the fee-elective space of the Neurophysics curriculum it is possible to follow this cross-specialisation programme, by including a set of coupled data-science courses.

The **obligatory** courses for the CDS minor are the same for all physics students:

Numerical Methods. (3 ec, Q3)

Advanced Programming. (3 ec, Q2)

Machine Learning. (3 ec, Q1) (is included in the mandatory part)

For the Neurophysics specialisation, the track has the following **elective** courses:

Advanced machine learning (6 ec, Q2)

Computational neuroscience (6 ec, Q2)

Machine Learning in Practice (6 ec, Q3)

Modelling of complex real-world systems (6 ec, Q3)

C. Master thesis project: at a DCN department, or elsewhere: 60 ects.²

¹ Approval from the Course Coordinator CNS is required. Contact AJ van Opstal.

² Within the Master thesis, an additional industrial project (or comparable) can be included.

Example table of Courses Specialisation Neurophysics

	Obligatory	Electives PI groups	Free electives (selection)	From the Bachelor Minor
Q1	- Electrodynamics 1 (3 ec) - Neurobiophysics (3 ec) - Neurophysics seminar () - Machine Learning (3 ec) - Professional prep. ()	- Auditory system (3 ec)	- Motor Control () (cns)** - Neuroimaging 1 () (cns)	- Introduction Machine Learning (3 ec) - Neurophysics 1 (3 ec)
Q2	- Computational Neuroscience (3 ec) - Neurophysics seminar () - Professional prep. ()	- Methods Neurosci (3 ec) - Advanced Machine Learning ()	- Motor Control (6 ec; cns) - Neuroimaging 1 (6 ec; cns) - Perception (cns)	- Neurophysics 2 (3 ec)
Q3	- Professional prep. () - Phycis/Philosophy 3 ec) - Reviews Neuroscience () - Neurophysics seminar ()	- Quantitative Brain Networks () - Psychophysics 2 () - Neuro-analysis (3 ec) - Advanced Machine Learning (6 ec) - Modelling complex real-world systems (3 ec)	- Curr. Adv. Neurosci. Techniques () - Cognitive Control () cns - Perception (6 ec; cns) - Machine Learning Apps ()	- Psychophysics 1 (3 ec)
Q4	- Reviews Neurosci. (6 ec) - Neurophysics seminar () - Professional prep (1 ec)	- Quantitative Brain Networks (6 ec) - Psychophysics 2 (6 ec)	- Curr. Adv. Neuroscience Techniques (6 ec) - Adv. Comp. Neurosci. (3 ec) - Machine Learning Apps (6 ec) - Cognitive Control (6 ec, cns)	- Nonlinear dynamics, chaos, and applications (3 ec)

** Enrollment in Courses at the Cognitive Neuroscience Research Master (cns) needs written permission from the Study Coordinator at CNS (info: AJ van Opstal).

Example Internship possibilities:

At the Science faculty:

- Dept. of Biophysics (Van Opstal, Kappen, Van Wezel, Noppeney, Coolen)
- Dept. of Neuroinformatics (Tiesinga, Battaglia, Vinck)
- Dept. of Neurophysiology (Celikel, Englitz, Zeldenrust)
- Donders Center for Cognitive Neuroimaging (Norris)

Medical faculty:

- Dept. of Cognitive Neuroscience (Goossens)
- Dept. of Otolaryngology (Mens, Lanting) and
- Neurology/Clinical Neurophysiology (Bloem)

Social sciences:

- Sensorimotor Lab (Medendorp)

Universities abroad (examples):

- Western Univ. London, Ont., Brain-Mind Inst. (prof. Corneil; systems neuro)
- Instituto Técnico Superior de Lisboa (prof. Bernardino; robotics)
- Max Planck Institute in Frankfurt (prof. Fries; primate neurophysiology)

Companies (examples):

- Philips Eindhoven (prof. Van Ee), Noldus (Wageningen; prof. Noldus)
- Other companies (Artinis (fNIRS), TMSi (EEG), hearing aid/cochlear implant companies: Cochlear (B), Advanced Bionics (D), Oticon (DK))

5. Double Master degree

As described in section 3, students of the FNWI specialisation Neuroscience obtain a diploma in Physics. However, it is possible for the best students to obtain a *double master degree* (Physics & CNS) by including an additional 60 ec of courses from the Cognitive Neuroscience Research master program in their curriculum (i.e., a total of 180 ec, 3 years, including the internship). Note that another 60 ec of the student's program will consist of overlapping courses (NM codes) from the two curricula.

Because of the large variety of potential backgrounds and preferences of students, there is no preset double-master curriculum with a fixed list of courses. Therefore, students who wish to do a double-master program should indicate this as early as possible in their FNWI master's specialisation, so that a full program can be defined and submitted for approval by the Exam Committees of both master's programs. Close coordination between the student and the program coordinators of the Neuroscience Specialisation at FNWI and at the Cognitive Neuroscience research master will be essential.

