The Danish National Research Foundation's

Center of Functionally Integrative Neuroscience

ANNUAL REPORT 2009

cognition PET statistics data tensor dendrite MR physics scanning music neuroanatomy

CFIN Annual Report 2009, published April 2010
Center of Functionally Integrative Neuroscience (CFIN)
Aarhus University / Aarhus University Hospital
Århus Sygehus, Building 10G, Nørrebrogade 44, DK-8000 Århus C, Denmark

www.cfin.au.dk

Editors: Leif Østergaard and Henriette Blæsild Vuust, CFIN
Design and layout: Henriette Blæsild Vuust
Printed in Denmark by GP-Tryk A/S

ISBN 978-87-992371-2-8

Getting organized ... just moved into the new DNC Building in March 2009.
Photos: Henriette Blæsild Vuust

Introduction - 2009 in words

by Leif Østergaard

2009 was a year of transition for CFIN. In March, CFIN researchers moved from the Yellow Villa, the old Box Factory and the offices in Sabroesgade, to our new home in the Danish NeuroscienceCenter building, with easy access to clinical collaborators across the Aarhus University Hospital Neurocenter, and to neuroimaging equipment in the new PET Center and the Neuroradiology Research Unit.

With grants from the Ministry of Science, Technology and Innovation, the Villum Kann Rasmussen Foundation and the Velux Foundation to acquire 3T MRI, MEG, TMS and EEG equipment, 2009 was a busy year for CFIN and PET Center staff, working closely with Aarhus University and Aarhus University Hospital to plan new buildings and building changes to house the MIND*Lab* core experimental facility.
We are grateful that, with considerable financial support from our mother institutions, we will be able to realize the ambition to provide access to cutting-edge neuroimaging experiments to scientists across Aarhus University, and Aarhus University Hospital and to our collaborators.

With the prestigious University Investment Capital (UNIK) grant from the Ministry of Science, Technology and Innovation awarded to Aarhus University in 2008, CFIN could strengthen collaborations across Neurocenter Departments, 6 Aarhus University Faculties, with the Royal Academy of Music, with Hammel Neurorecenter and Department of Psychiatry, and with our numerous collaborators abroad. With the support of AU Institutes, key CFIN researchers were recruited to permanent positions at Aarhus University. This is an important step towards securing CFIN investments in new research areas over the past 8 years, beyond the Danish National Research Foundation and UNIK funding periods.

The scientific production increased in 2009, much due to the attraction of increased funding and of leading scientists over recent years. Chris and Uta Frith, affiliated with CFIN through the Interacting Minds project, co-authored key papers on the neural correlates of social interaction and the psychopathology of Aspergers syndrome and schizophrenia in *Science*, *Nature Neuroscience* and *Nature Reviews in Neuroscience*. Morten Kringelbach, head of the TrygFonden Research Group and Tipu Aziz, both Aarhus University professors affiliated with CFIN, published key findings within Deep Brain Stimulation in the prestigious *Journal of the American Medical Association* (JAMA).

CFINs continuing effort to translate basic neuroscience research into better patient care was highlighted in 2009, as the CFIN stroke research team and the departments of Neuroradiology and Neurology recieved the *Golden Scalpel Award* for their effort to offer thrombolytic therapy using the advanced MR based diagnostics developed as part of CFIN research.

On a more personal note, 2009 concluded years of considerable sacrifice in my efforts to secure funding, infrastructure and opportunities to the 'flocks' I was determined to guard. This transition (and back-surgery) gave way to crucial personal and scientific reflections – and new priorities. I am much indebted to the loyalty and support I received from colleagues and friends in the process.

On behalf of the CFIN scientific coordinators, I wish to thank our researchers and collaborators for exciting work in 2009, and The Danish National Research Foundation, The Ministry of Science, Technology and Innovation, Aarhus University, the Central Denmark Region and our many other benefactors for their continued support.

Leif Østergaard

Leif Østergaard

by Albert Gjedde

The Final Frontier: Variable ATP Yields and uncoupling of Oxygen Consumption in Human Brain

Joel Aanerud, Ericka Peterson, Peter Iversen, Anders Rodell, Per Borghammer, Christopher Bailey, Albert Gjedde, PET Center Aarhus.

In the Neuroenergetics Column, we have come to realize that the cerebral metabolic rate for oxygen ($CMRO_2$) may not be the most accurate measure of brain energy turnover. Although as much as 95% of the oxygen is consumed in mitochondria, this consumption does not accurately reflect the adenosine triphosphate (ATP) turnover, also known as oxidative phosphorylation. The reason is that the exact coupling ratio of oxidative phosphorylation to oxygen consumption is unknown in human brain. It is a fact that neither the average nor the regional or cellular rates of ATP turnover are known exactly in the living human brain, in absolute terms or in relation to the values of oxygen consumption in the same compartments. This is important because recent reports make the point that the rate of ATP turnover may be the single most important factor in the maintenance of normal conscious states. The claim is that a certain minimum of cortical energy turnover as stimulated by projections from the thalamus creates the phase transition of cortical molecular structure that enables the interaction experienced as consciousness. Below the threshold, the interaction fails. The role of monoamines in the maintenance of an adequate energy turnover is important because monoamines appear to regulate cortical excitability.

In the Neuroenergetics Column, we have made the resolution of the relations between oxidative phosphorylation and oxygen consumption a major aim in 2009. The questions relating to this issue are important to the understanding of healthy aging in humans. The questions include the changes of cerebral oxygen consumption and ATP turnover with healthy and unhealthy aging, and the role of changes of coupling and uncoupling with specific disorders of unhealthy aging such as Alzheimer's and Parkinson's diseases, as well as potentially in other disorders of younger age groups. Recent reports suggest that higher degrees of uncoupling are associated with greater numbers of mitochondria and greater longevity, perhaps because uncoupled mitochondria produce lower quantities of reactive oxygen and nitrogen species (RONS).

The distribution of brain oxidative metabolism values among healthy humans is astoundingly wide for a measure that is presumed to reflect normal brain function and further is purported to change only minimally with changes of brain function. Under normal circumstances, as much as 90% of the glucose consumed undergoes oxidation to CO_2 but only about 75% of the total glucose consumption on average is coupled to oxidative rephosphorylation of ATP, according to recent estimates of ATP-turnover by means of *in vivo* 31P MR spectroscopy (Du et al. 2007). The remaining 15% of the glucose consumption is believed to be uncoupled from the resynthesis of ATP in mitochondria by means of pores in the inner membrane that dissipate the hydrogen ion gradient and thus help maintain the electron flux independently of the ATP turnover.

The estimates of oxidative metabolism in human brain make complete sense only when the oxygen consumption rate coupled to ATP turnover is similar in all healthy brains. The additional oxygen consumption then would reflect varying degrees of uncoupling in different individuals. To test the hypothesis that a lower threshold of about 70-80% of the oxygen consumption by human brain is common to all normally functioning individuals, we have determined the variability in a large group of normal healthy adults, as well as in patients with Alzheimer's disease in whom both oxygen consumption and cerebral blood flow values were determined with PET.

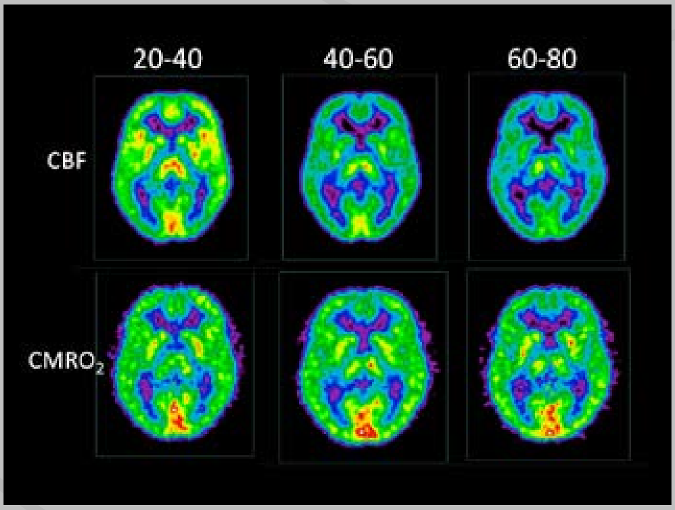


Figure 1
Average blood flow and oxygen consumption rates in three age groups with the relative color coding. Note that cerebral blood flow rates decline with aging while oxygen consumption rates do not.

To establish the degree of variability of brain oxidative metabolism in different regions of the human brain, we have completed the determination of regional and whole-brain cerebral metabolic rates for oxygen ($CMRO_2$) and cerebral blood flow rates (CBF) in more than 75 healthy volunteers aged 20-80 years. Some examples of the preliminary results will be discussed here. The full details of the PET and MRI methods have been published by Borghammer et al. (2008). Among other recordings, each subject underwent a [15O]O_2 emission recording that lasted 3 minutes (21 frames) from the onset of inhalation of 1 GBq [15O]O_2. The PET recordings were acquired in 3D mode with the original ECAT EXACT HR 47 (CTI/Siemens) whole-body tomograph with its transverse resolution of 3.6–7.4 mm and axial resolution of 4.0–6.7 mm (Wienhard et al. 1994). The same tomograph was used to ensure comparability of these recordings collected over a number of years.

Catheters were inserted in the left radial artery and right cubital vein, and arterial blood radioactivity determined with automated blood sampling, cross-calibrated to the tomograph and corrected for external delay and dispersion. In the usual way, we corrected the reconstructed images for random and scattered events, detector efficiency variations, and dead time. Anatomical MR images were used to co-register MR and PET images. Summed images of the individual emission recordings were co-registered and then transformed into common stereotaxic coordinate space, using a combination of linear and non-linear transformations. With the decay-corrected arterial inputs, parametric maps of $CMRO_2$ were calculated with the single step, two-compartment, and weighted-integration method originally developed in Montreal (Ohta et al., 1992).

In the analyses completed so far, coefficients of variation range from 10 to 15% in different regions of the cortex. The normalized regional metabolic rates range from 70% to 140% of the population average for each region, a two-fold variation. In this calculation, the hypothetical threshold of oxygen metabolism coupled to ATP turnover, presumed to be common to all subjects, would be close to the lower limit of the 70% of the average oxygen consumption of the population.

We can evaluate the average ATP gain of human brain at this lower limit by introducing the value of 29 mol per mol of glucose, argued by Brand (2005) to be the absolute maximum gain from oxidation of glucose (which may include obligatory uncoupling in the form of leaks), to which we

SELECTED RESEARCH PROJECTS:

Per Borghammer, Joel Astrup Aanerud, Albert Gjedde: Studies of brain flow and metabolism in humans.

Anders Nykjær, Dirk Bender: AD-ANA mice.

Jakob Linnet, Arne Møller, Albert Gjedde: Clinical, psychological and neurobiological aspects of gender differences in pathological gambling.

Susanne Lerche, Ole Schmitz, Albert Gjedde: Effect of GLP-1 on glucose uptake in CNS and heart in healthy persons evaluated with PET.

Aage Olsen, Joel Astrup Aanerud, Dirk Bender: Beta-amyloid imaging in older Goettingen minipigs.

Albert Gjedde, Søren Laurberg, Arne Møller: Cerebral activation response to sacral nerve stimulation in healthy animals and patients with fecal incontinence.

Ericka Peterson, Christopher Bailey, Per Borghammer, Arne Møller, Kim Vang Hansen, Jakob Linnet, Albert Gjedde: Sex-specific changes of CBF and $CMRO_2$ when men and woman gamble.

Bjørn Pedersen et al.: Cochlea implantation and neuroplasticity.

Joel Aanerud et al.: Cerebral energy metabolism, blood flow, 5-HT1A receptor binding and accumulation of beta-amyloid plaques in Alzheimer’s disease in young and old healthy volunteers.

must add 2 mol/mol for a total of 31 mol/mol glucose. We can then determine the probability distribution of ATP gains from the variable $CMRO_2$ values among individual subjects. The average ATP gain in the present studies would then be close to 22 mol/mol glucose, or about 70% of the maximum. Interestingly, the variability and range of $CMRO_2$ values was similar to the range and variability of body-mass indices of the subjects, although no correlation was found between the two measures. Nonetheless it raises the possibility that mitochondrial properties influence metabolic efficiency of the body as a whole.

The report by Du et al. (2008) is the only study of ATP turnover in a region of the human brain in vivo, the region being the occipital cortex, determined with MR at 7 Tesla. The average ATP-turnover in this study was 807 µmol/hg/min. In the determinations of regional $CMRO_2$ that we conducted, the occipital cortex averaged 202, µmol/hg/min, corresponding to a P:O ratio of almost exactly 2, compared to the conventional maximum of 3 (3 P added to ADP per O atom reduced to water). According to these preliminary findings, leaks in the form of uncoupled and heat-generating idling could account for the variability from 70% to 140% of the population average. The distribution of oxidative brain metabolic rates in this large group of normal healthy adults therefore is consistent with the claim that 70% of the oxygen consumption is common to all normal healthy adult brains, while the remainder of the total reflects different degrees of uncoupling, assuming that the ATP turnover varies minimally among cognitively normally functioning humans.

Genetically controlled differences of the degrees of uncoupling are now held to play roles in obesity and the onset of diabetes II (Fisler et al. 2006, Rabøl et al. 2009, Wortmann et al. 2009). It is tempting to claim that the variability of $CMRO_2$ values in healthy adult human beings may have a similar explanation, although the mechanism relating the two is speculative. Among the uncoupling pores in the inner mitochondrial membranes, responsible for hydrogen-ion gradient dissipating leaks, are the uncoupling proteins (UCP1-5), of which some operate in brain. These proteins could act as a clutch that would cause mitochondria to idle without changing the total oxygen consumption. The distribution of BMI values had no correlation to the distribution of cerebral oxygen metabolism values but there is no reason to expect mitochondrial properties to be the same in the brain and the body as a whole.

Higher degrees of uncoupling are held to be beneficial and neuroprotective because they prevent excessive reduction of cytochromes and the accompanying generation of reactive oxygen species that occurs when the electron flux is not maintained. In parallel with different degrees of uncoupling known to operate in other parts of the body, such as the thyroid gland and brown fat where uncoupling is a factor involved in thermogenesis, the uncoupling proteins may contribute to individual differences of body-mass index, as well as to the variability of cerebral oxygen consumption rates in healthy human beings.

It is of great interest to us that recent evaluations of energy turnover mechanisms in different cellular compartments of mammalian brain suggest that the oxygen-glucose index (OGI) of 5.5 that reflects the 10% of glucose that leads to lactate production actually varies greatly among cell types as well as within cells of the same type. Some evaluations suggest that the OGI in astrocytes may be as low as 1, and the corresponding OGI in neurons as high as 20 (Hyder et al. 2006).

References

Borghammer P, Jonsdottir KY, Cumming P, Østergaard K, Vang K, Ashkanian M, Vafaee M, Iversen P, Gjedde A. Normalization in PET group comparison stu-dies—the importance of a valid reference region. Neuroimage. 2008; 1; 40(2): 529-540.

Brand MD. The efficiency and plasticity of mitochondrial energy transduction. Biochem Soc Trans. 2005; 33(Pt 5): 897-904.

Du F, Zhu XH, Qiao H, Zhang X, Chen W. Efficient in vivo 31P magnetization transfer approach for noninvasively determining multiple kinetic parameters and metabolic fluxes of ATP metabolism in the human brain. Magn Reson Med. 2007; 57(1): 103-114.

Fisler JS, Warden CH. Uncoupling proteins, dietary fat and the metabolic syndrome. Nutr Metab (Lond). 2006; 12; 3: 38.

Hyder F, Patel AB, Gjedde A, Rothman DL, Behar KL, Shulman RG. Neuron-al-glial glucose oxidation and glutamatergic-GABAergic function. J Cereb Blood Flow Metab. 2006; 26(7): 865-877.

Ohta S, Meyer E, Thompson CJ, Gjedde A. Oxygen consumption of the living human brain measured after a single inhalation of positron emitting oxygen. J Cereb Blood Flow Metab. 1992; 12(2): 179-192.

Rabøl R, Højberg PM, Almdal T, Boushel R, Haugaard SB, Madsbad S, Dela F. Improved glycaemic control decreases inner mitochondrial membrane leak in type 2 diabetes. Diabetes Obes Metab. 2009; 11(4): 355-360

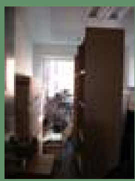
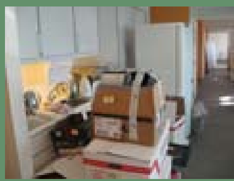
Wienhard K, Dahlbom M, Eriksson L, Michel C, Bruckbauer T, Pietrzyk U, Heiss WD. The ECAT EXACT HR: performance of a new high resolution positron scanner. J Comput Assist Tomogr. 1994; 18(1): 110-118.

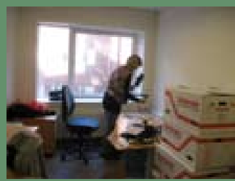
Wortmann SB, Zweers-van Essen H, Rodenburg RJ, van den Heuvel LP, de Vries MC, Rasmussen-Conrad E, Smeitink JA, Morava E. Mitochondrial energy production correlates with the age-related BMI. Pediatr Re. 2009; 65(1): 103-108.

CFIN move in March 2009

In March 2009, CFIN moved to the new Danish NeuroScience Center (DNC) bulding, completing the Neurocenter at Aarhus University Hospital, Århus Sygehus. The DNC building was barely finished when researchers from CFIN, PET Center Aarhus and Stereological Research Laboratory started moving in, and a period of apparent chaos ensued.



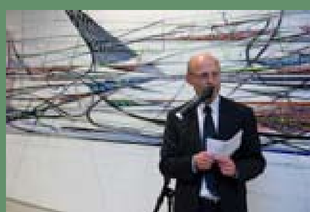


The DNC building is established by the Central Denmark Region in collaboration with Aarhus University. The aim is to stimulate new scientific breakthroughs and the development of new treatments for severe brain disorders. This is obtained by merging clinical and basic research, collaborations with industry and patient management, into one building complex.




Moving that many people, books and papers, computers and equipment requires not only a lot of preparations, but also a great deal of good mood, high spirits and strong coffee. After a few weeks of total chaos, CFIN researchers started to settle in the new house. With great views of the Aarhus University Campus across Nørrebrogade, the CFIN researchers enjoy a brand new modern building, designed by C.F. Møller Architects with a large area for scanners and cyclotrons below ground level, restaurant, an auditorium seating 135 people, laboratory and office spaces, of which CFIN occupies the 4th and 5th floor, and parts of the 6th floor.

The DNC building was officially opened by Bent Hansen, Head of the Regional Council in the Central Denmark Region, on 18 September 2009, during a ceremony for researchers, hospital employees and stakeholders from research, industry and public and private funding agencies.


Photos: Michael Harder, Aarhus University Hospital and Henriette Blæsild Vuust (top row)

NEUROTRANSMISSION

by Arne Møller

The year 2009 was a year of considerable activity in the groups involved in neurotransmission research. Jørgen Scheel-Krüger was welcomed to the PET Center and CFIN as a visiting associate professor. His vast experience in the study of neurotransmission is a valuable asset to several ongoing projects.

PhD projects

Ericka Peterson received her PhD entitled *Neurobiological Correlates of gambling in Men and Woman,* in September 2009, under the supervision of Albert Gjedde, Arne Møller and Jakob Linnet. She now continues her studies with Albert Gjedde.

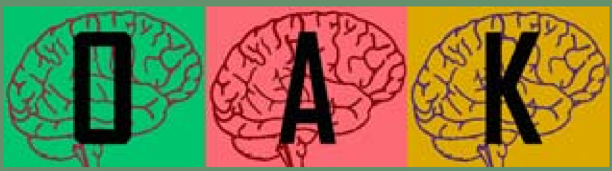
Joel Aanerud's project on ageing and Alzheimer's disease (AD) is also progressing well. He investigates oxygen extraction and its relation to amyloid deposits, the hallmark of AD in patients with memory loss, and the relationship between aging and serotonin receptor expression. Joel has completed the complex process of PET and MRI data acquisition and analysis is underway.

Rikke Fast has also completed scanning in her project on memory loss in older dogs. The dogs enrolled in Rikke's project have been scanned with MRI as well as PET, the latter with the tracer [11C]-PIB, a radioligand that binds to amyloid deposits in the brain.

Mette Buhl Callesen is doing good progress in her study on the development of pathological gambling as a side effect to treatment with dopamine agonists in patients with Parkinson's disease (PD). Mette has scanned patients with PD (gamblers and non-gamblers) as well as healthy controls. All participants were scanned twice in a gambling versus non-gambling situation, using the tracer [11C]-raclopride to determine changes in the dopamine concentration during gambling.

Adjmal Nahimi, a former medical research year student, has begun his PhD study at the PET Center and CFIN. His current interest (supervised by Albert Gjedde) involves alterations in binding in cannabinoid and glutamate receptors in rat models of dyskinesia and depression. He is performing part of his research with Dean Wong at Johns Hopkins University.

Eighth Annual OAK Meeting



The Danish neuroscience organisation OAK brings together laboratories in Odense, Aarhus and Copenhagen (hence the name - **O**dense, **A**arhus and **K**øbenhavn). OAK was founded in 2002 by Bente Finsen from Odense, Albert Gjedde and Paul Cumming from Aarhus and Flemming Fryd Johansen from Copenhagen. The organisation organizes an annual meeting where students from the three universities present their projects within the area of brain research.
The first Meeting took place in Aarhus in 2002 and the three cities take turns in organising the annual meetings.

Winner of Best Talk, Mette Buhl Callesen receiving the prize - a digital camera - from professor Bente Finsen. Photo: Jørgen Scheel-Krüger

On 12-13 June 2009 the Eighth Annual OAK Meeting was held in the new DNC auditorium (Palle Juul-Jensen Auditorium) at Aarhus University Hospital. The meeting gathered more than 70 participants from Odense, Aarhus and Copenhagen in a program with over 20 talks. A committee of senior scientists evaluated the talks and nominated *Best Talk*. Winner of the best talk prize this year was Mette Buhl Callesen from CFIN and PET Center Aarhus.

The Aarhus labs in the OAK organisation are CFIN, PET Center Aarhus, Stereological Research Laboratory and Department for Neurobiology at Aarhus University.

Read more about OAK at: www1.sdu.dk/multi/oak

Medical Research Year Student projects

Mette Hølzerman finalized her research year and passed her examination in 2009. Mette used microdialysis techniques to elucidate the role of serotonin and 5-HT_{1A} receptors in the development of L-DOPA-induced dyskinesia in the rat model of severe PD originally developed by Adjmal Nahimi. In these rats, Adjmal performed microPET studies. Mette was supervised by Albert Gjedde and Doris Doudet as well as Gregers Wegener from the Center of Basic Psychiatric Research, Risskov.

Jesper Fontain has undertaken a project with Gregers Wegener, Doris Doudet and Annie Landau to study the role of electroconvulsive therapy on monoamine receptor binding in a rat model of depression using receptor autoradiography.

Progress on ongoing projects

Studies by Annie Landau, Doris Doudet and Albert Gjedde using electroconvulsive therapy (in collaboration with Arne Møller, Gregers Wegener and Poul Videbech) and vagal nerve stimulation (in collaboration with Suzan Dyve) to induce brain stimulation in minipigs have led to exciting results. Using these two models of brain stimulation, clear alterations to monoaminergic receptor binding has been observed using PET, suggesting a common mechanism of antidepressant action, and brain stimulation therapies.

The gambling group has continued collecting data for several projects. They have published results on the relation of depressive symptoms and the severity of gambling in pathological gambling. Also they have presented data on the role of dopaminergic neurotransmission and personality traits (sensation seeking behavior) as well as changes in dopamine concentration in pathological gamblers in a gambling situation using the Iowa Gambling Task. These data showed that the dopaminergic system of the gamblers is very sensitive to the gambling situation as compared to non gamblers.

In 2009 Arne Møller organized the course in Neurotransmission, Psychiatry and Neuropharmacology as part of the Biomedical Engineering degree in Neuroscience. During three months, the country's greatest experts in the field taught participants on neurotransmission and the influence of errors in neurotransmission in various neurological and psychiatric diseases. See www.cfin.au.dk/menu741-en

SELECTED RESEARCH PROJECTS:

Rikke Fast, Mette Berendt, Joel A Aalerud, Aage KO Astrup, Arne Møller: Dementia in Geriatric Canines: A Neuroimaging Study.

Joel A Aanerud, Arne Møller, Hans Brændgaard, Manouchehr Vafaee, Johannes Jakobsen, Leif Østergaard, Albert Gjedde: Relationship between changes in amyloid deposits and loss of hippocampal neurons.

Adjmal Nahimi, Anne M Landau, Doris Doudet, Albert Gjedde: In-vivo and in-vitro evaluation of monoaminergic innervations in a rat model of Parkinson´s Disease.

Albert Gjedde, Yoshitaka Kumakura, Paul Cumming, Jakob Linnet, Arne Møller: Low dopamine receptor availability in brain of high sensation-seeking men.

Yoshitaka Kumakura, Doris Doudet, Jakob Linnet, Arne Møller, Albert Gjedde. Role of dopamine synthesis in the sensation seeking personality constitution.

Anne M Landau, Aage KO Astrup, Arne Møller, Albert Gjedde, Doris Doudet: Effects on electroconvulsive therapy in Parkinsons Disease.

Anne M Landau, Suzan Dyve, Doris Doudet, Albert Gjedde: Effects of Nervus Vagalstimulation on the brain.

Ericka Peterson, Arne Møller, Albert Gjedde, Jakob Linnet: SCR (Skin conduction reaction) and dopamine release.

Kristine Rømer Thomsen, Mette Buhl Callesen, Arne Møller, Jakob Linnet: Severity of Gambling is associated with severity of depressive symptoms in Pathological Gambling.

Jakob Linnet, Ericka Peterson, Doris Doudet, Albert Gjedde, Arne Møller: Immediate defeat: Inverse dopamine reward response in Pathological Gamblers and Non-Gamblers.

Hans Lou et al.: Dopaminergic neurotransmission in striatum during conscious awareness of sensations.

Adjmal Nahimi, Mette Høltzerman et al.: Modulation of exogenous L-DOPA derived dopamine in unilaterally lesioned animals with Parkinsonism and L-DOPA-induced dyskinesia

Arne Møller, Ericka Peterson, Doris Doudet, Albert Gjedde, Jakob Linnet: Dopaminergic neurotransmission and brain activity in ludomaniacs engaged in computerized games.

Jakob Linnet, Ericka Peterson, Doris Doudet, Albert Gjedde, Arne Møller: Dopamine release towards losses in ventral striatum of pathological gamblers.

Mette Buhl Callesen, Jakob Linnet, Doris Doudet, Albert Gjedde, Arne Møller: Pathological gambling in Parkinson's disease.

NEUROCONNECTIVITY

by Peter Vestergaard-Poulsen

We strive to develop and use MRI to study how the structural plasticity and function of the brain are regulated by changes in neurotransmission. This goal is pursued by diffusion weighted magnetic resonance imaging (DWI) which has proven to have excellent sensitivity - unrivaled by other techniques - to structural changes at the cellular level. While MRI is the dominating tool in human neuroimaging, the limited spatial resolution and relatively low sensitivity often prevent the understanding of how image contrast is linked to the underlying cellular mechanisms and morphology, thereby limiting the ability to test methods, hypotheses or therapies. Therefore we use a combination of biophysical modelling and ultra high-field magnets (16.4-17.5 T) due to the higher sensitivity and image resolution attainable at such field strengths compared to current clinical MR-systems.

CFIN, inSPIN (both Danish National Research Foundation Centers of Excellance) and professor Stephen J. Blackband's laboratory at McKnight Brain Institute, University of Florida (UFL) are the main collaborators in this effort. Thanks to a special grant program from The Danish National Research Foundation, Dr. Jeremy Flint was employed at CFIN in 2008 and his main task is the development of MR microscopy methods and neuroscientific research using advanced DWI techniques. This work is performed in a collaboration which combines researchers from CFIN and inSPIN and groups at the UFL. In a further effort to bridge these international collaborations the first summer school and workshop on "High Field Neuro-imaging" was held October 26th and 27th, 2009 at the McKnight Brain Institute, University of Florida, Gainesville, Florida. The workshop was sponsored by the Danish National Research Foundation, with support from the McKnight Brain Institute and the US National High Field Laboratory, and was very productive, bringing researchers from many institutions together to participate in fruitful scientific discussions (see below).

In 2009, as a first result of the collaboration, assistant professor Brian Hansen (CFIN) and Jeremy Flint published the first-ever MR imaging of alpha-motor neurons in the rat spinal cord, as well as a promising investigation of neuronal activity being associated with cellular volume modulation detectable with MRI. For further description of their work see Flint and Hansen's *Developing the MR microscope: The collaboration with the Blackband Lab at the McKnight Brain Institute, UFL* in this Annual Report.

Resources are currently directed towards investigating the biophysical properties of tissue at a cellular level using microscopic surface coils developed in collaboration with Bruker Biospin GmbH, Germany, and high field microscopy (16.4 - 17.4 T). A biophysical model developed by Sune Nørhøj Jespersen (CFIN) is now applied in studies of structural hippocampal plasticity during chronic stress and in the assessment of neurite and plaque density in Alzheimers disease.

NeuroPhysics

In 2009 the Neurophysics group headed by Sune Nørhøj Jespersen, finished a comprehensive project comparing a detailed biophysical model of diffusion in the brain to histology and stereology, now accepted for publication in *NeuroImage*. A very good agreement between microstructural parameters predicted by the model on the basis of diffusion MRI and corresponding measures obtained from histology and stereology was found. Therefore, a number of projects applying this model in different contexts of neuroplasticity have now been initiated, e.g. chronic stress, Alzheimer's disease, and cortical maturation. Preliminary results from the latter study, which is carried out in close collaboration with Christopher Kroenke and his colleagues at Oregon Health and Science University, were awarded with the first-place poster award at the 2009 annual meeting of the International Society for Magnetic Resonance in Medicine.

PhD student Niels Buhl spent several months at the Mallinckrodt Institute of Radiology in St. Louis working on a novel scheme of eddy current compensation, a potentially important prerequisite for more accurate diffusion MRI. He has also developed a theory for diffusion in networks which, in addition to its fundamental biophysical interest, may have practical implications for lung imaging.

High field Neuro-imaging summer school and workshop, 26-27 October 2009 at McKnight Brain Institute, University of Florida, Gainesville, Florida, USA.
Photo: Louise Munk Rydtoft

High field Neuro-imaging summer school and workshop, 26-27 October 2009 at McKnight Brain Institute, University of Florida, Florida, USA.

This workshop was the first of two planned summer schools and meetings focusing on topics within or related to high field neuro-imaging. The workshop was primarily sponsored by the Danish National Research Foundation, but also received financial and logistical support from the McKnight Brain Institute and the US National High Magnetic Field Laboratory. The second workshop is scheduled to take place at CFIN in spring 2011.

The 2009 meeting had approximately 60 participants from groups across continental USA, Canada and Europe: Oregon Health and Science University, Washington University in St. Louis, US National Institute of Health, Brookhaven National Laboratory, US National High Magnetic Field Laboratory, Carnegie Mellon University, University of Toronto as well as researchers from CFIN, inSPIN and the groups at UFL. Senior and junior scientists joined with PhD students in presentations and discussions of research using high field MRI to study everything from single neurons, over brain development and degeneration, to novel techniques to perform *in-vivo* cytometry.

The meeting was kept on a very informal level and well established collaborations between several of the groups secured a fruitful environment for exchange of research problems and results. In addition, the meeting fostered new collaborations, and served as a recruitment opportunity in our search for future CFIN researchers.

Dr. Peter J. Basser (NIH) presenting his work on diffusion tensor imaging. Dr. Basser's group is primarily known for the invention, development, and clinical implementation of MR diffusion tensor imaging (DTI), and for explaining the physical basis of magnetic stimulation of nerve fibers.
Photo: Louise Munk Rydtoft

SELECTED RESEARCH PROJECTS:

Sune N. Jespersen, Carsten R. Bjarkam, Jens R. Nyengaard, M. Mallar Chakravarty, Brian Hansen, Thomas Vosegaard, Leif Østergaard, Dmitriy Yablonskiy, Niels Chr. Nielsen, Peter Vestergaard-Poulsen. Neurite Density from High Field Magnetic Resonance Diffusion Measurements at Ultrahigh Field.

Peter Vestergaard-Poulsen, Gregers Wegener, Niels Chr. Nielsen, Thomas Vosegaard, Brian Hansen, Steve Blackband, Sune Jespersen. Quantification of dendritic remodeling in the stressed hippocampus by MRI.

Peter Vestergaard-Poulsen, Gregers Wegener, Brian Hansen, Doris Doudet, Sune Jespersen et al. Electroconvulsive therapy: regional visualization of hippocampal neurogenesis by diffusion weighted MRI?

Micah Allen, Peter Vestergaard-Poulsen Andreas Roepstorff, Chris Frith, Martijn van Beek, Michael Stubberup, Jes Bertelsen, Paul Grossman. Longitudinal effects of meditation.

Louise M. Rydtoft, Leif Østergaard, Peter Vestergaard-Poulsen, Niels Chr. Nielsen, Sune N. Jespersen. Ultra-high-field MR Studies of an Alzheimer's disease mouse model.

Mads Sloth Vinding. Thomas Vosegaard, Niels Chr. Nielsen, Sune N. Jespersen, Ryan Sangill and Peter Vestergaard-Poulsen. Optimal Control for reduced field-of-view MRI.

NEURONCONNECTIVITY

Long term meditators has increased gray matter density in the brainstem

by Peter Vestergaard-Poulsen

Several studies have shown that sustained practice of a skill is associated with plasticity-related structural changes in the cortex of the human brain, for instance taxi driving in London, preparing for an exam, or juggling. Meditation involves a wide variety of techniques of mental training with sustained attention to external or internal objects such as concepts, sounds (mantra) or bodily sensations – frequently those associated with breathing.

Attention to breathing is a common element in meditation training in many traditions, and meditation is known to have lasting effects on respiration control. Respiration rate, skin conductance, and oxygen consumption are all reduced in experienced meditators. Therefore it is plausible that the long term practice of such forms of meditation could induce structural changes in brain regions involved in basic autonomic regulation. To study the structural effects of long term meditation practice, researchers from CFIN, Institute of Anatomy, Aarhus University, and Vækstcenteret compared groups of highly experienced meditators and normal controls using voxel based morphometry of whole brain 3 Tesla MRI[1].

We observed higher gray matter density in lower brain stem regions (medulla oblongata) of experienced meditators compared with age-matched non meditators (Figure 1). These regions include the solitary nucleus (the so-called dorsal respiratory group) and the dorsal motor nucleus of the vagus nerve. Parasympathetic fibers from the dorsal motor nucleus of the vagus innervate, via the vagus (X. cranial nerve), the heart muscle and the smooth musculature and glands of the respiratory and intestinal tracts (Figure 2).

