New papers about near-infrared spectroscopy (NIRS) and imaging (NIRI)

Volume 2, Issue 4 (October-December 2014)

Felix Scholkmann | Biomedical Optics Research Laboratory (BORL), Division of Neonatology, University Hospital Zurich, 8091 Zurich, Switzerland, Felix.Scholkmann@usz.ch

Number of papers included: **128**

Note: The highlighted parts of the abstracts refer to the most important findings.

1. Takei et al. (2014). **Near-infrared spectroscopic study of frontopolar activation during face-to-face conversation in major depressive disorder and bipolar disorder**

Abstract: Major depressive disorder (MDD) and bipolar disorder (BD) patients show speech characteristics that vary greatly according to mood state. In a previous study, we found impaired temporal and right inferior frontal gyrus (IFG) activation in schizophrenia during face-to-face conversation; no study had, however, previously investigated mood disorders during face-to-face conversation. Here, we investigated frontal and temporal lobe activation during conversation in patients with MDD and BD. Frontal and temporal lobe activation was measured using near-infrared spectroscopy (NIRS) in 29 patients with MDD, 31 patients with BD, and 31 normal controls (NC). We compared continuous activation and rapid change of activation with talk/listen phase changes during the conversation and analyzed the correlation between these indices and clinical variables. Both the MDD and BD groups showed decreased continuous activation in the left dorsolateral prefrontal (DLPFC) and left frontopolar cortices (FPCs); they also showed decreased rapid change in bilateral FPC activation. In the MDD group, the rapid change of activation was positively correlated with Global Assessment of Functioning (GAF) scores. In the BD group, continuous activation was negatively correlated with age of onset. These results indicate that frontal activation during conversation decreases in both MDD and BD. However, both continuous activation and rapid change may reflect the pathophysiological character of MDD and BD; in particular, the reduced amount of rapid change in the right FPC may be related to impaired adaptive ability in MDD.

2. Pu et al. (2014). **Association between social functioning and prefrontal hemodynamic responses in elderly adults**

Abstract: Social functioning has received widespread attention as one of the most important outcomes in psychiatric disorders and has been related to cognitive functioning and the underlying brain activity. Cognitive decline, however, appears not only in the psychiatric population but also in aged individuals. In our previous study, we demonstrated a significant relationship between social functioning and prefrontal cortex (PFC) activity in patients with depression. However, it has not been shown whether the above relationship could be extended to healthy populations. The purpose of the present study was to investigate a possible association between social functioning and prefrontal hemodynamic responses in healthy elderly adults by using a non-invasive and low-constraint functional neuroimaging technique, near-infrared spectroscopy (NIRS). Study subjects included 55 healthy, elderly volunteers. We measured hemodynamic responses over prefrontal cortical (PFC) areas during the verbal fluency task by using multi-channel NIRS and analyzed the relationship between task-associated hemodynamic responses and social functioning as measured by the social adaptation self-evaluation scale (SASS). A significant positive relationship was observed between the SASS total score and PFC activation. Our findings suggest that PFC activation is associated with social functioning in healthy elderly adults. Furthermore, hemodynamic responses assessed using non-invasive NIRS could be a useful biological marker of these characteristics.

3. Lazaridis et al. (2014). **Brain Tissue Oxygenation, Lactate-Pyruvate Ratio, and Cerebrovascular Pressure Reactivity Monitoring in Severe Traumatic Brain Injury: Systematic Review and Viewpoint**

Abstract: Background: Prevention and detection of secondary brain insults via multimodality neuromonitoring is a major goal in patients with severe traumatic brain injury (TBI). Objective: Explore the underlying pathophysiology and clinical outcome correlates as it pertains to combined monitoring of ≥2 from the following variables: partial brain tissue oxygen tension (PbtO2), pressure reactivity index (PRx), and lactate pyruvate ratio (LPR). Methods: Data sources included Medline, EMBASE, and evidence-based databases (Cochrane DSR, ACP Journal Club, DARE, and the Cochrane Controlled Trials Register). The PRISMA recommendations were followed. Two authors independently selected articles meeting inclusion criteria. Studies enrolled adults who required critical care and monitoring in the setting of TBI. Included studies reported on correlations between the monitored variables and/or reported on correlations of the variables with clinical outcomes. Results: Thirty-four reports were included (32 observational studies and 2 randomized controlled trials) with a mean sample size of 34 patients (range 6–223), and a total of 1,161 patient-observations. Overall methodological quality was moderate. Due to inter-study heterogeneity in outcomes of interest, study design, and in both number and type of covariates included in multivariable analyses, quantitative synthesis of study results was not undertaken. Conclusion: Several literature limitations were identified including small number of subjects, lack of clinical outcome correlations, inconsistent probe location, and overall moderate quality among the included studies. These limitations preclude any firm conclusions; nevertheless we suggest that the status of cerebrovascular reactivity is not only important for cerebral perfusion pressure optimization but should also inform interpretation and interventions targeted on PbtO2 and LPR. Assessment of reactivity can be the first step in approaching the relations among cerebral blood flow, oxygen delivery, demand, and cellular metabolism.

4. Liu et al. (2014). **Non-invasive assessment of neonatal brain oxygen metabolism: A review of newly available techniques**

Abstract: Because oxidative metabolism is the primary form of energy production in the brain, the amount of oxygen consumed by the brain, denoted by a physiological parameter termed cerebral metabolic rate of oxygen (CMRO2), represents a key marker for tissue viability and brain function. Quantitative assessment of cerebral oxygen metabolism in the neonate may provide an important marker in better understanding normal brain development and in making diagnosis and treatment decisions in neonatal brain injuries. Measurement of CMRO2 in humans has been a challenging task, particularly in neonates. Recently, several promising techniques have been proposed to quantify neonatal CMRO2 and the purpose of this article is to provide a technical review of these techniques. Among these, we will focus the review on the NIRS optic based methods and MRI methods which are non-invasive, have been applied in normal and sick newborns and show great potentials. Potential clinical prospects of CMRO2 techniques are discussed in the context of their advantages, challenges and limitations.

5. Greisen et al. (2014). **Cerebral blood flow and oxygenation in infants after birth asphyxia. Clinically useful information?**

Abstract: The term 'luxury perfusion' was coined nearly 50 years ago after observation of bright-red blood in the cerebral veins of adults with various brain pathologies. The bright-red blood represents decreased oxygen extraction and hence the perfusion is 'luxurious' compared to oxygen needs. Gradual loss of cellular energy charge during the hours following severe birth asphyxia was observed twenty years later by sequential cranial magnetic resonance spectroscopy. This led to the concept of delayed energy failure that is linked to mitochondrial dysfunction and apoptotic cell death. Abnormally increased perfusion and lack of normal cerebral blood flow regulation are also typically present, but whether the perfusion abnormalities at this secondary stage are detrimental, beneficial, or a mere epiphenomenon remains elusive. In contrast, incomplete reoxygenation of the

brain during and following resuscitation is likely to compromise outcome. The clinical value of cerebral oximetry in this context can only be examined in a randomised clinical trial.

6. Riera et al. (2014). **New Time-Frequency Method for Cerebral Autoregulation in Newborns: Predictive Capacity for Clinical Outcomes**

Abstract: Objective: To describe an alternative analysis in the frequency-domain of the temporal relationship between 2 biological signals and evaluate the method's predictive capacity for classifying infants at risk for an adverse outcome. Study design: We studied 54 infants (mean gestational age 27 weeks) with invasive mean arterial blood pressure monitoring. The bivariate autoregressive spectral coherence (BiAR-COH) method and the spectral coherence methods were used to analyze the relationship between spontaneous changes in mean arterial blood pressure and the near-infrared tissue oxygenation index. Results: The mean postnatal age at the beginning and end of the autoregulation study was 6.0 (3.0) and 29.0 (7.5) hours, respectively. The BiAR-COH was superior to the spectral coherence in predicting low superior vena cava (SVC) flow (≤41 mL/kg per minute), with an area under the receiver operating characteristic curve of 0.84 (95% CI, 0.77-0.90; P < .001). The BiAR-COH threshold for identifying low SVC flow was 0.577, with 0.8 sensitivity and 0.76 specificity. After adjusting for the repeated measures effect (multiple epochs) in a given patient, the averaged BiAR-COH per patient and averaged COH per patient were calculated as the average value per patient. The pBiAR-COH (but not the pCOH) was associated with intraventricular hemorrhage grades 3 and 4 and predicted mortality. Conclusions: The BiAR-COH classifier identifies low SVC flow infants who are at risk for brain hypoperfusion. The BiAR-COH is superior to frequency domain methods in predicting adverse outcomes in infants.

7. Cuerci et al. (2014). **Cerebral oximetry assessed by near-infrared spectrometry during preeclampsia: an observational study: impact of magnesium sulfate administration**

Abstract: OBJECTIVES: To determine the regional cerebral oxygen saturation of hemoglobin (rcSO2) in severe preeclamptic parturients exhibiting neurologic symptoms compared with healthy pregnant women (control) and to describe the effects of MgSO4 infusion on rcSO2 and cerebral and systemic hemodynamic variables.
DESIGN: Prospective, observational study. SETTING: Obstetric critical care unit in a university-affiliated hospital. PATIENTS: Twenty severe preeclamptic parturients presenting with neurologic signs before any administration of MgSO4, and 20 control parturients. INTERVENTION: Infusion of MgSO4 in severe preeclamptic patients. MEASUREMENTS AND MAIN RESULTS: We measured rcSO2 using near-infrared spectroscopy, blood flow velocities of the middle cerebral artery, and cardiac output at baseline, 5 minutes, 1 hour, and 6 hours after the MgSO4 bolus (4 g), followed by continuous MgSO4 infusion (1 g/h). These measurements were also obtained in 20 control parturients at baseline and 6 hours. Baseline rcSO2 was significantly lower in the severe preeclamptic group: 61% (56-69) vs 66% (63-71) (p = 0.037). At inclusion, blood pressures were significantly higher in the severe preeclamptic group compared with the control group, whereas cardiac output and transcranial Doppler readings were similar. Five minutes after the MgSO4 bolus infusion, a median increase of 8.6% (3.2-18.1) in rcSO2 was observed (p = 0.007), reaching values of the control group that were maintained up to 6 hours. Blood pressures and systolic velocities of the middle cerebral artery significantly decreased (p < 0.01) after the MgSO4 bolus, whereas cardiac output did not change. The percentage increase in rcSO2 was negatively correlated to the mean blood pressure (r = 0.60, p < 0.0001). CONCLUSION: Cerebral oxygenation impairment can be detected by near-infrared spectroscopy monitoring in severe preeclamptic parturients. These results suggested the presence of disorders in cerebral microcirculation and/or changes in cerebral oxygenation. MgSO4 infusion in patients with severe preeclampsia restored rcSO2 to control levels with no systemic side effects. Further studies are needed to confirm the usefulness of near-infrared spectroscopy monitoring in patients with preeclampsia and to assess the action of other antihypertensive therapies on rcSO2.

8. Bauernfeind et al. (2014). **Separating heart and brain: on the reduction of physiological noise from multichannel functional near-infrared spectroscopy (fNIRS) signals**

Abstract: Objective. Functional near-infrared spectroscopy (fNIRS) is an emerging technique for the in vivo assessment of functional activity of the cerebral cortex as well as in the field of brain–computer interface (BCI) research. A common challenge for the utilization of fNIRS in these areas is a stable and reliable investigation of the spatio-temporal hemodynamic patterns. However, the recorded patterns may be influenced and superimposed by signals generated from physiological processes, resulting in an inaccurate estimation of the cortical activity. Up to now only a few studies have investigated these influences, and still less has been attempted to remove/reduce these influences. The present study aims to gain insights into the reduction of physiological rhythms in hemodynamic signals (oxygenated hemoglobin (oxy-Hb), deoxygenated hemoglobin (deoxy-Hb)). Approach. We introduce the use of three different signal processing approaches (spatial filtering, a common average reference (CAR) method; independent component analysis (ICA); and transfer function (TF) models) to reduce the influence of respiratory and blood pressure (BP) rhythms on the hemodynamic responses. Main results. All approaches produce large reductions in BP and respiration influences on the oxy-Hb signals and, therefore, improve the contrast-to-noise ratio (CNR). In contrast, for deoxy-Hb signals CAR and ICA did not improve the CNR. However, for the TF approach, a CNR-improvement in deoxy-Hb can also be found. Significance. The present study investigates the application of different signal processing approaches to reduce the influences of physiological rhythms on the hemodynamic responses. In addition to the identification of the best signal processing method, we also show the importance of noise reduction in fNIRS data.

9. Zhou et al. (2014). **Hyper-coupling between working memory task-evoked activations and amplitude of spontaneous fluctuations in first-episode schizophrenia**

Abstract: Working memory (WM) deficit is an important component of impaired cognition in schizophrenia. However, between-studies inconsistencies as to the specific functional substrate imply that inter-individual variability (IIV) in the WM performance is associated with IIV in brain activity in schizophrenia. To examine the neural substrate of this WM IIV, we studied whether the neural mechanisms that underlie individual differences in WM capacity are the same in schizophrenia patients and healthy people. We correlated the IIV of the task-evoked brain activity and task performance during an n-back WM task with the IIV of the moment-to-moment variability in intrinsic resting-state activity, as measured by the amplitude of low-frequency fluctuations (ALFFs) and further compared this relationship between 17 patients with first-episode schizophrenia (FES) and 18 healthy controls. Between-group comparisons of the correlation patterns indicated aberrant ALFF-WM activation correlations and ALFF-WM performance correlations in the FES patients, but no significant changes were detected in any single measurement of these three characteristics. Specifically, we found increased positive ALFF-WM activation correlations in the bilateral lateral prefrontal cortices, posterior parietal cortices and fusiform gyri in the FES patients. We also observed significant increases in positive ALFF-WM performance correlations in the bilateral ventromedial prefrontal cortices in the FES patients. This hyper-coupling between the ALFF and fMRI measures during a WM task may indicate that it was difficult for the patients to detach themselves from one state to transition to another and suggests that the inefficient cortical function in schizophrenia stems from the intrinsic functional architecture of the brain.

10. Myllylä et al. (2014). **Measurement of cerebral blood flow and metabolism using high power light-emitting diodes**

Abstract: In medical near-infrared spectroscopy (NIRS), particularly in the study of the brain, light illumination is commonly realised by lasers or laser diodes (LD). However, the rapid development of high-power light-emitting diodes (HPLED), increased optical output power and expansion of wavelengths of choice in particular, have made HPLEDs a feasible alternative, also for in vivo measurements of cerebral blood flow (CBF) and brain metabolism. These applications, however, require using sophisticated modulation techniques that enable

distinguishing low-level light signals that are back-scattered from the cerebral cortex. They also rely on separating different wavelengths when the illuminating light is emitted simultaneously by several HPLEDs with different wavelengths. In this paper, we study key properties of commercially available HPLEDs, with a focus on the study of the brain. Of particular interest here are optical output power and available wavelengths. Furthermore, we demonstrate a lock-in amplification technique suitable for use with HPLEDs in brain studies. Based on the presented measurement technique, we conduct experimental measurements on CBF in the cortex and analyse fluctuations in blood oxygen level at different combinations of wavelengths.

11. Imafuka et al. (2014). **"Mom called me!" Behavioral and prefrontal responses of infants to self-names spoken by their mothers**

Abstract: Development of a sense of self is a fundamental process needed for human social interaction. Although functional neuroimaging studies have revealed the importance of medial prefrontal cortex (mPFC) in self-referencing, how this function develops in infancy remains poorly understood. To determine the cerebral basis underlying processing of self-related stimuli, we used behavioral measures and functional multi-channel near-infrared spectroscopy (fNIRS) to measure prefrontal cortical responses in 6-month-old infants hearing their own names. We also investigated the influence of a mother's voice on name perception in infants — an ability that plays a crucial role in the recognition of social signals. Experiment 1 measured the behavioral preferences of infants for their own names and for other names, spoken either by their mothers or by strangers. Results showed that infants significantly preferred their own name to other names, regardless of speaker type. Experiment 2 examined hemodynamic responses to the same four conditions in the prefrontal cortex. Compared with other names, hearing their own names, especially when spoken by their mother, elicited greater activity in the infant's dorsal mPFC. Furthermore, the magnitude of the cerebral response correlated with the degree of behavioral preference only when involving their mother's voice. These findings suggest that, particularly in the context of their mothers' voice, the dorsal mPFC of infants is already sensitive to social signals related to self at 6 months. At the same time, familiarity and affection related processing are also discussed as possible factors modulating dorsal mPFC activation at this age.