Note that normal tuition fees and rules will apply for the duration of the double master, as long as students remain registered at the Radboud University.

6. Contact Information

Master Specialisation Neurophysics

Prof dr AJ (John) van Opstal (coordinator)
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Prof dr FP (Francesco) Battaglia
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Prof dr. M (Moritz) Helmstädter (professor by special appointment, MPI, Frankfurt)

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Prof dr D (David) Norris

Donders Centre for Cognitive Neuroimaging (DCCN, Trigon, Kapittelweg)

d.norris@donders.ru.nl

7. DCN neurophysics research departments at FNWI

Three departments at the science faculty offer internships for Neurophysics master and bachelor students: Biophysics, Neuroinformatics, and Neurophysiology. If you're interested in an internship, you can contact the researchers directly (see Section 6); more information on their research activities can be found on the DCN website: <https://www.ru.nl/science/dcn/>.

Department of Biophysics

HG00.800*

Staff: prof. dr. AJ van Opstal (head; director DCN), prof. dr. HJ Kappen, prof. dr. RJA van Wezel, prof. dr. R van Ee, dr. W Wiegerinck, dr. M. van Wanrooij, prof. dr. U. Noppeney, prof dr T. Coolen, dr Liya Ma, prof dr L Noldus

Experimental research of the department focuses on *the neural basis of sensorimotor behavior*, through psychophysical studies of the auditory system (directional hearing, and sound processing in the brain), the visual system (binocular vision, visual motion processing, decision making), balance control (rotational and translational accelerations of the body), and the eye-head motor systems.

We build testable models (using techniques from computational neuro-science, statistical inference and optimal control) to explain our findings.

Our auditory research also collaborates with the ear-nose-throat department of the University Medical Centre. We test patients with cochlear implants, or with different types of hearing aids in our setups to assess (and help to improve) directional hearing capabilities, and auditory processing with the devices.

Theoretical research of the department focuses on the computational principles that underlie intelligent behavior in natural systems, and in building artificial intelligence. Intelligent behavior is adaptive and changes on the basis of past experience (i.e., data). It thus integrates sensory data with prior knowledge, and it must be robust to noise. We develop theoretical insights and models to address these problems, which are highly relevant for neuroscience, as well as for a wide range of technical and societal applications.

The group uses and develops techniques from Machine Learning and Optimal Control theory. Bayesian methods also have considerable potential for immediate applications in areas outside science, such as medical diagnosis, and forensics (e.g., DNA profiling). The SNN group builds such applications with her spin-off company Smart Research.

Department of Neuroinformatics

HG00.800*

Staff: Prof. dr. PH Tiesinga (head), Prof. dr. F Battaglia, dr. L. Genzel, dr. R. Bakker, prof dr D Norris, dr M Vinck, prof dr S Fisher

The overall goal of the theoretical research within the department is to understand how neurons encode information and to understand the mechanisms by which this information is processed and modulated. To achieve these goals, we use techniques from physics and mathematics to build network models, ranging in size from single neurons to millions of neurons, and with the models for individual neurons ranging from the extremely simple to highly complicated biophysical models with thousands of degrees of freedom. Our focus is on models of hippocampus, visual cortex, barrel cortex and prefrontal cortex, and we investigate different coding schemes the brain might use. These theoretical and computational models and analyses have lead to a

deeper understanding of the role of oscillations in stimulus selection, communication between different brain areas, information transmission, memory and decision making. Neuroinformatics is also concerned with making it easier to share data between different neuroscience groups and integrate it in large, public accessible databases for this we participate in the 1 billion euro Human Brain Project.

The experimental research at the neurophysiological systems level, uses a range of cutting edge experimental tools to collect large samples (tens to hundreds of simultaneously recorded neurons) of neural activity. We aim to determine how information is encoded in neural activity, how it is stored in memory, and how different brain areas interact to exchange information. We look at these questions in the context of complex behavioral situations, including decision making and social interactions, using transgenic mouse models and optogenetics. In addition, we develop innovative analysis methods for time-frequency analysis and methods to determine the information content of neural activity.

Department of Neurophysiology

HG02.200*

Staff: prof. dr. T. Celikel (head), Dr. B. Englitz, dr. F. Zeldenrust, dr F. Olafsdóttir, prof. dr. M. Helmstädter

Sensation doesn't make sense except in reference to an embodied self. The brain therefore processes information from the environment through sensory organs in reference to their internal representations. These neural representations of the sensory world are continuously modified: Prof. Tansu Celikel and his team of Neurophysiology work towards a system level description of the neural circuits that process sensory information, and their plasticity to determine how adaptive changes in neural representations are translated into cognition and action. Our research topics include, but are not limited to, control of synaptic transmission and neural growth, structural and functional organisation of neural circuits, quantitative analysis and targeted control of brain plasticity, molecular control of network function, analytical study neural information processing, in silico (hardware and software) network models, close-loop neural control in robotic and virtual environments, neurotechnology: novel method development.

***As of September 2021, the full DCN staff will be housed in HG00.100**