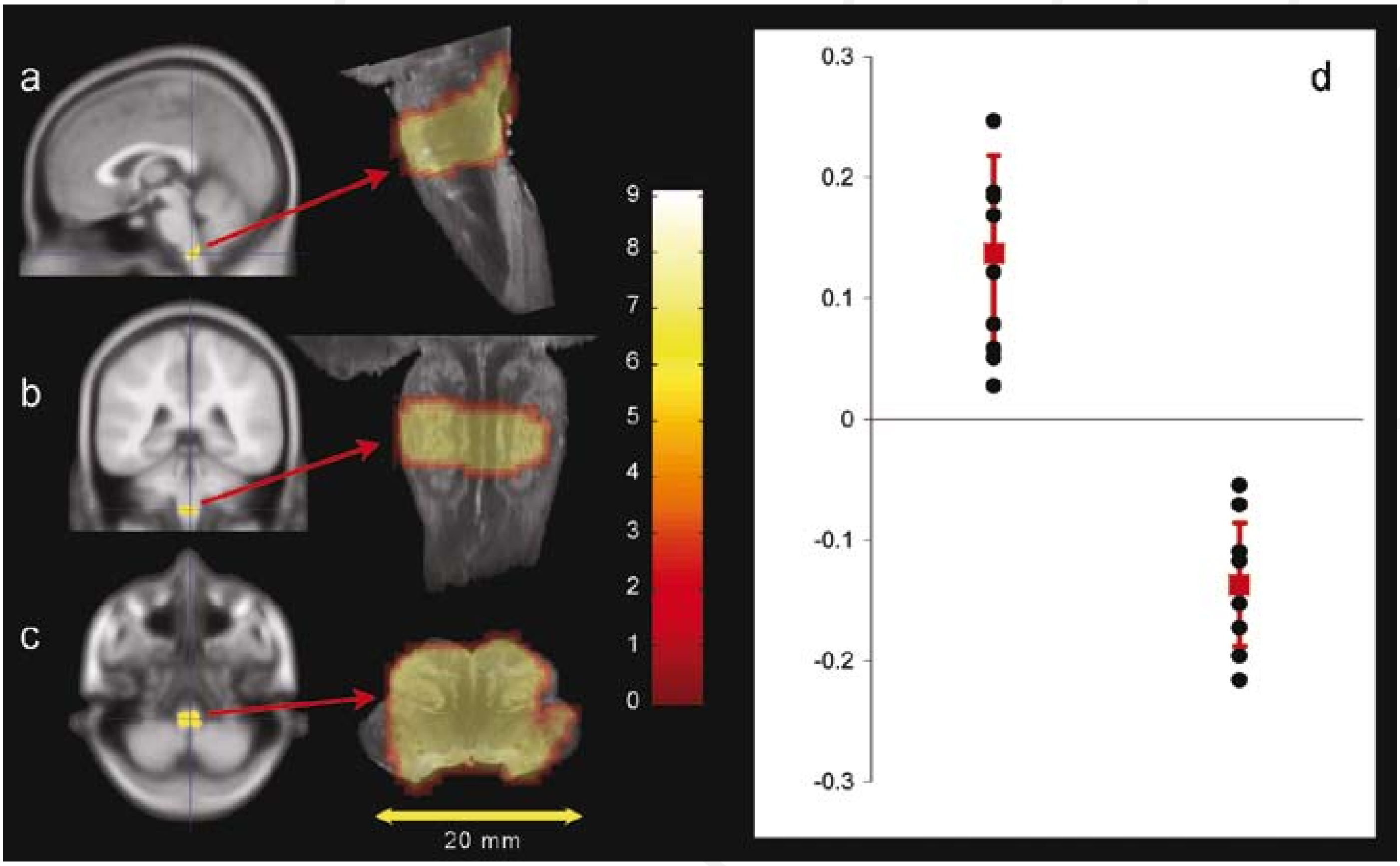


Figure 1
Increased gray matter density in the brain stem of the meditators
On the left (a,b,c) regions of increased gray matter density are superimposed on a T1 MR image of the brain. These regions are further superimposed on a 105 µm resolution MR image of the human medulla oblongata *in-vitro* which was coregistered to the stereotaxic space of all subjects d, Relative gray matter density difference in the peak voxel for the groups of meditators (left) and controls (right).

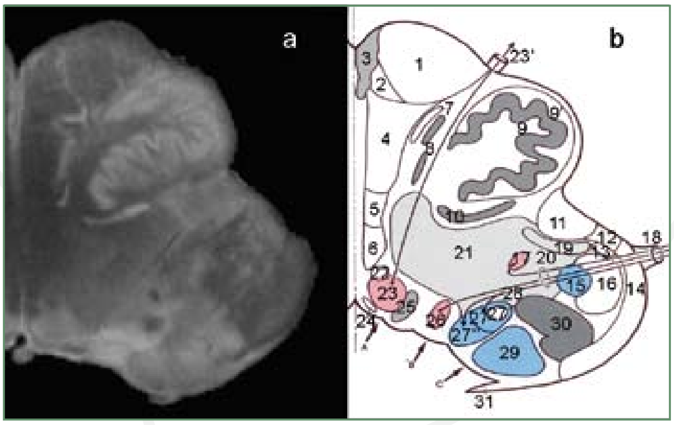


Figure 2
Identification of regions in the human lower brain stem.
Figure a shows a zoomed axial section of the medulla oblongata in Figure 1, panel c. Figure b shows a schematic axial section of the medulla oblongata at the level of the middle inferior olivary nucleus. *Regions*: 9. inferior olivary nucleus, 17. nucleus ambiguous, 18. fibers of the vagus nerve, 21. nucleus reticularis medullae oblongatae centralis, 26. dorsal motor vagal nucleus, 27. nucleus of the solitary tract, 27´. solitary tract, 27´´. nucleus gelatinosus of the solitary tract .

NEW FACE AT CFIN

Louise Munk Rydtoft, MSc in biomedical engineering from Aarhus University. In a collaboration between Center for Insoluble Protein Structures (inSPIN) and CFIN she is pursuing a PhD degree in neuroscience, investigating magnetic resonance microscopy of an Alzheimer's disease model.

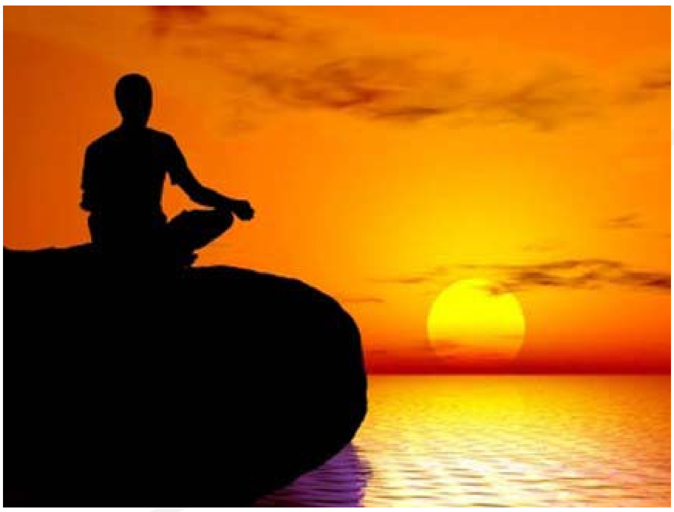
Preliminary studies of plaque deposition have led to successful detection of individual amyloid plaques within reasonable scanning time, approximately 2 hours at 16.4 T. Currently the focus is on further optimization and refinement of the methods towards *in vivo* plaque detection and combining this with 19F MRI based on fluorinated containing amyloid-binding compounds being developed at inSPIN.

Louise Munk Rydtoft is funded by the EliteForsk grant to Leif Østergaard (2008), and CFIN.

inSPIN
Center for Insoluble Protein Structures

Structural differences in the region of autonomic respiratory control centers are noteworthy because studies have shown that breathing and heart rate are reduced during the act of meditation – and that there are lasting effects on respiration control as a trait of meditation practice.

Studies have shown that several types of meditation practice are associated with increased vagal tone and related traits such as a lower cortisol level and an increased level of anti-bodies. Similarly, increased vagal tone has been associated with a higher attentional stability during exposure to stressful stimuli. In this context, our finding of structural differences in the vagal nuclei of the medulla oblongata suggests that the autonomic nerve system may be part of the neuroanatomical basis that is responsible for the cognitive, emotional and immuno-reactive effects in relation to with several types of meditation practice.



References

1. Vestergaard-Poulsen P, van Beek M, Skewes J, Bjarkam CR, Stubberup M, Bertelsen J, Roepstorff A. Long-term meditation is associated with increased gray matter density in the brain stem. Neuroreport. 2009 Jan 28;20(2):170-4.

ULTRA HIGH-FIELD MR IMAGING

Developing the MR microscope: collaboration with McKnight Brain Institute

by Brian Hansen and Jeremy J. Flint

In 1609, Italian polymath Galileo Galilei built what is considered the first compound light microscope, thus opening the microscopic world for scrutiny. This led to Robert Hooke's discovery of the biological cell (Figure 1 A&B) and van Leeuwenhoek's observations of living cells in 1674. These observations gave birth to the cell doctrine on which modern biology is founded.

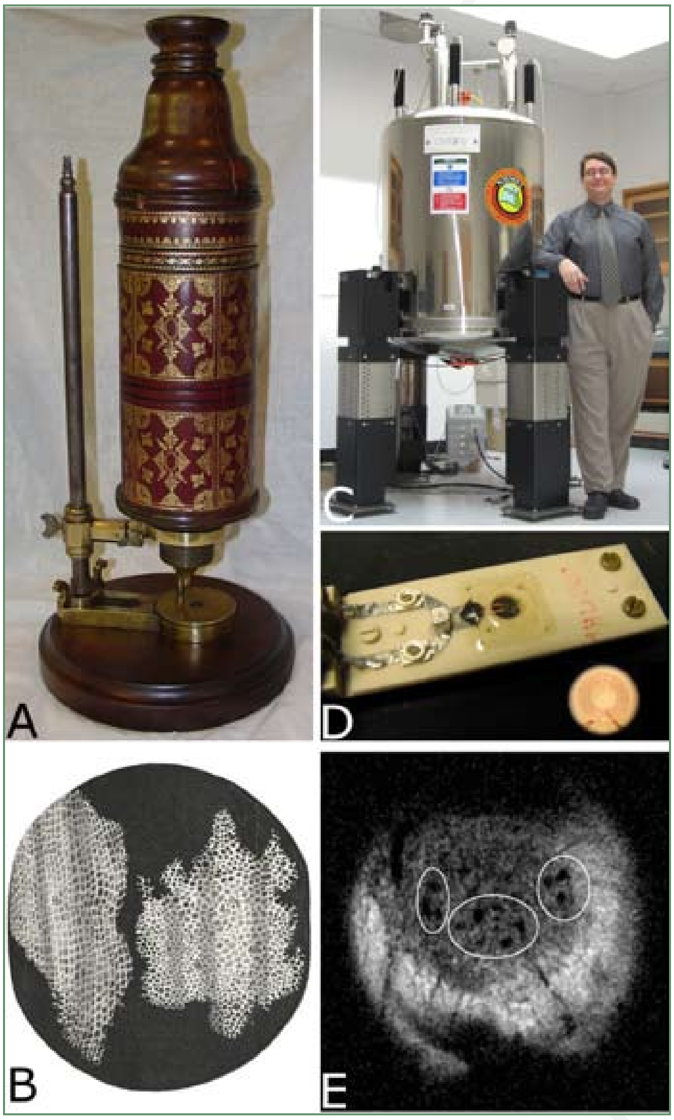


Figure 1
A: Robert Hooke's original microscope ca. 1660. B: Hooke's hand drawn sketch of the cells he observed in bark from the cork oak. C: The modern day MR-microscope and Dr Jeremy Flint. D: A radiofrequency micro surface coil – the "lens" of the MR-microscope. The coil itself is seen in the circular insert (coil diameter is 500 μm). E: The first verified MR-image of mammalian cells (alfa-motor neurons, ~50 μm in diameter) *in situ*[1]. This result was chosen for the front cover of NeuroImage for the July 2009 edition (Figure 2).

In 2009, 400 years after Galileo's invention, the magnetic resonance (MR) microscope (Figure 1C-E) is evolving into a useful tool for cellular imaging and investigation of tissue microstructure. In an age where a number of microscopy techniques are readily available this may seem a small feat but in the following we will explain why we are convinced that this technique is important, and its further development worth pursuing.

Modern neuroimaging relies - for a large part - on MR-techniques either alone or in combination with other imaging modalities. While the image quality produced by current MR-systems is impressive, the image resolution is still very coarse (about 1000 μm) compared to the scale of biological tissue structures (about 10 μm). One way of making the MR signal reflect tissue structures on the cellular scale includes sensitizing it to water self-diffusion. This has been found to make MR imaging very effective for detection of ischemic tissues e.g. in stroke. However, even with the sensitivity obtained in this manner, the specificity of the diagnostic method is lacking and the underlying mechanisms remain unclear. In the same manner, the diffusion-based tractographic methods used to produce synthetic maps of brain fiber trajectories from MR data are unvalidated and their precision remains difficult to assess. It is in answering questions such as these the MR-microscope holds promise. In an effort to shed light on these and other questions, our collaboration has focused on using MR-microscopy to visualize (Figure 1E and Figure 2) and study MR-characteristics of individual

Figure 2
The cover of NeuroImage from July 2009 showing figures from Flint et al.: "Magnetic resonance microscopy of mammalian neurons".

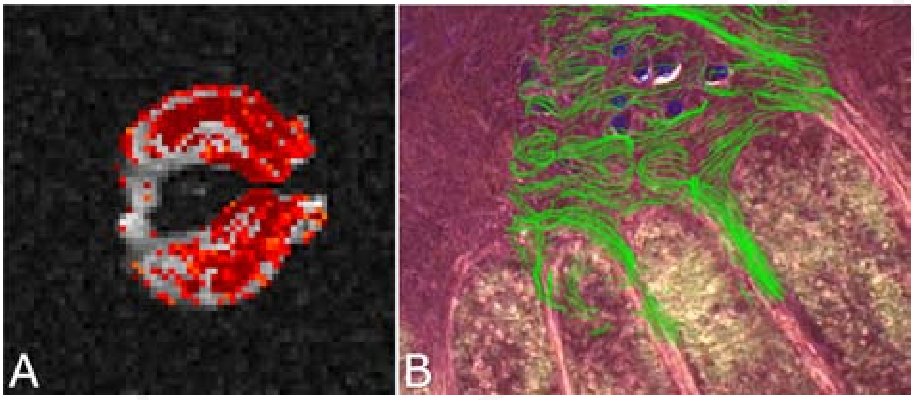


Figure 3
A: Areas in hippocampal tissue slices activated (red) by exposure to kainate[2]. Pixel size is 156 µm x 156 µm. B: Tissue microstructure extracted by MR-microscopy (green) compared to actual tissue histology[3]. The scale bar is 250 µm.

tissue components, regional tissue response to exposure to neuroactive substances (figure 3A) and high resolution investigations of brain tissue structure and the data processing methods used to visualize it from MR data (Figure 3B). MR-microscopy has obvious strengths in the study of biological tissue because, unlike other current microscopy methods, MR-microscopy employs a technique (magnetic resonance) which is one of the current imaging standards for disease diagnosis in the clinic. As such, MR-microscopy is capable of revealing the origins of MR signal - as well as alterations in that signal associated with disease pathology - at the cellular level. This information is crucial for the continued development of imaging-assisted differential diagnosis as microscopy studies will reveal exactly how and to what extent the MR signal changes as a result of specific disease states. Therefore the MR-microscope is a tool suitable for both the study of biological phenomena and the improvement of MR techniques already in use in the clinic.

A strong motivating factor for further research in this field is the prospect that, by using a combination of MR-microscopy and advanced mathematical modeling, we may become able to extract quantitative measures directly related to tissue microstructure far exceeding those which are possible using current techniques. Such techniques would be related to histological methods, but would not require stains, and - very importantly - could perhaps one day be performed *in vivo*. Such a method (call it virtual biopsy or MR-histology) would provide insight into a number of pathologies where tissue microstructure is known to change or degrade – one example being Alzheimer's disease. Our ability to investigate the normal brain would also increase by such methods for instance by improving our understanding of how the brain's microstructure is affected by external factors such as chronic stress, development, aging and learning.

By its invention 400 years ago, the optical microscope made possible a wealth of new scientific endeavors. While it is probably not fair to expect the MR-microscope to cause scientific breakthroughs comparable to those produced by the light microscope, it is certainly reasonable to say that the MR-microscope is now at a stage comparable to the stage of the light microscope at the time of Robert Hooke: We have a new tool that allows us to investigate many important topics that have so far been impossible to study using MRI. It is our hope that the MR-microscope may prove just as useful in the work of improving MR-based neuroimaging and diagnostics.

References

1. Flint, Lee, Hansen, Vestergaard-Poulsen and Blackband: "Magnetic resonance microscopy of mammalian neurons", NeuroImage 46(4) 2009.
2. Flint, Hansen, Vestergaard-Poulsen and Blackband: "Diffusion weighted magnetic resonance imaging of neuronal activity in the hippocampal slice model", NeuroImage 46(1) 2009.
3. Flint, Hansen, Vestergaard-Poulsen and Blackband: "Cellular-Level Diffusion Tensor Microscopy and Fiber Tracking in Mammalian Nervous Tissue With Direct Histological Correlation", in review with NeuroImage.

FUNCTIONAL HEMODYNAMICS

by Leif Østergaard

The development of robust methods to assess brain perfusion across patients in a range of diseases has been a key goal to functional hemodynamics research since CFIN was founded in 2001. Thanks to several breakthroughs in the understanding of MR signal formation during the passage of MR contrast agents through the vascular system, and advanced modeling of tracer kinetics, these methods now form the basic tools in our efforts to understand the role of cerebral hemodynamics in the progression of diseases such as stroke, dementia and brain tumors.

Birgitte Fuglsang Kjølby, MSc heads the effort to understand how the physics of susceptibility contrast affects the ability to measure contrast agent concentration based on MR-signal changes during intravascular passages intensity, in close collaboration with Valerij Kiselev, Freiburg University. The research has lead to a thorough understanding of the properties of arterial concentration signals used in perfusion analysis, published in *Magnetic Resonance in Medicine*, and improved understanding of how MR imaging protocols affect the ability to reliably detect tissue hypoperfusion (See the section on ***I-Know***). This work will undoubtedly be crucial in our efforts to build models of disease progression in stroke and in gleaning perfusion thresholds for irreversible tissue damage from existing multicenter studies.

Esben Thade-Pedersen, MSc, a graduate from the magnetic resonance biomedical engineering program at Aarhus University, finished his PhD work, formally enrolled in the PhD program at CFIN while working in Singapore. His groundbreaking work on perfusion methods utilizing the kinetics and contrast of intrinsic, spin labeled water, has proved the precision and clinical utility of arterial spin labeling (ASL) in the study of cerebral physiology and pathophysiology.

In collaboration with Manus Donahue and his colleagues at Oxford University, Jakob Blicher explored methods that detected blood flow and volume using intrinsic water. Such approaches allow simultaneous measurements of perfusion and blood oxygen level dependent (BOLD) contrast, providing the means of unraveling the flow-metabolism uncoupling that currently haunts not only neuroimaging, but our basic understanding of the brain oxidative metabolism.

Søren Christensen, MSc, another highly talented biomedical engineering graduate from Aarhus, finished his thesis in Melbourne, Australia, working with Professor Steve Davis' stroke group at Royal Melbourne Hospital, and Fernando Calamante at The Brain Research Institute in Melbourne. His innovative work within perfusion methodology and means of detecting and characterizing hypoperfusion in stroke is reported on the following pages.

As a testament to the translational impact of this research, CFIN researchers have been an integral part of developing acute stroke management for patients referred to the Neurocenter, Aarhus University Hospital. CFIN was proud to be the co-recipient of the *Golden Scalpel Award* for this effort in 2009.

NEW FACE AT CFIN

Anna Tietze, MD, PhD student, finished Medical School in Berlin, Germany, in 1997. After receiving her degree as a radiologist at the Aarhus University Hospital in 2007, she worked at the Radiology Department at the Royal Liverpool Children's NHS Trust Alder Hey, Liverpool, United Kingdom until 2008.

Today she is appointed as a clinical radiologist at the Department of Neuroradiology, Aarhus University Hospital, and has started her PhD study at CFIN in 2009.
Her research concentrates on the role of perfusion weighted MRI (PWI) in evaluating neovascularization and hypoxia in primary brain tumors. The aim of her study is to investigate new and more precise methods to identify the most aggressive parts of brain tumors, which would improve our understanding of tumor biology and could entail better treatment options for these patients.

Functional hemodynamics research engages in close collaborations with the neuroinformatics group headed by Kim Mouridsen. This collaborative work aims to integrate multimodal image data into models of disease progression, primarily in acute stroke. This work has been a crucial part of the EU funded ***I-Know*** project, whose first project phase was successfully completed in 2009.

Outreach

Much due to CFIN research, so-called perfusion CT and perfusion MRI is now widely used in the management of acute stroke, due to its sensitivity to local reductions in perfusion pressure in cerebrovascular disease. CFIN is committed to translate its newest research into freely available software tools (www.cfin.au.dk/software), and training of medical and engineering professionals to better utilize these tools for the benefit of patients world-wide. Leif Østergaard, who pioneered perfusion imaging, hence devotes part of his time to outreach and educational activities under the auspices of the International Society for Magnetic Resonance in Medicine (ISMRM), and the Europeans Society for Magnetic Resonance in Medicine and Biology (ESMRMB).

The ISMRM outreach initiative in Russia involved visits to Moscow and Irkutsk. Here, the Faculty: JL Bloem (Leiden University Medical Center), C Matos (Free University of Brussels), Georg Bongartz (University Hospital Basel), Heinz Peter Schlemmer (University of Tübingen), K Iliasov (Kazan), Jürgen Henning (Freiburg University), Leif Østergaard (CFIN) visits Bajkal Lake with Russian organizers. May 2009.
Photo courtesy of Jürgen Henning

SELECTED RESEARCH PROJECTS:

Anna Tietze, Per Borghammer, Suzan Dyve, Leif Østergaard. Advanced Magnetic Resonance Imaging techniques – a tool to predict brain tumor types and grades and to assess therapy response.

Irene Klærke Mikkelsen, Birgitte Fuglsang Kjølby, Leif Østergaard: Perfusion CT.

Birgitte Fuglsang Kjølby, Leif Østergaard, Valerij Kiselev (Freiburg University, Germany): Relationship between relaxation and contrast concentration in DSC MRI.

Peter Johannsen, Elisabeth Petersen, Kim Mouridsen, Leif Østergaard: Perfusion and Predictive Models in Hereditary Frontal Dementia.

Birgitte Fuglsang Kjølby, Irene Klærke Mikkelsen, Leif Østergaard, Valerij Kiselev (Freiburg University, Germany): Optimized deconvolution in perfusion imaging.

Kim Mouridsen, Sune Jespersen, Mahmoud Ashkanian, Leif Østergaard: Modelling of flow heterogenuity.

Kim Mouridsen, Kristjana Ýr Jonsdóttir, Kartheeban Nagenthiraja, Leif Østergaard: Inferential models in acute stroke.

Rikke Beese Dalby, Leif Østergaard, Raben Rosenberg, Poul Videbech: Perfusion and connectivity in late-onset dementia.

Paul von Weitzel-Mudersbach, Kristina Dupont, Jacob Blicher, Kim Vang, Grethe Andersen, Leif Østergaard, Arne Møller: Examination of oxygen metabolism and cerebral blood flow in the ischemic penumbra compared to healthy brain tissue, a PET study.

Mahmoud Ashkanian, Kim Mouridsen, Sune Jespersen, Grethe Andersen, Jean-Claude Baron, Leif Østergaard: Oxygen delivery in acute stroke.

Niels Hjort, Kristjana Ýr Jonsdottir, Kim Mouridsen, Lars Ribe, Leif Østergaard: I-Know: Integrating Information from Molecule to Man: Knowledge Discovery Accelerates Drug Development and Personalized Treatment in Acute Stroke” (I-Know project under EU's 6th framework program).

Kim Mouridsen, Kartheeban Nagenthiraja, Kristjana Ýr Jónsdottir, Niels Hjort, Leif Østergaard: Predictive models in acute stroke.

FUNCTIONAL HEMODYNAMICS

I-Know: Developing Future Computer Based Therapeutic Guidance

by Leif Østergaard

In 2009, the ***I-Know*** project, coordinated by CFIN, finalized its first project phase, funded by € 3M from the European Union ICT program. ***I-Know*** joins leading European Stroke experts, and experts within susceptibility physics, to improve image based markers of high tissue infarct risk in acute stroke, and to combine these with genetic, biochemical and clinical data into predictive algorithms to support acute stroke management and cost-effective drug development.

Novel Imaging Markers

The improvement of image markers primarily aimed to improve the quantification of perfusion weighted MRI – speculating that more accurate perfusion values relative to physiological thresholds ('penumbra') would improve predictions. The Freiburg group showed that this can be achived by simultaneous acquisition of gradient echo and spin echo based perfusion raw data. While such acquisition techniques are not currently available on clinical scanners, this development opens new avenues in perfusion MRI.
Another important break-through was achieved by the Aarhus and Freiburg groups during analysis of the impact of MRI acquisition paramters and the approach to reduce noise during calculation of perfusion maps (regularization): Current state-of-the-art methods were shown to be heavily biased by the temporal resolution of the acquired raw data, and to provide poor discrimination between poorly and normally perfused tissue. Instead, a novel filtering approach was developed to facilitate data comparison across modalities, and to more accurately distinguish hyperfused tissue. The graphs in Figure 1 show simulations of the retrieval of fixed flow values under the influence of noise: The resulting uncertainty in absolute flow values of extisting methods – lower three panels – is greatly reduced by the new method – two top panels. This discovery is believed to improve scientific comparison of perfusion thresholds across stroke studies and to improve the prediction algorithms developed in ***I-Know*** by providing more precise perfusion values.

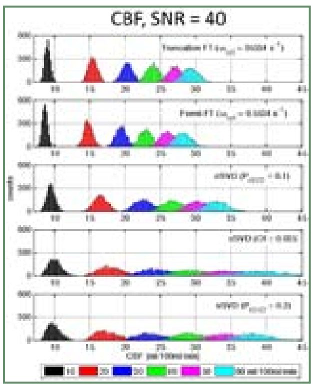


Figure 1
Sacrificing accuracy (the retrieval of 'true' CBF values - lower two panels) for higher precision (upper panels)) may help distinguish critically hypoperfused tissue. Intrasubject normalization to white matter values (remains constant with age at approximately 20 ml/100ml/min) allows better discriminatation of critically hypoperfused gray matter (CBF below normal gray matter values).

Unique Patient Data Base

The aim of the project is to develop software that predicts voxel-by-voxel outcome in stroke patients at hospitals world-wide with highest possible degree of accuracy, based on expert-classified stroke cases and data-integration models. Four leading European clinical stroke labs set out to characterize 120 acute stroke patients (1-12 hours after symptom onset) in terms of pre-existing risk factors, clinical and neuroimaging characteristics at presentation, and at follow-up. Evidence further suggeste that genotype and acute inflammatory markers may affect stroke outcome, just as early reperfusion (requiring an additional scan two hours after thrombolytic treatment) is believed to reduce subsequent tissue damage. The project therefore set out to include these data in as many patients as possible.

In total, about 350 patients were screened, and 170 patients included in the study database. Of these, 24 were excluded, mainly because patients died before follow-up, or because inclusion criteria or data quality requirements were not met. The final database is therefore believed to involve 146 patients, far beyond the 120 projected.

The database is – at an international level – the largest and most well-characterized to date, and will undoubtly be the source of scientific discoveries and futher refinement of predictive algorthms in years to come, supporting patient management discoveries.

Prediction and Inference

The ***I-Know*** project set out not only to provide a prediction engine to integrate known stroke cases into case-by-case tissue risk predictions to support patient management, but also to explore methods to detect subtle changes in disease progression across patient subgroups, in order to infer disease mechanisms, the specific effects of risk factors, and treatment effects.

Predictive modeling was relatively new as the project started, and the ***I-Know*** project has significantly contributed to the development of this field. Kristjana Jonsdottír discovered the crucial importance of correctly selecting the training material for predictive models, believed to have greatly biased previous work. The balanced training set approach, developed and published in *Stroke*, is now used in CFIN research, along with newly developed means of assessing predictive model performance, and of establishing and visualizing group and individual differences.

The *I-Know* Engines

The prototype contains a number of innovative scientific developments, facilitating automated analysis of acute stroke. The arterial input search, a manual and time-consuming step in the time-critical patient management, was made automatic and implemented in the software platform according to a method developed by Mouridsen et al. This is now embedded in user-fiendly software, performing crucial preprocessing and segmentation steps automatically, while providing the user with easy overview of the result and succes of each step.

Figure 2
Fast and reliable segmentation of lesioned tissue is crucial in acute management of stroke, as thrombolytic treatment of large lesions (beyond 100 ml tissue) may result in serious side-effects, and carry little chance of success. This step is now implemented as a user-friendly semiautomatic procedure.

In response to needs emerging during the project, Kim Mouridsen developed automated outlining algorithms for acute DWI (surrogate for initial infarct volume) and MTT (hypoperfused tissue, so MTT - DWI is a surrogate for salvagable tissue) lesio – see Figure 2. This software has been thoroughly tested by the partners sites as tools in the outlining of patient data (including follow-up lesions) - see Figure 3.

The ***I-Know*** prototype includes a unique feature, namely prediction models. During the project, we developed the concept of a 'best-case – worst-case' scenario, in which models based on non-reperfusing and reperfusing patients are shown side-by-side to display tissue that may be salvageable by succesful thrombolytic treatment. In Figure 4, the upper and

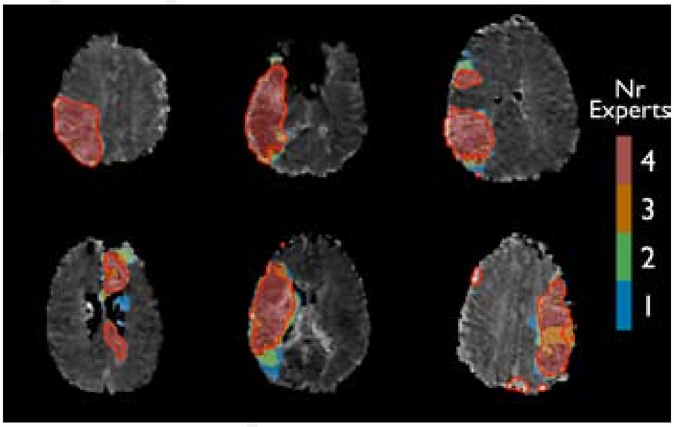


Figure 3
The detection of hypoperfused tissue is crucial to detect tissue that may benefit from thrombolytic treatment. This task depends on highly trained specialist, which often disagree on the extent of the lesion (the number of experts who agree on a given area being hypoperfused is shown by the overlay color). Automatic software now allow automatic detection of hypoperfused tissue (tissue within full red line) in agreement with the consensus of – in most cases – all four experts. Here shown in brain imaging slices from 6 patients

lower rows corresponds to a predictive model for untreated and treated patients, respectively, suggesting not only that treatment effect can be inferrred from the models, but that predictions specific to the treatment at hand may be made available prior to treatmet The current 'best-case – worst case' output of the ***I-Know*** predictive algorithm is a prediction model based on succesful or unsuccesful treatment at a patient level (reperfusion according to TOAST criteria). In the

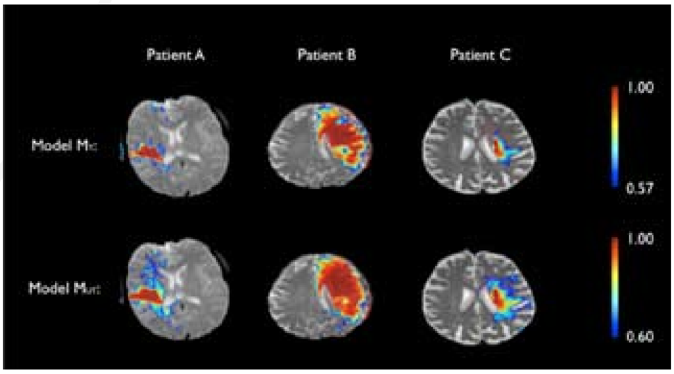


Figure 4
Two stroke progression models – one based on treated patients (M_T), the other on untreated patients (M_{UT}) – applied on acute data from three different patients. Note the difference in predicted risk of subsequent infarction.

near future, we will commence building such a model based on voxel-by-voxel reperfusion status after two hours in the ***I-Know*** database. This is a complex task as patients must be carefully balanced in terms of clinical presentation.

The I-Know inference Engine: The effects of risk factors and treatment

One of the goals of the study was to prove that the statistical power of predictive algorithms would allow the detection of subtle group differences (inference) in disease progression due to treatment, or clinical 'risk factors'.
In our early work, Wu et al. demonstrated that the effects of rtPA was detectable in small patient cohorts, comparing predicted and follow-up lesion volumes. Comparing predicted lesion volumes among treated and untreated patients, this finding was subsequently confirmed in the preliminary analysis of the ***I-Know*** database.

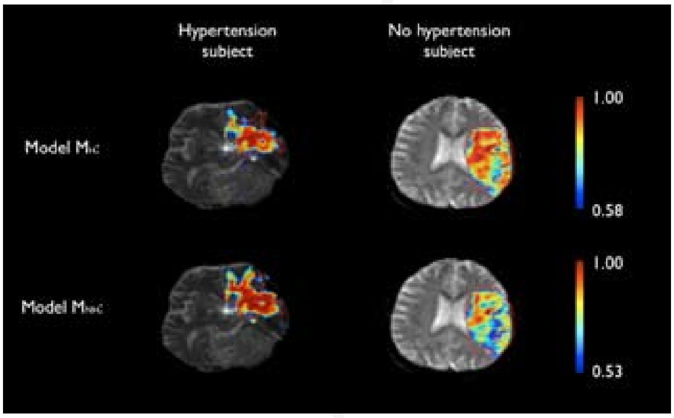


Figure 5
Stroke progression models – one based on hypertensive patients, one on normotensive patients – applied to acute data from two patients, one with hypertension, one without a history of hypertension. Note how the risk of subsequent infarction seemingly depend on prior hypertension.