12. Albinet et al. (2014). **Improved cerebral oxygenation response and executive performance as a function of cardiorespiratory fitness in older women: a fNIRS study**

Abstract: Cardiorespiratory fitness has been shown to protect and enhance cognitive and brain functions, but little is known about the cortical mechanisms that underlie these changes in older adults. In this study, functional near infrared spectroscopy (fNIRS) was used to investigate variations in oxyhemoglobin [HbO2] and in deoxyhemoglobin [HHb] in the dorsolateral prefrontal cortex (DLPFC) during the performance of an executive control task in older women with different levels of cardiorespiratory fitness (VO2max). Thirty-four women aged 60–77 years were classified as high-fit and low-fit based on VO2max measures. They all performed a control counting (CNT) task and the Random Number Generation (RNG) task at two different paces (1 number/1 s and 1 number/1.5 s), allowing to manipulate task difficulty, while hemodynamic responses in the bilateral DLPFCs were recorded using continuous-wave NIRS. The behavioral data revealed that the high-fit women showed significantly better performance on the RNG tasks compared with the low-fit women. The high-fit women showed significant increases in [HbO2] responses in both left and right DLPFCs during the RNG task, while the low-fit women showed significantly less activation in the right DLPFC compared with the right DLPFC of the high-fit women and compared with their own left DLPFC. At the level of the whole sample, increases in the [HbO2] responses in the right DLPFC were found to mediate in part the relationship between VO2max level and executive performance during the RNG task at 1.5 s but not at 1 s. These results provide support for the cardiorespiratory fitness hypothesis and suggest that higher levels of aerobic fitness in older women are related to increased cerebral oxygen supply to the DLPFC, sustaining better cognitive performance.

13. Eriksen et al. (2014). **Dopamine therapy is associated with impaired cerebral autoregulation in preterm infants**

Abstract: Aim: Hypotension is a common problem in newborn infants and is associated with increased mortality and morbidity. Dopamine is the most commonly used antihypotensive drug therapy, but has never been shown to improve neurological outcomes. This study tested our hypothesis that dopamine affects cerebral autoregulation (CA).
Methods: Near-infrared spectroscopy was used to measure the cerebral oxygenation index in 60 very preterm infants, and mean arterial blood pressure was monitored towards the end of their first day of life. Measurements were performed continuously for two to three hour periods. CA was quantified as the cerebral oximetry index (COx).
Results: We treated 13 of the 60 infants (22%) with dopamine during the measurements. COx was higher in the dopamine group than the untreated group (0.41 ± 0.25 vs. 0.08 ± 0.25, $p < 0.001$). Blood pressure tended to be lower in the dopamine group, but the anticipated difference in cerebral oxygenation was not detected. The need for mechanical ventilation in the first day of life and incidences of mortality was higher in the dopamine group.
Conclusion: Dopamine therapy was associated with decreased CA in preterm infants. We were unable to determine whether dopamine directly impaired CA or was merely an indicator of illness.

14. Liu (2014). **Positive correlation between drowsiness and prefrontal activation during a simulated speed-control driving task**

Abstract: The present study aimed to examine the relationship between drowsiness and prefrontal activation during simulated driving tasks using a wireless portable near-infrared spectroscopy device. Participants drove from start to goal along default routes with either intentional control of their driving speed (speed-control group) or not (speed-free group). Drowsiness level was assessed using a five-item Likert-type questionnaire. The behavioral data indicated longer driving time in the speed-control group than in the speed-free group, whereas no difference in the number of errors was found between the two groups. Importantly, the speed-control group showed a significant positive correlation between the drowsiness score and left prefrontal activation, whereas the speed-free group did not. The results suggest that drowsy individuals may show increased prefrontal activation as compensatory efforts to maintain the desired level of performance in tasks that require deliberate control of behaviors. Furthermore, the present study shows that near-infrared spectroscopy may provide us with a possibility to examine the state of drowsiness during daily-life operations.

15. Waetherall (2014). **Study protocol for the PHANTOM study: prehospital assessment of noninvasive tissue oximetry monitoring**

Abstract: Background: Traumatic brain injury is a major cause of mortality and morbidity worldwide. It can be worsened by secondary injury particularly with hypoxia or hypotension. Current prehospital guidelines emphasise regular measurement of peripheral oxygen saturation and blood pressure but there is no monitor in use to provide direct information relating to blood flow or oxygen delivery to the brain tissue. This prospective cohort study will assess the utility of near-infrared spectroscopy monitoring in prehospital medicine in demonstrating injury, pathophysiology and associations with long-term functional outcomes.
Methods/design: A prospective cohort study will be conducted in prehospital services where physician/paramedic teams respond rapidly to patients suffering significant traumatic injuries. A study observer accompanying the clinical team will apply non-invasive near-infrared spectroscopy tissue oximetry using a Nonin EQUANOX 7610 Regional Oximetry monitor (TM Nonin Medical, Inc.). This will be applied to patients with traumatic injuries less than 30 minutes old requiring transport. Measurements will be taken at two sites on the forehead and one on the forearm. Clinical teams will be blinded to all monitoring values. Near-infrared spectroscopy tissue oximetry parameters of oxyhaemoglobin%, deoxyhaemoglobin%, total tissue haemoglobin index and regional oxygen saturation will be recorded. Separate statistical analysis relating to time spent with cerebral regional

oxygen saturation values?<?45% and time series analysis will be performed to demonstrate associations with acute phase outcomes including injuries seen on cerebral imaging, and long-term functional outcomes measured by Glasgow Outcome Score and Extended Glasgow Outcome Score will then be undertaken.
Discussion: This prospective cohort study will demonstrate associations evident from the earliest stages of prehospital treatment between near-infrared spectroscopy tissue oximetry values and both acute and long-term outcomes of patients suffering traumatic injuries. This may provide the basis for future interventional studies utilising near-infrared spectroscopy tissue oximetry to guide prehospital trauma care.

16. Tajima et al. (2014). **Portable system for monitoring of regional cerebral oxygen saturation during prehospital cardiopulmonary resuscitation: a pilot study**

Abstract: Aim: We aimed to create a system for monitoring of regional cerebral oxygen saturation (rSO2) in patients with prehospital cardiopulmonary arrest and clarify the changes in rSO2 during cardiopulmonary resuscitation.
Methods: We measured rSO2 in cardiopulmonary arrest patients who were transferred by the emergency response vehicle of Nagasaki University Hospital. We developed a portable rSO2 monitor (HAND ai TOS), which is small enough to carry during prehospital treatment. The sensor is attached to the forehead of the patient and monitors rSO2 continuously during treatment and transfer.
Results: No difficulties were experienced in monitoring rSO2 during patient treatment and transfer. Median time (interquartile range) from the emergency medical service call to emergency response vehicle arrival was 15.0 min (11.0–19.5 min). Median rSO2 on emergency response vehicle arrival at the scene was 46.3% (44.0–48.2%) (n = 9; median age, 74.0 years; four men, five women). Median rSO2 showed significant increase within 5 min after return of spontaneous circulation (n = 6, 46.6% versus 58.7%, $P < 0.05$). There was no significant increase in rSO2 during prehospital cardiopulmonary resuscitation until return of spontaneous circulation was established.
Conclusions: We developed an rSO2 monitoring system for use during prehospital cardiopulmonary resuscitation. The monitoring system showed a significant increase in rSO2 after return of spontaneous circulation, whereas there was no significant increase in rSO2 during cardiopulmonary resuscitation after intubation but before return of spontaneous circulation.

17. Gefen et al. (2014). **Applying Functional Near Infrared (fNIR) Spectroscopy to Enhance MIS Research**

Abstract: This review paper introduces the emerging technology of optical brain imaging, also known as functional near infrared (fNIR) spectroscopy, and discusses its potential role in enhancing theory and methodology used in MIS research. We discuss basic fNIR principles including the technique's safe and portable nature, which allows ambulatory brain activity assessment in real world environments. We then touch on the neural correlates that fNIR measures, and the cortical oxygenation changes in the dorsal and anterior regions of the prefrontal cortex. We compare fNIR with traditional neuroimaging methods such as fMRI and PET. We also list case studies, future directions, and potential approaches relevant to MIS. fNIR may be used to inform theory and improve assessments in MIS-based studies, including informing theory, by identifying neural correlates, studying constructs that could not easily if at all be measured with traditional methods, applying objective constructs that subjects are unaware of, and designing better surveys.

18. Nagashima et al. (2014). **Neuropharmacological effect of atomoxetine on attention network in children with attention deficit hyperactivity disorder during oddball paradigms as assessed using functional near-infrared spectroscopy**

Abstract: The current study aimed to explore the neural substrate for atomoxetine effects on attentional control in school-aged children with attention deficit hyperactivity disorder (ADHD) using functional near-infrared spectroscopy (fNIRS), which can be applied to young children with ADHD more easily than conventional neuroimaging modalities. Using fNIRS, we monitored the oxy-hemoglobin signal changes of 15 ADHD children (6 to 14 years old) performing an oddball task before and 1.5 h after atomoxetine or placebo administration, in a randomized, double-blind, placebo-controlled, crossover design. Fifteen age-, gender-, and intelligence quotient-matched normal controls without atomoxetine administration were also monitored. In the control subjects, the oddball task recruited the right prefrontal and inferior parietal cortices. The right prefrontal and parietal activation was normalized after atomoxetine administration in ADHD children. This was in contrast to our previous study using a similar protocol showing methylphenidate-induced normalization of only the right prefrontal function. fNIRS allows the detection of differential neuropharmacological profiles of both substances in the attentional network: the neuropharmacological effects of atomoxetine to upregulate the noradrenergic system reflected in the right prefrontal and inferior parietal activations and those of methylphenidate to upregulate the dopamine system reflected in the prefrontal cortex activation.

19. Giles et al. (2014). **Acute exercise increases oxygenated and deoxygenated hemoglobin in the prefrontal cortex**

Abstract: Both acute and chronic exercise is consistently associated with a number of benefits to physical and mental health, including cardiovascular function, body weight, mood, and cognition. Near-infrared spectroscopy is an ideal method to measure changes in oxygenated and deoxygenated hemoglobin (O2Hb and dHb) levels in the prefrontal cortex (PFC) during exercise, to better understand the locus of such changes in affective and cognitive processes. The present study tracked time-dependent changes in O2Hb and dHb levels in the PFC as a function of parametrically manipulated target exercise intensity. Near-infrared spectroscopy was conducted as regular exercisers completed a 30-min bout of exercise with one of three target intensities: 52% (low condition), 68% (moderate condition), or 84% (high condition) of age-adjusted maximum heart rate. Heart rate data confirmed that the participants reached their goal intensities immediately, after 10 min, or after 20 min, respectively. Data showed that O2Hb and dHb levels in the PFC increased as a function of both exercise load and duration. An 84%>68%>52% difference was evident after 18 min of cycling for O2Hb and after 23 min of cycling for dHb. The present results add to the growing body of literature showing that at submaximal levels, increasing exercise intensities reliably promote prefrontal cerebral oxygenation.

20. Andrä et al. (2014). **Measuring the oxygen supply to the brain of children by means of near infrared spectroscopy under the "Moving School" project**

Abstract: Introduction: Akinesia and its ambivalent side effects are counted among the biggest challenges of modern industrialized societies. The holistic approach of "Moving school" [1] is meeting the challenge of tasks in the educational sector considering an appropriate space in everyday school life. The study investigated cerebral and muscular tissue-oxygenation changes when performing regular activities in every day school life, comparing the "Moving school" with a traditional school concept.
Methods: By means of near-infrared-spectroscopy (fNIRS [2]) a not invasive screening set was developed to detect regional and global oxygen saturation parameters. In a long-term study with three measuring times [3] 137 primary-school pupils of both sexes (intervention group: 67; traditional classes: 70) were occupied with dissolving mathematical problems and a motor exercise strengthening the forearm. Tissue oxygenation was measured by four optodes in both cerebral hemispheres (prefrontal cortex), the non-dominating arm (high/deep

finger bender) as well as the right leg (calf-muscle). Additionally, the perfusion index of oxygen saturation and heart rate was recorded.
Results: When performing cognitive exercises and muscular activities, it has been shown that the corresponding parameters in case of immediate stress are either decreasing or increasing. Beginning with targeted intervention respectively the distress of connected organs, we could identify immediate, significant changes when calculating (Δ rSO2max = left hemisphere: 3.16, $P < .01$; right hemisphere: 3,45, $P < .01$) or contracting the forearm muscles repeatedly (Δ rSO2max = 6.19, $P < .01$). Above all there is a tendency that students of "Moving school" achieve comparable cognitive results with moderate increase of cerebral oxygenation. Presumably, very complex and difficult tasks can rather be completed successfully by students from "Moving school".
Conclusion: The study shows that the concept of "Moving school" is very beneficial in terms of physical and mental development. It is absolutely advisable to integrate the whole body into all sectors of learning processes by means of regular exercises.

21. Shimoda et al. (2014). **Activation of the Prefrontal Cortex While Performing a Task at Preferred Slow Pace and Metronome Slow Pace: A Functional Near-Infrared Spectroscopy Study**

Abstract: Individuals have a preferred pace at which they perform voluntary repetitive movements. Previous studies have reported that greater activation of the prefrontal cortex was observed during self-initiated movements than during externally triggered movements. The purpose of the present study is to compare the activation of the prefrontal cortex induced when the subjects performed a peg-board task at their preferred slow pace (PSP, the self-initiated condition) with that induced when they performed the same task at metronome slow pace (MSP, the externally triggered condition) using functional near-infrared spectroscopy. Healthy subjects performed the task while sitting in a chair. By assessing the activated channels individually, we confirmed that all of the prefrontal regions of interest were activated by both tasks. In the second-level analyses, we found that the activation detected in the frontopolar cortex (FPPFC; Brodmann area 10) was higher during the PSP task than during the MSP task. The FPPFC is known to be at the top of prefrontal hierarchy, and specifically involved in evaluating self-generated information. In addition, the FPPFC plays a role in coordinating lateral prefrontal cortex. In the present study, the subjects evaluated and managed the internally generated PSP by coordinating the activity of other lower level prefrontal regions.

22. Lee et al. (2014). **Efficient classification system based on Fuzzy–Rough Feature Selection and Multitree Genetic Programming for intension pattern recognition using brain signal**

Abstract: Recently, many researchers have studied in engineering approach to brain activity pattern of conceptual activities of the brain. In this paper we proposed a intension recognition framework (i.e. classification system) for high accuracy which is based on Fuzzy–Rough Feature Selection and Multitree Genetic Programming. The enormous brain signal data measured by fNIRS are reduced by proposed feature selection and extracted the informative features. Also, proposed Multitree Genetic Programming use the remain data to construct the intension recognition model effectively. The performance of proposed classification system is demonstrated and compared with existing classifiers and unreduced dataset. Experimental results show that classification accuracy increases while number of features decreases in proposed system.

23. Selesnick et al. (2014). **Transient Artifact Reduction Algorithm (TARA) Based on Sparse Optimization**

Abstract: This paper addresses the suppression of transient artifacts in signals, e.g., biomedical time series. To that end, we distinguish two types of artifact signals. We define "Type 1" artifacts as spikes and sharp, brief waves that adhere to a baseline value of zero. We define "Type 2" artifacts as comprising approximate step discontinuities. We model a Type 1 artifact as being sparse and having a sparse time-derivative, and a Type 2

artifact as having a sparse time-derivative. We model the observed time series as the sum of a low-pass signal (e.g., a background trend), an artifact signal of each type, and a white Gaussian stochastic process. To jointly estimate the components of the signal model, we formulate a sparse optimization problem and develop a rapidly converging, computationally efficient iterative algorithm denoted TARA ("transient artifact reduction algorithm"). The effectiveness of the approach is illustrated using near infrared spectroscopic time-series data.