During patient inclusion, known risk factors were recorded, and as a first proof-of-concept, that we may detect the effects of risk-factors on stroke progression that are otherwise observed in large (N>1000) studies of neurological outcomes, we examined the effects of hypertension and diabetes on stroke progression. While the current N=87 fell just short of showing the poorer prognosis for diabetic patients, the worse infarct progression of patients with hypertension was significant – and striking (illustrated in Figure 5). We await the complete database for revisiting the effect of diabetes, and the final analysis of genetic markers. Following this more detailed analysis of the impact of risk factors, the need for 'patient specific' predicton modules for clinical usage will be evaluated.

CT prediction module

In addition to the original work plan, the Consortium chose to exploit the developments within predictive algorithms and know-how on perfusion algorithms to provide diagnostic and treatment support software for the growing use of CT perfusion in acute stroke management.

Irene Mikkelsen devised a fully automated CT perfusion software. Furthermore, a prototype CT-perfusion prediction module was established and compared with current, commercially available 'treatment guidance' based on perfusion thresholds. Our preliminary analysis suggest that the inclusion of more image modalities outperforms the current state-of-the-art-methods.

Considering the widespread availability and usage of CT in acute stroke management, this work-in-progress will be explored further. This integration of knowledge, methods and standards across imaging platforms will greatly increase the impact of the software, the flexibility of use for physicians, and hopefully the quality of care to patients.

Professor Jean-Claude Baron, Cambridge University, a leading international authority on stroke pathophysiology, arranged the Spring ***I-Know*** meeting in 2009. During the meeting Consortium members experienced at Queens's College 'Old Dining Hall', used by Fellows and students for over 500 years.

International collaborations

The European ***I-Know*** consortium formed strong links with ASIST-Japan, a national network for standardization of processing and visualization of stroke data, in order to promote the adoption of international standards. The Japanese network developed important software and visualization standards, and widely used free-ware, Perfusion-Diffusion Mismatch Aanalyzer (PMA).

With sponsorship and local logistical support from Nordic Imaging Lab and the Norwegian Embassy in Tokyo, a Neuroimaging Symposium, with mutual presentations from the ***I-Know*** and ASIST networks and software presentation by NIL was held, with participation from leading medical imaging companies and key, presenting ASIST leaders: Dr. Makoto Sasaki (ASIST Principal Investigator), Dr. Kohsuke Kudo (ASIST investigators and PMA developer), Dr. Kei Yamada (ASIST Investigator), Dr. Masaharu Sakoh (ASIST Collaborator). The meeting was a great succes, with a strong wish from the ASIST network to collaborate with the ***I-Know*** Consotium, and to develop common perfusion and image visualization standards. As a result, Dr. Kudo visited CFIN in July 2008 to develop common standards for the ***I-Know*** and PMA software platforms.

I-Know partners:

CFIN / Aarhus University Hospital
Leif Østergaard

Institut National de la Santé et de Recherche Medicale /
Université Claude Bernard
Professor Norbert Nighoghossian

Fundació Privada Institut d'Investigació Biomédica de Girona
Salvador Pedreza

University of Cambridge
Jean-Claude Baron

Universitätsklinikum Hamburg-Eppendorf
Jens Fiehler

Universitätsklinikum Freiburg für die Medizinische Fakultät der Albert-Ludwigs-Universität
Valerij G. Kiselev

Systematic Software Engineering A/S

Dimac A/S

References

Neumann AB, Jonsdottir KY, Mouridsen K, Hjort N, Gyldensted C, Bizzi A, Fiehler J, Gasparotti R, Gillard JH, Hermier M, Kucinski T, Larsson EM, Sørensen L, Ostergaard L. Interrater agreement for final infarct MRI lesion delineation. Stroke. 2009; 40(12): 3768-3771.

Cho TH, Hermier M, Alawneh JA, Ritzenthaler T, Desestret V, Østergaard L, Derex L, Baron JC, Nighoghossian N. Total mismatch: negative diffusion-weighted imaging but extensive perfusion defect in acute stroke. Stroke. 2009; 40(10): 3400-3402.

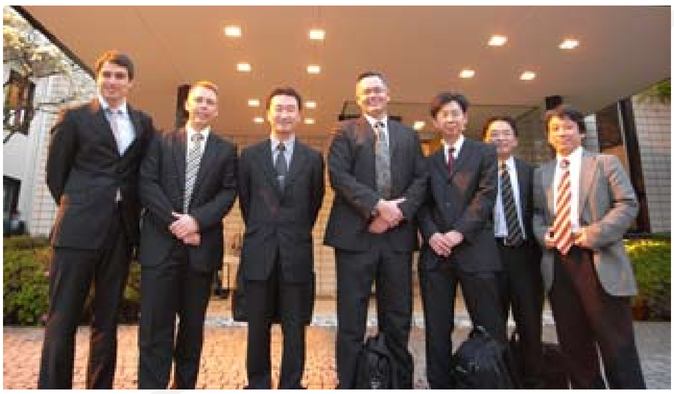
Jonsdottir KY, Østergaard L, Mouridsen K. Predicting tissue outcome from acute stroke magnetic resonance imaging: improving model performance by optimal sampling of training data. Stroke. 2009; 40(9): 3006-3011.

Siemonsen S, Mouridsen K, Holst B, Ries T, Finsterbusch J, Thomalla G, Ostergaard L, Fiehler J. Quantitative T2 values predict time from symptom onset in acute stroke patients. Stroke. 2009; 40(5): 1612-1616.

Takasawa M, Jones PS, Guadagno JV, Christensen S, Fryer TD, Harding S, Gillard JH, Williams GB, Aigbirhio FI, Warburton EA, Østergaard L, Baron JC. How reliable is perfusion MR in acute stroke? Validation and determination of the penumbra threshold against quantitative PET. Stroke. 2008; 39(3): 870-877.

Wu O, Christensen S, Hjort N, Dijkhuizen RM, Kucinski T, Fiehler J, Thomalla G, Röther J, Østergaard L. Characterizing physiological heterogeneity of infarction risk in acute human ischaemic stroke using MRI. Brain. 2006; 129(Pt 9): 2384-2393.

Hjort N, Butcher K, Davis SM, Kidwell CS, Koroshetz WJ, Röther J, Schellinger PD, Warach S, Østergaard L; UCLA Thrombolysis Investigators. Magnetic resonance imaging criteria for thrombolysis in acute cerebral infarct. Stroke. 2005; 36(2): 388-397.



From left to right: Kyrre Emblem, Rikshospitalet, Norway (Symposium Invited Speaker); Tormod Thomsen (CEO, Nordic Imaging Lab); Dr. Masaharu Sakoh (ASIST Collaborator); Leif Østergaard (***I-Know*** Principal Investigator); Dr. Kohsuke Kudo (One of eight ASIST investigators and PMA developer); Makoto Sasaki (ASIST Principal Investigator); Kei Yamada (ASIST Investigator) in front of the Norwegian Embassy in Tokyo.

Brain Perfusion Imaging: Quantification of CBF Using ASL Techniques

by Esben Thade Petersen

The measurement of quantitative cerebral blood flow (CBF) using non-invasive arterial spin labeling (ASL) techniques is challenging due to uncertainties in bolus arrival time, arteria input function (AIF), complex underlying kinetics, and static tissue parameters such as arterial bloods equilibrium-magnetization ($M_{a,0}$). As part of this PhD project, an ASL technique, capable of measuring the AIF and $M_{a,0}$, was proposed for CBF quantification using model-independent deconvolution.

The overall hypothesis was that this new ASL perfusion method, dubbed "Quantitative STAR Labeling of Arterial Regions" (QUASAR), would produce reproducible results across multiple clinical sites at 3T images. In addition, that its ability to measure individual perfusion territories would make it suitable for clinical evaluation of patients with cerebrovascular diseases.

While enrolled in the PhD program at CFIN in Aarhus, the majority of the work was performed on a 3.0 T Philips Intera Imager (Philips Medical Systems, Best, The Netherlands) located at National Neuroscience Institute in Singapore. The work was divided into three main parts: Technical Developments, Test-Retest validation, and Clinical validation and exploration.

The backbone of the thesis was the development of the QUASAR sequence published in MRM in 2006[1], allowing measurement of CBF (based on deconvolution by local AIFs), arterial blood volume (aBV) as well as arterial transit times (ATT).

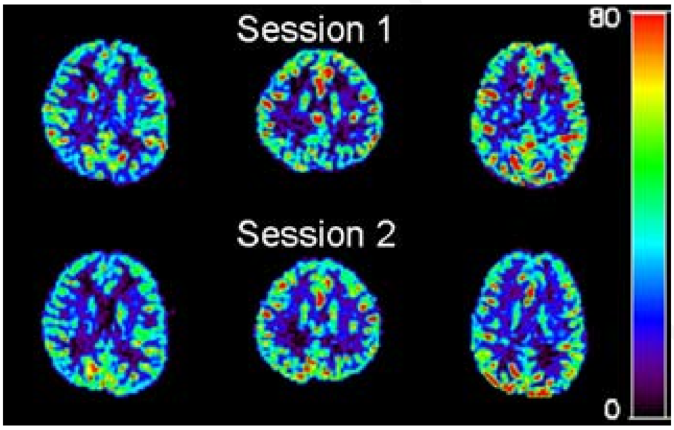


Figure 1
CBF maps from three different subjects at three different sites. The upper row is from session 1 and the lower row is from session 2. Note the good match of location between the two scan sessions, a direct result of using automatic planning.

The reproducibility of the technique was evaluated by means of a multi-center reproducibility trial in 284 healthy subjects at 28 different collaborating MRI sites. Based on these results, mean gray matter CBF was found to be 47.4±7.5 [ml/100g/min] with a between-subject standard deviation SD_b = 5.5 [ml/100g/min] and a within-subject standard deviation SD_w = 4.7. The corresponding repeatability of the technique was 13.0 [ml/100g/min] across all 28 sites and was found to be within the range of previous studies using other more invasive modalities. Figure 1 shows example perfusion maps from

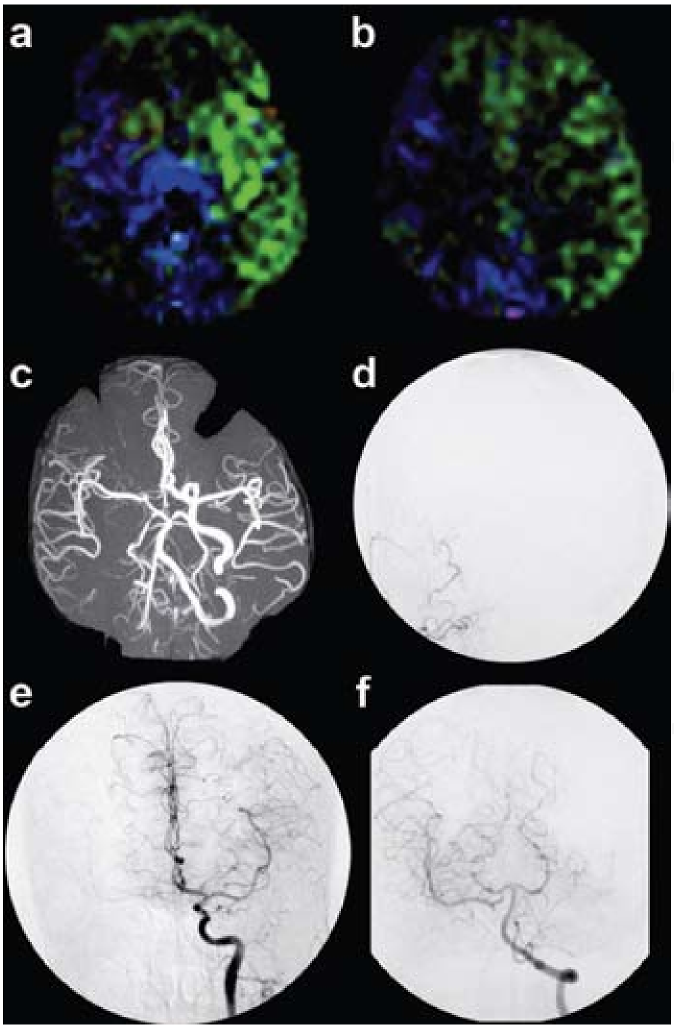


Figure 2
Patient with right ICA occlusion. **a** and **b**: TASL of the patient with posterior circulation coded in blue, left ICA in green and right ICA in red, showing collateral flow to the right ACA and right MCA territories from the left ICA and posterior circulation, respectively. **c**: TOF MRA of the same patient gave corresponding anatomicical information on the collateral flow pattern. This correlated with the patient's DSA study in **d** (right common carotid angiogram, frontal projection) which showed occluded right ICA, **e** (left ICA angiogram frontal projection) showing collateral flow to the right ACA territory via the ACommA, and **f** showing left vertebral artery collateral flow to the right MCA territory via the PCommA.

three different sites. Each subject was scanned twice with 1-2 weeks interval.

For clinical validation 177 patients were examined, aiming to establish ASL as a reliable clinical tool for the assessment of CBF, as well as collateral perfusion in cerebrovascular diseases.

The first study used the territorial labeling (TASL) capabilities of the QUASAR sequence. A pilot study comparing TASL and Digital subtraction angiography (DSA) in large vessel disease (N=18), suggested that TASL provides comparable information on collateral flow as DSA[2]. An example case is shown in Figure 2.

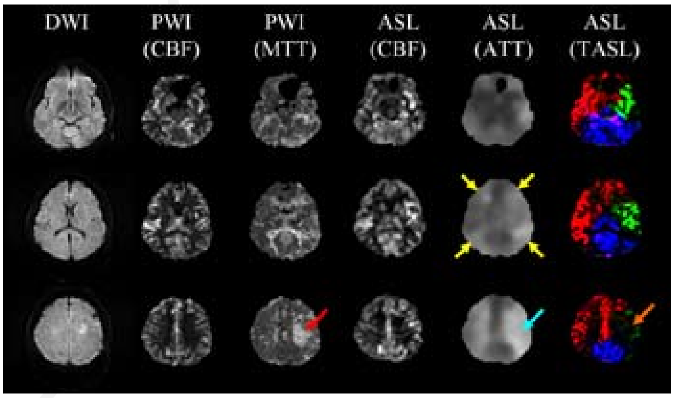


Figure 3
Three imaging slices from various MR modalities. From left: diffusion weighted images, contrast based- Cerebral Blood Flow, Mean Transit Time, and ASL based- Cerebral Blood Flow, Arterial Arrival Time (from labeling plane to image region) and finally the vascular territories depicted as red-green-blue for right and left internal carotid artery and posterior circulation, respectively.

In another study (N=159), the diagnostic information provided by perfusion territory imaging was found to be valuable for the classification of cortical and border zone infarcts[3]. However, future studies in acute stroke patients (<4.5 hours) are needed to establish whether the characterization of collateral flow with TASL MRI may predict tissue fate and clinical outcome.

Finally, exploration of ASL for determination of watershed areas (N=15)[4] and comparison of the established gadolinium based perfusion method (PWI) to ASL were performed (N=159)[5], see Figure 3 & 4.

The goal of this research was to further develop ASL towards a point where it can be considered a clinical tool for the evaluation of patients with cerebrovascular diseases. We showed that ASL, at this stage, is sufficiently robust to be

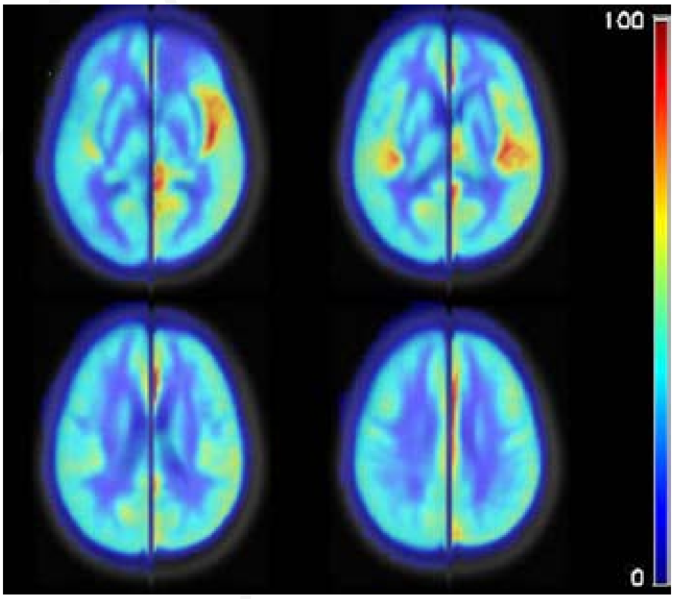


Figure 4
CBF maps from non-infarcted hemisphere have been registered to MNI space (N=87). In every slice, the left side shows the maps based on ASL and the right side shows the maps based on gadolinium PWI. Notice the dropout in the lower frontal area as compared to ASL and the large vessel artifacts often seen in PWI images (arrows).

performed across multiple clinical sites and that its ability to measure parameters such as collateral perfusion is comparable to DSA which is considered the gold standard. The ability to assess CBF, aBV, ATT and regional perfusion makes ASL a promising tool for predicting outcome and future risk of stroke in patients with cerebrovascular diseases. Our studies showed that ASL can successfully be applied in acute stroke patients and to some extent show comparable information to PWI, however studies in the early phase (<4.5 hours) with appropriate follow up imaging will be needed to further explore this potential.

References

1. Petersen ET, Lim TCC, Golay X. Model-Free Quantitative Arterial Spin Labeling Approach for Perfusion MRI. Magn. Reson. Med., 2006; 55(2): 219-232
2. Chng SM, Petersen ET, Zimine I, Sitoh YY, Lim CC, Golay X. Territorial Arterial Spin Labeling in the Assessment of Collateral Circulation. Stroke, 2008; 39(12): 3248-54
3. Hendrikse J, Petersen ET, Chèze A, Chng SM, Venketasubramanian N, Golay X. Relation Between Cerebral Perfusion Territories and Location of Cerebral Infarcts. Stroke, 2009; 40(5): 1617-1622
4. Hendrikse J, Petersen ET, van Laar PJ, Golay X. Magnetic Resonance Imaging of Cerebral Borderzones. Radiology, 2008; 246(2): 572-580
5. Petersen ET, Tchoyoson, Lim CC, Venketasubramanian N, Golay X. Comparison of ASL and PWI Perfusion in Stroke Patients, In proceedings of ISMRM, 2009; p. 32.

FUNCTIONAL HEMODYNAMICS

Optimization and Validation of Perfusion MRI Post-Processing Techniques

by Søren Christensen

Stroke is the second most common cause of death in the western world and a major cause of disability worldwide. Thrombolytic treatment can reopen the occluded vessel and salvage brain tissue by re-establishing blood flow, but this treatment also carries a risk of intracranial haemorrhage that worsen the outcome. Intravenous thrombolytic treatment is currently only considered safe and efficacious within 4.5 hours after stroke onset, based on recent studies in a large number of acute stroke patients (Hacke et al. 2008). It is believed that MRI techniques, with their unique abilities to image cerebral perfusion and cell integrity, can help select patients who benefit from thrombolytic therapy based on individualized evaluation of the brain tissue rather than by a one-size-fits-all cut-off time for this crucial treatment (Hjort et al. 2005).

The thesis addressed several aspects of how to optimize the prognostic value of perfusion weighted MRI:

A technique was developed to approximate the inflow pathways of blood from the larger vessels to the cerebral vasculature using a clinical MRI bolus tracking perfusion acquisition (Christensen et al. 2008). The method has potential for determining presence, location and timing of collateral flow which is a key factor in tissue survival during acute stroke. Figure 1 shows an example of how patterns of collateral flow can be depicted. In practice, there currently is no practical alternative to image collateral flow in acute stroke.

The technique also finds use in enhancing the processing of perfusions maps by so called local Arterial Input Function (AIF) methods, speculated to be superior to the conventional global AIF methods currently in use at many research centres (Lorenz et al. et al. 2006).

Using a retrospective cohort of 97 acute stroke patients imaged within 6 hours of stroke onset, the largest systematic comparison of perfusion maps so far, local AIF and conventional perfusions maps were compared in terms of their ability to predict final tissue infarction (Christensen et al. 2009). The best performing perfusion metrics were parameters that did not rely on any modelling ('First Moment' and 'Time-To-Peak' maps). These methods performed non-significantly better than measures based on global AIF techniques but significantly better than Local AIF techniques.

Finally, a *post hoc* analysis on the recently completed EPITHET trial (Davis et al. 2008) addressed the effect of changing mismatch definitions on observed treatment effect. It was shown that more restrictive definitions defined a sub-population with a larger response to treatment. Mismatch definitions are hence crucial not only in defining the target population, but also the efficacy signal in drug trials.

References

Christensen S, Calamante F, et al. (2008). Inferring origin of vascular supply from tracer arrival timing patterns using bolus tracking MRI. J Magn Reson Imaging 27(6): 1371-1381.

Christensen S, Mouridsen K, et al. (2009). Comparison of 10 perfusion MRI parameters in 97 sub-6-hour stroke patients using voxel-based receiver operating characteristics analysis. Stroke 40(6): 2055-2061.

Davis SM, Donnan GA, et al. (2008). Effects of alteplase beyond 3 hours after stroke in the Echoplanar Imaging Thrombolytic Evaluation Trial (EPITHET): a placebo-controlled randomised trial. Lancet Neurol 7(4): 299-309.

Hacke W, Kaste M, et al. (2008). Thrombolysis with alteplase 3 to 4.5 hours after acute ischemic stroke. N Engl J Med 359(13): 1317-1329.

Hjort N, Butcher K, et al. (2005). Magnetic resonance imaging criteria for thrombolysis in acute cerebral infarct. Stroke 36(2): 388-397.

Lorenz C, Benner T, et al. (2006). Automated perfusion-weighted MRI using localized arterial input functions. J Magn Reson Imaging 24(5): 1133-1139.

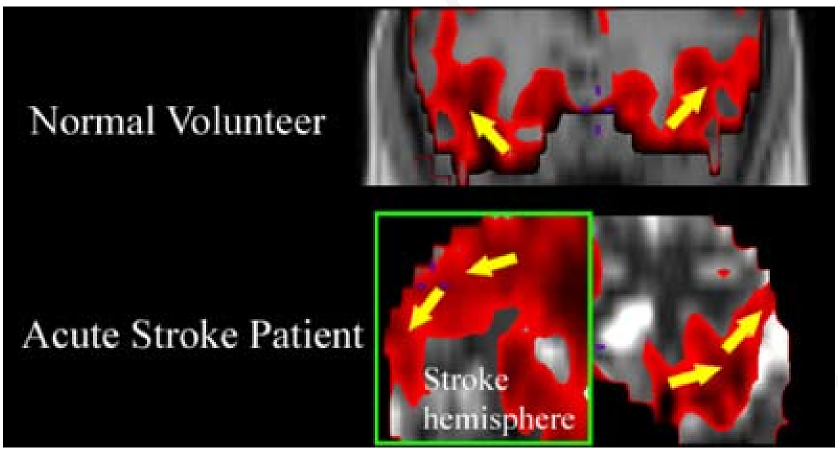


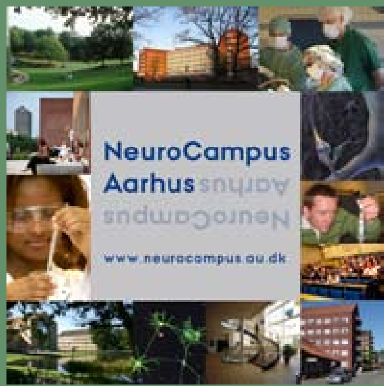
Figure 1
The inflow patterns in the volunteer (top) compared to the pattern seen in the patient. The patient image is a synthesized image of very long FM (left side of image where there is no small FM values) and very short (right side of image). The yellow arrows indicated the route of blood supply/arrival based on the observed patterns.

NEW RESEARCH CLUSTER AT AARHUS UNIVERSITY

NeuroCampus Aarhus,

In 2009 scientist from across Aarhus University created NeuroCampus Aarhus, a crosscutting research cluster within neuroscience. This collaboration is inspired by strong scientific and personal relations across AU neuroscience research labs, including Hammel Neurocenter and Center for Psychiatric Research, Risskov. About 50 scientists, and the deans from the Faculties of Science and Health Sciences, met for a founding, informal, NeuroCampus trademark 'wine and pizza' meeting in March 2009, discussing joint recruitment efforts and means of stimulating further collaboration. As a first initiative, the calls for three neuroscience professorships were coordinated and posted internationally, and monthly NeuroCampus seminars now combine basic and clinical lectures and discussions in the DNC building while Sigma Seminars gather neuroscientists at the Lake Auditorium. A task force of neuroscientists now works to further stimulate collaboration across basic and clinical neuroscience.

See www.neurocampus.au.dk



NeuroCampus Aarhus (NCA) strives to understand normal brain function and its changes in neurological and psychiatric diseases. NCA comprise basic sciences ranging from neurogenetics, molecular and cellular neurobiology to clinical neuroscience, rehabilitation research and cognitive neuroscience. NeuroCampus research has strong translational traditions, being partly embedded in the Aarhus University Hospital Neuocenter. NeuroCampus Aarhus is a focus area of AU and receives strong support from the Lundbeck Foundation, The Danish National Research Foundation, Aarhus University Hospitals, the Danish Ministry of Science, Technology and Innovation, and numerous industrial partners.

Aerial view of
Aarhus University campus
and Aarhus University Hospital

Hedonia: TrygFonden Research Group

The importance of the parent-infant relationship

by Morten L. Kringelbach and Alan Stein

Hedonia: TrygFonden Research Group is based both at CFIN and University of Oxford, UK. We are interested in understanding the functional neuroanatomy of pleasure (Figure 1), and in particular the brain mechanisms underlying the lack of pleasure, anhedonia, which is found in a range of disorders including depression, eating disorders and obesity. Our research is being carried out using a combination of neuroimaging methods in normal, neuropsychiatric and other clinical populations. The hope is that this research may help to improve the quality of life of affected patients.

In last year's report we described the progress in the part of our research linked to restoring normal function using deep brain stimulation. Deep brain stimulation is an exciting approach which has shown remarkable promise in alleviating the symptoms of these debilitating disorders and bettering the lives of the sufferers. This research is carried out in collaboration with Professor Tipu Aziz who has recently become an adjunct professor at Aarhus University. In the coming years we plan to extend the deep brain stimulation service to include Danish patients. At the same time we continue to write and lecture on the importance of the ethical considerations, and especially how we should be careful not to regress to the errors of psychosurgery (Kringelbach and Aziz, 2009).

This year we are focusing on describing a complementary part of our research which is related to understanding the development of pleasure, and in particular the functional neuroanatomy of the early interactions between parents and infants. This research is carried out in collaboration with Professor Alan Stein who has helped pioneer this field of research. Such research is not just for select patients but has the potential to better the lives of future generations. At the same time we have a moral obligation to expand this research beyond our European context and also try to help children in places such as Africa. Our collaborators have shown that some of the new insights can make a big difference in developing countries and we are committed to continuing this research by collecting further neuroscientific evidence (Cooper et al., 2009).

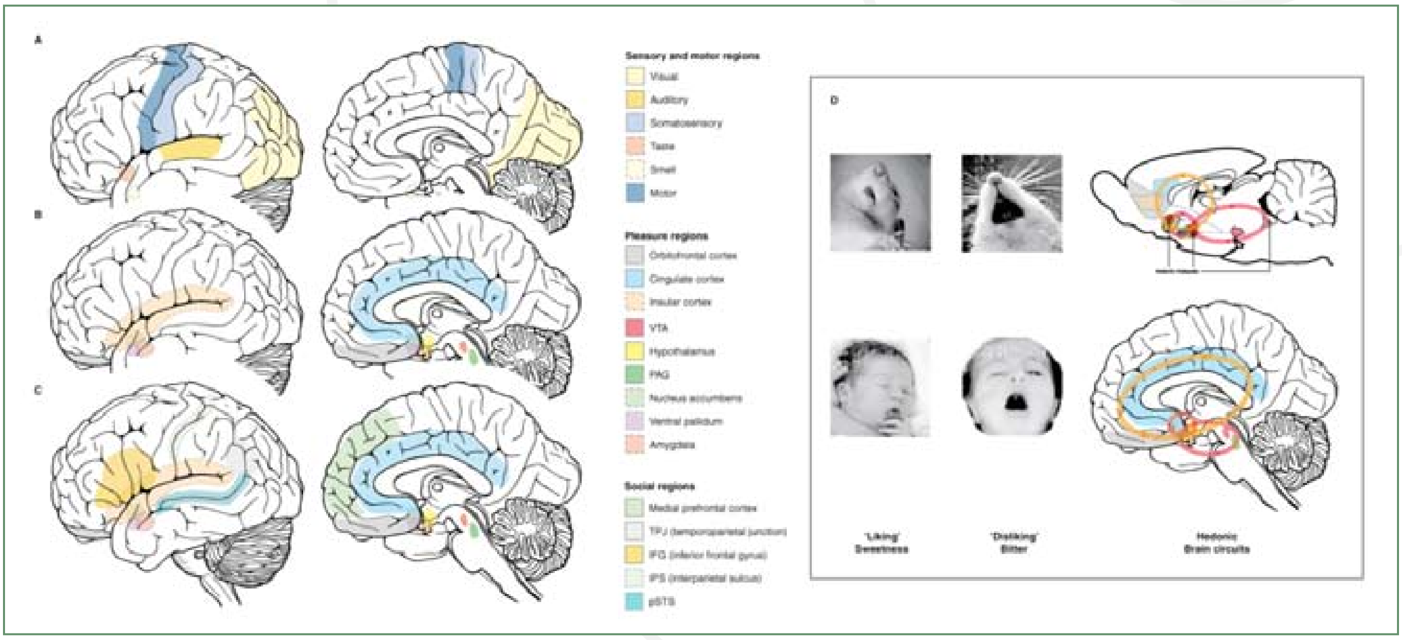


Figure 1

Adult brain systems from sensation to basic pleasures and higher-order social processing.

The schematic figure shows the approximate sensorimotor, pleasure and social brain regions in the adult brain. **(a)** The processing linked to the identification of and interaction with stimuli are carried out in the sensorimotor regions of the brain, **(b)** which are separate from the valence processing in the pleasure regions of the brain. **(c)** In addition to this pleasure processing, there is further higher-order processing of social situations (such as theory-of-mind) in widespread cortical regions. **(d)** The hedonic mammalian brain circuitry can be revealed using behavioural and subjective measures of pleasures in rodents and humans (Berridge and Kringelbach, 2008).

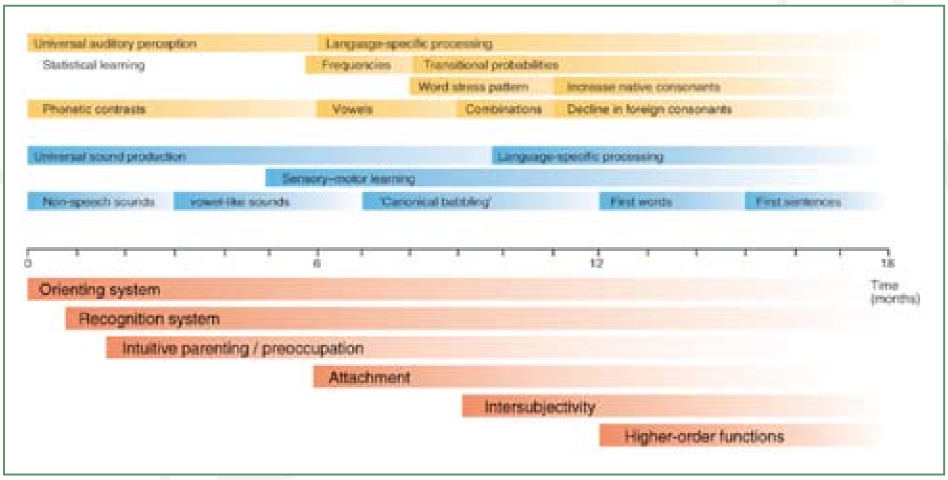


Figure 2
Timeline of the major developmental milestones (red), and examples of the infant development of auditory perception (orange) and speech production (blue).

Early parent-infant interactions

Early relationships between infants and parents are of fundamental importance for the survival and development of one's own infant, and ultimately ensure the survival of the species. Humanity is a very social species that invests heavily in nurturing and protecting the young. Accumulating evidence indicates that early life experiences have a major impact upon adult mental and physical health.

These important early parent-infant interactions are central to understanding human nature and have over the years been the subject of a large body of behavioural research. However, it has only recently become possible to link aspects of these interactions to brain activity in both infants and parents using advanced neuroimaging techniques. Affective and social neuroscience have begun to emerge as exciting disciplines characterising the brain networks involved in the processing of reward, pleasure, emotion and related behaviours. While a substantial amount of evidence has served to elucidate the intricacies of the social and affective brain in adults, less is known about its development in the early years.

Our focus is on understanding the development of the functional neuroanatomy of the evolving parent-infant relationship (Parsons et al., 2010). We try to extend our knowledge of what is known about the construction of the infant brain and the emerging abilities used to process uni- and multimodal sensory stimuli. Over time, these fundamental abilities allow infants to engage in complex social relationship with parents, caregivers and others. In the first instance we are interested in investigating how the complementary parental responses change over the course of infant development, and the neural basis of such responses.

The first 18 months form, in many respects, a developmental landmark which signifies the end of infancy (see Figure 2). While the first few years are particularly important because vital development occurs across all domains, major elements of the social and affective brain continue to develop well past early childhood. The fundamental research has important clinical applications because disturbances to normal early interactions, particularly in the context of parental psychological disorder, increase the risk of difficulties in child development. A better understanding of the development of the functional neuroanatomy of the early parent-infant relationship could thus have direct implications for enhancing affective development and experience.

Tools for understanding social attachment

We are using a number of scientific paradigms to study the nature of the social pleasures. We are using MEG to investigate how the adult brain reacts to baby faces and sounds. In the following we present some our recent findings using baby and adult faces.

The scientific interest in the cuteness of infant faces started with Charles Darwin who pointed out that in order for infants to survive and to perpetuate the human species, adults need to respond and care for their young (Darwin, 1872). The Nobel Prize-winner Konrad Lorenz proposed that it is the specific structure of the infant face that serves to elicit these parental responses (Lorenz, 1971), but the biological basis for this has remained elusive.