24. Kagawa et al. (2014). **Does shape discrimination by the mouth activate the parietal and occipital lobes? - near-infrared spectroscopy study**

Abstract: A cross-modal association between somatosensory tactile sensation and parietal and occipital activities during Braille reading was initially discovered in tests with blind subjects, with sighted and blindfolded healthy subjects used as controls. However, the neural background of oral stereognosis remains unclear. In the present study, we investigated whether the parietal and occipital cortices are activated during shape discrimination by the mouth using functional near-infrared spectroscopy (fNIRS). Following presentation of the test piece shape, a sham discrimination trial without the test pieces induced posterior parietal lobe (BA7), extrastriate cortex (BA18, BA19), and striate cortex (BA17) activation as compared with the rest session, while shape discrimination of the test pieces markedly activated those areas as compared with the rest session. Furthermore, shape discrimination of the test pieces specifically activated the posterior parietal cortex (precuneus/BA7), extrastriate cortex (BA18, 19), and striate cortex (BA17), as compared with sham sessions without a test piece. We concluded that oral tactile sensation is recognized through tactile/visual cross-modal substrates in the parietal and occipital cortices during shape discrimination by the mouth.

25. Fleck et al. (2014). **Propofol Effect on Cerebral Oxygenation in Children with Congenital Heart Disease**

Abstract: Propofol is a short-acting, intravenously administered hypnotic agent which is used in procedural sedation in children. Propofol is known to decrease systemic vascular resistance, arterial blood pressure and can lead to desaturations and decreased systemic perfusion in children with cardiac shunting. This may result in a reduction in cerebral blood flow and oxygenation. Near-infrared spectroscopy (NIRS) can monitor cerebral tissue oxygenation in the frontal neocortex. The objective of our study was to measure the changes in cerebral oxygen and blood supply after Propofol infusion in children with congenital heart disease. Propofol infusion may reduce cerebral oxygenation in children with congenital heart disease. The study group consisted of 32 children (f:m = 18:14), with median age of 49 (5–112) months and median weight of 15 (5–34) kg. We performed NIRS derived continuous measurement of cerebral oxygenation and cardiac output using Electrical velocimetry for 5 min before and after sedation with Propofol (1–2 mg/kg i.v.) for cardiac catheterization. Simultaneously, non-invasive arterial blood pressure and transcutaneous oxygen saturation were measured. Propofol sedation led to a significant decrease in mean arterial pressure (79 ± 16 vs. 67 ± 12 mmHg) ($p = 0.01$) and cardiac index (3.2 ± 0.8 vs. 2.9 ± 0.6 ml/min/m2) ($p = 0.03$). In contrast, cerebral tissue oxygenation index, increased significantly from 57 ± 11 to 59 ± 10 % ($p < 0.05$). Sedation with Propofol increased cerebral tissue oxygenation despite a decrease in cardiac index and arterial blood pressure. This may be caused by a decreased oxygen consumption of the sedated brain with intact cerebral auto-regulation.

26. Koga et al. (2014). **Effects of increased skin blood flow on muscle oxygenation/deoxygenation: comparison of time-resolved and continuous-wave near-infrared spectroscopy signals**

Abstract: Purpose: We quantified the contribution of skin blood flow (SkBF) to tissue oxygenation/deoxygenation of the flexor digitorum profundus muscle during cutaneous vasodilation.
Methods: Time-resolved near-infrared spectroscopy (TRS-NIRS) was utilized to measure the potential influence of optical factors [mean optical pathlength (PL) and coefficients of absorption (μa) and reduced scattering (μ′s)] on the NIRS-derived signals of eight male subjects.
Results: The approximately threefold elevation of SkBF during 1 h whole-body heating (increased internal temperature ~0.9 °C) increased both μa and μ′s without changing PL. Assuming that the μ′s coefficient remained constant, i.e., as with continuous-wave (CW) NIRS, resulted in a significant increase in the apparent oxygenation [oxy(Hb + Mb), from 113 ± 13 μM (mean ± SD) for control to 126 ± 13 for the increased SkBF condition, $P < 0.01$]: this was in marked contrast to the unchanged TRS-derived values. The deoxygenation [deoxy(Hb + Mb)] also increased from control to elevated SkBF (CW-NIRS, from 39 ± 8 to 45 ± 7; TRS, from 38 ± 6 to 44 ± 7 μM; $P < 0.01$ for both), but less than that seen for oxy(Hb + Mb) and not different between TRS- and CW-NIRS. Further, and in contrast to oxy(Hb + Mb), temporal profiles of deoxy(Hb + Mb) measured by the two NIRS methods were not different.
Conclusions: These findings support use of either NIRS method to estimate local muscle fractional O2 extraction, but not oxygenation, when SkBF is increased at rest.

27. Du et al. (2014). **Low-frequency calcium oscillations accompany deoxyhemoglobin oscillations in rat somatosensory cortex**

Abstract: Spontaneous low-frequency oscillations (LFOs) of blood-oxygen-level-dependent (BOLD) signals are used to map brain functional connectivity with functional MRI, but their source is not well understood. Here we used optical imaging to assess whether LFOs from vascular signals covary with oscillatory intracellular calcium (Ca(2+)i) and with local field potentials in the rat's somatosensory cortex. We observed that the frequency of Ca(2+)i oscillations in tissue (~0.07 Hz) was similar to the LFOs of deoxyhemoglobin (HbR) and oxyhemoglobin (HbO2) in both large blood vessels and capillaries. The HbR and HbO2 fluctuations within tissue correlated with Ca(2+)i oscillations with a lag time of ~5-6 s. The Ca(2+)i and hemoglobin oscillations were insensitive to hypercapnia. In contrast, cerebral-blood-flow velocity (CBFv) in arteries and veins fluctuated at a higher frequency (~0.12 Hz) and was sensitive to hypercapnia. However, in parenchymal tissue, CBFv oscillated with peaks at both ~0.06 Hz and ~0.12 Hz. Although the higher-frequency CBFv oscillation (~0.12 Hz) was decreased by hypercapnia, its lower-frequency component (~0.06 Hz) was not. The sensitivity of the higher CBFV oscillations to hypercapnia, which triggers blood vessel vasodilation, suggests its dependence on vascular effects that are distinct from the LFOs detected in HbR, HbO2, Ca(2+)i, and the lower-frequency tissue CBFv, which were insensitive to hypercapnia. Hemodynamic LFOs correlated both with Ca(2+)i and neuronal firing (local field potentials), indicating that they directly reflect neuronal activity (perhaps also glial). These findings show that HbR fluctuations (basis of BOLD oscillations) are linked to oscillatory cellular activity and detectable throughout the vascular tree (arteries, capillaries, and veins).

28. Wu et al. (2014). **Quantitative evaluation of atlas-based high-density diffuse optical tomography for imaging of the human visual cortex**

Abstract: Image recovery in diffuse optical tomography (DOT) of the human brain often relies on accurate models of light propagation within the head. In the absence of subject specific models for image reconstruction, the use of atlas based models are showing strong promise. Although there exists some understanding in the use of some limited rigid model registrations in DOT, there has been a lack of a detailed analysis between errors in geometrical accuracy, light propagation in tissue and subsequent errors in dynamic imaging of recovered focal activations in the brain. In this work 11 different rigid registration algorithms, across 24 simulated subjects, are

evaluated for DOT studies in the visual cortex. Although there exists a strong correlation (R2 = 0.97) between geometrical surface error and internal light propagation errors, the overall variation is minimal when analysing recovered focal activations in the visual cortex. While a subject specific mesh gives the best results with a 1.2 mm average location error, no single algorithm provides errors greater than 4.5 mm. This work demonstrates that the use of rigid algorithms for atlas based imaging is a promising route when subject specific models are not available.

29. Shi et al. (2014). **Correlation between LIFG and autonomic activation during stressful tasks: A functional near-infrared spectroscopy (fNIRS) study**

Abstract: It remains unclear whether language tasks in one's first (L1) or second (L2) language can cause stress responses and whether frontal, autonomic and behavioral responses to stressful tasks are correlated. In this study, we studied 22 Chinese subjects whose L2 was English and measured the cerebral blood oxygenation in their frontal lobe by using functional near-infrared spectroscopy (fNIRS) as participants engaged in a mental arithmetic task (MAT) and verbal fluency tasks (VFTs) in L1 (Chinese) and L2 (English). To examine the activated cortical areas, we estimated the channel location based on Montreal Neurological Institute (MNI) standard brain space by using a probabilistic estimation method. We evaluated heart rate (HR) changes to analyze autonomic nervous system (ANS) functioning. We found that the MAT and VFTs induced greater increases in HR than did the control (Ctrl) task. Furthermore, subjects developed greater increases in HR in the MAT and VFTL2 than they did in the VFTL1. Compared with the Ctrl task, the MAT and both VFTL1 and VFTL2 produced robust and widespread bilateral activation of the frontal cortex. Interestingly, partial correlation analysis indicated that the activity in the left inferior frontal gyrus (LIFG) [Brodmann's area (BA) 47] was consistently correlated with the increases in HR across the three tasks (MAT, VFTL2, and VFTL1), after controlling for the performance data. The present results suggested that a VFT in L2 may be more stressful than in L1. The LIFG may affect the activation of the sympathetic system induced by stressful tasks, including MATs and VFTs.

30. Vermeij et al. (2014). **An exploratory study of the effects of spatial working-memory load on prefrontal activation in low- and high-performing elderly**

Abstract: Older adults show more bilateral prefrontal activation during cognitive performance than younger adults, who typically show unilateral activation. This over-recruitment has been interpreted as compensation for declining structure and function of the brain. Here we examined how the relationship between behavioral performance and prefrontal activation is modulated by different levels of working-memory load. Eighteen healthy older adults (70.8 ± 5.0 years; MMSE 29.3 ± 0.9) performed a spatial working-memory task (n-back). Oxygenated ([O2Hb]) and deoxygenated ([HHb]) hemoglobin concentration changes were registered by two functional Near-Infrared Spectroscopy (fNIRS) channels located over the left and right prefrontal cortex. Increased working-memory load resulted in worse performance compared to the control condition. [O2Hb] increased with rising working-memory load in both fNIRS channels. Based on the performance in the high working-memory load condition, the group was divided into low and high performers. A significant interaction effect of performance level and hemisphere on [O2Hb] increase was found, indicating that high performers were better able to keep the right prefrontal cortex engaged under high cognitive demand. Furthermore, in the low performers group, individuals with a larger decline in task performance from the control to the high working-memory load condition had a larger bilateral increase of [O2Hb]. The high performers did not show a correlation between performance decline and working-memory load related prefrontal activation changes. Thus, additional bilateral prefrontal activation in low performers did not necessarily result in better cognitive performance. Our study showed that bilateral prefrontal activation may not always be successfully compensatory. Individual behavioral performance should be taken into account to be able to distinguish successful and unsuccessful compensation or declined neural efficiency.

31. Gao et al. (2014). **Cerebral autoregulation in response to posture change in elderly subjects-assessment by wavelet phase coherence analysis of cerebral tissue oxyhemoglobin concentrations and arterial blood pressure signals**

Abstract: This study aims to assess the dynamic cerebral autoregulation (dCA) in response to posture change using wavelet phase coherence (WPCO) of cerebral tissue oxyhemoglobin concentrations (Delta [HbO2]) and arterial blood pressure (ABP) signals in healthy elderly subjects. Continuous recordings of near-infrared spectroscopy (NIRS) and ABP signals were obtained from simultaneous measurements in 16 healthy elderly subjects (age: 68.9±7.1 years) and 19 young subjects (age: 24.9±3.2 years). The phase coherence between Delta [HbO2] and ABP oscillations in six frequency intervals (I, 0.6-2Hz; II, 0.15-0.6Hz; III, 0.05-0.15Hz; IV, 0.02-0.05Hz, V, 0.0095-0.02Hz and VI, 0.005-0.0095Hz) was analyzed using WPCO. The sit-to-stand posture change induces significantly lower WPCO in interval III (F=5.50 p=0.025) in the elderly subjects than in the young subjects. However, the stand-to-sit posture change induces higher WPCO in intervals II (F=5.25 p=0.028) and V (F=6.22 p=0.018) in the elderly subjects than in the young subjects. The difference of WPCO in response to posture change between the elderly and the young subjects indicates an altered CA due to aging. This study provides new insight into the dynamics of CA and may be useful in identifying the risk for dCA processes.

32. Zinszer et al. (2014). **Second language experience modulates neural specialization for first language lexical tones**

Abstract: Recent neuroimaging studies have revealed distinct functional roles of left and right temporal lobe structures in the processing of lexical tones in Chinese. In the present study, we ask whether knowledge of a second language (English) modulates this pattern of activation in the perception of tonal contrasts. Twenty-four native Chinese speakers were recruited from undergraduate and graduate students at Beijing Normal University, China. Participants listened to blocks of computationally manipulated /ba/ syllables which were varied to form within- and across-category deviants at equal acoustic intervals from a standard tone while their cortical blood oxygenation was measured by functional near-infrared spectroscopy (fNIRS). Blocks were analyzed for peak blood oxygenation (HbO) levels, and several linear models were estimated for these data, including effects of deviant tone type (within- or across-category), behavioral differences in tone identification, age of earliest exposure to English (spoken), and proficiency in English. Functional changes in HbO indicated a significantly greater response to within-category contrasts in right STG, consistent with previous findings. However, the effect of deviant type in left MTG was significantly modulated by the age of participants' earliest English exposure: Average across-category activation exceeded within-category activation only for participants exposed to English after 13 years of age. While previous research has established the importance of left MTG in the categorical perception of lexical tones, our findings suggest that the functional specialization of this region is sensitive to second language experience, even in the processing of native language.

33. Strait et al. (2014). **Measuring Users' Responses to Humans, Robots, and Human-like Robots with Functional Near Infrared Spectroscopy**

Abstract: The Uncanny Valley Hypothesis (UVH) describes the sudden change in a person's affect from affinity to aversion that is evoked by robots that border a human-like appearance. The portion of the human-likeness spectrum in which such aversion is posited to occur is referred to as the "uncanny valley". However, evidence in support of the UVH is primarily based on subjectively assessed evaluations. Thus it remains an open question as to whether there are behavioral or neurophysiological manifestations of uncanny valley effects. To address this gap in literature, we investigated the activation of the anterior prefrontal cortex (PFC) – a region of the brain associated with emotion regulation – in response to a series of robots with varying human-likeness. We hypothesized that highly human-like robots – which have been found to receive negative subjective attributions – will also elicit increased activity in the PFC versus humans or robots with lesser degrees of human-likeness in accordance with the UVH. Our results show a "valley" in brain activity in the PFC corresponding to the valley

observed via subjective measures alone, thus suggesting one neural manifestation (the PFC) of uncanny valley effects and further supporting the affective response (aversion) posited to occur by the UVH. However, the results also reveal a second "uncanny valley" in prefrontal hemodynamics, which suggests that the effects (and the contributing factors) are more complex than previously understood.

34. Binder-Heschl et al. (2014). **Cerebral tissue oxygen saturation is associated with N-terminal probrain natriuretic peptide in preterm infants on their first day of life**

Abstract: Aim: This prospective observational study investigated if N-terminal probrain natriuretic peptide (NT-proBNP), a cardiac biomarker, correlated with cerebral tissue oxygen saturation (crSO2) in preterm infants on their first day of life.
Methods: Using near infrared spectroscopy (NIRS), crSO2 was measured on the right forehead of preterm infants for 24 h. We also recorded arterial oxygen saturation (SpO2) and calculated fractional tissue oxygen extraction (cFTOE) values. At the end of the NIRS measurement, blood was taken to analyse NT-proBNP. Mean values for the 24-h period were calculated for crSO2, cFTOE, SpO2 and these values were correlated to NT-proBNP. An echocardiography was performed in all infants during the measurement period.
Results: We analysed 35 preterm neonates (33 ± 2 weeks, 1965 ± 523 g). NIRS measurements started at 3 ± 1 h and blood samples were taken at 24 ± 5 h postnatal. Echocardiography showed an open ductus arteriosus in all infants. Mean NT-proBNP was 4978 ± 3566 pg/mL, crSO2 was 76 ± 8%, and cFTOE was 0.20 ± 0.08. NT-proBNP correlated negatively with crSO2 ($r = -0.75$; $p \leq 0.001$) and positively with cFTOE ($r = 0.731$; $p \leq 0.001$).
Conclusion: These results emphasise that crSO2 is influenced by cardiac function, in addition to oxygen consumption, arterial oxygen saturation and vascular resistance, and this can be measured by NT-proBNP.