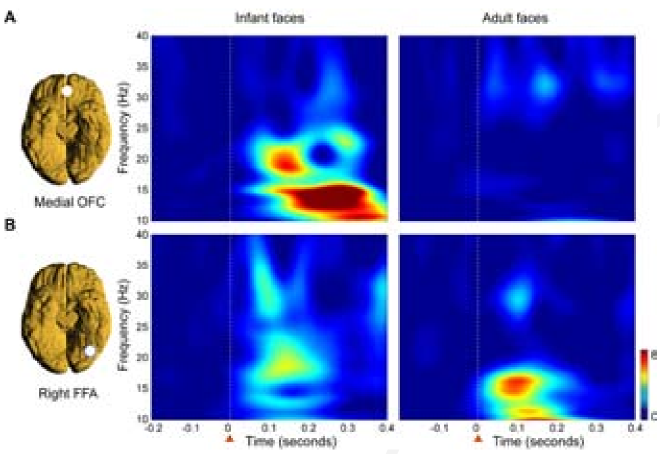


Figure 3

A parental signature? Early adult brain responses to infant faces.
Significant activity was present from around 130 ms in the right fusiform face area which did not discriminate between adult and infant faces, while the medial orbitofrontal cortex showed significant activity around the same time when viewing infant faces but not when viewing adult faces. The rows show time-frequency representations of the normalised evoked average group responses to baby and adult faces from the virtual electrodes, showing that the initial response to infant faces in the orbitofrontal cortex is present in the 12-20 Hz band from around 130 ms - and not present to adult faces (Kringelbach et al., 2008)

Using MEG in adults, we recently found that highly specific brain activity occurred within a seventh of a second in response to (unfamiliar) infant faces but not to adult faces. This activity occurred in the medial OFC, an area implicated in reward-related behaviour (Kringelbach, 2005), identifying for the first time a neural basis for this vital evolutionary process (see Figure 3) (Kringelbach et al., 2008).

Lorenz argued that infantile features serve as “innate releasing mechanisms” for affection and nurturing in adult humans and that most of these features are evident in the face including a relatively large head, predominance of the brain capsule, large and low lying eyes and bulging cheek region (Lorenz, 1971). Thus it is argued that these “babyish” features of infants increase the infant’s chance of survival by evoking parental responses, and the parents’ ability to respond is important for the survival of the species (Darwin, 1872).

While a considerable body of research has focussed on how the human brain processes adult faces, much less research has investigated the processing of infant faces. We used MEG to investigate the temporal and spatial distribution of the

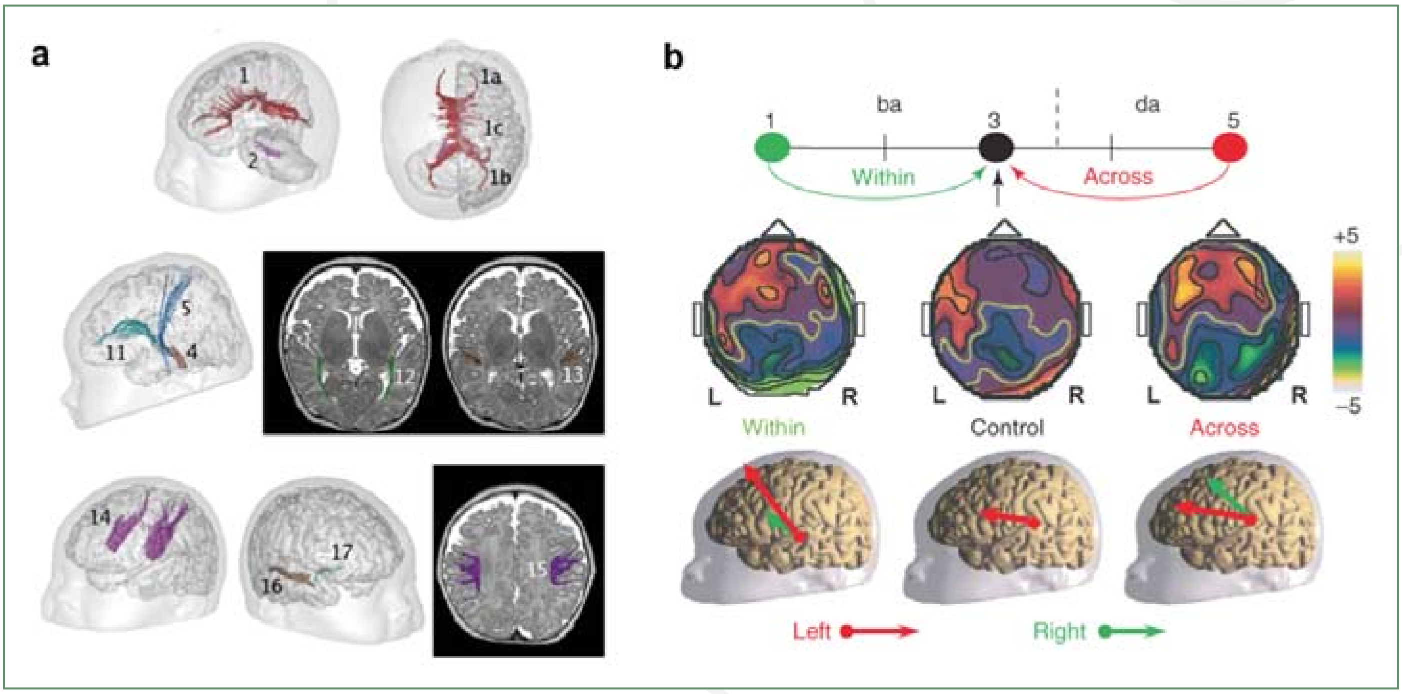


Figure 4

Development of structure and function in the infant brain.
More information is needed about the longitudinal structural changes in the infant brain. **(a)** An example is shown of using diffusion tensor imaging to track the development of the main fibre pathways (Dubois et al., 2006). Similarly more information is needed about the fine-grained temporal information of infant functional brain activity. **(b)** An example is shown from an ERP study of the infant’s phonetic processing (Dehaene-Lambertz et al., 2006)

underlying neural systems for these facial responses in 12 adult human participants. Consistent with previous findings, we found that face processing of both adult and infant faces elicits a wave of activity starting in the striate cortices and spreading along ventral and dorsal pathways.

In addition, however, we found that at around 130 ms after presentation of the infant faces, activity occurred in the medial OFC. This was not evident in response to the adult faces. These specific responses to unfamiliar infant faces occur so fast that they are almost certainly quicker than anything under conscious control suggesting that they are automatised.

Further investigations

We are currently extending these findings to further characterize these responses in parents with post-natal anxiety and depression. We are also further investigating the roots of neoteny by studying the brain responses in normal participants to infant and adult animal faces. We are also investigating how babies with cleft palate affect normal brain responses, given that we know that these facial abnormalities can negatively affect the long-term outcome of the babies (Murray et al., 2008). In future, we are planning to extend this further to look at the infant brain responses (see Figure 4).

Overall, we continue to study important aspects of the fundamental parent-infant relationship which may ultimately help generate much improved interventions. This in turn may help the well-being of future generations.

Selected references

Berridge KC, Kringelbach ML. (2008) Affective neuroscience of pleasure: Reward in humans and animals. Psychopharmacology 199, 457-480.

Cooper PJ, Tomlinson M, Swartz L, Landman M, Molteno C, Stein A, McPherson K, Murray L. (2009) Improving quality of mother-infant relationship and infant attachment in socioeconomically deprived community in South Africa: randomised controlled trial. BMJ 338: b974.

Darwin C. (1872) The Expression of the Emotions in Man and Animals. University of Chicago Press: Chicago.

Dehaene-Lambertz G, Hertz-Pannier L, Dubois J. (2006) Nature and nurture in language acquisition: anatomical and functional brain-imaging studies in infants. Trends in neurosciences 29, 367-373.

Dubois J, Hertz-Pannier L, Dehaene-Lambertz G, Cointepas Y, Le Bihan D. (2006) Assessment of the early organization and maturation of infants' cerebral white matter fiber bundles: a feasibility study using quantitative diffusion tensor imaging and tractography. Neuroimage 30, 1121-1132.

Kringelbach ML. (2005) The human orbitofrontal cortex: linking reward to hedonic experience. Nature Reviews Neuroscience 6, 691-702.

Kringelbach ML, Aziz TZ. (2009) Deep brain stimulation: Avoiding the errors of psychosurgery. JAMA 301, 1705-1707.

Kringelbach ML, Lehtonen A, Squire S, Harvey AG, Craske MG, Holliday IE, Green AL, Aziz TZ, Hansen PC, Cornelissen PL, Stein A. (2008) A specific and rapid neural signature for parental instinct. PLoS ONE 3, e1664. doi:1610.1371/journal.pone.0001664.

Lorenz K. (1971) Studies in Animal and Human Behavior, vol. II. Methuen: London.

Murray L, Hentges F, Hill J, Karpf J, Mistry B, Kreutz M, Woodall P, Moss T, Goodacre T. (2008) The effect of cleft lip and palate, and the timing of lip repair on mother-infant interactions and infant development. J Child Psychol Psychiatry 49, 115-123.

Parsons CE, Young KS, Murray L, Stein A, Kringelbach ML. (2010) The functional neuroanatomy of the evolving parent-infant relationship. Submitted.

TrygFonden

Professor Alan Stein
Professor of Child and Adolescent Psychiatry, University of Oxford, UK

His main area of research concerns the development of young children in the face of adversity. The ultimate aim of this work is to develop interventions to enhance children's early development and support their families.

The principal focus of the work has been on the impact of parental psychiatric and physical illness on children's development examining particularly the mechanisms involved in the pathways to both healthy and disturbed development. In terms of parental psychiatric illness his research team has examined the effects of maternal and paternal depression, maternal eating disorders and anxiety. His work on physical illness has involved mothers with HIV/AIDS, those experiencing poverty and malnutrition. Overall, his research involves a combination of observational, experimental and treatment studies.

COGNITION RESEARCH

by Andreas Roepstorff

Novel faces and new tools

2009 has been a year of transitions, of beginnings and endings. Via the MIND*Lab* initiative, funding for a number of researchers and for a state-of-the-art research infrastructure has come in place. This will give a strong momentum to cognitive research at CFIN and at AU in the years to come. The year also marked the end of BASIC, a Eurocores project that for the three last years has had a significant influence on the cognitive research environment.

PhD

In 2009, three PhD theses grew out of the research group, each from different insitutions: Uffe Schjødt's work on the neural substrates of prayer was based at the Institute for the Study of Religion, AU, Kamila Sip's work on neuroimaging was based at Section for Linguistics, AU, and Kristian Tylen's work on object mediated communication of deception came out of a collaboration with Institute of Language and Communication, University of Southern Denmark. All have embarked on post doc. positions in Denmark and in the US. We could also welcome four new PhD students: Martin Dietz who studies social cognition in right hemisphere patients and healthy controls, Vibeke Fuglsang Bliksted, who studies social cognition in schizophrenia, Else Marie Jegindø, who works on pain perception during religious practices and Micah Allen who works on neuroplasticity. With their backgrounds in clinical psychology, in the study of religion, in semiotics and in cognitive psychology and philosophy and with their strong links with hospitals, at the Psychiatric Hospital, at the Neurorehabilitation Unit, and at the Pain Clinic, they strengthen the research group as a nexus between basic, interdisciplinary research and translation into clinical practice.

BASIC

Every ambitious European collaboration begins as a more or less aptly named acronym and ends with an Evaluation report. Since 2006, the somewhat pretentiously titled project Brain, Agency, Self, Intersubjectivity and Consciousness has been hiding under the humble cover of BASIC. The project was part of CNCC, a European Science Foundation Eurocores programme for research on consciousness, also known as Consciousness in a Natural and a Cultural Context. BASIC brought together researchers from neuroscience, (Marc Raichle, Kai Vogeley, Marc Jeannerod and Vittorio Gallese), philosophy (Shaun Gallagher, Evan Thompson and Dan Zahavi), cognitive science (Tatjana Nazir, Patrick Haggard, Tony Jack, and Chris Frith) in a project coordinated by Andreas Roepstorff, CFIN. The aim was to examine relations between phenomenologically relevant markers of self and particular patterns of brain activity by developing both empirical research and conceptual refinement. The hope was to foster an interdisciplinary research field, where the validity is supported by a solid anchoring in well-established research traditions.

After a number of research collaborations and seminars in Europe and the US, the CNCC programme came to an end late 2009. In the final Consensus statement, the CNCC evaluation board in particular highlighted CNCC "as the most important synergistic effect, the strong interaction between natural and social sciences and the integration between philosophical and empirical investigations". BASIC, on its part, was credited with "advancing our understanding of subjectivity (along several distinct fronts) in important respects. It has yielded an increased understanding of the interplay between extended cognition and intersubjectivity and greater understanding of the role of narrative in social cognition. Methodologically, it has lead to novel attempts at integrating cultural and social processes and dynamics into research on consciousness and social cognition".

New trends in research

These keywords fit the development in the cognitive research at CFIN. Understanding the importance of cultural and social processes, and getting them right in experimental settings, is a key focus, as is the attempt of mapping out particular cases of human interaction. We have published imaging studies that focus on neuro aspects of particular social and cultural practices, e.g. in meditation (Vestergaard et al. 2009) or praying (Schjødt et al. 2009), and studies that detail particular aspects of communication such as negations (Christensen 2009) and object mediated communication (Tylen et al. 2009), and more are in the pipeline. However, as scanners are becoming more readily available in most developed countries, and as the number of publications is going up, finding 'blobs' in colourful pictures of brains appears not to be enough in itself, if it ever was...

Instead, good cognitive research seems increasingly to be about inventing novel and well characterized experimental paradigms, about coming up with motivated theories and specific and testable models, and about integrating cognitive research with underlying physiological and metabolic processes.

2009 has seen developments on all of these fronts. We have analysed a number of novel experiments, e.g. on joint action (Konvalinka et al. 2009), social judgement and joint perception. They form a pipeline of novel interactive paradigms. On the theory and modelling side, we have e.g. advanced the application of predictive coding models to the analysis of imaging data (Vuust et al. 2009) discussed how to study language as an interactive phenomenon in a material world (e.g. Tylen, Philipsen and Weed 2009, Tylen & Allen 2009), and taken the understanding of action into a complex system/emergence perspective (Skewes & Hooker 2009). As detailed in the following pages, Rasmus Aamand et al. (2009) have examined links between NO, blood-flow and neural activity, an approach that is currently to the level of cognition.

Contextualising cognitive research

In a novel, developing field, a key contribution is to open up new agendas for research, a number of review articles and opinion papers have come out in central journals, e.g. on culture and cognition (Vogeley & Roepstorff 2009), on herding behaviour (Raafat, Chater & Frith 2009), and on interacting minds (Roepstorff, Frith & Frith 2009). We are increasingly evidencing neuroscientific evidence creating an impact outside of the scientific fields themselves. Studying the use and circulation of neuroscientific facts across disciplines and contexts is an integral part of the cognitive research group, and it has been pursued e.g. through the European Neuroscience and Society Network, www.ensn.org and at the COST Law and Neuroscience conference, http://www.cost.esf.org/events/law_and_neuroscience. Another key topic is here the putative existence of sex and gender differences in the brain. Mikkel Wallentin produced a critical review of putative sex differences in language abilities and cortical structure (2009), concluding that there was little evidence to support popular claims to distinct male and female brains in this context, and the issue was the content of an extended research visit by Anelis Kaiser from Zürich. We also had an extended research visit by Ivan Tchalakov, Plovdiv University and from the winners of the ENSN social cognitive NeuroSchool in Vienna, that we co-organised. Daniel Campbell-Meicklejohn and Ivana Konvalinka were at extended research visit in London, Sanne Lodahl, were at Harvard University and Sita Kotnis were at University of Pennsylvania.

See references in publication list at page 58.

SELECTED RESEARCH PROJECTS:

Andreas Roepstorff, Peter Vestergaard-Poulsen, Martijn van Beek: Attention control: brain activity during meditation.

Chris Frith, Uta Frith, Andreas Roepstorff: Interacting minds - a biological basis.

Joshua Skewes, Andreas Roepstorff, Dan Zahavi: Agency, Self and Other, and Interdisciplinary investigation.

Mikkel Wallentin, Andreas Roepstorff, Svend Østergaard: Cognition, communication and context.

Sanne Lodahl: The selforganising brain: Context and interaction.

Joshua Skewes: As hard as it looks: Consequences of perceived difficulty for the two visual systems hypothesis.

Joshua Skewes, Bryan Patton and Jakob Hohwy : Predictive coding binocular rivalry and brain function.

Joshua Skewes: Contextual moduations of coordination dynamics in joint action.

Joshua Skewes: Bioagency and behavioural science.

Vibeke Bliksted: Social cognition in schizophrenia.

Ethan Weed: Language disturbances in right hemisphere lesioned patients.

Ivana Konvalinka: Joint tapping as a model of minimal social interaction.

Ivana Konvalinka: Synchronization of heart-rates during fire-walking.

Else Marie Jegindø: Modulation of pain by cognitive stance.

Sita Kotnis: Dual use of neurotechnologies.

Daniel Campbell-Meiklejohn: Interacting games, interacting brains.

Micah Allen: Brain plasticity

Rasmus Aamand: Carbondioxide anhydrase mediating blood flow, brain activity and cognition

Martin Dietz: Social Cognition and right hemisphere activation.

Bahador Bahrami and Dan Bang: Optimally interacting Minds

Micah Allen, Tony Jack, Han Shihui: Social cognition and default mode networks

Merlin Donald, Dan Bang, Karsten Olsen: The slow process

COGNITION RESEARCH

BOLD thoughts

by Rasmus Aamand Olesen

The field of functional brain imaging has grown wide and varied as it gathers researchers from all corners of the scientific field that share a common interest in the workings of the brain. Part of the reason for this development is the apparent ease with which one may conduct quantitative experiments that create stunning images of activity in the human brain by the use of fMRI (functional Magnetic Resonance Imaging). This technique uses changes in a Blood Oxygenation Level Dependent (BOLD) signal following brain activity as a surrogate measure of the neural activity itself. This allows researchers to explore the workings of the brain without the use of anaesthetics, surgery, tissue electrodes or sensors. In addition, fMRI provides researchers with an otherwise unparalleled spatial resolution of the “activity” of the brain. No wonder fMRI is hot! However, the use of “activity” in BOLD terms is still somewhat murky. How BOLD activity is translated from neuronal activity and metabolism, and how these aspects of the “brain puzzle” relate, is not exactly known, though we willingly use it as a measure of brain activity (e.g. read reference 1 for a review).

In order to shed a bit of light on this, we set out to search for mechanisms that could contribute to the first parts of the BOLD signal. Guided by recent findings that cerebral vasodilation (an important part of what constitutes the BOLD signal) appears to be heavily linked to astrocytic glycolysis (2, 3) and that it does not change the level of oxygenation as such (4) our primary interest was to see how the BOLD signal could relate to aerobic glycolysis. This is the first part of the energy demand time course that happens when neurons start to become metabolically active. A key enzyme in equilibrating CO_2 and pH between tissues and blood is carbonic anhydrase (CA), which, if it could convert nitrite into nitric oxide, a potent vasodilator (5), would be a perfect contender for mitigating the known relation between ensuing neuronal activity and changes in blood flow. I.e. we hypothesized that CA in this way could link changes in pH and CO_2 to the enzymatic conversion of nitrite to nitric oxide and thereby be part of a vasodilating cascade. This may appear to have been a long shot, but it turned out that it wasn’t entirely of the mark (6).

To make a long story short, by the use of NO electrodes, chemiluminescence and a vascular myograph, we showed that CA can generate NO from nitrite and apparently more effectively so at lower pH than at high pH (Figure 1). We then showed that the NO produced can take part in vasodilation

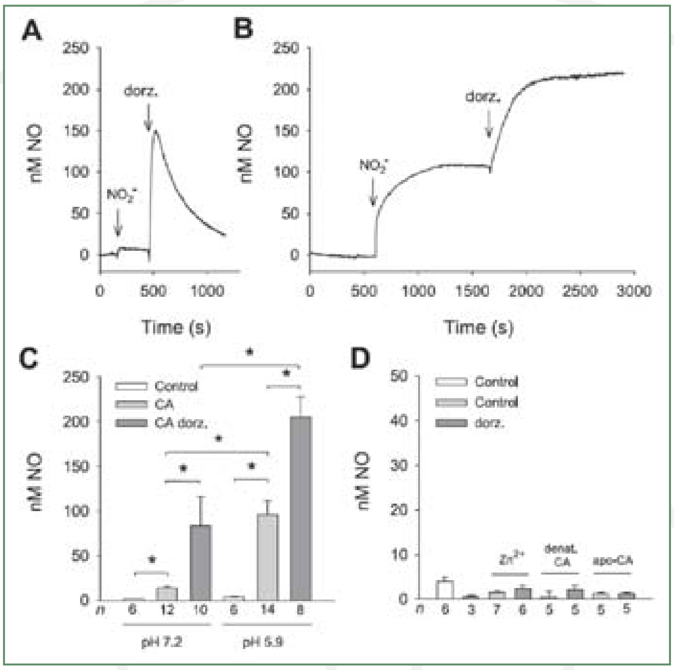


Figure 1
CA-dependent NO production from NO_2- is increased by dorzolamide and low pH. Traces obtained with a NO-sensitive microelectrode (NO100 Unisense A/S) in an open stirred chamber at 37 C. Conditions, 0.1 mM CA, 0.1 mM NO2- and 0.25 mM dorzolamide. Maximal NO signal was used for analyses (* $p < 0.05$).

(Figure 3) and, paradoxically, that two well-known inhibitors of the carbonic anhydrase reaction of CA (dorzolamide and acetazolamide) appears to potentiate CA’s ability to generate NO from nitrite (Figure 1, 2 and 3). This finding effectively also shed light upon the known cerebral vasodilating action of these drugs (7), of which e.g. acetazolamide is used clinically to assess the cerebral vascular reserve of patients suffering from occlusive cerebrovascular diseases. This particular finding we utilized to show that CA dependent NO generation

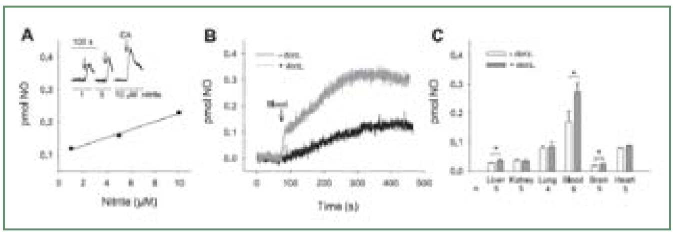


Figure 2
Physiological levels of NO_2- and CA generate NO. Furthermore NO_2- conversion to NO by rat tissues (liver, blood, brain) is enhanced by dorzolamide. Chemiluminescence, 37 C. A: 0.01 mM CA, pH 7.2. B and C: 2 mg/mL tissue homogenates (Final concentration) 0.1 mM NO_2-, 0.25 mM dorzolamide and pH 5.9. Maximal NO production was used for analyses. (*; $p < 0.05$).

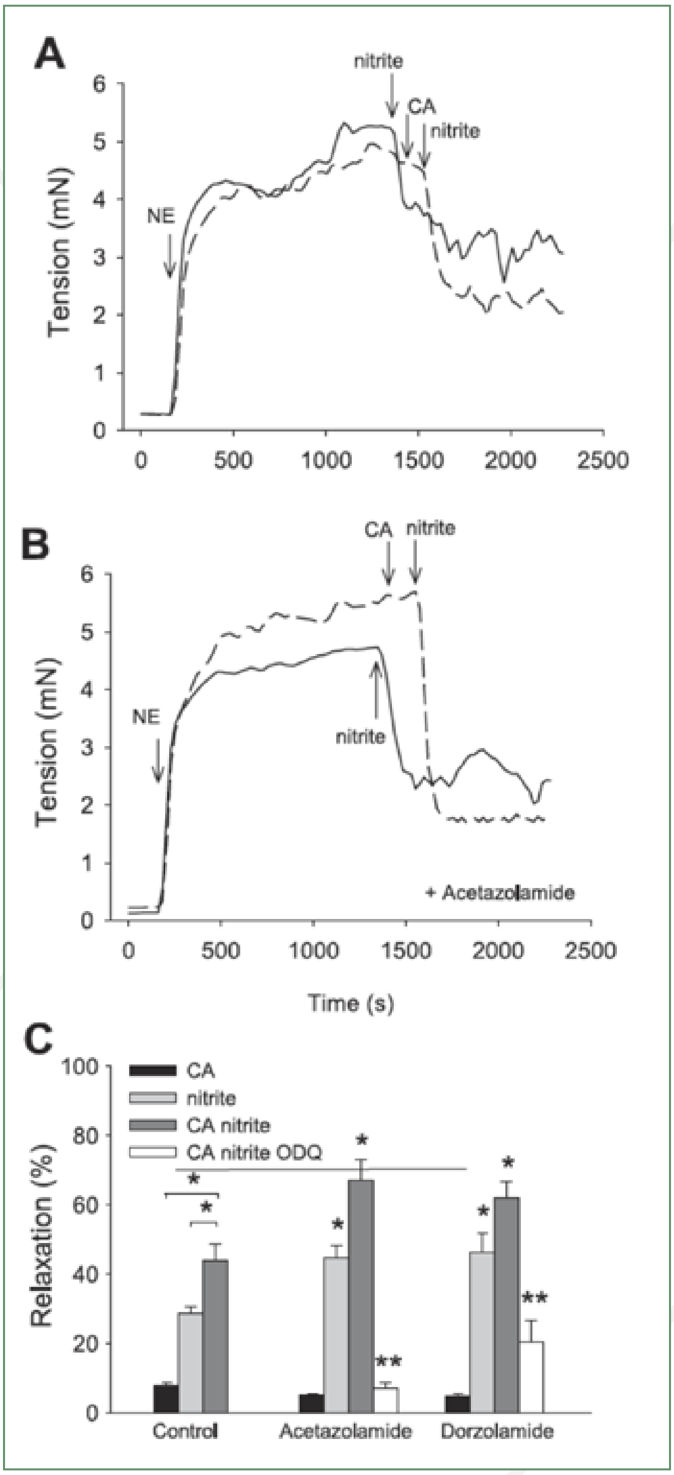


Figure 3
Vasoactivity of NO produced by 0.01 mM CA and 0.01 mM NO_2.
Rat aortic segments were initially contracted with norepinephrine (NE, 0.02 µM). The effects of acetazolamide (100 M), dorzolamide (250 M) and 1H-[1,2,4]oxadiazolo[4,3-a]quinoxalin-1-one (ODQ, 3 M) are shown. ADMA (300 µM) and indomethacine (3 µM) was applied to inhibit endogenous NOS and cyclooxygenase. * indicates $p < 0.05$.

is at least apparent in both brain and liver tissue as well as in the blood (Figure 2). Furthermore we showed that CA is able to generate NO from nitrite with oxygen present (Figure 1) and in the presence of physiological levels of CO_2 (Figure 3) rendering it a suitable candidate for the hypothesized role in linking neuronal activity to vasodilation.

For now, we do not know exactly how, at a molecular level, this conversion from nitrite to NO is carried out by CA or why it is potentiated by acetazolamide and dorzolamide, but work is underway by one of our collaborators, George B. Richter-Addo, to elucidate the structure of these complexes by the use of protein crystallography. We, on the other hand, have taken a step in the other direction: We use our novel understanding of the vasodilating action of acetazolamide in the brain to see whether vessels may modulate neuronal activity by signaling through NO. In this way we hope to help unveiling a piece of the puzzle put forward as the hemo-neural hypothesis (8). But as implied above, both of these undertakings are yet unresolved though highly promising and their outcomes still in the making. Suffice it to say, that we are trying to understand what it means to be BOLD!

References

1. Logothetis NK (2008) What we can do and what we cannot do with fMRI. Nature 453(7197):869-878.
2. Prichard J, et al. (1991) Lactate rise detected by 1H NMR in human visual cortex during physiologic stimulation. Proc Natl Acad Sci USA 88(13):5829-5831.
3. Gordon GRJ, Choi HB, Rungta RL, Ellis-Davies GCR, & MacVicar BA (2008) Brain metabolism dictates the polarity of astrocyte control over arterioles. Nature 456(7223):745-749.
4. Fox PT & Raichle ME (1986) Focal physiological uncoupling of cerebral blood flow and oxidative metabolism during somatosensory stimulation in human subjects.
Proc Natl Acad Sci U S A 83(4):1140-1144.
5. Ignarro LJ, Buga GM, Wood KS, Byrns RE, & Chaudhuri G (1987) Endothelium-derived relaxing factor produced and released from artery and vein is nitric oxide. Proc Natl Acad Sci U S A 84(24):9265-9269.
6. Aamand R, et al. (2009) Generation of nitric oxide from nitrite by carbonic anhydrase: a possible link between metabolic activity and vasodilation. Am J Physiol Heart Circ Physiol 297(6):H2068-2074.
7. Posner JB & Plum F (1960) The toxic effects of carbon dioxide and acetazolamide in hepatic encephalopathy. J Clin Invest 39:1246-1258.
8. Moore CI & Cao R (2008) The Hemo-Neural Hypothesis: On The Role of Blood Flow in Information Processing. J Neurophysiol 99(5):2035-2047.

CNRU

Consciousness Research at Cognitive Neuroscience Research Unit

by Morten Overgaard

Cognitive Neuroscience Research Unit, CNRU, is an interdisciplinary research group, performing experimental and theoretical research within cognitive neuroscience, neurorehabilitation, and philosophy of mind and science. For CNRU, it is a fundamental ideology that the interdisciplinary cooperation between basic science, clinical research and philosophy is reflected in all research projects. The study of human consciousness, i.e. subjective experience, is a special focus area for CNRU, and this motivation is also visible in all projects.

CNRU was formed based on a 14.5 Euro grant from the European Union's 6th Framework programme for *The MindBridge Project*. Morten Overgaard, who is head of CNRU, coordinated the project which lasted from 1 January 2007-1 January 2010 and involved six European universities. The project focused on the development of methodologies to study consciousness in the framework of experimental cognitive neuroscience.

Human consciousness can be defined as the inner subjective experience of mental states such as perceptions, judgments, thoughts, intentions to act, feelings or desires. We communicate about these experiences from a first-person account, e.g. by describing them in verbal reports. On the other hand, cognitive neurosciences explore the neural correlates with respect to brain topology and brain dynamics from an objective third-person account.

Recently, the increasingly widespread availability of new neuroscience methods (not least functional neuroimaging techniques) has inspired a large number of researchers to attempt the detailed exploration of the of the correspondences between subjective, conscious states and objective, neural states. Despite this enormous commitment to the study of consciousness covering philosophical, psychological, neuroscientific and modeling approaches, no stable strategies for the study of consciousness have emerged. One explanation is the fact that while the development of neuroscientific techniques has been overwhelmingly fast, very little has been done to develop valid and reliable measures of the subjective experience itself.

Morten Overgaard
Photo: AU-foto, Informationskontorets Fotoenhed, Aarhus University

MindBridge

MindBridge has made progress in a number of ways to address these issues. In one example, the project partner in Liege found that seemingly unconscious patients, diagnosed as vegetative, had brain activation patterns directly comparable to those of healthy subjects when instructed to perform conscious, visual imagery tasks[1, 2]. In other experiments, working with subjects and patients with a normal level of consciousness, we have compared different ways to make verbal reports about conscious content, and found that the most widely used methods in the air do not at all convey[3]. We have found statistical as well as theoretical arguments in support of one method which has been developed and refined by CNRU in recent years[4].

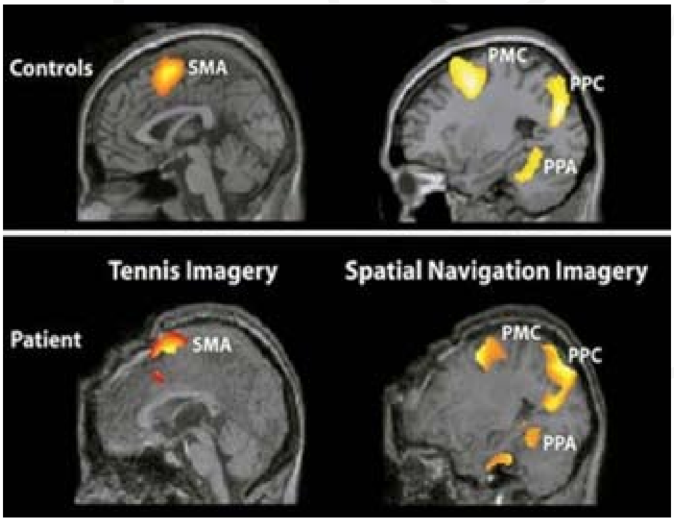


Figure 1
Activity related to consciously imagining playing tennis and navigation around a house in the healthy volunteers and a vegetative patient.
Owens et al., *Science*, 2006.

PhD student Kristian Sandberg and philosopher Mads Jensen trying out a visual stimulation experiment with transcranial magnetic stimulation.
Photo: AU-foto, Informationskontorets Fotoenhed, Aarhus University

MindRehab

From 1 January 2010, CNRU has been supported by a Starting Grant from European Research Council to Morten Overgaard to continue some of the central aspects of MindBridge in the 5-year project MindRehab. One of the central aims of MindRehab is to find clinical outcomes and usages of basic research and theory in consciousness research, thus underlining the CNRU triangulation of basic and clinical research and theoretical/philosophical work. Despite the aforementioned increased interest in consciousness over the last decades, there are as yet no structured attempts to draw conclusions from this body of work to make progress in the treatment of patients. While it, sadly, is rare that research in cognitive neuroscience has direct influence on clinical work, this is even rarer in consciousness studies. Here, there is essentially no connection to clinical practice. CNRU is physically located in Hammel Neurorehabilitation and Research Center and the DNC building, thus being in contact with both the university-related research groups and the clinically oriented neurorehabilitation hospital wards. These physical circumstances constitute in themselves an important foundation to achieve these goals.

Read more at: www.cnru.dk

CNRU
Cognitive Neuroscience
Research Unit

References

1. Owen A, Coleman M, Boly M, Davis M, Laureys S, Pickard J. Detecting awareness in the vegetative state. Science, 2006; 313 (5792): 1402.
2. Overgaard M. How can we know if patients in coma, vegetative state or minimal conscious state are conscious? Progress in Brain Research, 2009; 177: 11-19.
3. Sandberg K, Timmermans B, Overgaard M, Cleeremans A. Measuring consciousness: Is one measure better than the other? Consciousness and Cognition (in press).
4. Overgaard M, Timmermans B. How unconscious is subliminal perception? In: D. Schmicking & S. Gallagher (Eds): Handbook of Phenomenology and the Cognitive Sciences, Springer Verlag (in press).

Morten Overgaard receives ERC Starting Grant

Europe currently offers insufficient opportunities for young investigators to develop independent careers and make the transition from working under a supervisor to being independent researchers in their own right. This structural problem leads to a dramatic waste of research talent in Europe. It also limits or delays the emergence of the next-generation of research leaders, who bring new ideas and energy, and it encourages highly talented researchers at an early stage of their career to seek advancement elsewhere.

ERC Starting Independent Researcher Grants (ERC Starting Grants) aim to support up-and-coming research leaders who are about to establish or consolidate a proper research team and to start conducting independent research in Europe. The scheme targets promising researchers who have the proven potential of becoming independent research leaders. It will support the creation of excellent new research teams and will strengthen others that have been recently created.

Read more at: www.erc.europa.eu

CFIN and MIND*Lab* in China

Sino-Danish Center for Neuroscience and Cognition

by Leif Østergaard

In 2008, the Danish and Chinese Governments signed bilateral agreements to strengthen Sino-Danish relations within research, education and innovation. As part of this collaboration, a new university centre will be built by CAS (Chinese Academy of Sciences), GUCAS (Graduate University of Chinese Academy of Sciences) and 8 Danish universities. The university centre (SDC - the Sino-Danish Centre for Education and Research at Graduate University of Chinese Academy of Sciences) will be part of a future campus area north of Beijing.

Danish neuroscience and cognitive research is fortunate to be part of this strategic initiative. Following the close ties developed during the joint effort to establish a national neuroscience instrument platform, scientists from Aarhus University, Copenhagen University and the Danish Technical University formed a task force, working with Chinese colleagues to establish the Sino-Danish Center for Neuroscience and Cognition as an international centre that combines Chinese and Danish scientific strongholds within neuroscience and cognition, and related technology. The aim of this initiative is to create scientific breakthroughs, not only within these disciplines, but also in transforming neuroscience and cognitive research into strategies to reduce the burden of major neurological and psychiatric disorders to patients and Society, and frameworks for understanding social and cultural identities and differences in our globalised world.

During a scientific symposium in Beijing 19-21 October 2009, contacts were made with key Chinese scientists : Wenjun Ding, Executive Dean at GUCAS College of Life Sciences (Principal Coordinator, China), Professor Yan Zhuo, Vice-Director of the State Key Laboratory of Brain and Cognitive Science, Beijing MRI Center for Brain Research, CAS Institute of Biophysics, Professor Shu Li, PhD, Center for Social and Economic Behaviour, CAS Institute of Psychology, and Professor Tianzi Jian, Professor Yong Fan and Dr. Yong Liu, the LIAMA Research Center for Computational Medicine, National Laboratory of Pattern Recognition at the CAS Institute of Automation. Joint projects and plans for education are now being planned, with activities commencing in 2010.

The Sino-Danish Centre will focus on five main areas of research:

- Water & Environment
- Renewable Energy
- Life Sciences & Biomedicine
- Nanoscience & Nanotechnologies
- Innovation & Welfare Studies

Leif Østergaard, CFIN director, is Danish principal coordinator of SDC Life Sciences and Biomedicine projects.

The Danish Partners:

Center for Computational Cognitive Modeling
Professors Lars Kai Hansen, Tobias Andersen, Søren Kyllingsbæk
www.cfccm.dk, Technical University of Denmark

Center for Visual Cognition, Department of Psychology
Professors Claus Bundesen, Axel Larsen, Thomas Habekost
cvc.psy.ku.dk, University of Copenhagen

Danish Research Centre for Magnetic Resonance
Professor Olaf Paulson, Professor Hartwig Siebner
www.drcmr.dk and
Center for Integrated Molecular Brain Imaging,
Professor Gitte Moos Knudsen
www.cimbi.dk, University of Copenhagen

MIND*Lab*
Center of Functionally Integrative Neuroscience
Professor Leif Østergaard, Associate Professor Andreas Roepstorff
Cognitive Neuroscience Research Unit
Associate Professor Morten Overgaard
Religion, Cognition and Culture
Professor Armin Geertz
www.cfin.dk, Aarhus University

UNIVERSITY OF COPENHAGEN

DTU Technical University of Denmark

AARHUS UNIVERSITY

中國科學院 CHINESE ACADEMY OF SCIENCES

From Music to Experiment:
A Practical Workshop in Empirical Music Research with David Huron

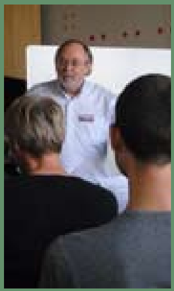
In 2009 the Music in the Brain group hosted a three day workshop in empirical music research, arranged by The Royal Academy of Music, Aarhus (RAMA), The Academy of Music, Aalborg and CFIN. The internationally acclaimed musicologist, professor David Huron (School of Music, Ohio State University, US) lead the workshop, and participants from five countries enjoyed an inspiring journey into the growing field of empirical music research.

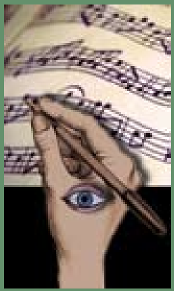
The workshop took place in August 2009 and aimed to help participants learn central techniques and concepts in modern empirical research. The workshop was designed specifically to develop practical research skills in empirical methods.

In addition to Huron's talks, that were delivered with tremendous engagement, the program consisted of talks by various acknowledged researchers: Visiting from Department of Psychology, Goldsmiths College London, UK, Lauren Stewart presented highlights from her neuroscientific research on congenital amusia, and Pam Heaton offered insights into current knowledge of music perception and cognition in neurodevelopmental disorders. Torben Ellegaard Lund (CFIN) talked about the use of technical equipment related to psychophysiological measurements, and Peter Vuust (CFIN, RAMA) presented research utilizing state-of-the-art methods in studying neural differences between musicians and non-musicians, specifically related to the intriguing question of whether musical talent can indeed be measured.

This truly interdisciplinary research workshop highlighted the importance of interdisciplinary collaboration such as between RAMA and CFIN, and the workshop proved to be a tremendous success as evidenced by participants' unanimous high ratings in the subsequent evaluation.

MUSIC IN THE BRAIN





Photos: Cecilie Møller

MUSIC IN THE BRAIN

by Peter Vuust

The Music in the Brain Group is a cross-institutional research group, founded by CFIN (AU) and the Royal Academy of Music, Aarhus Denmark, devoted to cognitive and neuroscientific research within music and to the study of the art, pedagogy and clinical application of music. The question of what music is and what it means to humans, has been discussed in musicology for ages. As a natural consequence of a biological approach, making sense of music must be seen as a two-way process in which the experience and the emotional qualities associated with a certain piece of music is shaped by the qualities of the actual musical expression as well as by the brain that interprets.

In the 2009 special issue of *Cortex*, we formulated this relationship between music and brain as a special case of Karl Friston's predictive coding theory[1] in the Predictive Coding of Music Hypothesis: That music, by creating an anticipatory framework in which the significance of each event is played out against a larger temporal structure of expectations, anticipations and tensions, taps into fundamental, survival-related brain mechanisms associated with predicting future events[2]. The predictive coding theory postulates that local brain structures at different hierarchical levels in the brain are responding to discrepancies between incoming signals and their prediction or model of these events with an error message that is fed forward in the system calling for an updated model that fits the input better. This hypothesis links to many of the projects within the MIB group as it lays out a fundamental understanding of how the brain perceives music and of the effects of musical training.

One obvious example of an auditory error message is the so called Mismatch Negativity[3], discovered by professor Risto Naatanen who joined CFIN and the MIB group in 2008. The mismatch negativity originates in the auditory cortex and is seen as a negative deflection on the event-related potential measured with EEG or MEG, elicited to change in some repetitive aspect of a sound sequence. The MMN has proven one of the most reliable measurements of cortical activity related to a mismatch between the brain's prediction of the immediate auditory future and the incoming sounds. One of the important implications of the predictive coding theory, however is that this comparison between prediction and actual events should take place at many different levels in the brain.

In an elegant study[4], PhD student Eduardo Garza has shown that un-anticipated chords embedded in authentic cadences give rise to error messages originating in different brain structures, depending on which kind of prediction they violate. Out-of-tune chords, violating predictions depending on the immediate auditory future, give rise to MMNs localized to the auditory cortices, whereas chords violating the rules of harmony causes an early-right anterior negativity (ERAN) originating in the inferior frontal gyrus.

One of the features of the MMN is that the amplitude and latency of the MMN correlate with auditory behavioral measures and that it is sensitive to discrimination learning. This makes it an effective tool for studying brain plasticity and learning, which is a particular focus of MIB. Together with Risto Näätänen, Elvira Brattico and Mari Tervaniemi from CBRU, Finland, we have developed a novel multi-feature MMN paradigm with 6 different deviant types integrated in a complex musical context of no more than 20 minutes in duration[5]. We found significant MMNs for all 6 deviant types indicating that in listening to real music, predictive coding of many different aspects of music takes place simultaneously in the brain. Earlier studies have indicated that realistic, complex musical stimuli are pre-requisites for disclosing fine-grained processing differences between musicians[6,7]. Hence, this short objective measure can potentially be used as an index for auditory and musical development, and possibly providing future tools for tailored individual ear-training. Such analysis of the neuronal substrate for musical performance may even guide the choice of the most appropriate instrument for a student on the basis of individual auditory neural aptitudes.

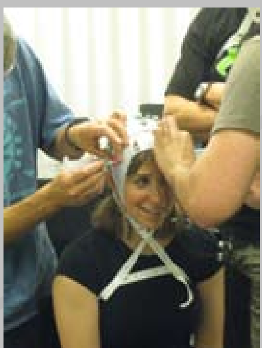
The musical multi-feature paradigm is just one example of MIB-projects with clinical and music pedagogic implications. We are currently investigating differences between musicians and non-musicians using behavioral measures[8] and structural[9] and functional MR-imaging, the effect of music training on speech and music processing of cochlear implantees[10], ERPs in a group of musicians with absolute pitch, and the effect of music on pain.

The MIB benefits greatly from collaboration with other groups within CFIN, in particular the Gambling group with whom we investigate dopamine release in musicians, and the Interacting Minds group with whom we study how we synchronize tapping[11-13]. The studies of the MIB group also take advantage of a growing number of national and international collaborations in investigating musical creativity, music emotions and pleasure, music and dance, the biological origin of music, dependency of musical liking on hearing loss, music in autism and music imagery.

As a delightful ending of an eventful year, College student Mads Bjørn Christiansen, won the Ministry of Science, Technology and Innovation's "forskerspire"-prize for young research talents on the project "The effect of sound compression on the brain's perception of music", developed together with the MIB group. In the following you can read about two selected MIB projects in greater detail.

References

1. Friston K. Beyond phrenology: what can neuroimaging tell us about distributed circuitry? Annu. Rev. Neurosci. 25, 221-250 (2002).
2. Vuust P, Østergaard L, Pallesen KJ, Bailey C, Roepstorff A. Predictive coding of music. Cortex 45, 80-92 (2009).
3. Näätänen R, Tervaniemi M, Sussman E, Paavilainen P, Winkler I. "Primitive intelligence" in the auditory cortex. Trends Neurosci. 24, 283-288 (2001).
4. Garza Villarreal EA, Brattico E, Leino S, Østergaard L, Vuust P. The frontal ERAN and temporal MMN: Two different brain responses to violations in chord progressions. 2009. 5-2-2009.
5. Vuust P et al. New fast MMN paradigm for determining the neural prerequisites for musical ability. Cortex (2009).
6. Vuust P. et al. To musicians, the message is in the meter: Pre-attentive neuronal responses to incongruent rhythm are left-lateralized in musicians. Neuroimage 24, 560-564 (2005).
7. Koelsch S, Schröger E, Tervaniemi M. Superior pre-attentive auditory processing in musicians. Neuroreport 10, 1309-1313 (1999).
8. Vuust P. et al. Personality influences career choice: Sensation seeking in professional musicians. Music Education Research (2009).
9. Chakravarty M, Vuust P. Got Rhythm? 2008.
10. Petersen B, Vuust P, Vejby Mortensen M, Gjedde A. Reestablishing Speech Understanding through Musical Ear Training after Cochlear Implantation. Ann NY Acad Sci 1169, 437-440 (2009).
11. Konvalinka I, Vuust P, Roepstorff A, Frith C. Synchronized Tapping as a Model of Minimal Social Interaction. 2009.
12. Konvalinka I, Vuust P, Roepstorff A, Frith C. A coupled oscillator model of interactive tapping. 2009.
13. Konvalinka I, Vuust P, Xygalatas D, Roepstorff A, Frith C. Synchronization in Joint Action: From Tapping to Fire-walking. 2009.



Researchers Ethan Weed, Ivana Konvalinka, Anders Dohn and Eduardo Garza testing EEG equipment on themselves in preparation for research experiments.
Photos: Henriette Blæsild Vuust

SELECTED RESEARCH PROJECTS:

Dohn A, Wallentin M, Tommerup N, Roepstorff A, Østergaard L, Vuust P. The neural foundation of absolute pitch ability.

Friis-Olivarius M, Wallentin M, Bechara A, Ramsøy TZ, Vuust P. Creativity, Brain and Emotion.

Garza-Villarreal E, Brattico E, Leino S, Østergaard L, Vuust P. Distinct neural generators of the MMN and the ERAN to chord violations.

Garza-Villarreal E, Brattico E, Vase L, Østergaard L, Vuust P. The placebo effect of music: A behavioral and physiological pain study.

Gebauer L, Møller A, Gjedde A, Doudet D, Linnet J, Vuust P. Why do we play music? Examining the role of dopamine.

Hvass-Schmidt J, Petersen B, Pedersen E, Vuust P. Musical preference and loss of hearing

Konvalinka I, Vuust P, Roepstorff A, Frith C. Joint tapping as a model of minimal social interaction.

Petersen B, Mortensen MV, Gjedde A, Vuust P. Reestablishing speech understanding through musical training after cochlear implantation

Rahman S, Vuust P, Christensen K, Bhattacharia J, Dickens R, Psillas A, Jensen H. Musical creativity.

Steenstrup K, Møller C, Friis-Olivarius M, Overgaard M, Vuust P. Motor Imagery in Musicians

Vuust P, Brattico E, Seppänen M, Näätänen R, Glerean E, Tervaniemi M. Differentiating Musicians Using a Fast, Musical Multi-feature Paradigm.

Vuust P, Josefsen LG, Hansen NC, Ramsgaard Jørgensen S, Møller A, Linnet J. Sensation seeking in professional musicians.

Vuust P, Kringelbach M. The pleasure of music

Vuust P, Østergaard L, Pallesen KJ, Bailey C, Roepstorff A. Predictive coding of music.

Wallentin M, Nielsen AH, Friis-Olivarius M, Vuust C, Vuust P. The Musical Ear Test, a new reliable test for measuring musical competence.

MUSIC IN THE (deaf) BRAIN

Musical ear training with cochlear implants

by Bjørn Petersen

> "What would you do if I sang out of tune,
> would you stand up and walk out on me?"
>
> Ringo Starr in "With a little help from my friends"
> (Lennon & McCartney 1967).

Electronic ears

A Cochlear Implant (CI) is a neural prosthesis that helps deaf people to hear. A surgically inserted electrode in the cochlea stimulates the neurons, whereby the auditory nerve is activated. This way sound signals reach the brain's auditory system, in many cases allowing recipients to converse on the phone. The implant is most successful in users who suffer from an acquired hearing loss and have developed language before their deafness. In the case of prelingually deaf patients, whose pattern-recognition system has never been established, the central auditory system must learn to interpret a whole new set of inputs, which takes time and training[1].

Technological amusia

Despite this immense technological and medical achievement, CI users face several limitations in their auditory perception. The degraded spectral and temporal resolution of the implant makes perception of music very poor. It is like "walking colour-blind through a Paul Klee exhibit" as American CI recipient and author Michael Chorost describes it[2]. To some it may well be far worse, which is sad since music in many cases has been an essential part of their cultural and social life. Some studies, however, have shown that by training a specific musical listening task intensely, music discrimination abilities can be improved significantly[3,4]. So far, no studies have examined the effect of training that involves personal tuition and active music making.

Music and language

Music and language rely on brain processing of fundamental aspects of sound sequences such as pitch, timing and timbre. This involves partly overlapping brain structures and recent studies have shown that complex music tasks activate brain areas associated with language processing [5,6]. This suggests that improved perception of music could generalize to speech perception, especially the prosodic properties of language.

Musical training and testing

Sixteen newly operated adult CI users (21-73 years) matched in two groups, took part in this longitudinal study. Shortly after switch-on of the CI the eight subjects in the music group began weekly one-to-one musical ear training lessons, that contained a variety of musical activities and listening exercises. For home practice, we provided specially adapted audio-visual training material. The remaining eight subjects acted as controls, and did not receive any musical training.

To detect the progress in discrimination of pitch, rhythm and timbre we created a battery of music tests (Figure 1). Perception of speech and prosody was measured with the Hagerman test and a vocal emotion test. Testing took place at three different milestones: (1) Initial (~ first week after switch-on of the implant), (2) after 3 months, and (3) after 6 months.

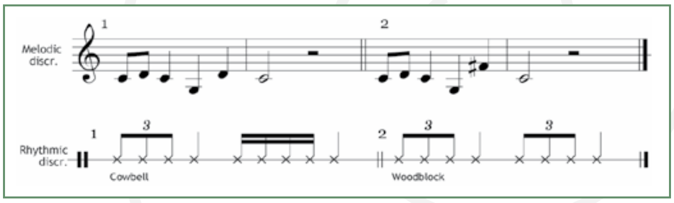


Figure 1
Examples of musical pairs for the melodic (top) and rhythmic (bottom) discrimination tests. In both cases the correct answer is "different".

Brain scanning

To be able to correlate behavioral data with possible changes in brain activity, we used Positron Emission Tomography (PET). PET detects relative changes in regional cerebral blood flow allowing for localization of activated brain areas. We ran four scans at three sequential sessions, concurrently with the behavioral tests. For contrasting stimuli, the subjects listened to either babble or running speech through the external input of their implant.

Change at the "speed of sound"

It is well known that CI recipients adapt quickly to their new hearing, especially in the first months after activation. Our results indeed confirmed this. During the study's 6 months, the music and the control group on average increased their speech perception scores by 160% and 94% respectively (Figure 2). Musical performance also increased in both groups with a larger increase in the music group in almost all tests. The most prominent differences were observed in the abilities to identify melodic contours and musical instruments

(Figures 3 & 4). Rhythm and pitch discrimination also showed a difference in favor of the music group, though smaller. We observed a progress but no difference in the ability to discriminate melodies and vocal emotions.

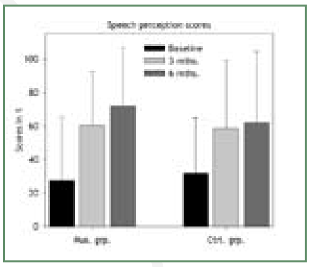


Figure 2
Speech perception scores

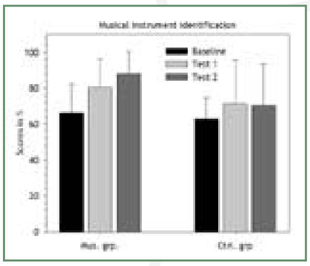


Figure 3
Musical instrument identification scores

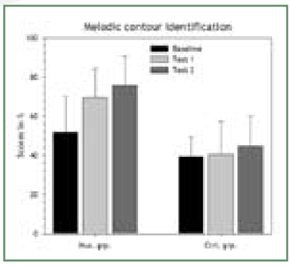


Figure 4
Melodic contour identification scores

Plastic powers in the brain

Such dramatic changes are fine evidence of the powers of neuroplasticity in the human brain. Our approach makes it possible to correlate the observed behavioral development with functional changes in the brain, as shown in two single subjects (Figure 5). In both cases the PET images show an increase in cortical activation and integration of both hemispheres linked to the steep progress in three behavioral tasks. The activation in visual cortex in both subjects has been shown in other studies involving deaf subjects, and is explained by their dependence on visual communication[7].

Every bird sings his song

Music teaching is much like running a shop. If the students return, you were successful - if not, you failed. All subjects in this study returned and completed the training program. In general they found that the different activities were beneficial in their rehabilitation process. Interestingly, singing has proved particularly fruitful and profitable in spite of the obvious intonation challenges. Of course, singing comprises all the important elements of ear training: It is expressive

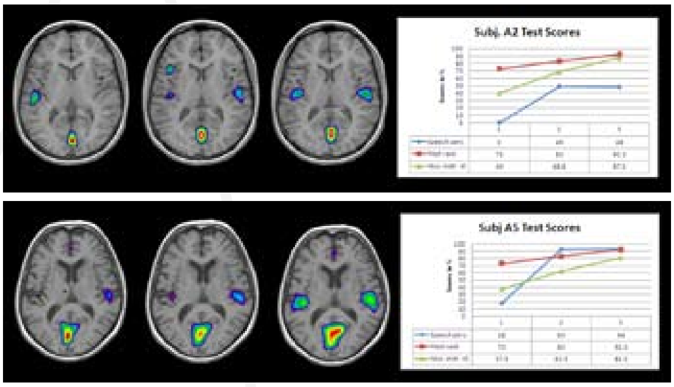


Figure 5
Two single subject cases of neurological and behavioral plasticity as documented in PET scans and behavioral tests done at 0, 3 and 6 months after switch-on of the CI sound processor. PET stimulus is running speech. Top: 21 year old congenitally deaf female; CI=Right ear. Bottom: 70 year old postlingually deaf female; CI=Right ear; duration of deafness: 20 years. (Analysis in progress).

and impressive at the same time, it features pitch, timing and timbre, and, evenly important, it has a linguistic-lyrical dimension.

This study has offered a unique and rare chance to study brain plasticity in the human brain – in this case the awakening of hibernated auditory cortices. Also the behavioral results are promising and indicate that the proposed training program has a potential as a complementary method to improve fine grained auditory skills in CI users, thereby contributing to an improved quality of life.

References

1. Moore DR, Shannon RV. Beyond cochlear implants: awakening the deafened brain. Nat Neurosci 2009;12(6):686-691.
2. Chorost M. My Bionic Quest for Bolero. Wired . 2005. Conde Nast Publications, Inc.
3. Galvin JJ, Fu QJ, Nogaki G. Melodic Contour Identification by Cochlear Implant Listeners. [Article]. Ear & Hearing 2007.
4. Gfeller K, Witt S, Adamek M. et al. Effects of training on timbre recognition and appraisal by postlingually deafened cochlear implant recipients. J Am Acad Audiol.; 2002.
5. Vuust P, Roepstorff A, Wallentin M, Mouridsen K, Østergaard L. It don't mean a thing ... Keeping the rhythm during polyrhythmic tension, activates language areas (BA47). Neuroimage 2006;31(2):832-841.
6. Levitin DJ, Menon V. Musical structure is processed in "language" areas of the brain: a possible role for Brodmann Area 47 in temporal coherence. Neuroimage 2003;20(4):2142-2152.
7. Giraud AL, Price CJ, Graham JM, Truy E, Frackowiak RSJ. Cross-modal plasticity underpins language recovery after cochlear implantation. Neuron 2001;30(3):657-663.

MUSIC IN THE BRAIN

Personality influences career choice: Sensation seeking in musicians

by Line Gebauer Josefsen and Peter Vuust

Do you like to party with the “jet set” all night long, and get wasted on exotic cocktails? Or would you rather enjoy a cozy evening in the company of a few close friends, while listening to old classics? The degree of arousal and novelty that we strive for in our daily living is reflected by the personality trait *sensation seeking*, which was first identified by Marvin Zuckerman in 1971. Sensation seeking is found to be highly genetically determined (Fulker et al. 1980; Koopman et al. 1995). Men tend to be more sensation seeking than women, and though sensation seeking peaks in adolescence, people who have a high level of sensation seeking during their youth will also be more sensation seeking later in life. We aimed to investigate the association between sensation seeking and choice of musical genre in professional musicians.

The Royal Academy of Music
Photo: Nikolaj Lund

Choosing to devote your life to music and becoming a professional musician requires a great deal of courage and possibly a strong personality regardless of style of music. Certainly, it seems that personality traits differ between classical musicians and musicians in improvisational styles of music such as jazz, rock, pop, reggae and a whole range of contemporary types of music (in the following termed ‘rhythmic music’, which is the official Danish term for these styles of music). The distinction between classical and ‘rhythmic’ music is one of the most fundamental in Western culture musical styles. Classical music is characterized by through-composed, highly structured compositions, being played on acoustic instruments, and is pre-dominantly intended for listening purposes. ‘Rhythmic music’ typically involves the use of improvised parts, electrically amplified instruments, and is often used for social purposes such as dancing. The association between ‘rhythmic’ music and motion, and the focus on rhythm, meter and the sensation of swing in this style of music, is the rationale behind the term ‘rhythmic’. Also, stage performance differs to a great extent between classical and ‘rhythmic’ music. Typically, classical musicians sit relatively motionless with their instrument. Contrary to this, ‘rhythmic’ musicians often move around on stage, attracting a lot of visual attention, and concerts frequently involves direct interaction between musicians, and between audience and musicians (Vuust, 2000).

95 students from the Royal Musical Academies in Denmark were included in this questionnaire study, which revealed that ‘rhythmic’ students had significantly higher sensation seeking personality than did classical students. Our results thus indicate that ‘rhythmic’ musicians are more inclined to be impulsive and engage in risky activities than classical musicians. A main feature of ‘rhythmic’ music is its improvisational freedom, which is in good accordance with our results suggesting an aversion for repetitive experiences of any kind including routine work and restless reactions when things are unchanging especially in ‘rhythmic’ musicians (Zuckerman and Neeb, 1979). This aversion of repetitive experiences is likewise reflected by the finding that ‘rhythmic’ students in general practice fewer hours than do classical students. Moreover, this difference in personality between the ‘rhythmic’ and the classical students seems to be associated with features specific to the practice of the two styles of music. Classical musicians practice more overall than ‘rhythmic’ and prefer to practice by themselves. The motor demands of classical music are larger than for ‘rhythmic’ music, and it requires a high amount of practice to excel in this style of music (Jabusch et al. 2009). By practicing alone classical

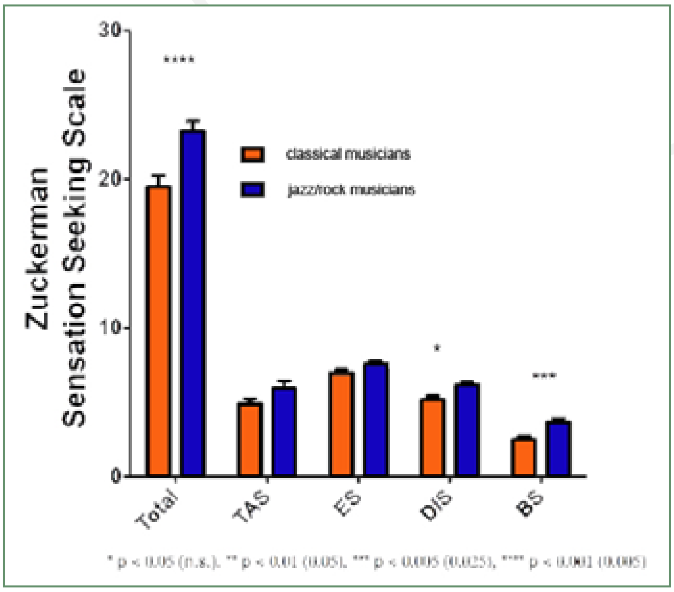


Figure 1
Sensation seeking scores in classical and ‘rhythmic’ students. Depicted are the total score, and the scores on the four subscales of the sensation seeking scale, thrill and adventure seeking (TAS), experience seeking (ES), disinhibition (DIS) and boredom susceptibility (BS).

musicians have a controlled setting for perfecting their technique. Hence, the practice of classical music entails more repetition of instrumental exercises and exact lines of music than 'rhythmic' music in concert as well as in the practice room. On the other hand, 'rhythmic' students prefer to practice in a social setting, with their band or orchestra. This makes the context of their practice more unpredictable and the lines that they play improvised as a consequence of the relative unpredictability of the interaction with the other musicians. The higher level of sensation seeking in 'rhythmic' musicians is corroborated by these more improvisational and social practicing routines, which also suggests that 'rhythmic' musicians are more extrovert and seek out social relations, also in professional settings.

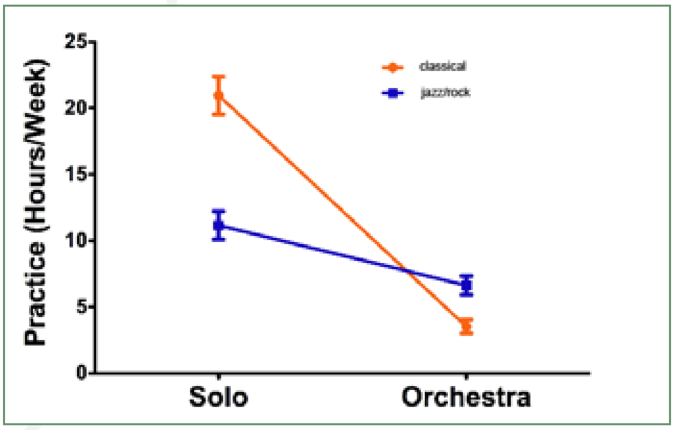
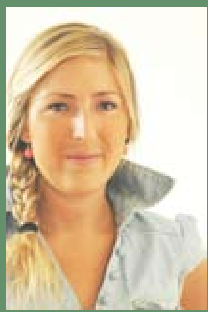


Figure 2
The number of solo practice hours per week, and practice hours with an orchestra/band per week, in classical and 'rhythmic' students, respectively.

Thus, it seems possible that people are predisposed, not only by environment and talent, but also by personality, to become professional musicians within a specific style of music. High sensation seekers seek out high arousing activities and careers, matching their personalities and low sensation seekers seek out controllable environments (Zuckerman M, 2007a p. 309). Still, it should be kept in mind that excessive exposure to a specific environment and a strong identification with icons (Cheung and Yue, 2003) may influence the individual's choice of career. Our data indicate, that the choice between musical styles is often taken in childhood, relatively independently of external advice. Engaging in a career as a professional musician takes a lot of commitment, extensive practice and is often driven by a strong passion for the music. Thus it makes good sense that the genre you decide to make this strong commitment to match your personality dispositions and your level of sensation seeking.


The Royal Academy of Music
Photo: Nikolaj Lund

NEW FACE AT CFIN



Line Gebauer Josefsen, Master of Science (Psychology), PhD student, just finished her studies at the Department of Psychology at Aarhus University. She has been working as a research assistant in the Gambling group since 2006. In 2007 she did a half-year research internship at The Division on Addictions, Cambridge Health Alliance and Harvard Medical School. During the past year Line has been working on her masters thesis on musical pleasure and the reward system in collaboration with the Music in the Brain research group.

Line's PhD project aims to investigate how people with Autism Spectrum Disorder (ASD) experience musical emotions compared to typically developing individuals, and to investigate whether the brain structures involved in processing of musical emotions are identical in people with ASD and typically developing people.

The main hypothesis is that music may provide a 'safe zone' for people with ASD to experience and experiment with emotions, without the involvement of other people, which typically causes them difficulties. A better understanding of the emotional impact of music on people with ASD may be important, both in relation to treatment and to the general wellbeing of people with ASD.

The PhD project starts in March 2010 and is financed by Aarhus University and the Lundbeck Foundation.

Awards and Honors in 2009

Chris and Uta Frith awarded the European Latsis Prize 2009

Professors Chris and Uta Frith were awarded the European Latsis Prize for their contribution to understanding the human mind and brain. The prize was presented during the Annual Assembly of the European Science Foundation in Strasbourg, France on 19 November 2009.

The European Latsis Prize is funded by the Geneva-based Latsis Foundation and awarded by the European Science Foundation to an individual or a research group who, in the opinion of their peers, has made the greatest contribution to a particular field of European research.

The research field for the 2009 prize was *The Human Brain - The Human Mind*. The work of Chris and Uta Frith has shaped the way researchers and clinicians think about mind and brain and various socio-cognitive deficits. They are responsible for paradigm shifts across areas as wide-ranging as autism and schizophrenia research, consciousness studies, dyslexia and social neuroscience. The prize was awarded to them as a couple, and they were nominated as such. The criteria used in the selection procedure are scientific excellence, a focus on the relation between brain and mind, societal impact, and contribution to European progress. The nominations were evaluated by a jury of eminent scientists in the field.

Leif Østergaard appointed member of The ATV Think Tank

In June 2009 head of CFIN, professor Leif Østergaard was appointed member of *The ATV Think Tank*. ATV is The Danish Academy of Technical Sciences (Akademiet for de Tekniske Videnskaber), a private, independent institution, the objective of which is to promote technological and scientific research and ensure the application of research results to further the generation of value and welfare in Danish society.

Morten Overgaard received ERC grant to MindRehab project

In October 2009 neuropsychologist, PhD, Morten Overgaard received a grant from the European Research Counsil (ERC) to the MindRehab research project - a project focusing on basic reseach methods in among other things reduced consiousness (vegetative condition) and visual neglect.

The research will primarily take place at CNRU, Cognitive Neuroscience Research Unit, a part of the research center at Regionshospitalet Hammel Neurocenter. Part of the project will also take place at Danish NeuroscienceCenter (DNC), Aarhus University Hospital, Aarhus Sygehus.
The ERC grant is one of the most prestigious competitive grants, for young researchers.

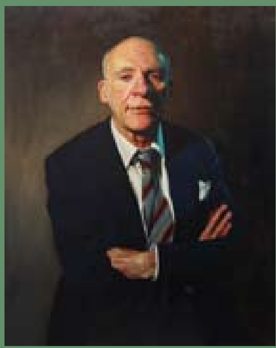
Read more about CNRU and the MindRehab project at page 34-35.

The Golden Scalpel Award to the Stroke Team at Aarhus University Hospital

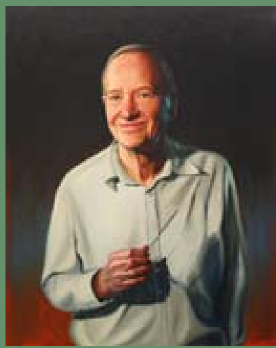
On 18 June 2009 The Golden Scalpel Award (Den Gyldne Skalpel), presented annually by the Danish medical newspaper *Dagens Medicin* was awarded to the Stroke Team at Aarhus University Hospital (part of which is CFIN and Department of Neuroradiology). Grethe Andersen, Leif Østergaard, Hanne Søndergaard and Edith Nielsen received the award on behalf of their collaborators during a ceremony in the Palle Juul-Jensen Auditorium. The award was presented by the Danish minister of Health, Jacob Axel Nielsen.