35. Woodside et al. (2014). **Systemic oxidative–nitrosative–inflammatory stress during acute exercise in hypoxia; implications for microvascular oxygenation and aerobic capacity**

Abstract: Exercise performance in hypoxia may be limited by a critical reduction in cerebral and skeletal tissue oxygenation, although the underlying mechanisms remain unclear. We examined whether increased systemic free radical accumulation during hypoxia would be associated with elevated microvascular deoxygenation and reduced maximal aerobic capacity (inline image). Eleven healthy men were randomly assigned single-blind to an incremental semi-recumbent cycling test to determine inline image in both normoxia (21% O2) and hypoxia (12% O2) separated by a week. Continuous-wave near-infrared spectroscopy was employed to monitor concentration changes in oxy- and deoxyhaemoglobin in the left vastus lateralis muscle and frontal cerebral cortex. Antecubital venous blood samples were obtained at rest and at inline image to determine oxidative (ascorbate radical by electron paramagnetic resonance spectroscopy), nitrosative (nitric oxide metabolites by ozone-based chemiluminescence and 3-nitrotyrosine by enzyme-linked immunosorbent assay) and inflammatory stress biomarkers (soluble intercellular/vascular cell adhesion 1 molecules by enzyme-linked immunosorbent assay). Hypoxia was associated with increased cerebral and muscle tissue deoxygenation and lower inline image ($P < 0.05$ versus normoxia). Despite an exercise-induced increase in oxidative–nitrosative–inflammatory stress, hypoxia per se did not have an additive effect ($P > 0.05$ versus normoxia). Consequently, we failed to observe correlations between any metabolic, haemodynamic and cardiorespiratory parameters ($P > 0.05$). Collectively, these findings suggest that altered free radical metabolism cannot explain the elevated microvascular deoxygenation and corresponding lower inline image in hypoxia. Further research is required to determine whether free radicals when present in excess do indeed contribute to the premature termination of exercise in hypoxia.

36. McKendrick et al. (2014). **Using functional Near Infrared Spectroscopy (fNIRS) to Evaluate the Neurocognitive Effects of Transient Events Design Matrix Mixed Effects Analysis**

Abstract: A spatial memory task with an event related design was used as a proxy for showcasing a design matrix regression on fNIRS data for neuroergonomic studies of complex tasks involving transient workload transitions. The analysis identified a region of ventrolateral prefrontal cortex (VLPFC) in which oxygenated hemoglobin (HbO2) was increased during memory maintenance. Task performance negatively modulated HbO2 in this brain region during memory maintenance. The results show that neural effects specifically within the period of memory maintenance, as opposed to other cognitive components (e.g., encoding or retrieval) can be reliably identified. Similar analytical methods could be used for the analysis of cortical hemodynamics in more complex tasks involving transient events (e.g., workload transitions) and in related neuroergonomic applications.

37. Bemichet et al. (2014). **Cerebral oxygenation with different nasal continuous positive airway pressure levels in preterm infants**

Abstract: Objectives: This study evaluates the effect of varying nasal continuous positive airway pressure (NCPAP) level on cerebral blood flow (CBF) and oxygenation in preterm infants.
Methods: Oxy-haemoglobin (HbO2) and total haemoglobin (HbTot), as CBF estimates, and the ratio between HbO2 and HbTot (HbO2/HbTot), as cerebral oxygenation estimate, were assessed by near-infrared spectroscopy in 26 stable preterm newborns at a postmenstrual age between 26 and 33 weeks. Baseline HbO2, HbTot and HbO2/HbTot values were initially collected with NCPAP at 5 cm H2O and then compared with values obtained with NCPAP levels at both 3 and 8 cm H2O.
Results: Compared with 5 cm H2O, cerebral HbO2, HbTot and HbO2/HbTot remained unchanged both after increasing (to 8 cm H2O) and decreasing (to 3 cm H2O) the NCPAP level. This result was observed both in regional areas (24 sites) and in the overall monitored area (frontal and parietal cortex). Compared with 8 cm H2O, peripheral oxygen saturation significantly decreased at 3 cm H2O ($p=0.021$). Heart rate did not change.
Conclusions: No differences in CBF and cerebral oxygenation were observed with NCPAP levels in the range 3–8 cm H2O despite a decrease in peripheral oxygenation with 3 cm H2O.

38. Horiuchi et al. (2014). **Impact of Viewing vs. Not Viewing a Real Forest on Physiological and Psychological Responses in the Same Setting**

Abstract: We investigated the impact of viewing versus not viewing a real forest on human subjects' physiological and psychological responses in the same setting. Fifteen healthy volunteers (11 males, four females, mean age 36 years) participated. Each participant was asked to view a forest while seated in a comfortable chair for 15 min (Forest condition) vs. sitting the same length of time with a curtain obscuring the forest view (Enclosed condition). Both conditions significantly decreased blood pressure (BP) variables, i.e., systolic BP, diastolic BP, and mean arterial pressure between pre and post experimental stimuli, but these reductions showed no difference between conditions. Interestingly, the Forest viewing reduced cerebral oxygenated hemoglobin (HbO2) assessed by near-infrared spectroscopy (NIRS) and improved the subjects' Profile of Mood States (POMS) scores, whereas the Enclosed condition increased the HbO2 and did not affect the POMS scores. There were no significant differences in saliva amylase or heart rate variability (HRV) between the two conditions. Collectively, these results suggest that viewing a real forest may have a positive effect on cerebral activity and psychological responses. However, both viewing and not viewing the forest had similar effects on cardiovascular responses such as BP variables and HRV.

39. Maghawry et al. (2014). **Cerebral oxygen saturation monitoring during hypotensive anesthesia in shoulder arthroscopy: A comparative study between dexmedetomidine and esmolol**

Abstract: Background: Beach chair position (BCP) is used in arthroscopic shoulder operations for its advantages. The BCP together with deliberate hypotension used to decrease intraoperative blood loss during arthroscopic shoulder procedures, this may have risk to cause postoperative neurological insults. Dexmedetomidine and esmolol are used to induce deliberate hypotension. Near-infrared spectroscopy (NIRS) provides a non-invasive technique of continuous monitoring of regional cerebral tissue oxygen saturation (rScO2). In this study we evaluate the prevalence of rScO2 during hypotensive anesthesia induced by intra-operative infusion of either dexmedetomidine or esmolol in patients undergoing elective arthroscopic shoulder surgery in the BCP.
Patients and methods: Fifty patients scheduled for elective arthroscopic shoulder surgery under general anesthesia with hypotensive technique in BCP, randomly assigned into two equal groups, dexmedetomidine group (D Group) and esmolol group (E Group) according to the drug used for deliberate hypotension. MAP, HR, BIS and rScO2 were recorded before induction of anesthesia T0, post-induction of anesthesia T1 as baseline, 5 min after BCP T2, 5 min after starting the studied drug T3, 30 min T4, 60 min T5, 90 min T6, 5 min after stopping the studied drug T7, 5 min after return to supine T8 and after extubation T9.
Results: In D group there was significant decrease in Lt.rsco2 and Rt.rsco2, at T2 to T7 compared to T1. In E group there was significant decrease in Lt.rsco2 and Rt.rsco2 at T2, to T7 compared to T1. In D group two patients had CDEs compared to five patients in E group.
Conclusion: In patients undergoing shoulder arthroscopic surgery under general anesthesia, the BCP significantly decreases rScO2, with further slight decrease of rScO2 with dexmedetomidine and esmolol induced hypotension with no affection of postoperative cognitive function with both drugs. Dexmedetomidine and esmolol are safe drugs with better safety of dexmedetomidine over esmolol.

40. Zephaniah et al. (2014). **Recent functional near infrared spectroscopy based brain computer interface systems: Developments, applications and challenges**

Abstract: Functional Near Infrared Spectroscopy (fNIRS) based Brain Computer Interface (BCI) systems have grown in popularity in the last years, and has shown itself as a useful tool in developing portable and convenient BCI systems. The purpose of this review paper is to highlight the recent developments, applications, and challenges that research groups have achieved in the field of fNIRS-BCI. We will show how fNIRS can be paired with another modality (i.e. EEG, fTCD, etc.) to drastically improve classification accuracy. From there, we will discuss the recent achievements in classification techniques researchers have had with fNIRS or a combined fNIRS modality. Finally, we will look at how fNIRS-BCI systems are used to enhance human-robot interactions and assistive technologies. Throughout our review paper, we will note challenges groups have had with their studies, as to provide a framework for future research topics for the fNIRS-BCI community.

41. Ono et al. (2014). **Prefrontal Hemodynamic Changes Associated with Subjective Sense of Occlusal Discomfort**

Abstract: We used functional near-infrared spectroscopy to measure prefrontal brain activity accompanying the physical sensation of oral discomfort that arose when healthy young-adult volunteers performed a grinding motion with mild occlusal elevation (96 μm). We simultaneously evaluated various forms of occlusal discomfort using the visual analogue scale (VAS) and hemodynamic responses to identify the specific prefrontal activity that occurs with increased occlusal discomfort. The Oxy-Hb responses of selected channels in the bilateral frontopolar and dorsolateral prefrontal cortices increased in participants who reported increased severity of occlusal discomfort, while they decreased in those who reported no change or decreased occlusal discomfort during grinding. Moreover, the cumulative values of Oxy-Hb response in some of these channels were statistically significant predictive factors for the VAS scores. A generalized linear model analysis of Oxy-Hb

signals in a group of participants who reported increased discomfort further indicated significant cerebral activation in the right frontopolar and dorsolateral prefrontal cortices that overlapped with the results of correlation analyses. Our results suggest that the increased hemodynamic responses in the prefrontal area reflect the top-down control of attention and/or self-regulation against the uncomfortable somatosensory input, which could be a possible marker to detect the subjective sense of occlusal discomfort.

42. Zamparini et al. (2014). **Noninvasive assessment of peripheral microcirculation by near-infrared spectroscopy: a comparative study in healthy smoking and nonsmoking volunteers**

Abstract: Smokers are exposed to early endothelial dysfunction. This microcirculatory damage can be demonstrated by near-infrared spectroscopy (NIRS). The aim of this study was to compare microvascular reactivity by NIRS during a dynamic vascular occlusion test in healthy smokers and nonsmokers volunteers. Twenty healthy volunteers (10 men, 10 women), aged from 22 to 38 years old, were included after approval of the local Ethics Committee and divided into two groups: smokers (n = 10) and nonsmokers (n = 10). Tissue oxygen saturation (StO2) was measured at the level of each individual's calves during an ischemia and reperfusion test. In addition, during the ischemia phase, the slope of decline in StO2 was determined. Therefore, for each group, we were able to deduce the speed of desaturation (ΔStO2/ischemia time). The same was applied for resaturation rates during the reperfusion phase (ΔStO2/reperfusion time). StO2 values were comparable at all experimental steps between smokers and nonsmokers. During the vascular occlusion test, rates of desaturation were the same between smokers and nonsmokers [respectively 3.7 % ·min−1 (range 2.5–12.6) and 3.7 % ·min−1 (range 1.8–15.1); p = 0.50]. It was the same for the rate of resaturation [smokers 30.4 % ·min−1 (range 14.2–51.6) and nonsmokers 30.5 % ·min−1 (range 18.6–44.5); p = 0.82]. NIRS study of microvascular reactivity during a dynamic vascular occlusion test did not reveal any difference between smokers and nonsmokers. Therefore, NIRS could not be sensitive enough to highlight endothelial dysfunction in healthy subjects exposed to tobacco smoke.

43. Zhao et al. (2014). **Temporal orienting of attention: An fNIRS study on the illusion of "a watched pot never boils"**

Abstract: The present study used a single-task paradigm in which participants received guidance to focus more attention (waiting for someone) on the temporal intervals in the "waiting" condition and to stay relaxed in the control condition. The reported time was longer in the waiting condition than in the control condition. Functional near-infrared spectroscopy was used to measure simultaneously the activation levels of the dorsolateral prefrontal cortex (DLPFC) for each condition. Greater oxyhemoglobin (oxy-Hb) activation in the waiting condition was observed compared with the control condition, whilst deoxyhemoglobin data showed no difference between the two conditions. The gradual changes in oxy-Hb in the DLPFC in increments of 100 ms yielded further insights into the role of this region in the "watched pot never boils" phenomenon.

44. Oussaidene et al. (2014). **Aerobic fitness influences cerebral oxygenation response to maximal exercise in healthy subjects**

Abstract: The study examined whether the aerobic fitness level modifies the cerebral oxygenation response to incremental ramp exercise, and more specifically the decline in cerebral oxygenation from heavy exercise up to maximal intensities. 11 untrained (View the MathML sourceV˙O2max 47.3 ± 4.0 mL min−1 kg−1) and 13 endurance-trained (View the MathML sourceV˙O2max 61.2 ± 8.0 mL min−1 kg−1) healthy men performed a maximal ramp cycle exercise. Left prefrontal cortex oxygenation (ΔHbO2) was monitored by near-infrared spectroscopy. A cerebral oxygenation threshold decline (ThCOx) during exercise was determined. ThCox occurred in all subjects but for higher View the MathML sourceV˙O2 (mL min−1 kg−1) in endurance-trained than in untrained subjects (P < 0.01). At submaximal exercise intensity corresponding to ThCOx, ΔHbO2 was higher in endurance-trained than in untrained subjects (P < 0.05). View the MathML sourceV˙O2 at ThCox was related to

View the MathML sourceV˙O2 at respiratory compensation point (n = 24, r = 0.93, P < 0.001) and to View the MathML sourceV˙O2max (n = 24, r = 0.92, P < 0.001). These findings indicate that above the respiratory compensation point the prefrontal O2 demand exceeds the supply in untrained and in endurance-trained subjects. In addition, the occurrence of ThCOx was delayed to higher absolute exercise intensities in endurance-trained in relation with their higher View the MathML sourceV˙O2max than untrained men. These results demonstrated that aerobic fitness influences cerebral oxygenation during exercise.

45. Grounauer et al. (2014). **The Somnogen Visual Training a New CBT to Fight Insomnia through Closed Eyes and fNIRS Neuroimaging**

Abstract: The use of a red light observed through closed eyes is a new CBT Cognitive Behavioral Therapy to fight insomnia. Its principles are based on the high transmission of the colour red through eyelids, the great sensitivity to light of the retina when it is adjusted to darkness and the mental distraction obtained by the perception and attentive observation of variations of intensity. The prefrontal and occipital fNIRS recordings document this method which is correlated to the sleep EEG state II.

46. Matsuo et al. (2014). **A Preliminary Near-Infrared Spectroscopy Study in Adolescent and Adult Patients with Attention-Deficit/Hyperactivity Disorder Symptoms**

Abstract: Prefrontal dysfunction in patients with attention-deficit/hyperactivity disorder (AD/HD) has been repeatedly detected on a behavioral level, and various brain-imaging studies have elucidated the pathophysiology of AD/HD. Recent advances in near-infrared spectroscopy (NIRS) have enabled noninvasive investigations of brain function in various mental disorders, especially major depression, schizophrenia, and bipolar disorder. The objective of this preliminary study was to use NIRS to evaluate changes in frontal lobe blood flow in post childhood or adult patients with AD/HD symptoms. The subjects included five patients with a range of mental disorders and AD/HD symptoms, and a matched (age, sex, and dominant hand) control group of five healthy subjects. We compared the changes in cerebral blood flow during verbal fluency tasks between the two groups. The duration of the elevated oxygenated hemoglobin was notably shorter in the AD/HD group than that in the healthy control group. We suggest that the shorter elevation durations of oxygenated hemoglobin concentrations might be a biological indicator for post childhood or adult AD/HD or of impaired executive functioning.

47. Baker et al. (2014). **Modified Beer-Lambert law for blood flow**

Abstract: We develop and validate a Modified Beer-Lambert law for blood flow based on diffuse correlation spectroscopy (DCS) measurements. The new formulation enables blood flow monitoring from temporal intensity autocorrelation function data taken at single or multiple delay-times. Consequentially, the speed of the optical blood flow measurement can be substantially increased. The scheme facilitates blood flow monitoring of highly scattering tissues in geometries wherein light propagation is diffusive or non-diffusive, and it is particularly well-suited for utilization with pressure measurement paradigms that employ differential flow signals to reduce contributions of superficial tissues.

48. Otsuka et al. (2014). **Effects of Mandibular Retrusive Deviation on Prefrontal Cortex Activation: A Functional Near-Infrared Spectroscopy Study**

Abstract: The objective of this study was to evaluate occlusal condition by assessing brain activity in the prefrontal cortex, which is associated with emotion. Functional near-infrared spectroscopy (fNIRS) was used to detect changes in cerebral blood flow in the prefrontal cortex of 12 healthy volunteers. The malocclusion model

was a custom-made splint that forced the mandible into retrusion. A splint with no modification was used as a control. The cortical activation during clenching was compared between the retrusive position condition and the control condition. A visual analog scale score for discomfort was also obtained during clenching and used to evaluate the interaction between fNIRS data and psychiatric changes. Activation of the prefrontal cortex was significantly greater during clenching in the mandibular retrusive condition than during clenching in the control condition. Furthermore, Spearman rank-correlation coefficient revealed a parallel relation between prefrontal cortex activation and visual analog scale score for discomfort. These results indicate that fNIRS can be used to objectively evaluate the occlusal condition by evaluating activity in the prefrontal cortex.

49. Misawa et al. (2014). **Possibility for Predicting the Evaluation of Product Price in the Prefrontal Cortex : A NIRS Study**

Abstract: Neuromarketing, an actively studied field in recent years, uses measurements of brain activity to understand the purchasing motives of consumers. This field has expanded due to the development of noninvasive brain measurement techniques and newfound knowledge relating to human decision-making from the viewpoint of behavioral economics. Previous studies have indicated that activity in medial prefrontal cortex, medial orbitofrontal cortex, and dorsolateral prefrontal cortex react to reward and punishment, and thus may act as neurologic predictive factors concerning purchasing. This study focuses on price, which is one of a purchasing decision-making factor. We used near-infrared spectroscopy (NIRS) to measure brain activity changes induced by evaluation of product price. We determined the classification accuracy of price evaluation (i.e., subjects felt it was "expensive" or "inexpensive") offline using machine learning; the average overall accuracy was more than 75%. In addition, the rate of divergence between the product price and the price predicted by the subject was correlated with change in oxygenated hemoglobin concentrations. These findings suggest that brain activity can be used to evaluate the extent to which consumers feel a product price to be "expensive" or "inexpensive".

50. Vilke et al. (2014). **Predictive value of early near-infrared spectroscopy monitoring of patients with traumatic brain injury**

Abstract: Background and objective: Traumatic brain injury (TBI) is the leading cause of death and disability in young adults. Study aimed to define the predictive value of early near-infrared spectroscopy (NIRS) monitoring of TBI patients in a Lithuanian clinical setting.
Materials and methods: Data of 61 patients was analyzed. Predictive value of early NIRS monitoring, computed tomography data and regular intensive care unit (ICU) parameters was investigated.
Results: Twenty-six patients expressed clinically severe TBI; 14 patients deceased. Patients who survived expressed higher NIRS values at the periods of admission to operative room (75.4% ± 9.8% vs. 71.0% ± 20.5%; P = 0.013) and 1 h after admission to ICU (74.7% ± 1.5% vs. 61.9% ± 19.4%; P = 0.029). The NIRS values discriminated hospital mortality groups more accurately than admission GCS score, blood sugar or hemoglobin levels. Admission INR value and NIRS value at 1 h after admission to ICU were selected by discriminant analysis into the optimal set of features when classifying hospital mortality groups. Average efficiency of classification using this method was 88.9%. When rsO2 values at 1 h after admission to ICU did not exceed 68.0% in the left hemisphere and 68.3% in the right hemisphere, the hazard ratio for death increased by 17.7 times ($P < 0.01$) and 5.1 times ($P < 0.05$), respectively.
Conclusions: NIRS plays an important role in the clinical care of TBI patients. Regional brain saturation monitoring provides accurate predictive data, which can improve the allocation of scarce medical resources, set the treatment goals and alleviate the early communication with patients' relatives.

51. Bakksheshi et al. (2014). **Non-invasive monitoring of brain temperature by near-infrared spectroscopy**

Abstract: Optical techniques are promising methods for measuring tissue temperature noninvasively due to the transparency of tissue to near infrared-light and the temperature dependent light-absorbing properties of endogenous absorbers, particularly water. Besides being noninvasive, the instruments are compact and portable, permitting bedside monitoring.

52. Grinspan et al. (2014). **Multimodal Monitoring in the Pediatric Intensive Care Unit: New Modalities and Informatics Challenges**

Abstract: We review several newer modalities to monitor the brain in children with acute neurologic disease in the pediatric intensive care unit, such as partial brain tissue oxygen tension (PbtO2), jugular venous oxygen saturation (SjvO2), near infrared spectroscopy (NIRS), thermal diffusion measurement of cerebral blood flow, cerebral microdialysis, and EEG. We then discuss the informatics challenges to acquire, consolidate, analyze, and display the data. Acquisition includes multiple data types: discrete, waveform, and continuous. Consolidation requires device interoperability and time synchronization. Analysis could include pressure reactivity index and quantitative EEG. Displays should communicate the patient's current status, longitudinal and trend information, and critical alarms.

53. Urakawa et al. (2014). **Selective Medial Prefrontal Cortex Responses During Live Mutual Gaze Interactions in Human Infants: An fNIRS Study**

Abstract: To investigate the role of the prefrontal cortex (PFC) in processing multimodal communicative ostensive signals in infants, we measured cerebral hemodynamic responses by using near-infrared spectroscopy (NIRS) during the social interactive play "peek-a-boo", in which both visual (direct gaze) and auditory (infant-directed speech) stimuli were presented. The infants (mean age, around 7 months) sat on their mother's lap, equipped with an NIRS head cap, and looked at a partner's face during "peek-a-boo". An eye-tracking system simultaneously monitored the infants' visual fixation patterns. The results indicate that, when the partner presented a direct gaze, rather than an averted gaze, toward an infant during social play, the infant fixated on the partner's eye region for a longer duration. Furthermore, hemodynamic activity increased more prominently dorsomedial prefrontal cortex (mPFC) in response to social play with a partner's direct gaze compared to an averted gaze. In contrast, hemodynamic activity increased in the right dorsolateral prefrontal cortex (R-lPFC) regardless of a partner's eye gaze direction. These results indicate that a partner's direct gaze shifts an infant's attention to the partner's eyes for interactive communication, and specifically activates the mPFC. The differences in hemodynamic responses between the mPFC and R-lPFC suggest functional differentiation within the PFC, and a specific role of the mPFC in the perception of face-to-face communication, especially in mutual gaze, which is essential for social interaction.

54. Ota et al. (2014). **Increased prefrontal hemodynamic change after atomoxetine administration in pediatric attention-deficit/hyperactivity disorder as measured by near-infrared spectroscopy**

Abstract: Aim: Atomoxetine, approved in Japan for the treatment of pediatric attention-deficit/hyperactivity disorder (ADHD) in April 2009, is a nonstimulant that is thought to act presynaptically via the inhibition of norepinephrine reuptake. Near-infrared spectroscopy is a non-invasive optical tool that can be used to study oxygenation and hemodynamic changes in the cerebral cortex. The present study examined the effects of a clinical dose of atomoxetine on changes in prefrontal hemodynamic activity in children with ADHD, as measured by near-infrared spectroscopy using the Stroop Color–Word Task.

Methods: Ten children with ADHD participated in the present study. We used 24-channel near-infrared spectroscopy to measure the relative concentrations of oxyhemoglobin in the frontal lobes of participants in the drug-naïve condition and those who had received atomoxetine for 8 weeks. Measurements were conducted every 0.1 s during the Stroop Color–Word Task. We used the ADHD Rating Scale-IV-Japanese version (Home Version) to evaluate ADHD symptoms.
Results: We found a significant decrease in ADHD Rating Scale-IV-Japanese version scores, from 30.7 to 22.6 ($P = 0.003$). During the Stroop Color–Word Task, we found significantly higher levels of oxyhemoglobin changes in the prefrontal cortex of participants in the atomoxetine condition compared with those in the drug-naïve condition.
Conclusions: This increase in oxyhemoglobin changes might indicate an intensified prefrontal hemodynamic response induced by atomoxetine. Near-infrared spectroscopy is a sensitive tool for measuring the pharmacological effects of atomoxetine in children with ADHD.

55. Shoureshi et al. (2014). **Fluctuations in Frequency Composition of Neural Activity Observed by Portable Brain Intention Detection Device**

Abstract: As part of the goal of developing wearable sensor technologies, we have continued the development of a headset system for monitoring activity across the primary motor cortex of the brain. Through the combination of electroencephalography (EEG) and near-infrared spectroscopy (NIRS), the headsets are capable of monitoring event-related potentials and hemodynamic activity, which are wirelessly transmitted to a computer for real-time processing to generate control signals for a motorized prosthetic limb or a virtual embodiment of one or more limbs. This paper focuses on recent observations that have been made regarding the frequency content of EEG data, which we believe is responsible for the high performance we have previously reported using artificial neural networks to infer user's intentions. While the inference engine takes advantage of frequency content from 0-128 Hertz (Hz), distinct fluctuations in alpha (8-13 Hz), beta (13-30 Hz), and gamma (30-100 Hz) frequency bands are human-observable across varying upper limb motor exercises when observed at the group level. In addition to prosthetic limbs, this technology is continuing to be investigated for application in areas including pain treatment, robotic arm control, lie detection, and more general brain-computer interfaces.

56. Carlier-Torres et al. (2014). **The hemodynamic response to acoustically modified syllables in premature and full term newborn infants aquired by near infrared spectroscopy**

Abstract: This research assesses, in newborns, the hemodynamic response to acoustically modified syllables (pronounced in a prolonged manner), versus the response to unmodified syllables (pronounced at a normal rate). The aim was to assess which of these stimulation conditions produced better syllable discrimination in two groups of neonates: 13 preterm (mean gestational age 30 weeks, SD 3 weeks), and 13 full term newborns (mean age 38 weeks, SD 1 week). Syllable discrimination, in each condition, was assessed by using an oddball paradigm (equal syllable trials vs. different syllable trials). The statistical analysis was based on the comparison between the hemodynamic response [oxyHbO] obtained by Near Infrared Spectroscopy (NIRS) to different syllable trials vs. equal syllable trials, in each condition. The modified syllable condition was better in producing trial discrimination in both groups. The amplitude of the hemodynamic response to the different syllable trials was greater than the one to the equal syllable trials: for term infants, $t = 2.59$, $p = 0.024$, and for preterm $t = 2.38$, $p = 0.035$. This finding occurred in the left temporal lobe. These data suggest that the modified syllables facilitate processing of phonemes from birth.

57. Hirano et al. (2014). **Reduction in Cortical Activation in the Sensorimotor Cortex during Motor Skill Learning of a Pursuit Rotor Task: A Functional Near-Infrared Spectroscopy Study**

Abstract: To investigate the cerebral mechanisms underlying learning of motor skills, we assessed serial changes of brain activation patterns during a pursuit rotor (PR) task in 12 right-handed healthy subjects using functional near-infrared spectroscopy (fNIRS). The subjects performed the task with their right hand for 15-s, alternated with a 30-s rest period, for 18 repetitions (cycles 1 to 18). Gains in motor skill were evaluated by recording the time for which the stylus remained on the target. Performance improved with repetition of the task. Task-related increases of oxygenated hemoglobin (oxy-Hb) were observed around the predicted location of the sensorimotor cortices on both hemispheres. The increased oxy-Hb levels appeared to reduce with repetition of the task in the channels covering the left sensorimotor area. Furthermore, there was a significant correlation between PR task performance gain and the oxy-Hb signal in the left and right sensorimotor areas. Our results suggest that cortical activation in the sensorimotor cortex reflects changes in a number of factors including sensory feedback processing, correct motor commands, and perceptual or cognitive function during learning of a PR task. Therefore, changes in contralateral sensorimotor cortical activation may serve as a motor sequence learning biomarker for rehabilitation purposes or the prediction of recovery.

58. Schudlo et al. (2014). **A review of past and future near-infrared spectroscopy brain computer interface research at the PRISM lab**

Abstract: Single-trial classification of near-infrared spectroscopy (NIRS) signals for brain-computer interface (BCI) applications has recently gained much attention. This paper reviews research in this area conducted at the PRISM lab (University of Toronto) to date, as well as directions for future work. Thus far, research has included classification of hemodynamic changes induced by the performance of various mental tasks in both offline and online settings, as well as offline classification of cortical changes evoked by different affective states. The majority of NIRS-BCI work has only involved able-bodied individuals. However, preliminary work involving individuals from target BCI-user populations is also underway. In addition to further testing with users with severe disabilities, ongoing and future research will focus on enhancing classification accuracies, communication speed and user experience.

59. Liu et al. (2014). **Monitoring the reduced scattering coefficient of bone tissues on the trajectory of pedicle screw placement using near-infrared spectroscopy**

Abstract: Pedicle screw (PS) fixation has been widely used for spine diseases. Scientists and clinicians employ several approaches to navigate PS during operation. We have demonstrated the feasibility of monitoring the reduced scattering coefficient ($\mu's$) on the trajectory of PS using near-infrared spectroscopy (NIRS). To perform the in-vitro monitoring, an NIRS measurement system was introduced and the reduced scattering coefficients of different sites in porcine pedicle were accurately deduced from the spectrum. Moreover, the changes of the reduced scattering coefficient along the different paths were studied. The results show reduced scattering coefficients on different regions of bones can be significantly distinguished. Furthermore, monitoring experiments along different paths confirmed that a reduced scattering coefficient would change versus the depth of puncture in pedicles. Thus, the proposed monitoring system based on NIRS provides a potential for guiding PS during operation.

60. Tanifuji et al. (2014). **Noninvasive determination of absorption and reduced scattering coefficients of adult heads by time-resolved reflectance measurements for functional near infra-red spectroscopy**

Abstract: Absorption and reduced scattering coefficients (μa and μ's) of adult heads have been noninvasively determined by time-resolved reflectance measurements. The finite difference time domain (FDTD) analysis was used to calculate time-resolved reflectance from realistic adult head models with brain grooves containing a non-scattering layer. In vivo time-resolved reflectances of human heads were measured by a system composed of a time-correlated single photon counter and a diode laser. By minimizing the objective functions that compare theoretical and experimental time resolved reflectances, μa and μ's of brain were determined. It became clear that time-resolved measurements have enough sensitivity to determine both μa and μ's for superficial tissues, gray matter and white matter, except μs for white matter.

61. Hou et al. (2014). **A non-linear iterative method for multi-layer DOT sub-surface imaging system**

Abstract: Diffuse Optical Tomography (DOT) has become an emerging non-invasive technology, and has been widely used in clinical diagnosis. Functional near-infrared (FNIR) is one of the important applications of DOT. However, FNIR is used to reconstruct two-dimensional (2D) images for the sake of good spatial and temporal resolution. In this paper we propose a multiple-input and multiple-output (MIMO) based data extraction algorithm method in order to increase the spatial and temporal resolution. The non-linear iterative method is used to reconstruct better resolution images layer by layer. In terms of theory, the simulation results and original images are nearly identical. The proposed reconstruction method performs good spatial resolution, and has a depth resolutions capacity of three layers.