Minister of Health Jacob Axel Nielsen presenting The Golden Scalpel Award 09 to The Stroke Team at Aarhus University Hospital.
From left: Jacob Axel Nielsen, research radiographer at CFIN Dora Zeidler, charge nurse at the Stroke Unit Hanne Søndergaard, consultant at Department of Neuroradiology Edith Nielsen and consultant at Department of Neurology Grethe Andersen.
Photo: Søren Braad Andersen, Aarhus University Hospital

Chris & Uta Frith



Risto Näätänen



Hans C. Lou

Carsten Gyldensted

CFIN Portrait Gallery

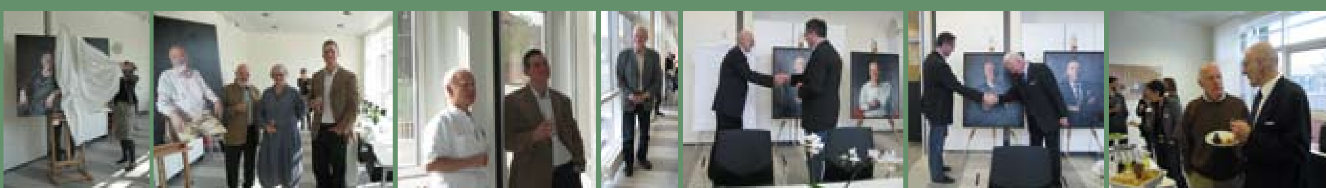
In the fall of 2008, a double portrait of Professors Chris and Uta Frith was finished, and in April 2009 CFIN celebrated their contributions to science in general and to the development of CFIN in particular at an official unveiling of the painting.

The young Danish artist Niels Corfitzen (born 1980) painted Chris and Uta Frith after having visited them in their London home. Niels Corfitzen is a young Danish artist who has already impressed the public with his realism - working in a super-naturalistic style he carries on the tradition from classic portrait painting. Niels Corfitzen has had several individual exhibitions in galleries in Denmark - Copenhart Gallery, J.C. Jacobsens Nordic Portrait Exhibition at Frederiksborg Castle, and Brøndsalen Frederiksberg. He won the public award at the censored portrait exhibition at Frederiksborg Castle, where his portrait of the Danish politician Svend Auken was on show. He works mostly in oil on canvas and is a remarkably detailed observer, mastering to transform both physical features and personality onto the canvas. Niels Corfitzen opened his own gallery in Copenhagen in the fall 2009.

See: www.corfitzengallery.com

CFIN was very pleased with the double portrait of Chris and Uta Frith and subsequently decided to have three more of the CFIN affiliated professors portrayed in appreciation of their work. During the spring of 2009 this resulted in portraits of Professor Risto Näätänen, Professor Hans. C. Lou, and Professor Carsten Gyldensted. The three new portraits were officially unveiled in November 2009, and all the paintings can now be admired in the new CFIN residence in Danish NeuroscienceCenter, DNC.

The portraits are made possible by reimbursements for science-related consultancy and communication work by CFIN director Leif Østergaard and communications coordinator Henriette Blæsild Vuust, subsequently invested in the decoration of our new office space.



From the official unveilings of the portraits in April and November 2009
Photo: Henriette Blæsild Vuust

CFIN staff

Head of CFIN - Professor Leif Østergaard

Professors:
Tipu Aziz
Doris Doudet
Chris Frith
Uta Frith
Albert Gjedde
Morten L. Kringelbach
Hans C. Lou
Risto Näätänen
Leif Østergaard

Associate professors:
Sune Nørhøj Jespersen
Jørgen Scheel-Krüger, visiting associate professor
Jakob Linnet
Arne Møller
Andreas Roepstorff
Peter Vestergaard-Poulsen
Peter Vuust

Senior scientists / Post.docs:
Bhador Bahrami
Jakob Blicher
Daniel Campbell-Meiklejohn
Ken Ramshøj Christensen
Brian Hansen
Niels Hjort
Kristjana Yr Jonsdottir
Anne M. Landau
Torben Ellegaard Lund
Irene Klærke Mikkelsen
Kim Mouridsen (Harvard Medical School)
Thomas Nielsen
Anders Bertil Rodell
Donald F. Smith
Mikkel Wallentin

PhD students:
Joel Fredrik Astrup Aanerud
Micah Allen
Christopher Bailey
Vibeke Bliksted Fuglsang
Niels Buhl
Mette Buhl Callesen
Søren Christensen (Melbourne) (PhD degree 12 May 2009)
Martin Dietz
Anders Dohn
Jeremy Flint (PhD degree 26 June 2009)
Jesper Frandsen
Jacob Geday (Doctoral degree 2 October 2009)
Louise Gyldensted
Yi Ching Lynn Ho (Singapore)

CFIN and MIND*Lab* researchers during the annual retreat at Sandbjerg Manor, 6-8 October 2009
Photo: Torben E. Lund

Kristina Dupont Hougaard
Else Marie Jegindø
Birgitte Fuglsang Kjølby
Ivana Konvalinka
Sita Ramchandra Kotnis
Line Burholt Kristensen
Sanne Lodahl
Kaare Mikkelsen
Kartheeban Nagenthiraja
Adjhmal Nahimi
Rasmus Aamand Olesen
Elisabeth Pedersen
Esben Thade Pedersen (Singapore) (PhD degree 3 July 2009)
Bjørn Petersen
Ericka Peterson (PhD degree 17 August 2009)
Peter Mondrup Rasmussen
Louise Munk Rydtoft
Uffe Schjødt (PhD degree 7 May 2009)
Kamila Ewa Sip (PhD degree 29 September 2009)
Joshua Charles Skewes
Kristine Rømer Thomsen
Anna Tietze
Kristian Tylén, Guest Researcher (PhD degree 17 April 2009)
Eduardo Adrián Garza Villarreal
Mads Sloth Vinding
Ethan Weed

Affiliated researchers:

Mahmoud Ashkanian
Per Borghammer
Mallar Chakravarty
Anders Christian Green
Malene Vejby Mortensen
Mette Møller
Yoshiyuki Nomura
Karen Johanne Pallesen
Astrid Frøhlich Staanum
Christine Sølling
Manouchehr Seyedi Vafaee

Research year students:

Line Andersen
Jesper Fontain
Erik Søndergaard Poulsen

Thesis students:

Anders Frodo Stegmann Mikkelsen
Rune Vingborg

Research Assistants:

Martin Carlsen
Søren Frimann
Mette Frøslev
Mads Jensen
Line Gebauer Josefsen
Stine Ramsgaard Jørgensen
Arndis Simonsen
Victoria Wohlert

Technical Staff:

Michael Geneser, Radiographer
Kim Vang Hansen, Imaging Analyst
Jørgen Kold, IT support
Poul Erik Nielsen, System Administrator
Lars Riisgaard Ribe, Software Engineer
Ryan Sangill, MR Physicist
Dora Zeidler, Research Radiographer

Administrative Staff:

Mai Drustrup, Secretary
Cecilie Møller, Secretary
Mette Steenberg, Secretary
Henriette Blæsild Vuust, Communications Coordinator

CFIN and MIND*Lab* researchers
hard at work in the group rooms and meeting room at Sandbjerg Manor, October 2009
Photo: Henriette Blæsild Vuust

Mikkel Wallentin, Morten Kringelbach, Torben Lund and Peter Vuust
hard at work on the Petanque court at Sandbjerg Manor, October 2009
Photo: Henriette Blæsild Vuust

Invited lectures

Leif Østergaard:

- *Fra Grundforskning til sundheds-IKT: I-Know under EU's ICT program*. Workshop on Health Innovation, Central Denmark EU-office, Forsknings- og Innovationsstyrelsen, 29 January 2009.
- *Processing and Analysis Tools in Perfusion MRI*. Tissue Structure and Function: Processing and Analysis Tools for Multi-Dimensional Medical Images, Dept. Medical Radiation Physics, Lund, Sweden. 30 January 2009.
- *Imaging of Transient Ischemic Attack and Stroke*. Policy and Strategy on Stroke and Transient Ischemic Attack: Italy - United Kingdom Summit, Italian Embassy, London, UK. 12 February 2009.
- *Forskning i Apopleksi: Avancerede skannings-teknikker*. Brain Awareness Week, Society for Neuroscience, Aarhus Chapter and Aarhus University Graduate Neuroscience Program, Århus, Denmark. 16 March 2009.
- *Hjerneforskning i et tværdisciplinært forskningsmiljø*. Temadag om forskningssamarbejde, Institut for sygeplejevidenskab, Århus, Denmark. 16 March 2009.
- *Magnetic Resonance Imaging of Brain Function*. Danish Neurosurgical Societys 20th Annual Meeting, Danish Neurosurgical Society, 20 March 2009.
- *Measurements of Perfusion by Bolus Tracking: The Basics*. International Society for Magnetic Resonance in Medicines 17th Scientific Meeting and Exhibition, International Society for Magnetic Resonance in Medicine, Honolulu, Hawaii, USA. 18 April 2009.
- *Hjernen og Læring*. Department of Science Studies, Aarhus University, 14 May 2009.
- *Perfusion MRI*. Odense, Danish Society for Medical Physics, 15 May 2009.
- *Advanced Neuroimaging: Imaging of Transient Ischemic Attack and Stroke*. Russian National Congress of Radiologists and ISMRM Global Outreach Workshop: State-of-the-Art in Clinical MR, ISMRM, Moscow, Russia. 28 May 2009.
- *Advanced Neuroimaging: Perfusion and Diffusion Weighted MRI in Stroke and Brain Tumors*. ISMRM Global Outreach Workshop: State-of-the-Art in Clinical MR, Irkutsk, Russia. 1 June 2009.
- *Imaging the stressed brain*. Nineth Annual Meeting: Stressful impact on brain functions, Aarhus Stress Group, 10 June 2009.
- *Perfusion Techniques*. School of MRI: Advanced Neuro Imaging - Diffusion, Perfusion and Spectroscopy, European Society for Magnetic Resonance in Medicine and Biology, Budapest, Hungary. 25 June 2009.
- *Neuroscience - and Research Support in a Cross-disciplinary and Cross-Institutional Research Environment*. DARMA Annual Meeting, Danish Association for Research Managers and Administrators, 9 July 2009.
- *Om Hjernen, Musik og Motivation*, Rotary Århus, 24 August 2009.
- *Stroke Imaging: New Developments*, Annual meeting of the German Neurological Society, Nürnberg, Germany. 25 September 2009.
- *Nye MR-teknikker hjælper kræft-patienter*, Aarhus University Hospital, Århus Sygehus, Forskningens dag, 30 September 2009.
- *Challenges in Neuroscience and Cognition Research*, Graduate University of the Chinese Academy of Sciences, Workshop, Sino-Danish Centre for Education and Research at Graduate University of Chinese Academy of Sciences, Beijing, China. 19 October 2009.
- *The Development of Predictive Algorithms based on Multiparametric Stroke MRI*, State Key Laboratory of Brain and Cognitive Science, Beijing MRI Center for Brain Research, 20 October 2009.
- *Fysik og Hjerneforskning*, Folkeuniversitetet og Det Naturvidenskabelige Fakultet, Aarhus University, 28-29 October 2009.
- *Interdisciplinary Neuroscience and Cognition Research at Aarhus University*, Aarhus University, U.S. Ambassador to Denmark, Ms. Fultons visit to Aarhus University, 5 November 2009.
- *MINDLab Interdisciplinary Neuroscience and Cognition Research*, Religion, Cognition and Culture, Aarhus University, 19 November 2009.
- *Hjernen og Musik*, Folkekuniversitetet, 19 November 2009.
- *Nye Metoder: Magnetisk Resonans, Magnetoencephalografi*, Continuing Education in Psychiatry: Diagnostic Imaging, Risskov, Denmark. 1 December 2009.

Andreas Roepstorff:

- *Culture and the Evolution of Brains: a Culture of Cultures*, Brian Butterworth, Brain and Culture Symposium, European Workshop on Cognitive Neuropsychology, Brixen/Bressanone, Italy, 28 January 2009.
- *Mediation*, VIA Center for Undervisningsmidler, Copenhagen, Denmark, 4 February 2009.
- *Neurospirituality* (with Martijn van Beek), Nicolas Langlitz & Fernando Vidal, Neurocultures, Germany, 21 February 2009.
- *Brain Plasticity and Mind Technologies, Neuroscience in Context, Human Nature and its alterability*. Past Present and Future of Human Becoming, Berlin, Germany, 13 March 2009.
- *Crash course in brain imaging*, ENSN school in social neuroscience, Austria, 2 April 2009.
- *Neuroteknologi*, Folkeuniversitetet, Fagre nye verden, 30 April 2009.
- *Mirroring and Perspective Taking. Two Complementary Processes?*, Center for Subjektivitetsforskning, Copenhagen University, Workshop with Tomasello and Rochat, Denmark, 22 September 2009.
- *When a lie is not a lie - Neuroimaging of deception in social interaction and lie- detection*, Law and Neuroscience: Our Growing Understanding of the Human Brain and its Impact on our Legal System, Acqua di Maratea, Italy, 27 September 2009.

- *Interobjectivity: Extended minds in interaction*, CNCC closing conference, Edinburgh, UK, 2 October 2009.
- *Hjernens Betydning?*, Folkeuniversitetet i Århus, Få styr på din hjerne, 5 November 2009.
- *Kunsten og Hjernen*, Trapholt Museum, Denmark, 9 November 2009.
- *Neuropædagogik og den nye hjerneforskning*, Neuropædagogik, Denmark, 25 November 2009.
- *Den Nye Hjerneforskning: Mind Plasticity and Brain Technologies*, Folkeuniversitetet i Århus, Denmark, 25 November 2009.
- *Den nye hjerneforskning*, Temadag om Neuropædagogik, 25 November 2009.
- *Humans and their brains: Anthropology in and of neuroscience*, Denmark, 9 December 2009.
- *Brain Matters. An anthropology in and of the new neurosciences*, Instituts-Kolloquium Wintersemester 2008/2009: Naturalismus und Konstruktivismus, Berlin, Germany, 16 December 2009.

Peter Vuust:

- *Neural Processing of Polyrhythmic Structures in Music*. Eminent Speaker Series, Storbritannien, Music and Brain Club, Goldsmiths, University of London, UK. 15 January 2009.
- *Musical communication, improvisation and creativity*. Complexity Series, Storbritannien, Imperial College, London, UK. Department of Mathematics and Institute for Mathematical Sciences, 20 January 2009.
- *Vi hører med hjernen*. Værløse, Høreapparatsvirksomheden Widex, 17 February 2009.
- *The High and Low Roads to Musical Emotions*. Aarhus University, Music Department, 4 March 2009.
- *Musik og Kognition*. Center for Semiotics, Aarhus University, 13 March 2009.
- *It don't mean a thing - Musik og hjerne*. Rådhushallen, Århus, 17 March 2009.
- *It don't mean a thing*. Huset, Aalborg, 28 April 2009.
- *How to practice*. Copenhagen, Det Kgl. Danske Musikkonservatorium, 29 April 2009.
- *It don't mean a thing - Musik og hjerne*. Roskilde, Roskilde oplysningsforbund, 18 May 2009.
- *Just do it - how to practice and what that does to the brain*. Skanderborg, Skanderborg kulturhus, 26 May 2009.
- *Just do it! How to practice and what that does to the brain*. National and Kapodistrian University of Athens, Excellence 2009 - Education and Human Development, Greece, 2 July 2009.
- *It don't mean a thing . . ., or does it? Neural processing of polyrhythmic structures in music.*, Experimental Psychology Society, EPS- Music in Mind and Brain, UK, 9 July 2009.
- *It don't mean a thing - or does it? Neural processing of polyrhythmic structures in music*, UCL Institute of Cognitive Neuroscience, Timing in speech and music workshop, UK, 11 July 2009.
- *Can we measure musical talent?* From Music to Experiment - A Practical Workshop in Empirical Music Research, Royal Academy of Music Aarhus, 20 August 2009.
- *Musik på hjernen*. Alsion, Sønderjyllands symfoniorkester, 26 August 2009.
- *Music and the brain*. Neuroplasticity based Intervention, Elsass, 27 August 2009.
- *Forskeruddannelser på musikkonservatorierne*. Arkitektskolen, Copenhagen, Danske Forskerskoler i Arkitektur og Design, 27 August 2009.
- *It Don't Mean a Thing, . . . ?- Musikalsk udvikling af hjernen*. Strandskolen, Aarhus, 22 September 2009.
- *Kan man tale med musik?*: Music lecture with Alex Riel og Henrik Gunde. Vanløse kulturhus, 5 October 2009.
- *Billedkunstens relation til musik og lyd*. Kunsthal Charlottenborg, Carnegie Art Award 2010, 22 October 2009.
- *Den kreative hjerne*. Dronninglund Hotel, Dansk Oplysnings Forbund, 7 November 2009.
- *Jazz og innovation*. Region Midtjylland, Århus, Midtlab, 23 November 2009.
- *Hvordan bliver man god til at skabe: Musikalsk udvikling af hjernen*. Horsens Kunstmuseum, VIA University College, Horsens, 24 November 2009.
- *It Don't Mean a Thing*. Musikkens Virkning, Norway, Griegakademiet, 30 November 2009.
- *Just do it - What musical practice does to the brain*. Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, 2 December 2009.

Chris Frith:

- *Neuroscience, Free will and Responsibility*, James Martin Advanced Research Seminar, Oxford, UK. 18 February 2009.
- *Making up the Mind: how the brain creates our mental and physical worlds*, Dana Centre, London, UK. 18 March 2009.
- *What is Consciousness for?* Cambridge Neuroscience Seminar/ Cambridge Science Festival. Keynote Speaker.19 March 2009.
- *Making up the Mind*. British Psychological Society Book Award Talk, Brighton, UK, 2 April 2009.
- *What can Studying the Brain tell us about the Mind?* Templeton-Cambridge Journalism Fellowships in Science & Religion, Cambridge, UK, 18 April 2009.
- *The role of facial expressions in social interactions*. Computation of emotions in man and machines, Royal Society, UK. 20 April 2009.
- *Neuroscience, Free will and Responsibility*. Royal Society of Arts, UK. 23 April 2009.
- *Facial Expressions: From Emotion to Communication*. Dahlem Institute for Neuroimaging of Emotion Berlin, Germany. Keynote Speaker. 21 May 2009.
- *The neural basis of empathy and altruism*. Sympathies and Antipathies, CRASSH, Cambridge, UK. 29 May 2009.
- *A Bayesian approach to hallucinations and delusions*. Frontiers in Cellular and Molecular Psychitary, CSC workshop, London, UK. 2 June 2009.

- *What can Studying the Brain tell us about the Mind?* Seminar - MIND 11 – ICI, Berlin, Germany. 12 June 2009.
- *Neuroscience, Free will and Responsibility*. Leipzig encounters in Cognition and Action, 2nd Symposium: Conscious Awareness in Volition and Action, Leipzig, Germany. 26 June 2009.
- *What is consciousness for?* Big Issues at Burgh House, Hampstead, UK. 30 July 2009.
- *Our Social Brain: The Future of Social Cognition*, Wellcome Trust School on Biology of Social Cognition, WTCC, Hinxton, UK. Keynote Speaker. 15 August 2009.
- *The Social Brain*. Edinburgh Cognitive Neuroimaging Seminars, UK. 8 September 2009.
- *The Social Brain and its Failures*. 41st EBBS meeting, Rhodes, Greece. 15 September 2009.
- *Neuroscience, Free Will & Responsibility*. Exploring Science & Society Seminar, UCL, UK. 26 November 2009.
- Organiser of Workshop on Reputation Management, Aarhus University, 2 December 2009.
- *Free Will, Responsibility & Consciousness*. The Continuity of Evolution and the Special Character of Humans, Jena, Germany. 9 December 2009.

Uta Frith:
- *Autism – Insights from autism research*. Otto Wolff Lecture, Institute of Child Health, UCL, UK. 19 January 2009.
- *The enigma of autism*. Stevenson Annual Science Lecture, Royal Holloway College London University, UK. 19 February 2009.
- *How our social brain modifies our behaviour.* Biannual Herbert Spencer Lecture, Oxford University, UK. 5 March 2009.
- *What is it like to be autistic?* York Science Lecture, UK. 18 March 2009.
- *Social brain and autism*. Rotterdam Autism Conference, Holland. Keynote talk, 19 March 2009.
- *What is and why do we study Social Cognitive Neuroscience?* Tagung Experimentell arbeitender Psychologen (TeaP) Jena, Germany. Keynote Lecture. 30 March 2009.
- *Autism - recent research*. Odense SIKON Autism conference, Denmark. Plenary Lecture, 27-28 April 2009.
- *What we learn from autism about the social brain*. Berlin Mind11 meeting. Master Class and Public lecture, Germany. 20-22 May 2009.
- *Theory of Mind in Words and Actions*. Max Planck Institute for Brain and Cognition, Leipzig, Germany. Colloquium. 30 June 2009.
- Leipzig workshop on the study of eye movements in relation to action and attentional mechanisms, Germany. July 2009.
- *Die Rolle der Hirnforschung in der Entwicklungs- und Lernpsychologie: Zwischen Euphorie und Ablehnung*. Keynote Talk and Podiumsdiskussion. Kaiserslautern, Germany. 9 September 2009.
- *The social brain and its failures*. EBBS 41st meeting Rhodes, Greece. Invited Lecture. 13-18 September 2009.
- *What autism teaches us about the social brain*. York Departmental Seminar, UK. 20 October 2009.
- Organiser of Workshop on Reputation Management, Aarhus University. 2 December 2009.

Morten Kringelbach:
- *The pleasure center*, Thorshavn, Faroe Islands, 10 January 2009.
- *Pleasures of art: conversation with A.S.Byatt*, Thorshavn, Faroe Islands, 10 January 2009.
- *TrygFonden Research Group*, Oxford, UK. 14 January 2009.
- *Neural correlates of pleasure*, MEGUK2009, Oxford, UK. 15 January 2009.
- *The pleasures of consciousness*, Hans Lou 70th Symposium, Aarhus University, 30 January 2009.
- *The pleasures of creativity*, Creative Brain, London, UK. 28 February 2009.
- *Creativity with brain and body in mind*, Dana Centre, Oxford, UK. 12 March 2009.
- *Pleasure in the brain*, Nordiske Mediatorer, Denmark, 13 March 2009.
- *Deep brain stimulation for chronic pain*, Danish Neurosurgical Society, Århus, Denmark, 20 March 2009.
- *Studying pleasure with MEG*, Oxford MEG Centre, UK, 24 April 2009.
- *Phantom Pains*, St Barnabas School, UK, 12 May 2009.
- *Pleasure, placebo and pain*, Aarhus Interacting Minds, Denmark, 18 May 2009.
- *Centering on pleasure*, Latitude Music Festival, UK, 18 July 2009.
- *The pleasure of dance*, British Science Association, Guildford, UK, 8 September 2009.
- *Pain and pleasure*, NCP2009, Stockholm, Sweden, 23 September 2009.
- *Affective neuroscience of pleasure and hedonic experience*, Stockholm, Sweden, 24 September 2009.
- *Lyst til læring*, Gymnasiedage, Odense, Denmark, 30 September 2009.
- *The pleasure of early parent-infant relationship*, CFIN retreat, Denmark, 6 October 2009.
- *The brain and pleasure*, Oxford High School, UK, 15 October 2009.
- *Hedonia: TrygFondens Research Group*, Middelfart, Denmark, 23 October 2009.
- *Den nydelselsesfulde hjerne*, Offentlig Topledelse, Denmark, 4 November 2009.
- *Affective neuroscience of pleasure*, Gothenburg, Sweden, 12 November 2009.
- *Nydelse i hjernen*, VISO, Denmark, 1 December 2009.
- *Finding pleasure in the brain*, Maynooth, Ireland, 7 December 2009.
- *The neurobiology of happiness and pleasure*, BNA, Royal Society, UK, 16 December 2009.

Risto Näätänen:

- *The Mismatch Negativity (MMN) in clinical research*. Finnish-Russian Winter School of Cognitive Neuroscience, Tvärminne, Finland, 23-28 March 2009.
- *Automatic sensory intelligence in audition - the core of cognitive processes?* MMN09, Budapest, Hungary, 4-7 April 2009.
- *How should professors be selected in the university system?* Meeting of Finland's Association of University Professors, Helsinki, Finland, 19 May 2009.
- *The Mismatch Negativity (MMN) in clinical research.* II International Symposium Topical Problems of Biohtonics, Niznyi Novgorod, Russia. 19-24 July 2009.
- *Mismatch Negativity in clinical research.* 10-years Anniversary of the Cognitive Clinical Neurology Research, University of Oulu, Oulu, Finland, 28 August 2009.
- *Scientific excellence - how to achieve and maintain it?* Lecture in the University of Helsinki Forum, University of Helsinki, Finland, 23 October 2009.
- *Brain mechanisms of conscious perception in audition.* Consciousness and its Measures Conference, Limassol, Cyprus, 29 November - 1 December 2009.
- *The Mismatch Negativity as an index of auditory perception and discrimination.* University of Antwerpen, Belgium, 16-18 December 2009.

Hans C. Lou:

- Co- chairman, Self: Mind and Brain, symposium. Aarhus University. 30 January 2009. Oral presentation: *Unity of consciousness.*
- Discussion leader and presentation: *Consciousness research.* Kolonien Filadelfia, 12 November 2009.

Jakob Linnet:

- *Attention-deficit/hyperactivity disorder (ADHD): Diagnosis and Prognosis*. Aarhus University, CFIN, 5 May 2009.
- *Reinforcering og udslukning af adfærd på spilleautomater*. Keynote speaker. Århus, Dansk Automat Ekspert, 5 May 2009.
- *Spilleautomater, Poker og Dopamin*. Keynote speaker. Odense, Center for Ludomani, 6 May 2009.
- *Introduktion til SCID-I*. Keynote speaker. Copenhagen, Institut for Militærpsykologi, 14-15 September and 15 October 2009.
- *Kognitive bias i poker*. Keynote speaker. Odense, Center for Ludomani, 8 October 2009.

Peter Vestergaard-Poulsen

- *Hjernevidenskab og opmærksomhedstræning - forandrer meditation hjernen?* Den Niende Intelligens. Falkoner centret, Copenhagen, 5 February 2009.
- *Towards seeing the stress in the brain…* High field Neuro-imaging summer school and workshop. McKnight Brain Institute, University of Florida, Gainesville, Florida, USA. 26-27 October 2009.

Mikkel Wallentin:

- *Narratives in the brain*. Narrative Cognition - Winter Symposium 2009, Aarhus University. 29 January 2009.
- *Are there sex differences in the way the brain processes language?* Department of Linguistics, Aarhus University, 17 April 2009.
- *Spatial language in the brain*. Copenhagen University, Lingvistkredsen, 27 October 2009.

Ken Ramshøj Christensen:

- *On the role of Broca's area and premotor cortex in language and mathematics*. Centre for Integrative Neurosciences and Neurodynamics, Reading, UK, 12 January 2009.
- *On Negation*, Syntax, and the Brain, The Syntax Lab, Cambridge, UK, 13 January 2009.
- *Hjernebark og Syntaktiske Træer*, Neurolinguistics, Lingvistkredsen, Denmark, 27 October 2009.
- *Brains & Trees*, Neurolinguistics, Department of Linguistics, Denmark, 13 November 2009.
- *On Quantifiers*, SLK, Aarhus University, Denmark, 10 December 2009.

Other CFIN researchers:

- Callesen, Mette Buhl. *Dopamine Agonist Induced Pathological Gambling in Parkinson's Disease*. 8th Annual OAK Meeting, Aarhus, Denmark, PET Center Aarhus, Aarhus University Hospital, 12 June 2009.
- Hansen, Brian. *High Field and Diffusion MRI*. Keynote speaker. Dansk selskab for medicinsk fysik, Odense, DK. 16 May 2009.
- Jespersen, Sune Nørhøj. *Characterising brain cytoarchitecture with diffusion MRI - evalution and applications*. Oregon Health and Science University, USA. 27 August 2009.
- Jespersen, Sune Nørhøj. *Characterising brain cytoarchitecture with diffusion MRI - evalution and applications*. University of Florida, USA. 26 October 2009.
- Josefsen, Line Gebauer. *The Drummer's High*. 8th Annual OAK Meeting, Aarhus, Denmark, 12 June 2009.
- Petersen, Bjørn. *Musikalsk høretræning med voksne CI-brugere*. Netværket af CI-undervisere, 27 October 2009.
- Thomsen, Kristine Rømer. *Den nydelsesfulde hjerne*. Aarhus University, Folkeuniversitetet, 29 October 2009.
- Villarreal, Eduardo Adrian Garza. *Harmony want to sit in the front: Different brain responses to violations in chord progressions*. PhD Day, Århus, Danmark, Aarhus University, 16 January 2009.
- Villarreal, Eduardo Adrian Garza. *Harmony wants to sit in the front: Different brain responses to chord progressions*. Braintuning Workshop, Helsinki, Finland, 4 February 2009.
- Villarreal, Eduardo Adrian Garza. *Harmony wants to sit in the front*: *Different brain responses to chord progressions.* 16th CNS Meeting, San Francisco, USA, 20 March 2009.
- Villarreal, Eduardo Adrian Garza. *Schizophrenia and Eating Disorders*. Neurotransmission, Psychiatry and Neuropharmacology course, Aarhus University, 11 May 2009.

Conferences

Leif Østergaard:

- National Institute of Neurological Disorders and Stroke: Workshop on Expanding the Time Window of Reperfusion Therapy in Acute Ischemic Stroke: Opportunities and Challenges, San Diego, USA. 17 February 2009.
- International Stroke Conference 2009. San Diego, USA. 18-20 February 2009.
- International Society for Magnetic Resonance in Medicines 17th Scientific Meeting and Exhibition. Honolulu, Hawaii, USA. 18-24 April 2009.
- The Second International Workshop on Hyperpolarized Carbon-13 and its Applications in Metabolic Imaging. Philadelphia, USA. 22-25 July 2009.

Arne Møller:

- Society for Neuroscience 2009, 17-21 November 2009, Chicago, USA.
- American Epilepsy Society 2009 - 63rd Annual Meeting, 4-8 December 2009, Boston, USA.

Peter Vestergaard-Poulsen:

- High field Neuro-imaging summer school and workshop. McKnight Brain Institute, University of Florida, Gainesville, Florida, USA. 26-27 October 2009.
- Den Niende Intelligens. Falkoner centret, Copenhagen, 5 February 2009.

Andreas Roepstorff:

- Brain and Culture Symposium, European Workshop on Cognitive Neuropsychology, Brixen/Bressanone, Italy, 28 January 2009.
- Den Niende Intelligens. Falkoner centret. Copenhagen, Denmark, 5 February 2009.
- Neurocultures, Berlin, Germany, 21 February 2009.
- Past Present and Future of Human Becoming, Berlin, Germany, 13 March 2009.
- ENSN school in social neuroscience, Austria, 2 April 2009.
- Workshop with Tomasello and Rochat, Denmark, 22 September 2009.
- Law and Neuroscience: Our Growing Understanding of the Human Brain and its Impact on our Legal System, Acqua di Maratea, Italy, 27 September 2009.
- CNCC closing conference, Edinburgh, UK, 2 October 2009.
- ATACD Changing Cultures, Cultures of Change, Barcelona, Spain, 10-12 December 2009.
- Instituts-Kolloquium Wintersemester 2008/2009: Naturalismus und Konstruktivismus, Berlin, Germany, 16 December 2009.

Peter Vuust:

- CNS Meeting, San Fransisco, USA. 2-23 March 2009.
- Excellence - Education and Human Development, Athens, Greece. 1-2 July 2009.
- Experimental Psychological Society Meeting, York, UK. 8-10 July 2009.
- UCL Institute of Cognitive Neuroscience, Timing in Speech and Music Workshop, London, UK. 11 July 2009.
- ESCOM, 7th Triennial Conference of the European Society for the Cognitive Sciences of Music, University of Jyväskylä, Finland. 12-16 August 2009.
- Neuroplasticity-based Intervention, Elsass Center, Denmark. 24-28 August 2009.
- Holbergdagene i Bergen: Musikkens virkning, Bergen, Norway. 30 November 2009.

Risto Näätänen:

- MMN09, Budapest, Hungary, 4-7 April 2009.
- II International Symposium Topical Problems of Biohtonics, Niznyi Novgorod, Russia. 19-24 July 2009.
- Consciousness and its Measures Conference, Limassol, Cyprus, 29 November - 1 December 2009.

Other CFIN researchers:

- Christensen, Ken Ramshøj. Neurolingvistik - Hjerne, Sprogforståelse, Syntaks, Nægtelse og fMRI, Copenhagen, Denmark. 22 January 2009.
- Christensen, Ken Ramshøj. Neurolinguistics: On language, brain, and fMRI, Uppsala, Sweden. 2-3 April 2009.
- Christensen, Ken Ramshøj. Master class on EEG/ERP with Professor. J.D. Saddy, CINN, University of Reading, UK. CFIN, Aarhus University, 22-23 October 2009.
- Hansen, Brian. ISMRM, Honolulu Hawaii, USA. 18-24 April 2009.
- Hansen, Brian. Diffusion Fundamentals. 23-26 August 2009.
- Hansen, Brian. High Field Neuro Imaging Summer School and Workshop. McKnight Brain Institute, Gainesville Florida, USA. 26-27 October 2009.
- Jespersen, Sune Nørhøj. ISMRM, Honolulu Hawaii, USA. 18-24 April 2009.
- Jespersen, Sune Nørhøj. High Field Neuro Imaging Summer School and Workshop, McKnight Brain Institute, Gainesville Florida, USA. 26-27 October 2009.
- Villarreal, Eduardo Adrian Garza. Braintuning Workshop, Helsinki, Finland. 4 February 2009.
- Villarreal, Eduardo Adrian Garza. Neuroscience of Music, Århus, DK. 28 February 2009.
- Villarreal, Eduardo Adrian Garza. CNS Meeting, San Fransisco, USA. 20-23 March 2009.
- Villarreal, Eduardo Adrian Garza. Placebo, Pain and Pleasure, Århus, DK. 19-20 May 2009.
- Villarreal, Eduardo Adrian Garza. Master Class on EEG/ERP, Aarhus University/CFIN. 23-25 October 2009.

Radio / TV / newspress

CFIN researchers have participated in the following in 2009:

Leif Østergaard
- *De udforsker hjernen: TV2 Østjylland Regionale Nyheder.* TV2 Østjylland, 19 January 2009.
- *Kulturnyt: Musik virker som sex*. Carsten Ortman. DR P2, 2 March 2009.

Arne Møller
- *Parkinson & Ludomani.* Kontant, DR1, 14 April 2009.
- *Parkinson & Ludomani*, Ekstra Bladet, 14 April 2009.
- *Parkinson & Ludomani*. Station 2, TV2, 21 April 2009.

Andreas Roepstorff
- *God Morgen P3, TV forbrug*, 14 January 2009.
- *Agenda*, Danmarks Radio P1, 18 January 2009.
- *Middagsnyhederne, MHs hjerne dissekeret online,* P1, DR, 4 December 2009.
- *P1 Morgen, Ritualer på Mauritius*, DR Radio, 29 December 2009.