62. Bauernfeind et al. (2014). **Single trial classification of fNIRS-based brain-computer interface mental arithmetic data: A comparison between different classifiers**

Abstract: Functional near infrared spectroscopy (fNIRS) is an emerging technique for the in-vivo assessment of functional activity of the cerebral cortex as well as in the field of brain-computer-interface (BCI) research. A common challenge for the utilization of fNIRS for BCIs is a stable and reliable single trial classification of the recorded spatio-temporal hemodynamic patterns. Many different classification methods are available, but up to now, not more than two different classifiers were evaluated and compared on one data set. In this work, we overcome this issue by comparing five different classification methods on mental arithmetic fNIRS data: linear discriminant analysis (LDA), quadratic discriminant analysis (QDA), support vector machines (SVM), analytic shrinkage regularized LDA (sLDA), and analytic shrinkage regularized QDA (sQDA). Depending on the used method and feature type (oxy-Hb or deoxy-Hb), achieved classification results vary between 56.1 % (deoxy-Hb/QDA) and 86.6% (oxy-Hb/SVM). We demonstrated that regularized classifiers perform significantly better than non-regularized ones. Considering simplicity and computational effort, we recommend the use of sLDA for fNIRS-based BCIs.

63. Durantin et al. (2014). **Moving Average Convergence Divergence filter preprocessing for real-time event-related peak activity onset detection : Application to fNIRS signals**

Abstract: Real-time solutions for noise reduction and signal processing represent a central challenge for the development of Brain Computer Interfaces (BCI). In this paper, we introduce the Moving Average Convergence Divergence (MACD) filter, a tunable digital passband filter for online noise reduction and onset detection without preliminary learning phase, used in economic markets analysis. MACD performance was tested and benchmarked with other filters using data collected with functional Near Infrared Spectoscopy (fNIRS) during a digit sequence memorization task. This filter has a good performance on filtering and real-time peak activity

onset detection, compared to other techniques. Therefore, MACD could be implemented for efficient BCI design using fNIRS.

64. Yao et al. (2014). **A portable multi-channel wireless NIRS device for muscle activity real-time monitoring**

Abstract: Near-infrared spectroscopy (NIRS) is a relative new technology in monitoring muscle oxygenation and hemo-dynamics. This paper presents a portable multi-channel wireless NIRS device for real-time monitoring of muscle activity. The NIRS sensor is designed miniaturized and modularized, to make multi-site monitoring convenient. Wireless communication is applied to data transmission avoiding of cumbersome wires and the whole system is highly integrated. Special care is taken to eliminate motion artifact when designing the NIRS sensor and attaching it to human skin. Besides, the system is designed with high sampling rate so as to monitor rapid oxygenation changes during muscle activities. Dark noise and long-term drift tests have been carried out, and the result indicates the device has a good performance of accuracy and stability. In vivo experiments including arterial occlusion and isometric voluntary forearm muscle contraction were performed, demonstrating the system has the ability to monitor muscle oxygenation parameters effectively even in exercise.

65. Ang et al. (2014). **Single-trial classification of NIRS data from prefrontal cortex during working memory tasks**

Abstract: This study presents single-trial classification performance on high density Near Infrared Spectroscopy (NIRS) data collected from the prefrontal cortex of 11 healthy subjects while performing working memory tasks and idle condition. The NIRS data collected comprised a total of 40 trials of n-back tasks for 2 difficulty levels: n=1 for easy and n=3 for hard. The single-trial classification was performed on features extracted using common average reference spatial filtering and single-trial baseline reference. The single-trial classification was performed using 5×5-fold cross-validations on the NIRS data collected by using mutual information-based feature selection and the support vector machine classifier. The results yielded average accuracies of 72.7%, 68.0% and 84.0% in classifying hard versus easy tasks, easy versus idle tasks and hard versus idle tasks respectively. Hence the results demonstrated a potential feasibility of using high density NIRS-based BCI for assessing working memory load.

66. Heger et al. (2014). **Combining feature extraction and classification for fNIRS BCIs by regularized least squares optimization**

Abstract: In this paper, we show that multiple operations of the typical pattern recognition chain of an fNIRS-based BCI, including feature extraction and classification, can be unified by solving a convex optimization problem. We formulate a regularized least squares problem that learns a single affine transformation of raw HbO2 and HbR signals. We show that this transformation can achieve competitive results in an fNIRS BCI classification task, as it significantly improves recognition of different levels of workload over previously published results on a publicly available n-back data set. Furthermore, we visualize the learned models and analyze their spatio-temporal characteristics.

67. Yu et al. (2014). **Design of a single-fiber, wavelength-resolved system for monitoring deep tissue oxygenation**

Abstract: We propose a single-fiber, zero source-detector separation system with wavelength-resolved detection for measuring oxygen saturation in deep brain structures. The system consists of a white light emitting diode (LED) source, optics to couple light into a 240-μm-diameter fiber, a beam splitter to separate the collected from

the delivered photons and a spectrometer for detection. Depth resolution is achieved by inserting the fiber, comparable in size to microelectrodes used for electrophysiology, into the tissue of interest. Since most of the diffuse reflected light travels through a small volume at the tip of the fiber, this arrangement allows efficient collection of signal. Fresnel reflections are minimized using polarizers. Monte Carlo simulations across 400-1000 nm indicate that ~0.5% of the incident light can be collected and effectively interrogate a ~0.02 mm3 volume at the fiber tip. System design, characterization data and phantom experiments using an absorptive dye in scattering media are presented. The simple nature of the instrumentation can potentially lead to a miniaturized system capable of detecting oxygen saturation in deep brain structures in freely-moving animals.

68. Kawagishi et al. (2014). **Brain Activity during Stereognostic Discrimination Using the Tongue Measured By Functional Near-Infrared Spectroscopy**

Abstract: We previously reported our investigation of the stereognostic ability of the tongue to recognize the shape and size of materials in the mouth and its clinical applications. In the present study, we observed brain activity while performing stereognostic discrimination using the tongue; the changes in levels of oxyhemoglobin (oxy-Hb), deoxyhemoglobin (deoxy-Hb), and total hemoglobin (total-Hb) in the frontal cortex area of 37 healthy individuals (18–75 years old) were measured using a functional near-infrared spectrometer with 45 channels. As an experimental task, the stereognostic test piece (TP) was placed on the center of the tongue dorsum, and subjects moved the TP for shape discrimination without letting it touch the teeth or gums. As a control task, subjects did not move the TP placed on the tongue. Stereognostic task-attributed changes in Hb levels were obtained by subtracting the Hb level of the control task from that of the experimental task. During the stereognostic task, oxy-Hb levels increased in the frontal cortex, including the prefrontal area, in most subjects. However, the results also demonstrated large individual variability. When the degree of change in Hb levels during the stereognostic task was mapped, it was found that the changes in the oxy- and total-Hb levels were similar, while the deoxy-Hb level did not change to the same degree. When subjects were divided into three groups, highly-, moderately- and mildlyincreased oxy-Hb levels, there was a significant negative correlation between age and degree of oxy-Hb level increase. The present study suggests stereognosis may be involved in several different information processing pathways, and that aging may also be a factor in the large variability we observed.

69. Ozgen et al. (2014). **Cesarean under general or epidural anesthesia: Does it differ in terms of regional cerebral oxygenation?**

Abstract: Objective: It is aimed to evaluate whether there is a difference in regional cerebral saturation of newborns measured by near infrared spectroscopy born either by general anesthesia or combined spinal epidural anesthesia during elective cesarean deliveries.
Methods: After approval from the ethics committee of our hospital, and informed consents of the parturients were taken, 68 patients were included in the study. The regional cerebral oxygen saturations (RcSO2) of newborns were measured by near infrared spectroscopy (NIRS) measurements at 1st, 5th min after birth. In group I (n=32), general anesthesia was performed for the cesarean operation and in group II (n=36), combined spinal epidural anesthesia (CSEA) was the anesthetic management. The age of the mother, gestation, the problems related to the pregnancy, heart rate, blood pressure, oxygen saturation (SpO2) of the mother had been recorded. The measurements of the newborn were; SpO2 of right hand, RcSO2 measured by NIRS, the delivery time (from incision to the cessation of circulation in the placental cord), Apgar score. Data were analyzed using GraphPad Prism 5.0 (GraphPad Software, La Jolla, California) and presented as mean +/− SD. Results obtained in different groups were compared using upaired t-test. Differences were statistically significant at $p < 0.05$.
Results: There were no significant differences between the groups related to the mother's age, gestation week and baseline blood pressure. Both the systolic and diastolic blood pressures measured at 1st and 5th min after induction or start of the spinal block were significantly lower in the mothers who had undergone combined spinal epidural anesthesia. The heart rates of the mothers who had been under CSEA were significantly higher than

the general anesthesia group. The Apgar at the 1st min were observed significantly higher in Group II. Oxygen saturation of the newborns were significantly higher in Group II. Regional cerebral oxygenation measured by NIRS were significantly higher in CSEA group.
Conclusion: Combined spinal epidural anesthesia, besides other known advantages, had been shown to be superior to general anesthesia as a means of regional cerebral oxygenation of the newborns.

70. Mikawa et al. (2014). **Left temporal activation associated with depression severity during a verbal fluency task in patients with bipolar disorder: A multichannel near-infrared spectroscopy study**

Abstract: Background: Neuroimaging studies using multichannel near-infrared spectroscopy (NIRS) have provided compelling evidence about the dysfunction of the frontotemporal cortices in patients with bipolar disorder (BD). However, it remains unclear whether the dysfunction is associated with mood state or symptom severity. Using NIRS, we aimed to clarify differences in oxygenated hemoglobin (oxy-Hb) activation between depressive and euthymic states as well as regional brain dysfunction in relation to symptom severity in BD.
Methods: Fifty-five patients with BD, including 30 with bipolar depression (BPD) and 25 with euthymic bipolar disorder (BPE), and 28 healthy controls (HCs) participated in the study. Regional hemodynamic changes during a verbal fluency task (VFT) were monitored using a 52-channel NIRS apparatus.
Results: The mean oxy-Hb changes induced by VFT were significantly smaller in the BD patients than in the HCs in 18 channels in the frontotemporal regions (false-discovery rate $p<0.05$, $p=0.000–0.011$). The BPD group exhibited significantly smaller changes in mean oxy-Hb compared with the BPE group in three channels of the left temporal region ($p=0.005–0.014$). In the BD patients, significant negative correlations were observed between mean oxy-Hb changes in the left temporal regions and the severity of depression.
Limitations: Our sample size was small, making the results susceptible to type II errors.
Conclusions: BD patients have persistent hypofunction of the frontotemporal cortical regions. Moreover, the hemodynamic response in the left temporal regions is associated with symptom severity.

71. Verhagen et al. (2014). **Cerebral oxygenation is associated with neurodevelopmental outcome of preterm children at age 2 to 3 years**

Abstract: Aim: The aim of the study was to determine whether regional cerebral tissue oxygen saturation (rcSO2) and fractional tissue oxygen extraction (FTOE), using near-infrared spectroscopy, are associated with neurodevelopmental outcome of preterm infants.
Method: We measured rcSO2 on days 1, 2, 3, 4, 5, 8, and 15 after birth in 83 preterm infants (<32wks gestational age), and calculated FTOE=(SpO2–rcSO2)/SpO2. Cognitive, motor, neurological, and behavioural outcomes were determined at 2 to 3 years using the Bayley Scales of Infant and Toddler Development, Third Edition (BSID-III), an age-specific neurological examination, and the Child Behavior Checklist (CBCL) respectively. Multiple linear regression analyses were used to determine whether rcSO2 and FTOE contributed to outcome.
Results: We followed up 67 infants. The lower quartile (P25–50) and highest quartile (P75–100) of rcSO2 on day 1 were associated with poorer cognitive outcome ($p=0.044$ and $p=0.008$ respectively). A lower area under the curve (AUC; over 15d) of rcSO2 was associated with poorer cognitive outcome ($p=0.014$). The lower quartile (P25–50) AUC of rcSO2 was associated with poorer fine motor outcome ($p=0.004$). The amount of time rcSO2 <50% on day 1 was negatively associated with gross motor outcome ($p=0.002$). The highest quartile of FTOE on day 1 was associated with poorer total motor outcome ($p=0.041$).
Interpretation: Cerebral oxygen saturation during the first 2 weeks after birth is associated with neurodevelopmental outcome of preterm infants at 2 to 3 years. High and low rcSO2 on day 1 were associated with poorer neurodevelopmental outcome.

72. Urban et al. (2014). **Functional Near-Infrared Spectroscopy Reveals Reduced Interhemispheric Cortical Communication after Pediatric Concussion**

Abstract: Concussion, or mild traumatic brain injury (mTBI), is a growing concern, especially among the pediatric population. By age 25, as many as 30% of the population are likely to have had a concussion. Many result in long-term disability, with some evolving to postconcussion syndrome. Treatments are being developed, but are difficult to assess given the lack of measures to quantitatively monitor concussion. There is no accepted quantitative imaging metric for monitoring concussion. We hypothesized that because cognitive function and fiber tracks are often impacted in concussion, interhemispheric brain communication may be impaired. We used functional near-infrared spectroscopy (fNIRS) to quantify functional coherence between the left and right motor cortex as a marker of interhemispheric communication. Studies were undertaken during the resting state and with a finger-tapping task to activate the motor cortex. Pediatric patients (ages 12–18) had symptoms for 31–473 days, compared to controls, who have not had reported a previous concussion. We detected differences between patients and controls in coherence between the contralateral motor cortices using measurements of total hemoglobin and oxy-hemoglobin with a $p<0.01$ (n=8, control; n=12 mTBI). Given the critical need for a quantitative biomarker for recovery after a concussion, we present these data to highlight the potential of fNIRS coupled with interhemispheric coherence analysis as a biomarker of concussion injury.

73. Thing et al. (2014). **Transient hyperoxia does not affect regional cerebral tissue oxygen saturation in moderately preterm or term newborns**

Abstract: Aim: Even short periods of hyperoxia may induce prolonged cerebral vasoconstriction in newborn infants, and this could theoretically lead to cerebral ischaemia even once normoxia is re-established. This study aimed to investigate the effect of brief hyperoxic exposures on regional cerebral tissue oxygen saturation (rStO2) and to evaluate whether any observed prolonged cerebral vasoconstriction was related to maturity.
Methods: The study included 30 infants with a postmenstrual age of more than 32 weeks, who were treated with nasal continuous positive airway pressure and a fraction of inspired oxygen of ≤0.3. The INVOS 5100C oximeter was used to measure rStO2 before, during and after two hyperoxic exposures. If hyperoxia induced a prolonged cerebral vasoconstriction, posthyperoxic rStO2 would be expected to decrease.
Results: rStO2 increased slightly after the first hyperoxic exposure, with a mean difference of 1.37% (95% CI 0.15, 2.6). After the second oxygen exposure, rStO2 remained unchanged with a mean difference of −0.4% (95% CI −1.6, 0.78). Differences in rStO2 were not related to gestational age in either of the two hyperoxic episodes.
Conclusion: We found no evidence to support the theory that transient hyperoxia induces prolonged cerebral vasoconstriction in infants with a postmenstrual age above 32 weeks.

74. Hervey et al. (2014). **Motion tracking and electromyography-assisted identification of mirror hand contributions to functional near-infrared spectroscopy images acquired during a finger-tapping task performed by children with cerebral palsy**

Abstract: Recent studies have demonstrated functional near-infrared spectroscopy (fNIRS) to be a viable and sensitive method for imaging sensorimotor cortex activity in children with cerebral palsy (CP). However, during unilateral finger tapping, children with CP often exhibit unintended motions in the nontapping hand, known as mirror motions, which confuse the interpretation of resulting fNIRS images. This work presents a method for separating some of the mirror motion contributions to fNIRS images and demonstrates its application to fNIRS data from four children with CP performing a finger-tapping task with mirror motions. Finger motion and arm muscle activity were measured simultaneously with fNIRS signals using motion tracking and electromyography (EMG), respectively. Subsequently, subject-specific regressors were created from the motion capture or EMG data and independent component analysis was combined with a general linear model to create an fNIRS image representing activation due to the tapping hand and one image representing activation due to the mirror hand.

The proposed method can provide information on how mirror motions contribute to fNIRS images, and in some cases, it helps remove mirror motion contamination from the tapping hand activation images.

75. Schecklmann et al. (2014). **Functional Near-Infrared Spectroscopy to Probe State- and Trait-Like Conditions in Chronic Tinnitus: A Proof-of-Principle Study**

Abstract: Objective. Several neuroscience tools showed the involvement of auditory cortex in chronic tinnitus. In this proof-of-principle study we probed the capability of functional near-infrared spectroscopy (fNIRS) for the measurement of brain oxygenation in auditory cortex in dependence from chronic tinnitus and from intervention with transcranial magnetic stimulation. Methods. Twenty-three patients received continuous theta burst stimulation over the left primary auditory cortex in a randomized sham-controlled neuronavigated trial (verum = 12; placebo = 11). Before and after treatment, sound-evoked brain oxygenation in temporal areas was measured with fNIRS. Brain oxygenation was measured once in healthy controls . Results. Sound-evoked activity in right temporal areas was increased in the patients in contrast to healthy controls. Left-sided temporal activity under the stimulated area changed over the course of the trial; high baseline oxygenation was reduced and vice versa. Conclusions. By demonstrating that rTMS interacts with auditory evoked brain activity, our results confirm earlier electrophysiological findings and indicate the sensitivity of fNIRS for detecting rTMS induced changes in brain activity. Moreover, our findings of trait- and state-related oxygenation changes indicate the potential of fNIRS for the investigation of tinnitus pathophysiology and treatment response.

76. Roberts et al. (2014). **fNIRS suggests increased effort during executive access in ecstasy polydrug users**

Abstract: Background: Ecstasy use is associated with cognitive impairment, believed to result from damage to 5-HT axons. Neuroimaging techniques to investigate executive dysfunction in ecstasy users provide a more sensitive measure of cognitive impairment than behavioural indicators. The present study assessed executive access to semantic memory in ecstasy polydrug users and non-users.
Methods: Twenty ecstasy polydrug users and 20 non-user controls completed an oral variant of the Chicago Word Fluency Test (CWFT), whilst the haemodynamic response to the task was measured using functional near-infrared spectroscopy (fNIRS).
Results: There were no between-group differences in many background measures including measures of sleep and mood state (anxiety, arousal, hedonic tone). No behavioural differences were observed on the CWFT. However, there were significant differences in oxy-Hb level change at several voxels relating to the left dorsolateral prefrontal cortex (DLPFC) and right medial prefrontal cortex (PFC) during the CWFT, indicating increased cognitive effort in ecstasy users relative to controls. Regression analyses showed that frequency of ecstasy use, total lifetime dose and amount used in the last 30 days was significant predictors of oxy-Hb increase at several voxels after controlling for alcohol and cannabis use indices.
Conclusion: The results suggest that ecstasy users show increased activation in the PFC as a compensatory mechanism, to achieve equivalent performance to non-users. These findings are in agreement with much of the literature in the area which suggests that ecstasy may be a selective serotonin neurotoxin in humans.

77. Amiri et al. (2014). **An Exploration of the Effect of Hemodynamic Changes Due to Normal Aging on the fNIRS Response to Semantic Processing of Words**

Abstract: Like other neuroimaging techniques assessing cerebral blood oxygenation, near-infrared spectroscopy (NIRS) has been applied in many neurocognitive studies. With NIRS, neural activation can be explored indirectly via hemodynamic changes in the imaged region. In studies of aging, changes in baseline physiology and brain anatomy confound NIRS measures seeking to investigate age-related changes in neuronal activity. The field is thus hampered by the complexity of the aging process itself, and statistical inferences from

functional data acquired by optical imaging techniques must be interpreted with care. Multimodal integration of NIRS with both structural and baseline physiological assessments is crucial to avoid misinterpreting neuroimaging signals. In this study, a combination of two different optical techniques, anatomical MRI and Arterial Spin Labeling (ASL), was used to investigate age-related changes in activation during a lexical-semantic processing task. Quantitative analysis revealed decreased baseline oxyhemoglobin and cerebral blood flow in the older adults. Using baseline physiology measures as regressors in the investigation of functional concentration changes when doing analyses of variance, we found significant changes in task-induced areas of activity. In the right hemisphere, more significant age-related activity was observed around the junction of the inferior frontal gyrus and inferior precentral sulcus, along with engagement of Wernicke's area. In the left hemisphere, the degree and extent of frontal activation, including the dorsolateral prefrontal cortex and inferior frontal gyrus, differed between age groups. Measuring background physiological differences and using their values as regressors in statistical analyses allowed a more appropriate, age-corrected understanding of the functional differentiations between age groups. Age-corrected baselines are thus essential to investigate which components of the NIRS signal are altered by aging.

78. Paggetti et al. (2014). **The role of the posterior parietal cortex in stereopsis and hand-eye coordination during motor task behaviours**

Abstract: The field of 'Neuroergonomics' has the potential to improve safety in high-risk operative environments through a better appreciation of the way in which the brain responds during human–tool interactions. This is especially relevant to minimally invasive surgery (MIS). Amongst the many challenges imposed on the surgeon by traditional MIS (laparoscopy), arguably the greatest is the loss of depth perception. Robotic MIS platforms, on the other hand, provide the surgeon with a magnified three-dimensional view of the environment, and as a result may offload a degree of the cognitive burden. The posterior parietal cortex (PPC) plays an integral role in human depth perception. Therefore, it can be hypothesized that differences in PPC activation between monoscopic and stereoscopic vision may be observed. In order to investigate this hypothesis, the current study explores disparities in PPC responses between monoscopic and stereoscopic visual perception to better de-couple the burden imposed by laparoscopy and robotic surgery on the operator's brain. Fourteen participants conducted tasks of depth perception and hand-eye coordination under both monoscopic and stereoscopic visual feedback. Cortical haemodynamic responses were monitored throughout using optical functional neuroimaging. Overall, recruitment of the bilateral superior parietal lobule was observed during both depth perception and hand-eye coordination tasks. This occurred contrary to our hypothesis, regardless of the mode of visual feedback. Operator technical performance was significantly different in two- and three-dimensional visual displays. These differences in technical performance do not appear to be explained by significant differences in parietal lobe processing.

79. Barker et al. (2014). **Accuracy of oxygen saturation and total hemoglobin estimates in the neonatal brain using the semi-infinite slab model for FD-NIRS data analysis**

Abstract: Frequency domain near-infrared spectroscopy (FD-NIRS) is a non-invasive method for measuring optical absorption in the brain. Common data analysis procedures for FD-NIRS data assume the head is a semi-infinite, homogenous medium. This assumption introduces bias in estimates of absorption (μa), scattering ([Formula: see text]), tissue oxygen saturation (StO2), and total hemoglobin (HbT). Previous works have investigated the accuracy of recovered μa values under this assumption. The purpose of this study was to examine the accuracy of recovered StO2 and HbT values in FD-NIRS measurements of the neonatal brain. We used Monte Carlo methods to compute light propagation through a neonate head model in order to simulate FD-NIRS measurements at 690 nm and 830 nm. We recovered μa , [Formula: see text], StO2, and HbT using common analysis procedures that assume a semi-infinite, homogenous medium and compared the recovered values to simulated values. Additionally, we characterized the effects of curvature via simulations on homogenous spheres of varying radius. Lastly, we investigated the effects of varying amounts of extra-axial

fluid. Curvature induced underestimation of µa , [Formula: see text], and HbT, but had minimal effects on StO2. For the morphologically normal neonate head model, the mean absolute percent errors (MAPE) of recovered µa values were 12% and 7% for 690 nm and 830 nm, respectively, when source-detector separation was at least 20 mm. The MAPE for recovered StO2 and HbT were 6% and 9%, respectively. Larger relative errors were observed (~20-30%), especially as StO2 and HbT deviated from normal values. Excess CSF around the brain caused very large errors in µa , [Formula: see text], and HbT, but had little effect on StO2.

80. Muramatsu et al. (2014). **Assessment of local muscle fatigue by NIRS - development and evaluation of muscle suit**

Abstract: Although the machinery automation technology and robotics have made significant progress in making production and distribution easy and efficient, there is still a need for manual work such as nursing and other manufacturing work. Those work could possibly cause the work-related disorders. In order to reduce the risk of work-related injury or illness, we have been developing a compact and lightweight wearable robot "Muscle Suit" to provide direct and physical motion supports for assisting human motion. The development of the Muscle Suit becomes possible through the use of the McKibben artificial muscle. This type of artificial muscle has the advantages of being compact, lightweight and reliable. The wearable Muscle Suit has high versatility and conveyance, it supports the user physically with the capability of loading more weights. The evaluation of effectiveness is a key point in the development of the Muscle Suit and it could be estimated by evaluating the muscle fatigue. The evaluation of muscle fatigue is required not only for muscle suit but also for rehabilitation, muscle training and human physical support. Although the frequency transition of electromyogram (EMG) method is generally used for fatigue assessment, it has certain drawbacks depending on conditions and environment. For instance, it is impossible to apply it in the case of isotonic contraction. There are no apparatus or methods which measure muscle fatigue noninvasively and simply. In this study, we used near-infrared spectroscopy (NIRS) to measure the serum oxygenated hemoglobin and deoxygenated hemoglobin concentration of wearer's muscle indirectly, the new term ΔHbt has been defined and the degree of fatigue has also been evaluated. And then, we had the evaluation experiment of muscle suit using blood oxygenation and the new term ΔHbt to estimate the effects of muscle suit.

81. Santosa et al. (2014). **Lateralization of music processing with noises in the auditory cortex: an fNIRS study**

Abstract: The present study is to determine the effects of background noise on the hemispheric lateralization in music processing by exposing 14 subjects to four different auditory environments: music segments only, noise segments only, music + noise segments, and the entire music interfered by noise segments. The hemodynamic responses in both hemispheres caused by the perception of music in 10 different conditions were measured using functional near-infrared spectroscopy. As a feature to distinguish stimulus-evoked hemodynamics, the difference between the mean and the minimum value of the hemodynamic response for a given stimulus was used. The right-hemispheric lateralization in music processing was about 75% (instead of continuous music, only music segments were heard). If the stimuli were only noises, the lateralization was about 65%. But, if the music was mixed with noises, the right-hemispheric lateralization has increased. Particularly, if the noise was a little bit lower than the music (i.e., music level 10~15%, noise level 10%), the entire subjects showed the right-hemispheric lateralization: This is due to the subjects' effort to hear the music in the presence of noises. However, too much noise has reduced the subjects' discerning efforts.

82. Anderson et al. (2014). **Prefrontal cortex hemodynamics and age: a pilot study using functional near infrared spectroscopy in children**

Abstract: Cerebral hemodynamics reflect cognitive processes and underlying physiological processes, both of which are captured by functional near infrared spectroscopy (fNIRS). Here, we introduce a novel parameter of Oxygenation Variability directly obtained from fNIRS data —the OV Index—and we demonstrate its use in children. fNIRS data were collected from 17 children (ages 4–8 years), while they performed a standard Go/No-Go task. Data were analyzed using two frequency bands—the first attributed to cerebral autoregulation (CA) (<0.1 Hz) and the second to respiration (0.2–0.3 Hz). Results indicate differences in variability of oscillations of oxygen saturation (SO2) between the two different bands. These pilot data reveal a dynamic relationship between chronological age and OV index in CA associated frequency of <0.1 Hz. Specifically, OV index increased with age between 4 and 6 years. In addition, there was much higher variability in frequencies associated with CA than for respiration across subjects. These findings provide preliminary evidence for the utility of the OV index and are the first to describe the relationship between cerebral autoregulation and age in children using fNIRS methodology.

83. Filippetti et al. (2014). **Neural Mechanisms of Body Awareness in Infants**

Abstract: The ability to differentiate one's body from others is a fundamental aspect of social perception and has been shown to involve the integration of sense modalities attributable to the self. Though behavioral studies in infancy have investigated infants' discrimination of body-related multisensory stimuli, whether they attribute this information as belonging to the self is still unknown. In human adults, neuroimaging studies have demonstrated the recruitment of a specific set of brain regions in response to body-related multisensory integration. To test whether the infant brain integrates this information similarly to adults, in a first functional near-infrared spectroscopy study we investigated the role of visual–proprioceptive feedback when temporal cues are manipulated by showing 5-month-old infants an online video of their own face while the infant was performing movements. To explore the role of body-related contingency further, in a second study we investigated whether cortical activation in response to self-initiated movements and external tactile stimulation was similar to that found in the first study. Our results indicate that infants' specialized cortical activation in response to body-related contingencies is similar to brain activation seen in response to body awareness in adults.

84. Ha et al. (2014). **fNIRS-Based Wavelet Thresholds for Motor Area Determination**

Abstract: The brain is the most important part in human body. In order to determine and evaluate the activities of the body, brain signals measured using non-invasive technique - functional Near Infrared Spectroscopy (fNIRS) will be investigated. In this paper, Oxy- Hb signals in the cerebral cortex that was collected from 24 channels put into preprocessing to smooth using a Savitzky - Golay filter. Data removed noise will be transformed discrete wavelets into different frequency components. Threshold algorithms are applied to identify the channels (the mobile areas) that have Oxy - Hb changes while biting spacer and lifting object. This research is conducted experiments on five subjects with changes of biting or lifting for collection of the Oxy - Hb changes on the mobile areas. This method will help researchers save a lot of effort and archive the proper assessment of human activities through brain signals.

85. Grounauer & Metraux (2014). **Prefrontal fNIRS Neuroimaging during a Sleep Induction Task Using Perception of a Red Light through Closed Eyes to Fight Insomnia: A Pilot Study**

Abstract: The use of a red light observed through closed eyes is a new CBT Cognitive Behavioral Therapy to fight insomnia. Its principles are based on the high transmission of the colour red through eyelids, the great

sensitivity to light of the retina when it is adjusted to darkness and the mental distraction obtained by the perception and attentive observation of variations of intensity. The prefrontal and occipital fNIRS recordings document this method which is correlated to the sleep EEG state II.

86. Giang et al. (2014). **Evaluation of Hemodynamic Responses to Visual Tasks Using Functional Near Infrared Spectroscopy**

Abstract: Functional near-infrared spectroscopy (fNIRS) is becoming widely applied in many practical researches, especially in vivo researches on human. This study focuses on the hemodynamic responses of visual cortex when the human eye is excited by different conditions of flickering light stimulus. In our experiment, visual cortex is activated by flickering light at various spatial frequencies and modulation depths while the hemodynamic responses of the visual cortex are simultaneously monitored by fNIRS. Our experimental results suggest that flickering light can activate hemodynamic responses of the visual cortex but those changes are not significantly distinct among different stimulus conditions.

87. Thao et al. (2014). **Evaluation of Frontal and Visual Cortices on Mental Working Tasks Using Functional Near Infrared Spectroscopy**

Abstract: This paper investigated the hemodynamic responses over the frontal and visual cortices in order to find out the contributions of these two brain areas to workload memory activities during a graded load-related memorizing task that involves visual perception. Factorial ANOVA was performed on the mean values of oxyHemoglobin (oxy-Hb) and deoxyHemoglobin (deoxy-Hb) concentration changes from three subjects over visual and prefrontal cortices to observe the interaction of factors like channels, subjects and workload levels. Besides, the t-maps of these two brain areas pointed out the regions of interest (channels 1, 2, 3, 4, 5, 6, 7, 8, 10, 13 and 14) are shown to reflect the significance in workloads differentiation. The results of statistical analysis and t-map investigations successfully explored the capability of multichannel functional near infrared spectroscopy (fNIRS) to detect two neurophysiological workloads under investigation and distinguish their activation patterns over multiple cortical areas.