Peter Vuust
- *De udforsker hjernen: TV2 Østjylland Regionale Nyheder*, 19 January 2009.
- *Musik er orgasme mellem ørerne*. Thomas Søie Hansen. Berlingske Tidende, 31 January 2009.
- *Formiddag på 4'eren*. DR P4, 6 February 2009.
- *Kulturnyt: Musik virker som sex*. DR P2 morgen, 2 March 2009.
- *P1 Morgen 1. time: Musik kan gøre at vi oplever samme følelse som ved sex*, 2 March 2009.
- *P2 aften - Kulturnyt*. DR P2, 2 March 2009.
- *Skru op for musikken.* Kåre Welinder. B.T., 8 March 2009.
- *Videnskabens verden*. DR P1, 18 April 2009.
- *P1 morgen*, 3 May 2009.
- *Kulturnyt*, DR, 5 May 2009.
- *Aftenshowet*, DR1, 12 May 2009.
- *P4 Sjælland*, DR, 18 May 2009.
- *TV2 Østjylland - Nyhederne*, 10 June 2009.
- *Apropos - musik og personlighed*. DR P1, 25 June 2009.
- *P1 Morgen 1. time: Musik og livsstil hænger sammen*, DR, 25 June 2009.
- *Den musikalske hjerne*. Annegerd Kristiansen. Politiken, 5 July 2009.
- *Videnskabens Verden - Musikken og dens påvirkning*. DR P1, 12 September 2009.
- *Akademisk rock*. Ida Hammerich Nielson. Campus, 15 September 2009.
- *P4-morgen*. DR, 21 September 2009.

Morten Kringelbach
- *From cars run on air to orgasm machines – it's a hi-tech world*, Irish Independent (Kim Bielenberg), 3 January 2009.
- *Sexchip sætter dig i stødet*, Ekstra Bladet (Denmark), 5 January 2009.
- *Griskhed får os til at gå i nettet.* Fyens Stiftstidende (Malene Birkelund), 8 February 2009.
- *Review: Pleasure Center.* New Scientist (Michael Bond), 11 February 2009.
- *Review: Pleasure Center*. Sacramento Book Review (Tom Rejek), 11 February 2009.
- *Brains over bunnies*. Daily Express (David Ingham), 20 March 2009.
- *Desarrollan chip para estimular el deseo sexual*. Terra México, 1 April 2009.
- *Forårskåd,* DR P1 Formiddag på 4'eren, (Diana Bach), 10 April 2009.
- *Brain reads word-by-word*. Science News (Tina Hesman Saey), 29 April 2009.
- *Turn It Up, Dear*. Scientific American (Gary Stix), 29 April 2009.
- *Serie om kronisk smerte*. TV2 Praxis: Jason Watts, (Teddy Bruslund), 19 May 2009.
- *Frygt og forelskelse*. DR P3 Formiddag (Adam Duvå Hall & Sara Bro), 26 May 2009.
- *Lykken er nu*. Ældresagen Nu (Lone Nyhuus), 1 June 2009.
- *Den gode og den farlige flokfølelse*. Socialdemokraten (Lone Nyhuus), 1 June 2009.
- *Temaaften om sex*. DR2 Temalørdag, (Robert Lubarski), 6 June 2009.
- *The future of sex*. Playboy.com (Chip Rowe), 13 July 2009.
- *Being gay is natural*. The Telegraph India (T.V. Jayan), 13 July 2009.
- *A sedução dos bebês.* uol.com.br (Brazil), 30 July 2009.
- *Din hjerne er meget social*. Ældresagen Nu (Lone Nyhuus), 1 August 2009.
- *Science and art.* BBC Radio 4 Leading Edge, (Geoff Watts), 10 September 2009.
- *Sex In The Future Will Be Weird*. San Francisco Chronicle (Violet Blue), 1 October 2009.
- *Kan en kalktablet virkelig være så effektiv som en rigtig pille?* Politiken (Henrik Larsen), 4 October 2009.
- *Det lykkelige liv?* DR P1, Tro og Eksistens (Kaare Gade), 25 October 2009.
- *Den farverige hjerne* (with Kristine Rømer Thomsen), Louisiana Nyt, 1 November 2009.
- *The science of hedonism*. Scope (Ireland), 1 November 2009.
- *Chũa bênh chán sex băng điên*. VNExpress (Vietnam), 30 December 2009.
- *Himlen er grøn og skoven er blå*, in M. Søndergaard (ed): AF STED, 2009.

Peter Vestergaard-Poulsen

- *Hjernen er som en muskel*. Christian Nørr. Berlingske Tidende, 13 January 2009.
- *Meditation forandrer vores hjerner*. Lasse Fogsgaard. Jyllandsposten, 13 January 2009.
- *Meditation forandrer vores hjerner*. Lasse Foghsgaard. videnskab.dk, 14 January 2009.
- *Meditationsforsøg giver håb om ny stressbehandling*. Laura Elisabeth Schanabel. Kristeligt Dagblad, 25 February 2009.
- *Meditation forandrer vores hjerner*. Tina Løvbom Petersen. Arbejdsmiljømagasinet, det nationale center for arbejdsmiljø, 1 May 2009.
- *DR P4*. Jesper Ingerstrup og Gitte Hansen. Danmarks Radio P4, 25 May 2009.
- *Godmorgen P3*. Danmarks Radio, P3, 25 May 2009.

Uta Frith

- Interview by Steve Ayan in *Gehirn und Geist*
- Video Interview and podcast for Royal Society website 350th Anniversary year, Special issue of Philosophical Transactions B

Other CFIN researchers

- Blicher, Jakob. Pas på! Marketing-guru i omløb. Berlingske Tidende. 19 January 2009.
- Petersen, Bjørn. Fra sans og samling: Hørelsen. Susanna Sommer. DR P1, 30 November 2009.
- Wallentin, Mikkel. DR/P4 Formiddag på 4'eren. DR P4, 19 October 2009.

Boards / Committees / Editorials

CFIN researchers are involved in the following:

Leif Østergaard

- Member, Royal Danish Academy for Sciences and Letters (Det Kongelige Danske Videnskabernes Selskab). From September 2008.
- Member, Forskningsledernetværket FL1. From December 2007.
- Member, Nomination Committee, International Society for Magnetic Resonance in Medicine. 1 June 2008 - 1 May 2009.
- Member, Akademiet for de Tekniske Videnskabers Tænketank. From 10 June 2009.

Albert Gjedde

- Chairman, Kongelige Biblioteks vejledende forskningsråd, 1 August 2006 - 31 July 2011.
- Member, Forskningsrådet for Sundhed og Sygdom, 1 August 2005 - 30 July 2011.
- Executive council member, European Dana Alliance for the Brain, From 1 January 2001.
- Deputy member – Udvalget vedrørende videnskabelig uredelighed.

Andreas Roepstorff

- Member, Steering Committee, A Topological Approach to Cultural Dynamics, From 1 July 2008.
- Member, Programstyret: ELSA program for bioteknologi, nanoteknologi og kognitive videnskaber, From 1 August 2007.
- Member, Steering Committee, Neuroscience and Society Network (ENSN), 24 April 2007 - 31 December 2011.
- Project leader, BASIC (Brain, Agency, Self, Intersubjectivity, Consciousness), a ESF EUROCORES CNCC Project, 27 November 2006 - 27 November 2009.
- Member, Scientific Committe, EUROCORES Project CNCC (Consciousness in a Natural and a Cultural Context), 14 November 2006 - 14 November 2009.
- Member, Det strategiske forskningsråd, programkomiteen for strategiske vækstteknologier. From 1 January 2009.

Uta Frith

- Member, British Academy, Chair of Psychology Section (2008 -)
- Member, Royal Society, Chair of Library Committee (2008)
- Member, Royal Society, Chair of Ralph Kohn Award Committee
- Member, Royal Society, Programme Evaluations Panel
- Member, Royal Society, Rosalind Franklin Award Panel
- Member, Leopoldina (Halle), Mitwirkung in der Bibliotheks- /Archivkommission
- Member of Advisory Board, COEDUCA Project on Cognition and Education, (Coordinator Manuel Carreiras Basque Centre on Cognition, Brain and Language, San Sebastian)
- Member of Advisory Board Pufendorf Institute, Lund (Director Sture Forsen)
- Member of Advisory Board, Lund University Linneaus Grant: Thinking in time, Cognition, Communication and Learning (Rector Sven Strömqvist)
- Member of Advisory Board, Berlin School of Mind and Brain, part of the German Excellence Initiative (Speaker Arno Villringer)
- Member of Advisory Board, Glasgow Social Interactions: a cognitive neuroscience approach (Directors Simon Garrod and Philippe Schyns)

Risto Näätänen

- First Vice President 2004 - present of International Organization of Psychophysiology (IOP).
- Member of Editorial boards:
  - International Journal of Psychophysiology
  - Audiology and Neuro-Otology
  - Clinical Neurophysiology
- Editor of International Journal of Psychophysiology.

Hans C. Lou

- Member, Editorial board, Acta Paediatrica
- Meritorious member, Child Neurology Society, USA.
- Associate Fellow, Queens College, Oxford.

Morten Kringelbach
- Fellow of Association for Psychological Science (APS), USA. For "... sustained outstanding contributions to the science of psychology".
- Board of advisers, Scientific American, USA.

Peter Vestergaard-Poulsen
- Staff-student committee for Biomedical Engineering, Clinical Institute, Aarhus University.

Peter Vuust
- Chairman, Forskningsudvalget ved Det Jyske Musikkonservatorium (Royal Academy of Music Aarhus). From 1 August 2005.
- Member, Kulturministeriets forskningsudvalg (Ministry of Culture Research Committée). From 1 January 2008.

Mikkel Wallentin
- ESF Pool of peer reviewers (1 May 2009 - 1 May 2010).

Teaching

- Jespersen, Sune Nørhøj. Lectures for visiting physics classes in high school. From 1 December 2007.
- Østergaard, Leif. A-Course in diagnostic radiology: Neuroradiology. MR in acute stroke. 3 February 2009. Sundhedsstyrelsen, Aarhus, Denmark.

Research stays abroad

- Campbell-Meiklejohn, Daniel. Research visit, UCL, London, UK
- Hansen, Brian. Research visit, McKnight Brain Institute, Gainesville, FL, USA. 11-21 July 2009.
- Jespersen, Sune Nørhøj. Research visit at Oregon Health and Science University, Portland, USA. August 2009.
- Jespersen, Sune Nørhøj. Research visit at Potsdam University, Potsdam, Germany. November 2009.
- Konvalinka, Ivana. Research visit at UCL, London, UK
- Kotnis, Sita R. Research visit, University of Pennsylvania, USA
- Lodahl, Sanne. Research visit, Harvard University, USA
- Lou, Hans C. Visiting research fellow, Queens College Oxford, UK. February-September 2009.
- Mouridsen, Kim. MGH Athinoula A. Martinos Center, Massachusetts General Hospital, Harvard Medical School, Boston, USA

Research stays at CFIN

- Professor Norbert Nighoghossian, Université Claude Bernard, Lyon, France. Research visit at CFIN. 1 April - 12 May 2009.

Scholarships & awards

- Frith, Chris & Uta. 2009 European Latsis Prize *The Human Brain - The Human Mind*.
- Frith, Chris. 2009 Fondation Fyssen Prize, *Neuropsychology*.
- Hansen, Brian. Support for participation in ISMRM 2009: DKK 20.000. 18-24 April 2009. Helga og Peter Kornings Foundation.
- Jespersen, Sune Nørhøj. The diffusion tensor reveals gray matter cytoarchitecture: First place poster award. 24 April 2009. International Society for Magnetic Resonance in Medicine, Honolulu, USA.
- Jespersen, Sune Nørhøj. Support from Helga and Peter Kornings Foundation, DKK 20.000.
- Mouridsen, Kim. Scholarship: Quantifying the Efficacy of Antiangiogenetic Agents in Normalizing Tumor Hemodynamics. 1 January - 31 December 2009. Danish Agency for Science Technology and Innovation, Denmark.
- Østergaard, Leif. Den Gyldne Skalpel: Initiativpris med apopleksisamarbejdet ved Århus Universitetshospital 'for et enestående samarbejde om behandling af patienter med blodprop eller blødning i hjernen'. 18 June 2009. Dagens Medicin, Denmark.

International scientific partners

- Institut National de la Santé et de Recherche Medicale / Université Claude Bernard, Lyon, Frankrig (Professor Norbert Nighoghossian)
- Fundació Privada Institut d'Investigació Biomédica de Girona, Girona, Spain (Professor Salvador Pedraza)
- University of Cambridge, Cambridge, UK (Professor Jean-Claude Baron)
- Universitätsklinikum Hamburg-Eppendorf, Hamburg, Germany (Professor Jens Fiehler)
- Universitätsklinikum Freiburg für die Medizinische Fakultät der Albert-Ludwigs-Universität, Freiburg, Germany (Dr. Valerij Kiselev)
- Royal Melbourne Hospital, Melbourne, Australia (Professor S. Davis)
- MGH Athinoula A. Martinos Center, Massachusetts General Hospital, Boston, USA. (Dr. O. Wu and Dr. A.G. Sorensen)
- Brain Research Institute, Heidelberg West, Victoria, Australia (Dr. F. Calamante)
- McKnight Brain Institute, University of Florida, USA (Professor Steve Blackband)
- Mallinckrodt Institute of Radiology, Washington University, St. Louis, USA (Dr. D. Yablonski and Professor J. Ackerman)
- Dan Zahavi, Center for Subjektivitetsforskning, Københavns Universitet, Denmark
- Patrick Haggard, UCL, London, UK
- Nikolas Rose, LSE, London, UK

- Harvey Whitehouse, Oxford University, UK
- Doug Saddy, Reading Universitet, UK
- Simon Cohn, Goldsmith College, London, UK
- Celia Lury, Goldsmith College, London, UK
- Jules Davidoff, Goldsmith College, London, UK
- Evan Thompson, University of Toronto, Canada
- Marc Raichle, Washington University, St. Louis, USA
- Anthony Jack, Washington University, St. Louis, USA
- Alva Noë, University of California, Berkeley, US A
- Kai Vogeley, Köln Universitet, Germany
- Albert Newen, Tübingen University, Germany
- Vittorio Gallese, Parma University, Italy
- Tatjana Nazir, Lyon University, France
- Jakob Hohwy, Monash University, Melbourne, Australia
- McKnight Brain Institute, University of Florida, Gainesville, Florida, USA (Professor Steve Blackband)
- Mari Tervaniemi, Cognitive Brain Research Unit, Department of Psychology, University of Helsinki (CBRU) and Helsinki Brain Research Center, Helsinki, Finland
- Elvira Brattico, CBRU and Helsinki Brain Research Center, Helsinki, Finland
- Sakari Leino, CBRU and Helsinki Brain Research Center, Helsinki, Finland
- Eckart Altenmüller, Institut für Musikphysiologie und Musikermedizin, Hannover, Germany
- Lauren Steward, Psychology Department, Goldsmiths, University of London, UK
- Karl Friston, Functional Imaging Laboratory (FIL), Wellcome Centre of Cognitive Neuroscience, UCL, UK
- Satu Pakarin, CBRU and Helsinki Brain Research Center, Helsinki, Finland
- Professor Roger Dean, Vice-Chancellor and President, University of Canberra, ACT 2601, Australia; Fellow of the Australian Academy of the Humanities (FAHA).
- Antoine Bechara, University of Iowa, USA
- Rebecca German, Professor and Vice-Chair for Research, Department of Physical Medicine and Rehabilitation, Johns Hopkins University School of Medicine, Baltimore, USA

Industriel partners

- Systematic Software Engineering A/S, Århus, Denmark
- Dimac A/S, Højbjerg, Denmark
- Nordic Neurolab, Bergen, Norway
- GlaxoSmithKline, Cambridge, UK
- Schering AG, Berlin, Germany
- GE Medical Systems, Milwaukee, USA
- Danaflex A/S, Birkerød, Denmark

Completed Doctoral dissertations, 2009

- Jacob Geday, MD. *Functions of the Medial Frontal Cortex. A Model of Monoaminergic Modulation*. 2 October 2009.

Completed PhD dissertations, 2009

- Kristian Tylén, MA. *Roses, Icebergs, Hoovers and all that Language: An investigation of the cognitive foundations of our comprehension of object mediated communication*. PhD defended at University of Southern Denmark, Odense. 17 April 2009.
- Uffe Schjødt, MA. *The Neural Substrates of Prayer: Toward an experimental neuroscience of religion*. 7 May 2009.
- Søren Christensen, MSc. *Optimization and Validation of Perfusion MRI Post-Processing Techniques.* 12 May 2009.
- Jeremy Flint, M.Sc. *Examination of tissue microstructure, contrast enhancement and neural activity in the brain slice model using magnetic resonance microscopy*. 26 June 2009.
- Esben Thade Petersen, MSc. *Brain Perfusion Imaging: Quantification of Cerebral Blood Flow Using ASL Techniques*. 3 July 2009.
- Ericka Peterson, BS, MA Neuroscience. *Neurobiological Correlates of Gambling in Men and Women*. 17 August 2009.
- Kamila Ewa Sip, MA. *Neuroimaging of deception in social interaction and lie-detection*. 29 September 2009.

Completed Master theses, 2009

- Rune Vingborg, MSc. *Internal Models of Movement in Functional Electrical Stimulation: an fMRI study*. 13 November 2009.

CFIN Friday Seminars 2009

CFIN seminar coordinators:
Associate Professor Arne Møller,
Communications Coordinator Henriette Blæsild Vuust.
Read more at: http://www.cfin.au.dk//cfinseminars

Spring seminars:
- Manus J. Donahue, PhD, Postdoctoral MR Physicist, Dept. of Clinical Neurology, University of Oxford: *Functional Brain Imaging using MRI: Novel Methods and Applications*
- Anna Shestakova, Centre for Developmental Language Disorders and Cognitive Neuroscience: *'Sensory intelligence' in the auditory cortex: brain responses to native and non-native phonetic stimuli*

- Donald F. Smith, Research Psychologist, Center for Psychiatric Research / CFIN: *PET neuroimaging of Treatment-resistant Depression*
- Peter R. Ogilby, Center for Oxygen Microscopy and Imaging Department of Chemistry, University of Aarhus: *Singlet Oxygen in Single Cells: Killing Cells Softly and Watching them Die*
- Eduardo Adrian Garza Villarreal, MD, PhD student, CFIN: *Neural correlates of music-induced analgesia and susceptible subjects*
- Mark West, Professor, DrMedSc, Anatomical Institute, University of Aarhus: *Structural Changes in the brain in Alzheimers Disease*
- Claus Jacobsen, Journalist, Communications Counsellor: *Journalistisk tænkning på redaktionerne – i trykte medier, radio og TV, og formidling af ny viden*
- Norbert Nighoghossian, Professor, Université Claude Bernard, Lyon, France: *Unstable carotid artery plaque a main cause of ischemic stroke, a new approach*
- Rasmus Aamand, MSc, Department of Biology / CFIN, Aarhus University: *Carbonic anhydrase generates vasoactive nitric oxide from nitrite*
- Angela Fago, PhD, Associate Professor, Dept. of Biological Sciences, Aarhus University: *How the brain protects itself against stroke: The role of neuroglobin*
- Bente Finsen & Trevor Owens, Medical Biotechnology Center University of Southern Denmark: *Microglial cells as sensors and modulators of brain pathology*
- Poul Jennum, Glostrup Hospital: *The hypocretinergic system: Importance for neurodegenerative disorders*

Fall seminars:

- Douglas Saddy, Centre for Integrative Neuroscience and Neurodynamics, University of Reading, UK: *An introduction to the University of Reading's Centre for Integrative Neuroscience and Neurodynamics (CINN)*
- Leif Østergaard, Head of CFIN: *MINDLab: Interdisciplinary neuroscience at Aarhus University*
- Kristine Rømer Thomsen, CFIN & PET Center Aarhus: *Elucidating the functional neuroanatomy of social pleasure - some insights from my stay in Oxford*
- Daniel Campbell-Meiklejohn, Postdoctoral Researcher, Interacting Minds & Ludomani at CFIN: *Learning in a Social World: Influence and Freeriding*
- Morten Overgaard & Jørgen Feldbæk Nielsen, CFIN and CNRU / Hammel Neurorehabilitation Center: *MindRehab*
- Albert Gjedde, Professor, University of Copenhagen & CFIN: *Molecular Basis of Healthy Aging – and international network possibilities*
- Merete Raarup & Anja Fjorback, Stereology and EM Research Lab: *Fluorescence and FRET microscopy of proteins and protein-protein interactions*
- Merlin Donald, Department of Psychology & Education, Queen's University, Kingston, Ontario, Canada: *The Slow Process*
- Philippe Grandjean, Professor, University of Southern Denmark: *Developmental neurotoxicity due to industrial chemicals*
- Pál Weihe, Research Associate Professor,University of Southern Denmark: *Functional MRI evidence of methylmercury neurotoxicity in Faroese adolescents*
- Sofia Dahl, Assistant Professor, Aalborg University Copenhagen, Department of Media Technology, Section for Medialogy: *Movement and timing control in drumming*
- Gorm Bennedsen, PhD Student, Stereology, AU: *The Brain Distribution of Sortilin and SorLA and the role of Sortilin in Cerebral Ischemia and Trauma*
- Luis Garcia-Larrea, MD, PhD, Director of Research, Inserm, Head, Central Integration of Pain Unit - U879 INSERM & University Lyon 1: *My brain, may pain and the pain of others: From sensory resonance to compassive hyperalgesia*
- Ryota Kanai, Post.doc., UCL (University College London), UK: *Two types of subjective invisibility: Attentional and perceptual blindness*
- Mette Berendt, Head of Post Graduate Research School KLINIK, Department of Small Animal Clinical Sciences, Faculty of Life Sciences, University of Copenhagen: *Canine epilepsy - a spontanious animal model of epilepsy in man?*

CFIN and MIND*Lab* Retreat 2009

The annual CFIN Retreat was held at Sandbjerg Manor 6-8 October 2009. This year's program was:

- Anders Nykjær, Lundbeck's MIND Center, AU: *Identification of novel drug targets for treatment of bipolar disorder*
- Morten Kringelbach, Oxford, TrygFonden Research Group: *The development of Parent-Infant relationships*
- Prof. Doug Saddy, Reading: *You can't always get what you want - incommensurable levels of descriptions and the need for interdisciplinarity*
- Torben E. Lund, Sune N. Jespersen, Dmitris Xygalatas: *Are we in sync? Is inter-subject synchronization key to measure interaction – and how is it done?*
- Daniel Campbell-Meicklejohn, Jørgen Scheel-Krüger: *Addiction - reward? What are their key behavioral and neurochemical components?*
- Uffe Schjødt, Jesper Sørensen: *What's in the Power of Charisma?*
- Eva Vedel-Jensen, Leif Østergaard: *What's in the noise? Are the assumptions underlying current fMRI analysis void? Does BOLD noise reflect an underlying, overlooked physiological phenomenon?*
- Doug Saddy, Ken Ramshøj: *Between Nouns and Neurons. How can we map between structures in language and cortical activity?*

2009 Publications

Peer reviewed articles:

Aamand R, Dalsgaard T, Jensen FB, Simonsen U, Roepstorff A, Fago A. Generation of nitric oxide from nitrite by carbonic anhydrase: a possible link between metabolic activity and vasodilation, American Journal of Physiology: Heart and Circulatory Physiology, 2009; 297: H2068-H2074.

Ashkanian M, Gjedde A, Mouridsen K, Vafaee M, Hansen KV, Østergaard L, Andersen G. Carbogen inhalation increases oxygen transport to hypoperfused brain tissue in patients with occlusive carotid artery disease Increased oxygen transport to hypoperfused brain. Brain research. 2009; 1304: 90-95.

Baad-Hansen L, Blicher J, Lapitskaya N, Nielsen JF, Svensson P. Intra-cortical excitability in healthy human subjects after tongue training. Journal of Oral Rehabilitation. 2009; 36(6): 427-34.

Blicher J, Jakobsen JK, Andersen G, Nielsen JF. Cortical Excitability in Chronic Stroke and Modulation by Training: A TMS Study. Neurorehabilitation and Neural Repair. 2009; 23(5): 486-493.

Borghammer P, Cumming P, Aanerud J, Förster S, Gjedde A. Subcortical elevation of metabolism in Parkinson's disease - a critical reappraisal in the context of global mean normalization. Neuroimage. 2009; 47(4): 1514-1521.

Borghammer P, Cumming P, Aanerud JFA, Gjedde A. Artefactual subcortical hyperperfusion in PET studies normalized to global mean: lessons from Parkinson's disease. NeuroImage. 2009; 45(2): 249-257.

Borghammer P, Aanerud JFA, Gjedde A. Data-driven intensity normalization of PET group comparison studies is superior to global mean normalization. Neuroimage. 2009; 46(4): 981-988.

Brattico E, Pallesen KJ, Varyagina O, Bailey C, Anourova I, Järvenpää M, Eerola T, Tervaniemi M. Neural discrimination of nonprototypical chords in music experts and laymen: an MEG study. J Cogn Neurosci. 2009; 21(11): 2230-2244.

Burnett S, Bird G, Moll J, Frith C, Blakemore S-J. Development during adolescence of the neural processing of social emotion. Journal of Cognitive Neuroscience. 2009; 21(9): 1736-1750.

Cho T-H, Hermier M, Alawneh JA, Ritzenthaler T, Desestret V, Østergaard L, Derex L, Baron J-C, Nighoghossian N. Total mismatch: negative diffusion-weighted imaging but extensive perfusion defect in acute stroke. Stroke; 2009; 40; 10: 3400-3402.

Christensen KR. Negative and affirmative sentences increase activation in different areas in the Brain. Journal of Neurolinguistics, 2009; 22: 1-17.

Christensen S, Mouridsen K, Wu O, Hjort N, Karstoft H, Thomalla G, Röther J, Fiehler J, Kucinski T, Østergaard L. Comparison of 10 Perfusion MRI Parameters in 97 Sub 6 Hour Stroke Patients using Voxel based Receiver Operating Characteristics Analysis. Stroke. 2009; 40(6): 2055-2061.

Corlett PR, Frith CD, Fletcher PC. From drugs to deprivation: a Bayesian framework for understanding models of psychosis. Psychopharmacology. 2009; 206(4): 515-530.

Cornelissen PL, Kringelbach ML, Ellis AW, Whitney C, Holliday IE, Hansen PC. Activation of the left inferior frontal gyrus (pars opercularis) in the first 200 msec of reading: evidence from magnetoencephalography (MEG). PLoS ONE. 2009; 4(4): e5359.

Cowan R, Frith C. Do calendrical savants use calculation to answer date questions? A functional magnetic resonance imaging study. Philosophical Transactions of the Royal Society of London. Biological Sciences. 2009; 364(1522): 1417-1424.

Donahue M, Blicher J, Østergaard L, Feinberg D, MacIntosh B, Miller K, Gunther M, Jezzard P. Cerebral blood flow, blood volume and oxygen metabolism dynamics in human visual and motor cortex as measured by whole-brain multi-modal magnetic resonance imaging. Journal of Cerebral Blood Flow and Metabolism. 2009; 29(11): 1856-1866.

Duncan CC, Barry RJ, Connolly JF, Fischer C, Michie PT, Näätänen R, Polich J, Reinvang I, Van Petten C. Event-related potentials in clinical research: Guidelines for eliciting, recording, and quantifying mismatch negativity, P300, and N400. Clinical Neurophysiology, 2009; 120: 1883-1908.

Eskildsen SF, Østergaard LR, Rodell A, Østergaard L, Nielsen JE, Isaacs AM, Johannsen P. Cortical volumes and atrophy rates in FTD-3 CHMP2B mutation carriers and related non-carriers. NeuroImage. 2009; 45(3): 713-721.

Fletcher PC, Frith CD. Perceiving is believing: a Bayesian approach to explaining the positive symptoms of schizophrenia. Nat Rev Neurosci, 2009; 10(1): 48-58.

Flint J, Hansen B, Vestergaard-Poulsen P, Blackband SJ. Diffusion weighted magnetic resonance imaging of neuronal activity in the hippocampal slice model. Neuroimage. 2009; 46(2): 411-418.

Flint JJ, Lee CH, Hansen B, Fey M, Schmidig D, Bui JD, King MA, Vestergaard-Poulsen P, Blackband SJ. Magnetic resonance microscopy of mammalian neurons. Neuroimage. 2009; 46(4): 1037-1040.

Frith C. Role of facial expressions in social interactions. Philosophical Transactions of the Royal Society B-Biological Sciences, 2009; 364(1535): 3453-3458.

Frith C. Role of facial expressions in social interactions. Philosophical Transactions of the Royal Society of London. Biological Sciences. 2009; 364(1535): 3453-3458.

Frith U. Foundations of sand? Psychologist. 2009; 21(1): 900.

Geday J, Gjedde A. Attention, emotion, and deactivation of default activity in inferior medial prefrontal cortex. Brain Cogn. 2009; 69(2): 344-352.

Geday J, Gjedde A. Monoaminergic modulation of emotional impact in the inferomedial prefrontal cortex. Synapse. 2009; 63(2): 160-166.

Geday J, Østergaard K, Johnsen E, Gjedde A. STN-stimulation in Parkinson's disease restores striatal inhibition of thalamocortical projection. Hum Brain Mapp. 2009; 30(1): 112-121.

Gilbert SJ, Meuwese JDI, Towgood KJ, Frith CD, Burgess PW. Abnormal functional specialization within medial prefrontal cortex in high-functioning autism: a multi-voxel similarity analysis. Brain. 2009; 132(4): 869-878.

Gjedde A, Geday J. Deep brain stimulation reveals emotional impact processing in ventromedial prefrontal cortex. PLoS One. 2009; 4(12):e8120.

Green AL, Wang S, Stein JF, Pereira EA, Kringelbach ML, Liu X, Brittain JS, Aziz TZ. Neural signatures in patients with neuropathic pain. Neurology. 2009; 72(6): 569-571.

Grover PJ, Pereira EAC, Green AL, Brittain JS, Owen SLF, Schweder P, Kringelbach ML, Davies PT, Aziz TZ. Deep brain stimulation for cluster headache. Journal of Clinical Neuroscience. 2009; 16: 861-866.

Hamilton AFC, Brindley R, Frith U. Visual perspective taking impairment in children with autistic spectrum disorder. Cognition. 2009; 113(1): 37-44.

Haruno M, Frith CD. Activity in the amygdala elicited by unfair divisions predicts social value orientation. Nature Neuroscience. 2009; 13(2): 160-161.

Ho Y-CL, Cheze A, Sitoh Y-Y, Petersen ET, Goh K-Y, Gjedde A, Golay X. Residual neurovascular function and retinopy in a case of hemianopia. Annals of the Academy of Medicine Singapore. 2009; 38(9): 827-831.

Jonsdottir KY, Østergaard L, Mouridsen K. Predicting Tissue Outcome From Acute Stroke Magnetic Resonance Imaging. Improving Model Performance by Optimal Sampling of Training Data. Stroke. 2009; 40: 3006-3011.

Kalbitzer J, Frokjaer VG, Erritzoe D, Svarer C, Cumming P, Nielsen FA, Hashemi SH, Baare WF, Madsen J, Hasselbalch SG, Kringelbach ML, Mortensen EL, Knudsen GM. The personality trait openness is related to cerebral 5-HTT levels. NeuroImage. 2009; 45(2): 280-285.

Kilner JM, Neal A, Weiskopf N, Friston KJ, Frith CD. Evidence of mirror neurons in human inferior frontal gyrus. Journal of Neuroscience. 2009; 29(32): 10153-10159.

Kilner JM, Marchant JL, Frith CD. Relationship between activity in human primary motor cortex during action observation and the mirror neuron system. PLoS ONE. 2009; 4(3): e4925.

Kjølby BF, Mikkelsen IK, Pedersen M, Østergaard L, Kiselev V. Analysis of Partial Volume Effects on Arterial Input Functions Using Gradient Echo: A Simulation Study. Magnetic Resonance in Medicine. 2009; 61(6): 1300-1309.

Kringelbach ML, Aziz TZ. Deep brain stimulation: Avoiding the errors of psychosurgery. JAMA - Journal of the American Medical Association. 2009; 301(16): 1705-1707.

Kringelbach ML, Green AL, Pereira EAC, Owen SLF, Aziz TZ. Deep brain stimulation. The Biologist. 2009; 56: 144-148.

Kringelbach ML, Pereira EAC, Green AL, Owen SLF, Aziz TZ. Deep brain stimulation for chronic pain. Journal of Pain Management. 2009; 3: 301-314.

Kringelbach ML, Berridge KC. Towards a functional neuroanatomy of pleasure and happiness. Trends in cognitive sciences. 2009; 13(11): 479-487.

Kumakura Y, Danielsen EH, Gjedde A, Vernaleken I, Buchholz H-G, Heinz A, Gründer G, Bartenstein P, Cumming P. Elevated [(18)F]FDOPA utilization in the periaqueductal gray and medial nucleus accumbens of patients with early Parkinson’s disease. NeuroImage. 2009; 49(4): 2933-2939.

Kwon MS, Kujala T, Huotilainen M, Shestakova A, Näätänen R, Hämäläinen H. Preattentive auditory information processing under exposure to the 902 MHz GSM mobile phone elecromagnetic field: a mismatch negativity (MMN) study. Bioelectromagnetics, 2009; 30: 241-248.

Larsen EKU, Nielsen T, Wittenborn T, Birkedal H, Vorup-Jensen T, Jakobsen MH, Østergaard L, Horsman MR, Besenbacher F, Howard KA, Kjems J. Size-Dependent Accumulation of PEGylated Silane-Coated Magnetic Iron Oxide Nanoparticles in Murine Tumors. ACS Nano. 2009; 3: 1947-1951.

Lovio R, Pakarinen S, Huotilainen M, Alku P, Silvennoinen S, Näätänen R, Kujala T. Auditory discrimination profiles of speech sound changes in 6-year-old children as determined with the multi-feature MMN paradigm. Clinical Neurophysiology, 2009; 120: 916-921.

Mobbs D, Yu R, Meyer M, Passamonti L, Seymour B, Calder AJ, Schweizer S, Frith CD, Dalgleish T. A key role for similarity in vicarious reward. Science. 2009; 324(5929): 900.

Mobbs D, Hassabis D, Seymour B, Marchant JL, Weiskopf N, Dolan RJ, Frith CD. Choking on the money: reward-based performance decrements are associated with midbrain activity. Psychological Science. 2009; 20(8): 955-962.

Mobbs D, Marchant JL, Hassabis D, Seymour B, Tan G, Gray M, Petrovic P, Dolan RJ, Frith CD. From threat to fear: the neural organization of defensive fear systems in humans. The Journal of neuroscience. 2009; 29(39): 12236-12243.

Møller M, Rodell A, Gjedde A. Parametric mapping of 5HT1A receptor sites in the human brain with the Hypotime method: theory and normal values. J Nucl Med. 2009; 50(8): 1229-1236.

Näätänen R, Kähkönen S. Central auditory dysfunction in schizophrenia as revealed by the mismatch negativity (MMN) and its magnetic equivalent MMNm: a review. The International Journal of Neuropsychopharmacology, 2009; 12: 125-135.

Näätänen R. Somatosensory mismatch negativity: a new clinical tool for developmental neurological research? Developmental Medicine and Child Neurology, 2009; 51: 930-931.

Nelson S, Josefsen LG, LaBrie R, Shaffer H. Gambling Problem Symptom Patterns and Stability across Individual and Timeframe. Psychology of Addictive Behaviors. 2009; 23(3): 523-533.

Neumann AB, Jonsdottir KY, Mouridsen K, Hjort N, Gyldensted C, Bizzi A, Fiehler J, Gasparotti R, Gillard JH, Hermier M, Kucinski T, Larsson E-M, Sørensen L, Østergaard L. Interrater Agreement for Final Infarct MRI Lesion Delineation. Stroke. 2009; 40: 68-71.

Nielsen E, Smerup M, Nielsen PA, Frandsen J, Ringgaard S, Pedersen M, Vestergaard-Poulsen P, Nyengaard JR, Andersen JB, Lunkenheimer PP, Anderson RH, Hjortdal V. Normal Right Ventricular Three-Dimensional Architecture, as Assessed with Diffusion Tensor Magnetic Resonance Imaging, is Preserved During Experimentally Induced Right Ventricular Hypertrophy. Anatomical Record. 2009; 292(5): 640-651.

Pakarinen S, Lovio R, Huotilainen M, Alku P, Näätänen R, Kujala T. Fast multi-feature paradigm for recording several mismatch negativities (MMNs) to phonetic and acoustic changes in speech sounds. Biological Psychology, 2009; 82: 219-226.

Pallesen KJ, Brattico E, Bailey CJ, Korvenoja A, Gjedde A. Cognitive and emotional modulation of brain default operation. J Cogn Neurosci. 2009; 21(6): 1065-1080.

Petersen B, Vuust P, Mortensen MV, Gjedde A. Reestablishing Speech Understanding through Musical Ear Training after Cochlear Implantation: A Study of the Potential Cortical Plasticity in the Brain. Annals of the New York Academy of Sciences. 2009; 1169: 437-440.

Raafat RM, Chater N, Frith C. Herding in humans. Trends in Cognitive Sciences. 2009; 13(12): 504.

Ramsøy TZ, Liptrot MG, Skimminge A, Lund TE, Sidaros K, Christensen MS, Baaré W, Paulson OB, Jernigan TL. Regional activation of the human medial temporal lobe during intentional encoding of objects and positions. Neuroimage. 2009; 47(4): 1863-1872.

Ray NJ, Jenkinson N, Kringelbach ML, Hansen PC, Pereira EA, Brittain JS, Holland P, Holliday IE, Owen S, Stein J, Aziz T. Abnormal thalamocortical dynamics may be altered by deep brain stimulation: using magnetoencephalography to study phantom limb pain. Journal of Clinical Neuroscience. 2009; 16(1): 32-36.

Rohrer JD, Ahsan RL, Isaacs AM, Nielsen JE, Østergaard L, Scahill R, Warren JD, Rossor MN, Fox NC, Johannsen P, FReJA consortium. Presymptomatic generalized brain atrophy in frontotemporal dementia caused by CHMP2B mutation. Dementia and Geriatric Cognitive Disorders. 2009; 27(2): 182-186.

Rosendal F, Frandsen J, Chakravarty MM, Bjarkam C, Pedersen M, Sangill R, Sørensen JC. New surgical technique reduces the susceptibility artefact at air-tissue interfaces on in vivo cerebral MRI in the Göttingen minipig. Brain Research Bulletin. 2009; 80(6): 403-407.

Saldaña D, Carreiras M, Frith U. Orthographic and phonological pathways in hyperlexic readers with Autism Spectrum Disorders. Developmental Neuropsychology. 2009; 34(3): 240-253.

Sanganahalli BG, Bailey CJ, Herman P, Hyder F. Tactile and non-tactile sensory paradigms for fMRI and neurophysiologic studies in rodents. Methods in Molecular Biology. 2009; 489: 213-242.

Schjødt U, Roepstorff A, Stødkilde-Jørgensen H, Geertz AW. Highly religious participants recruit areas of social cognition in personal prayer, Social Cognitive and Affective Neuroscience, 2009; 4(2): 199-207.

Schroeder H, Wacher J, Larsson H, Rosthøj S, Rechnitzer C, Petersen BL, Carlsen NLT. Unchanged incidence and increased survival in children with neuroblastoma in Denmark 1981-2000: a population-based study. British Journal of Cancer. 2009; 100(5): 853-857.

Senju A, Southgate V, White S, Frith U. Mindblind eyes: an absence of spontaneous theory of mind in Asperger syndrome. Science. 2009; 325(5942): 883-885.

Siemonsen S, Mouridsen K, Holst B, Ries T, Finsterbusch J, Thomalla G, Østergaard L, Fiehler J. Quantitative t2 values predict time from symptom onset in acute stroke patients. Stroke. 2009; 40(5): 1612-1616.

Skewes J, Hooker CA. Bio-agency and the problem of action, Biology and Philosophy, 2009; 24(3): 283-300.

Smerup M, Nielsen E, Agger P, Frandsen J, Vestergaard-Poulsen P, Andersen J, Nyengaard JR, Pedersen M, Ringgaard S, Hjortdal V, Lunkenheimer PP, Anderson RH. The three-dimensional arrangement of the myocytes aggregated together within the Mammalian ventricular myocardium. Anatomical Record. 2009; 292(1): 1-11.

Stephan KE, Friston KJ, Frith CD. Dysconnection in schizophrenia: from abnormal synaptic plasticity to failures of self-monitoring. Schizophrenia Bulletin. 2009; 35(3): 509-527.

Sølling C, Ashkanian M, Hjort N, Gyldensted C, Andersen G, Østergaard L. Feasibility and logistics of MRI before thrombolytic treatment. Acta Neurol Scand. 2009; 120(3): 143-149.

Sølling C, Hjort N, Ashkanian M, Østergaard L, Andersen G. Safety and efficacy of MRI-based Selection for rtPA Treatment.Responder Analysis of Outcome in the 3 Hour Time Window. Cerebrovascular Diseases. 2009; 27(3): 223-229.

Sølling C, Johnsen SP, Ehlers L, Østergaard L, Andersen G. Upgraded acute stroke care including thrombolysis is associated with reduced length of hospital stay among non-stroke patients. Cerebrovascular Diseases. 2009; 27(1): 60-66.

Takegata R, Heikkilä R, Näätänen R. Neural process underlying gap detection for spectrally rich and asymmetrical markers. NeuroReport, 2009; 20: 1120-1124.

Talmi D, Dayan P, Kiebel SJ, Frith CD, Dolan RJ. How humans integrate the prospects of pain and reward during choice. Journal of Neuroscience. 2009; 29(46): 14617-14626.

Teinonen T, Fellman V, Näätänen R, Alku P, Huotilainen M. Statistical language learning in neonates revealed by event-related brain potentials. BMC Neuroscience, 2009; 10: 21.

Thomsen KR, Callesen MB, Linnet J, Kringelbach ML, Møller A. Severity of gambling is associated with severity of depressive symptoms in pathological gamblers. Behavioural Pharmacology. 2009; 20(5-6): 527-536.

Tylén K, Wallentin M, Roepstorff A. Say it with flowers! An fMRI study of object mediated communication. Brain and Language. 2009; 108(3): 159-166.

Tylén K, Philipsen JS, Weed E. Taking the Language Stance in a Material World, Pragmatics & Cognition, 2009; 17(3): 573-595.

Vestergaard-Poulsen P, Beek M, Skewes J, Bjarkam C, Stubberup M, Bertelsen J, Roepstorff A. Long-term meditation is associated with increased gray matter density in the brain stem. NeuroReport. 2009; 20(2): 170-174.

Vogeley K, Roepstorff A. Contextualising Culture and Cognition, Trends in Cognitive Sciences, 2009; 13(12): 511-516.

Vuust P, Østergaard L, Pallesen KJ, Bailey C, Roepstorff A. Predictive coding of music: Brain responses to rhythmic incongruity. Cortex. 2009; 45(1): 80-92.

Wallentin M. Er der kønsforskelle i hjernens bearbejdning af sprog? Tidsskrift for Sprogforskning. 2009.

Wallentin M. Putative sex differences in verbal abilities and language cortex: A critical review. Brain and Language. 2009; 108(3): 175-183.

White S, O'Reilly H, Frith U. Big heads, small details and autism. Neuropsychologia. 2009; 47(5): 1274-1281.

White S, Hill E, Happé F, Frith U. Revisiting the strange stories: revealing mentalizing impairments in autism. Child Development. 2009; 80(4): 1097-1117.

Whitehead C, Marchant JL, Craik D, Frith CD. Neural correlates of observing pretend play in which one object is represented as another. Social Cognitive and Affective Neuroscience. 2009; 4(4): 369-378.

Østergaard L, Jonsdottir KY, Mouridsen K. Predicting tissue outcome in stroke: New approaches. Current Opinion in Neurology. 2009; 22(1): 54-59.

Books and book chapters:

Cornelissen PL, Hansen PC, Kringelbach ML, Pugh K. The neural basis of reading. Oxford: Oxford University Press, 2009.

Frith CD. Free Will and Top-Down Control in the Brain. In N. Murphy, G. Ellis, F,R. & T. O'Connor (Eds.), Downward Causation and the Neurobiology of Free Will (pp. 199-209). Berlin: Springer, 2009.

Hansen PC, Kringelbach ML, Salmelin R. MEG. An introduction to methods. Oxford University Press, 2009.

Kringelbach ML, Fejerskov O. Indsigt og udsyn: et internationalt perspektiv på fremtidens danske universitet. Fremtidens Universitet. Edited by Helge Sander. Gyldendal, 2009: 92-108.

Kringelbach ML, Berridge KC. Introduction: the many faces of pleasure. Pleasures of the brain. Oxford University Press, 2009.

Kringelbach ML, Berridge KC. Pleasures of the Brain. Oxford University Press, 2009.

Kringelbach ML. The hedonic brain: A functional neuroanatomy of human pleasure. Pleasures of the brain. Oxford University Press, 2009.

Kringelbach ML. The pleasure center: trust your animal instincts. Oxford University Press, 2009.

Kringelbach ML. Neural basis of mental representations of motivation, emotion and pleasure. Handbook of Neuroscience for the Behavioral Sciences. / red. GG Berntson, JT Cacioppo. John Wiley & Sons, 2009: 807-828.

Linnet J. Denmark. Problem Gambling in Europe: Challenges, Prevention, and Interventions. NY: Springer Publishing Company, 2009.

Petersen MB, Roepstorff A, Serritzlew S. Social Capital in the Brain?, in Tinggaard, G., Svendsen, G. (red.) Handbook of Social Capital, Edward Elgar Publishing, 2009: 75-92.

Tylén K, Allen M. Interactive Sense-Making in the Brain, in Enacting Intersubjectivity: A Cognitive and Social Perspective on the Study of Interactions. Morganti, F., Carassa, A. and Riva, G. Eds., IOS Press. 2009: 224-241.

Vuust P, Kringelbach ML. The pleasure of music. Pleasures of the brain. Oxford University Press, 2009: 77-104.

Vuust P. Musik på hjernen. Musik & videnskabsteori. / red. Helle Kornum, Mads Krogh, Birgitte Næslund Madsen. 2009.

Vuust P. Perception, Cognition, and Learning: Cognitive Research at the Music Academies in Denmark. Dansk årbog for musikforskning. 2009; 36.

Zinck A, Lodahl S, Frith CD. Making a case for introspection. Behavioral and Brain Sciences, 2009; 32(2): 163.

Østergaard L. Cerebral perfusion imaging by exogenous contrast agents. In: J Gillard, A Waldman, P Barker (Eds) Clinical MR Neuroimaging: Physiological and Functional Techniques, Cambridge University Press. 2009.

PhD Dissertations:

Christensen, S. Optimization and Validation of Perfusion MRI Post-Processing Techniques. Aarhus University, 2009.

Flint J. Examination of tissue microstructure, contrast enhancement and neural activity in the brain slice model using magnetic resonance microscopy. University of Florida, USA, 2009.

Petersen, E.T. Brain Perfusion Imaging: Quantification of Cerebral Blood Flow Using ASL Techniques. Aarhus University, 2009.

Peterson, E. Neurobiological Correlates of Gambling in Men and Women. Aarhus University, 2009.

Schjødt, U. The Neural Substrates of Prayer: Toward an experimental neuroscience of religion. Aarhus University, 2009.

Sip, K.E. Neuroimaging of deception in social interaction and lie-detection. Aarhus University, 2009.

Tylén, K. Roses, Icebergs, Hoovers and all that Language: An investigation of the cognitive foundations of our comprehension of object mediated communication. University of Southern Denmark, Odense, 2009.

Posters and published abstracts:

Aamand R, Dalsgaard T, Jensen FB, Roepstorff A, Fago A. A new function of an "old enzyme": carbonic anhydrase catalyses the production of nitric oxide from nitrite, Third International Role of Nitrite in Physilogy, Pathophysiology and Therapeutics Meeting, Stockholm, 17-18 June 2009.

Dalby RB, Madsen JA, Chakravarty MM, Sørensen L, Rosenberg R, Østergaard L, Videbech P. White matter lesions and cerebral perfusion imaging in late-onset major depression. ISMRM 17th Scientific Meeting and Exhibition, Honolulu, Hawaii, USA, 18-24 April 2009.

Devantier TA, Videbech P, Østergaard L, Nørgaard B. Associations between depression and cardiovascular disease in patients with late onset single episode major depressive disorder. WFSBP, 9th World Congress of Biological Psychiatry, Paris, France, 28 June - 2 July 2009.

Donahue M, Blicher J, MacIntosh B, Miller K, Østergaard L, Feinberg D, Guenther M, Jezzard P. Whole-Brain Non-Invasive Hemodynamic Imaging, Enabled by a Novel CBV-Weighted Single-Shot 3D VASO-FLAIR GRASE Sequence Combined with CBF-Weighted ASL and BOLD FMRI, Identifies Regional Hemodynamic and Metabolic Discrepancies. International Society for Magnetic Resonance in Medicine's 17th Scientific Meeting, Honolulu, Hawaii, USA, 18-24 April 2009.

Flint JJ, Hansen B, Fey M, Schmidig D, King MA, Vestergaard-Poulsen P, Blackband SJ. Diffusion tensor tractography of individual nerve fibers in the ventral spinal cord of the rat with histological validation. ISMRM, Honolulu, Hawaii, USA, 18-24 April 2009.

Flint JJ, Lee C, Hansen B, Fey M, Schmidig D, Bui JD, King M, Vestergaard-Poulsen P, Blackband SJ. Magnetic resonance microscopy of mammalian neurons. ISMRM, Honolulu, Hawaii, USA, 18-24 April 2009.

Friis-Olivarius M, Wallentin M, Vuust P. Improvisation - A neural foundation for creativeness. Hvidovre Hospitals Forskningsdag 2009.

Friis-Olivarius M, Wallentin M, Vuust P. When music becomes language. Left-lateralized frontal brain activity during call-response improvisation. Society for Neuroscience 2009, Chicago, USA, 17-19 October 2009.

Friis-Olivarius M, Wallentin M, Vuust P. When music becomes language. Left-leteralized DLPFC activity during call-response improvisation. ACM Creativity and Cognition, 2009, Berkeley, USA, 27-30 October 2009.

Friis-Olivarius M, Wallentin M, Vuust P. Improvisation: the neural foundation for creativity. Creativity and Cognition: Proceeding of the seventh ACM conference on Creativity and cognition. Berkeley. 2009: 411-412.

Furtula J, Fuglsang-Frederiksen A, Johnsen B, Pugdahl K, Christensen PB, Østergaard L, Sunde N, Lamm TT, Finnerup NB. Integration of diagnostic studies in amyotrophic lateral sclerosis. PhD Day 2009, The Faculty of Health Sciences, University of Aarhus, Denmark, 16 January 2009.

Garza Villarreal, EA. Harmony wants to sit in the front: Different brain responses to chord progressions. Conference of the European Society for the Cognitive Sciences of Music, no. 7, Jyväskylä, Finland, 12-16 August 2009.

Garza Villarreal, EA. Harmony wants to sit in the front: Different brain responses to chord progressions. Cognitive Neuroscience Society meeting 2009, San Francisco, USA, 20-23 March 2009.

Garza Villarreal EA, Brattico E, Leino S, Østergaard L, Vuust P. The frontal ERAN and temporal MMN: Two different brain responses to violations in chord progressions. Braintuning Workshop 2009, Helsinki, Finland, 5-6 February 2009.

Hansen B, Østergaard L, Vestergaard-Poulsen P. A fractal model of diffusion weighted MRI in cortical grey matter. Diffusion Fundamentals, no. 3, Athens, Greece, 23-26 August 2009.

Hansen B, Flint JJ, Vestergaard-Poulsen P, Blackband SJ. Diffusion weighted magnetic resonance imaging of neuronal activity in the hippocampal slice model. ISMRM, no. 17, Honolulu, Hawaii, USA, 18-24 April 2009.

Hjerrild S, Renvillard SG, Østergaard L, Leutscher P, Videbech P. Påvirkning af hjernen hos patienter med kronisk smitsom leverbetændelse vurderet ved MR-skanning. Psykiatriens Forskningsdag 2009, Aarhus, Denmark, 23 November 2009.

Jespersen SN, Leighland L, Cornea A, Kroenke C. The diffusion tensor reveals gray matter architecture. ISMRM Annual meeting 2009, Honolulu, Hawaii, USA, 18-24 April 2009.

Josefsen LG, Doudet D, Møller A, Gjedde A, Linnet J, Vuust P. The Drummer's High : The role of midbrain dopamine in live musical performance. Neurodag, University of Copenhagen. 6 November 2009.

Josefsen LG, Doudet D, Møller A, Gjedde A, Linnet J, Vuust P. The Drummer's High : Dopaminfrigivelse hos en jazz-trommeslager. Forskningens dag, AUH, Aarhus, Danmark, 30 September 2009.

Konvalinka I, Vuust P, Xygalatas D, Roepstorff A, Frith C. Synchronization in Joint Action: From Tapping to Fire-walking. Joint Action Meeting, no. 3, Amsterdam, Holland. 27-29 July 2009.

Konvalinka I, Vuust P, Roepstorff A, Frith C. Synchronized Tapping as a Model of Minimal Social Interaction. Cognitive Neuroscience Society Meeting, no. 16, San Francisco, USA, 20 March 2009.

Konvalinka I, Vuust P, Roepstorff A, Frith C. A coupled oscillator model of interactive tapping. European Society for the Cognitive Sciences of Music (ESCOM), no. 7, Jyväskylä, Finland. 12-16 August 2009.

Kringelbach ML, Green A, Hyam J, Moir L, Parsons C, Thomsen KR, Young K, Kalbitzer J, Brittain JS, Holland P, Owen SLF, Stein J, Lou HOC, Stein A, Aziz T. Using deep brain stimulation to alleviate the suffering in chronic pain: Dissociable regions of the human anterior cingulate cortex. Society for Neuroscience 2009, Chicago, USA, 17-21 November 2009.

Linnet J, Peterson E, Doudet D, Gjedde A, Møller A. Dopamine is associated with maladaptive gambling in pathological gamblers. Society for Neuroscience, Chicago, USA, 17-21 October 2009.

Linnet J, Wohlert V, Jørgensen SR, Frøslev M. Økonomiske og sociale spillesymptomer hos poker problemspillere og ludomaner. Forskningens dag, Aarhus, Denmark, 30 September 2009.

Nagenthiraja K, Jonsdottir KY, Østergaard L, Mouridsen K. Predicting tissue outcome in acute ischemic stroke using projection pursuit regression. Proceeding of ISMRM, Honolulu, Hawaii, USA, 18-24 April 2009.

Nahimi A, Høltzermann M, Simonsen M, Jacobsen S, Møller A, Wegener G, Gjedde A, Doudet D. Serotoninergic modulation of exogenous L-DOPA-derived dopamine release in rats with unilateral 6-OHDA lesions revealed with microPET imaging. Scandinavian College of Neuro-psychopharmacology (SCNP), 50th annual meeting, Copenhagen, Denmark, 27-29 April 2009.

Nielsen PA, Smerup MH, Nielsen EA, Møller-Madsen MK, Ringgaard S, Pedersen M, Vestergaard-Poulsen P, Frandsen J, Nyengaard JR, Andersen JB, Lunkenheimer PP, Anderson RH, Hjortdal VE. Myocardial three dimensional architecture of the right ventricle is significantly altered due to dilatation - Assessment with cardiac diffusion tensor magnetic resonance imaging. 19th Annual Meeting of the Scandinavian Society for Research in Cardiothoracic Surgery, Geilo, Norway, 5-7 February 2009.

Poulsen ES, Olsen AK, Zeidler D, Hjort N, Østergaard L. Dose Optimization for Combined Perfusion Weighted Imaging and Constrast Enhanced MRA Using Gadofosveset. ISMRM 17th Scientific Meeting and Exhibition, Honolulu, Hawaii, USA, 18-24 April 2009.

Schjødt U, Stødkilde-Jørgensen H, Roepstorff A, Geertz AW. Talking to God, Organization for Human Brain Mapping 15th Annual Meeting, San Francisco, USA, 18-23 June 2009.

Schjødt U, Roepstorff A, Stødkilde-Jørgensen H, Lund TE, Geertz AW. The Power of Charisma : Perceived Charisma inhibits the attentional and executive systems of believers in intercessory prayer. Social and Affective Neuroscience, New York, USA, 9-11 October 2009.

Vuust P, Brattico E, Seppänen M, Näätänen R, Glerean E, Tervaniemi M. Differentiating Musicians Using a Fast, Musical Multi-feature Paradigm. Fifth Conference on Mismatch Negativity (MMN) and its Clinical and Scientific Applications 2009, Budapest, Hungary, 4-7 April 2009.

Wallentin M, Vuust P, Mouridsen K, Roepstorff A, Lund TE. Co-variance structures in narratives studied with fMRI – Proof of concept. The 16th Annual Cognitive Neuroscience Society Meeting, San Francisco, USA. 21-24 March 2009.

Wallentin M, Vuust P, Mouridsen K, Dohn A, Nielsen AH, Roepstorff A, Lund TE. Word co-occurrence effects driving language cortex during listening to a narrative. Organization for Human Brain Mapping 2009 Annual Meeting, San Francisco, USA.

Weed E, McGregor W, Nielsen JF, Roepstorff A. Moving pictures, in Linguistics: the Challenge of Clinical Application, 2009: 247-248.

Wittenborn T, Nygaard JV, Horsman MR, Vorup-Jensen T, Kjems J, Thim T, Nielsen T, Larsen EKU, Falk E. A Novel in Vivo Angiogenesis Mouse Model. 2009. Conference: 10th Annual Conference on Arteriosclerosis, Thrombosis and Vascular Biology, Washington DC, USA, 29 April - 1 May 2009. Arteriosclerosis, Thrombosis, and Vascular Biology. 29(7).

Xygalatas D, Bulbulia J, Konvalinka I, Schjødt U, Jegindø EM, Roepstorff A. Cognitive Approaches to a Study of Fire-walking. Cognitive Science Society: Workshop on New Developments in the Cognitive Science of Religion, Amsterdam, Holland. 29 July-1 August 2009.

Other contributions for journals:

Callesen MB, Møller A. Parkinsons sygdom og ludomani. Parkinson-nyt. 2009; 29(1): 10-11.

Frith C. Think hard. New Scientist, 2009; 202(2703): 65-65.

Frith C. Making up the mind. Psychologist, 2009; 22(10): 842-845.

Näätänen R. Welcoming address of the Vice-President (Academic Affairs) at the opening ceremonies of the 14th World Congress of Psychophysiology, - the Olympics of the Brain - I.O.P. 2008. International Journal of Psychophysiology, 2009; 73: 81.

Roepstorff A, Frith CD, Frith U. How our brains build social worlds. New Scientist. 2009; 2737: 32-33.

Stokic D, Yablon S, Blicher J. Letter to the Editor. Neurorehabilitation and Neural Repair. 2009; 23(8): 870.

Weed E. Når “godt gået” betyder “dumt gjort”: Pragmatik og læsioner i hjernens højre hemisfære. LOGOS. 2009; 57: 12-13.

CFIN Funding & Bibliometry

by Leif Østergaard

Funding

The highly competitive University Investment (UNIK) grant awarded to Aarhus University and Principal Investigator Leif Østergaard in early 2009 was a crucial milestone for CFIN. The growing focus on interdisciplinary neuroscience and cognition research across AU faculties lead to consolidation through permanent positions within the field towards end 2009; a crucial prerequisite to maintain a critical mass of competences within this rapidly growing field. The experimental core facility (3 Tesla MRI, PET), maintained thusfar with contributions from varying *ad hoc* funding sources, will be upgraded in terms of staff to provide advice and assistance in performing advanced neuroimaging research.

The CFIN leadership is particularly pleased that in the coming years, more funds will be available for administrative support. The research group has by far outgrown even CFINs hardworking director and administrative staff.

Bibliometry

CFIN funding comes from many sources – and we remain committed to pay back to Society and to Private benefactors by increasing knowledge and awareness of the brain and brain disorders. This annual report illustrates the impressive activity of CFIN researchers in terms of public outreach in news media, popular journals and public lectures. In 2009, thousands of citizens from across Denmark attended talks by CFIN researchers as part of the 'Folkeuniversitet' lecture series, and as part of the Brain Awareness Week, during which the newly formed Århus chapter of The Society for Neuroscience gave talks on brain diseases and brain research. Meanwhile, CFIN researchers gave scientific talks and educational lectures to peers and professionals, disseminating our newest discoveries to the ongoing, globalized scientific puzzle of solving the mysteries of the mind and the brain.

Another tangible result of our research is the number of scientific papers published in high-impact international journals. With increased funding and the employment of more researchers over recent years, projects and ideas mature into publications - the quantity and quality of which continues to grow (Figure 1 and Table 1).

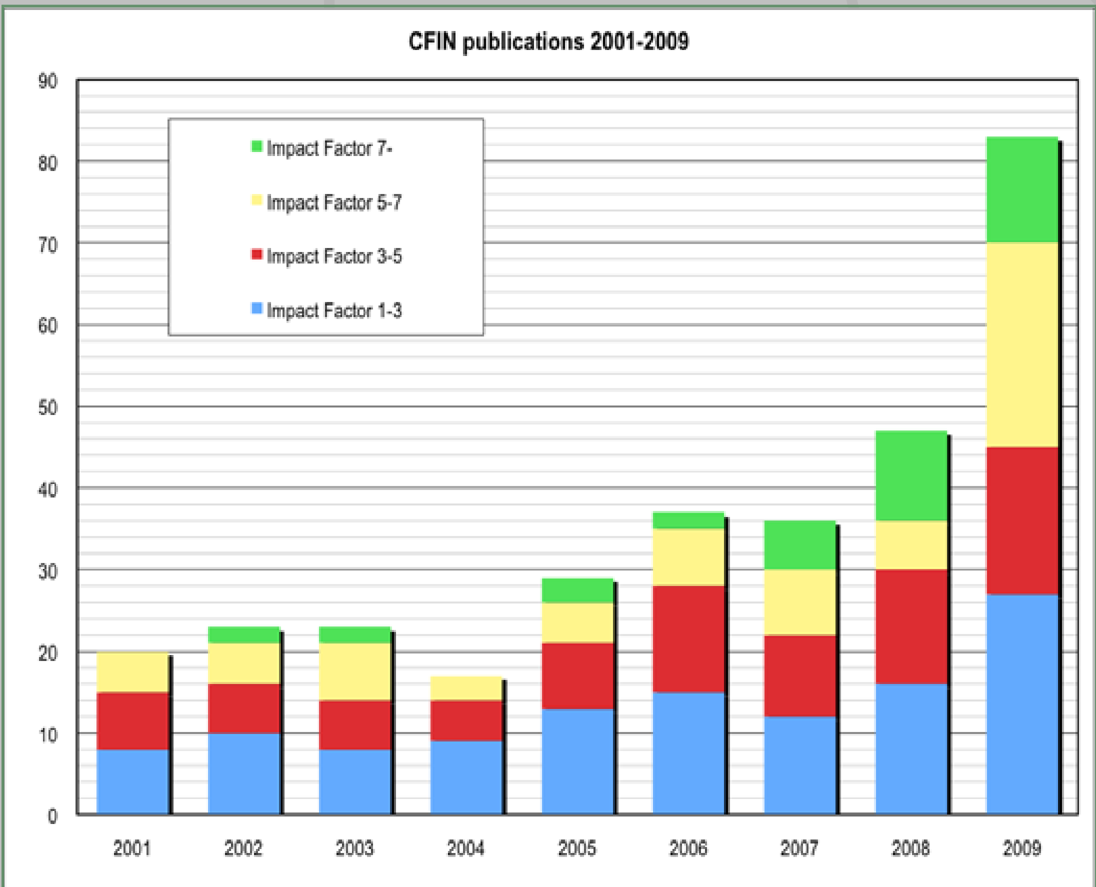


Figure 1
CFIN Publications 2001-2009

Table 1
Publication Impact Factor 2001-2009

According to some, research centers are much like football clubs: Talents are typically identified and trained locally, and mature to be part of local elite teams, or to pursue careers abroad. This is a lengthy process, where - in our case - scientific breakthroughs and highly cited publications may require decades of investments. The recruitment of established productive talents typically increases scores – in our case publication statistics - while providing valuable new scientific ideas, and competences. We have been able to attract highly productive scientists to Århus. Fortunately our high-profile researchers are attracted to Århus by our ideas, opportunities and ability to collaborate, rather than salaries – while their ‘stardom’ and high productivity lasts for many decades - unlike most football players.

.com


Christiano Ronaldo

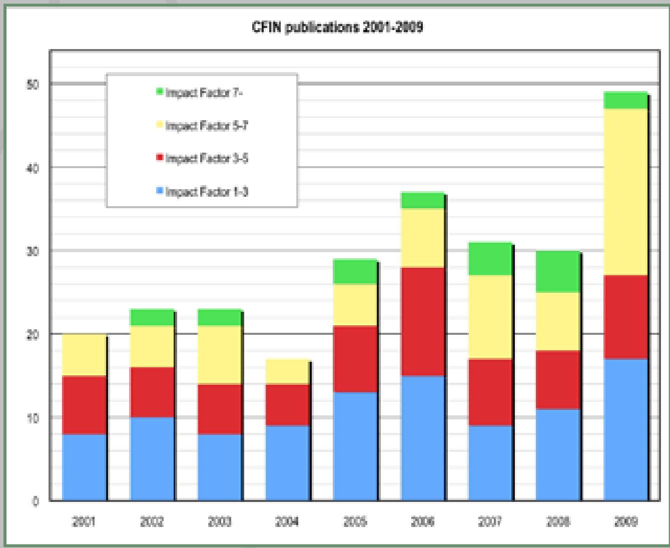


Figure 2
CFIN Publications 2001-2009 - without high-profile international scientists recruited to CFIN 2007-2008.

Illustrating the scientific impact of The Danish National Research Foundation’s Niels Bohr Professorship initiative and the support of TrygFonden to attract international scientific ‘Superstars’, such as Chris and Uta Frith, Risto Näätänen and Morten Kringelbach, Figure 2 shows CFIN publication statistic as it would have been without their contributions.

To illustrate the many forms of scientific dissemination, Morten Kringelbach, leader of the TrygFonden Research Group and expert within deep brain stimulation and pleasure, published in JAMA (Impact Factor 31.7) while his work reached the attention of Playboy.com in 2009.

From 2010, CFIN will extend our ongoing evaluation of the scientific impact of our production, tracking citation statistics of our publications.

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Impact Factor 0-1	6	4	12	8	8	3	11	9	10
Impact Factor 1-3	8	10	8	9	13	15	12	16	27
Impact Factor 3-5	7	6	6	5	8	13	10	14	18
Impact Factor 5-7	5	5	7	3	5	7	8	6	25
Impact Factor 7-	0	2	2	0	3	2	6	11	13
Total	26	27	35	25	37	40	47	56	93

Thanks

CFIN wishes to thank the financial support of the Foundations and Institutions listed below:

The Danish Ministry for Science, Technology and Innovation's University Investment Capital Program.
The Danish National Research Foundation.
The Danish Ministry for Science, Technology and Innovation's Infrastructure Program.
Villum Kann Rasmussen Fonden and Velux Fonden.
Aarhus University.
Central Denmark Region.
TrygFonden.
Oxford University.
Aarhus University Research Foundation.
Aarhus University Hospital, Århus Sygehus.
Department of Neuroradiology.
PET Center Aarhus.
The Danish Council for Independent Research within the Medical Sciences.
Research Council for Communication and Culture.
Danish Agency for Science, Technology and Innovation (ludomania).
Cambridge Health Alliance.
The European Commission's 6th Framework Programme (ICT).
Danish Ministry of Culture.
Royal Academy of Music.
The Lundbeck Foundation.
Dansk Parkinsonforening.
Novo Nordisk Foundation.
Danish Council for Strategic Research Programme Commission on Non-ionizing Radiation.
Danish Council for Strategic Research Programme Commission on Nanoscience, Biotechnology and IT.
GlaxoSmithKline.
BayerSchering Pharma AG.
Toyota Fonden.
The Carlsberg Foundation.
Danish Cancer Society.
The John and Birthe Meyer Foundation.
Ulla og Mogens Folmer Andersens Fond.
Hørslevfonden.
Grosserer L.F. Foghts Fond.
Augustinusfonden.
The Denmark-America Foundation.
Dagmar Marshall's Foundation.
Julie von Müllen's Foundation
(The Royal Danish Academy of Sciences and Letters).
The Oticon Foundation.
Savværksejer Jeppe Juhl og Hustru Ovita Juhls Mindelegat.

CFIN director, Leif Østergaard, explores new horizons, wearing the traditional outfit for boat trips on the chilly Bajkal Lake, Sibiria, Russia. May 2009.
Photo courtesy of Jürgen Henning.

neuroinformatics
emotion
ctional hemodynamics
neurotransmission
brain
MEG
neuroconnectivity
fMRI
neuroenergetics
subject
stroke

ISBN 978-87-992371-2-8