88. Kawashima et al. (2014). **Cortical Activity while Riding Motorcycles Measured with a Wearable Near Infrared Topography System**

Abstract: The purpose of this study was to clarify the cortical activity of the dorsolateral prefrontal cortex (DLPFC) while motorcycles were being ridden. Sixteen healthy right-handed men who use motorcycles in their daily lives were recruited. Their brain activity was measured using a prototype of wearable optical topography while they were actually riding a motorcycle. We found that their brain activation patterns, which reflect the cognitive strategies behind their riding behaviors, differed depending on whether they were users of road bikes or scooters. Also, DLPFC activity, which reflects an increase in cognitive and motor demands, was greater in riders of on-road type motorcycles than scooters.

89. Santos-Concejero et al. (2014). **Maintained cerebral oxygenation during maximal self-paced exercise in elite Kenyan runners**

Abstract: The purpose of this study was to analyze the cerebral oxygenation response to maximal self-paced and incremental exercise in elite Kenyan runners from the Kalenjin tribe. On two separate occasions, 15 elite Kenyan distance runners completed a 5-km time trial (TT) and a peak treadmill speed test (PTS). Changes in cerebral oxygenation were monitored via near-infrared spectroscopy through concentration changes in oxy- and deoxy-hemoglobin (Δ[O2Hb] & Δ[HHb]), tissue oxygenation index (TOI) and total hemoglobin index (nTHI).

During the 5-km TT (15.2 ± 0.2 min), cerebral oxygenation increased over the first half (increased Δ[O2Hb and Δ[HHb]) and, thereafter, Δ[O2Hb] remained constant (Effect size, ES=0.33, small effect), whereas Δ[HHb] increased until the end of the trial ($p<0.05$, ES=3.13, large effect). In contrast, during the PTS, from the speed corresponding to the second ventilatory threshold, Δ[O2Hb] decreased ($p<0.05$, ES=1.51, large effect), whereas Δ[HHb] continued to increase progressively until exhaustion ($p<0.05$, ES=1.22, large effect). Lastly, the TOI was higher during the PTS than during the 5-km TT ($p<0.001$, ES=3.08; very large effect), whereas nTHI values were lower ($p<0.001$, ES=2.36, large effect). This study shows that Kenyan runners from the Kalenjin tribe are able to maintain their cerebral oxygenation within a stable range during a self-paced maximal 5-km time trial, but not during an incremental maximal test. This may contribute to their long-distance running success.

90. Redford et al. (2014). **Absolute and Trend Accuracy of a New Regional Oximeter in Healthy Volunteers During Controlled Hypoxia**

Abstract: BACKGROUND: Traditional patient monitoring may not detect cerebral tissue hypoxia, and typical interventions may not improve tissue oxygenation. Therefore, monitoring cerebral tissue oxygen status with regional oximetry is being increasingly used by anesthesiologists and perfusionists during surgery. In this study, we evaluated absolute and trend accuracy of a new regional oximetry technology in healthy volunteers.
METHODS: A near-infrared spectroscopy sensor connected to a regional oximetry system (O3TM, Masimo, Irvine, CA) was placed on the subject's forehead, to provide continuous measurement of regional oxygen saturation (rSO2). Reference blood samples were taken from the radial artery and internal jugular bulb vein, at baseline and after a series of increasingly hypoxic states induced by altering the inspired oxygen concentration while maintaining normocapnic arterial carbon dioxide pressure (PaCO2). Absolute and trend accuracy of the regional oximetry system was determined by comparing rSO2 against reference cerebral oxygen saturation (SavO2), that is calculated by combining arterial and venous saturations of oxygen in the blood samples.
RESULTS: Twenty-seven subjects were enrolled. Bias (test method mean error), standard deviation of error, standard error of the mean, and root mean square accuracy (ARMS) of rSO2 compared to SavO2 were 0.4%, 4.0%, 0.3%, and 4.0%, respectively. The limits of agreement were 8.4% (95% confidence interval, 7.6%–9.3%) to −7.6% (95% confidence interval, −8.4% to −6.7%). Trend accuracy analysis yielded a relative mean error of 0%, with a standard deviation of 2.1%, a standard error of 0.1%, and an ARMS of 2.1%. Multiple regression analysis showed that age and skin color did not affect the bias (all $P > 0.1$).
CONCLUSIONS: Masimo O3 regional oximetry provided absolute root-mean-squared error of 4% and relative root-mean-squared error of 2.1% in healthy volunteers undergoing controlled hypoxia.

91. Kishi et al. (2014). **Verification of the effect on "Finger Pointing and Calling" method from observation of brain activity related driver's attention**

Abstract: We propose a driving style with "Finger Pointing and Calling (FPC)" as each driver checks safety on his own, in order to maintain alertness constantly and to reduce human error while driving. We examined the effectiveness of this safety check method by monitoring increase blood flow toward the brain. Additionally we propose "Imagined Pointing and Calling (IPC)", which has the same effect as FPC, and can be applied in lieu of FPC. We also examined the effect by IPC in the same way. As a result, FPC and IPC increased brain activity and is likely to improve driver's alertness.

92. Esnault al. (2014). **Assessment of cerebral oxygenation in neurocritical care patients: comparison of a new four wavelengths forehead regional saturation in oxygen sensor (EQUANOX™) with brain tissue oxygenation. A prospective observational study**

Abstract: BACKGROUND: Because of restricted information given by monitoring solely intracranial pressure and cerebral perfusion pressure, assessment of the cerebral oxygenation in neurocritical care patients would be

of interest. The aim of this study was to determinate the correlation between the non--invasive measure regional saturation in oxygen (rSO2) with a third generation NIRS monitor and an invasive measure of brain tissue oxygenation tension (PbtO2).
METHODS: We conducted a prospective, observational, unblinded study including neurocritical care patients requiring a PbtO2 monitoring. Concomitant measurements of rSO2 were performed with a four wavelengths forehead sensor (EQUANOX Advance™) of the EQUANOX™ 7600 System. We determined the correlation between rSO2 and PbtO2 and the ability of the rSO2 to detect ischemic episodes defined by a PbtO2 less than 15 mmHg. The rSO2 ischemic threshold was 60%.
RESULTS: During 2 months, 8 consecutives patients, including 275 measurements, were studied. There was no correlation between rSO2 and PbtO2 (r = 0.016 [--0.103 - 0,134], r2 = 0.0003, p = 0.8). On the 86 ischemic episodes detected by PbtO2, only 13 were also detected by rSO2. ROC curve showed the inability for rSO2 to detect cerebral hypoxia episodes (AUC = 0.54). CONCLUSIONS: rSO2 cannot be used as a substitute for PbtO2 to monitor cerebral oxygenation in neurocritical care patients.

93. Ayes al. (2014). **Near-infrared Spectroscopy to Assess Cerebral Perfusion during Head-up Tilt-table Test in Patients with Syncope**

Abstract: Objective: Neurocardiogenic syncope (NCS) is the most common cause of syncope in children and adolescents. Neurocardiogenic syncope occurs secondary to cerebral hypotension because of bradycardia, hypotension, or both. Head-up tilt-table test (HUTT) is the primary diagnostic test. Near-infrared spectroscopy (NIRS) is a noninvasive technology that directly monitors trends in regional tissue oxygen saturations over a specific body region. Placing an NIRS probe over the temporal region allows an indirect measurement of cerebral perfusion. Our hypothesis is that regional tissue oxygen saturation will decrease during an NCS episode and will remain stable in patients without syncope.
Patients and Design: The investigators conducted a retrospective review of all HUTT utilizing cephalic NIRS performed at our institution from August 2012 to January 2013. Tests were classified as positive, negative, or psychogenic reactions. Paired t-test was used to determine statistical significance of NIRS changes and one-way analysis of variance was used to analyze baseline characteristics among the three groups.
Results: Twelve patients were included in the study (female = 10). The average age was 14.4 years (range: 12–17). Five tests were positive for NCS, four were negative, and three demonstrated psychogenic reactions. Patients with a positive test had a sudden, significant decrease in regional tissue oxygen saturations (P = .009) by an average of 11.3 ± 5.2% compared with baseline. The decrease in regional tissue oxygen saturation preceded symptoms, hypotension, and bradycardia in all patients. Regional tissue oxygen saturation levels remained stable in patients with a negative test or psychogenic syncope.
Conclusions: NIRS monitoring during HUTT produces a reliable, positive result that precedes clinical signs and symptoms. Further, it helps distinguish NCS from psychogenic syncope.

94. Armeloot al. (2014). **Which Cerebral Saturation Should We Target in Post--Cardiac Arrest Patients?**

Abstract: Purpose: Current guidelines recommend targeting mean arterial pressure above 65mmHg and SVO2 above 70% in post-cardiac arrest patients. Blood pressure and SVO2 are only surrogate parameters for cerebral perfusion. Alternatively, cerebral saturation can be assessed directly and non-invasively with near infrared spectroscopy (NIRS), using the FORE-SIGHTTM technology (CAS Medical systems, Branford, CT, USA). It is unclear which cerebral saturation we should target to maximize patient survival. The aim of the present study was to explore the association between SctO2 and survival in post-cardiac arrest patients.
Methods: Prospective observational study in 82 post-cardiac arrest patients treated with therapeutic hypothermia. Cerebral saturation was measured every 2 seconds.
Results: During the first 24 hours after ICU admission, the average SctO2 was 65.5±4.5%. For each patient, the percentage of time was calculated per percentage cerebral saturation. Patients were stratified according to no

(<2%), low (2-12.5%), intermediate (12.5-25%) or high exposure (>25% of time) per 3 percentage cerebral saturation. Logistic regression revealed a maximal association between cumulative SctO2 exposure and survival for the SctO2 range between 66-68% (OR 1.58, 95%CI [1.00; 1.51], p=0.04]. Multivariate regression revealed that administration of early bystander CPR, presenting shockable rhythm and high cumulative SctO2 exposure between 66-68% (OR 1.73, 95%CI [1.00; 3.01] were significant independent predictors of survival. ANOVA revealed that the percentage of early bystander CPR, presenting shockable rhythm, global hemodynamics (MAP, SVO2) and blood gasses (including pO2, pCO2) were comparable between patients with no, low, intermediate or high exposure to SctO2 66-68%.
Conclusion: The target SctO2 seems to be between 66-68%. Prospective intervention studies to reach or maintain this SctO2 target are needed to confirm these findings.

95. Kiguchi al. (2014). **Algorithm for removing scalp signals from functional near-infrared spectroscopy signals in real time using multidistance optodes**

Abstract: A real-time algorithm for removing scalp-blood signals from functional near-infrared spectroscopy signals is proposed. Scalp and deep signals have different dependencies on the source-detector distance. These signals were separated using this characteristic. The algorithm was validated through an experiment using a dynamic phantom in which shallow and deep absorptions were independently changed. The algorithm for measurement of oxygenated and deoxygenated hemoglobins using two wavelengths was explicitly obtained. This algorithm is potentially useful for real-time systems, e.g., brain-computer interfaces and neuro-feedback systems.

96. Guo al. (2014). **A wireless wearable sEMG and NIRS acquisition system for an enhanced human-computer interface**

Abstract: Surface electromyography (sEMG) is extensively explored in human-computer interface (HCI); complementary to the electrophysiological activity of the muscles, the hemodynamic information that measured from near infrared spectroscopy (NIRS) is less investigated. Properly combining the sEMG and NIRS would provide a novel approach for HCI applications. This paper presents a multi-channel wireless wearable sEMG and NIRS acquisition system aiming for enhanced human-computer interaction, by providing more information about the muscle activity for subject's motor intention decoding. Extensive tests were carried out to evaluate the system performance. It showed that this novel system proved to be able to capture sEMG signals similar to those of the commercialized sEMG acquisition devices, and had a comparable NIRS sensor performance. Furthermore, simultaneously recording of sEMG and NIRS signals, the system had shown the ability to provide more information about the muscle activities for a better HCI performance. The classification accuracy of 13 hand gesture motions was significantly (P<;0.001) improved by using combined sEMG and NIRS features comparing to sEMG or NIRS features individually, suggesting that the proposed sEMG and NIRS system could be potentially available for an enhanced HCI.

97. Sasai al. (2014). **Frequency-specific network topologies in the resting human brain**

Abstract: A community is a set of nodes with dense inter-connections, while there are sparse connections between different communities. A hub is a highly connected node with high centrality. It has been shown that both "communities" and "hubs" exist simultaneously in the brain's functional connectivity network (FCN), as estimated by correlations among low-frequency spontaneous fluctuations in functional magnetic resonance imaging (fMRI) signal changes (0.01-0.10 Hz). This indicates that the brain has a spatial organization that promotes both segregation and integration of information. Here, we demonstrate that frequency-specific network topologies that characterize segregation and integration also exist within this frequency range. In investigating the coherence spectrum among 87 brain regions, we found that two frequency bands, 0.01-0.03 Hz (very low

frequency [VLF] band) and 0.07-0.09 Hz (low frequency [LF] band), mainly contributed to functional connectivity. Comparing graph theoretical indices for the VLF and LF bands revealed that the network in the former had a higher capacity for information segregation between identified communities than the latter. Hubs in the VLF band were mainly located within the anterior cingulate cortices, whereas those in the LF band were located in the posterior cingulate cortices and thalamus. Thus, depending on the timescale of brain activity, at least two distinct network topologies contributed to information segregation and integration. This suggests that the brain intrinsically has timescale-dependent functional organizations.

98. Stolwijk al. (2014). **The effects of CO_2-insufflation with 5 and 10 mmHg during thoracoscopy on cerebral oxygenation and hemodynamics in piglets: an animal experimental study**

Abstract: Objective: To evaluate the effect of CO2-insufflation with 5 and 10 mmHg on cerebral oxygenation and hemodynamics in neonates.
Background: An increasing percentage of surgical interventions in neonates are performed by minimal invasive techniques. Recently, concerns have been raised regarding a decrease of cerebral oxygenation in neonates during thoracoscopy as a result of CO2-insufflation.
Methods: This was an animal experimental study. Piglets were anesthetized, intubated, ventilated, and surgically prepared for CO2-insufflation. Insufflation was done with 5 or 10 mmHg CO2 during 1 h. Arterial saturation (SaO2), heart rate (HR), mean arterial blood pressure (MABP), and cerebral oxygenation (rScO2) were monitored. CFTOE, an estimator of cerebral oxygen extraction ((SaO2 − rScO2)/SaO2)), was calculated. Arterial blood gases were drawn every 15′: pre (T0), during (T1-T4) and after CO2-insufflation (T5).
Results: Ten piglets (4 kg) were randomized for 5 (P5) and 10 (P10) mmHg CO2-insufflation. Two P10 piglets needed resuscitation after insufflation, none P5. Linear mixed-effect modeling of paCO2, pH, and SaO2 showed that values were dependent on time and time squared ($p < 0.001$) but were not different between the 5 and 10 mmHg groups. Analysis demonstrated significant changes over time in heart rate and MABP between the 5 and 10 mmHg groups, with a significant higher heart rate and lower blood pressure in the 10 mmHg group ($p < 0.001$). For rScO2 and cFTOE, no group differences could be demonstrated, but a significant effect of time was found: rScO2 increased and cFTOE decreased ($p < 0.001$).
Conclusions: Insufflation of CO2 during thoracoscopy with 10 mmHg caused more severe hemodynamic instability and seems to be related with a decrease of cerebral perfusion as represented by a higher oxygen extraction. CO2-insufflation of 5 mmHg for thoracoscopy seems to have no adverse effects on cerebral oxygenation.

99. Wijayatilake et al. (2014). **The Monitoring and Management of Severe Traumatic Brain Injury in the United Kingdom: Is there a Consensus?: A National Survey**

Abstract: Background: To survey the current practice of monitoring and management of severe traumatic brain injury (TBI) patients in the critical care units across the United Kingdom.
Methods: A structured telephone interview was conducted with senior medical or nursing staff of all the adult neurocritical care units. Thirty-one neurocritical care units that managed adult patients with severe TBI were identified from the Risk Adjustment in Neurocritical Care (RAIN) study and the Society of British Neurological Surgeons.
Results: Intracranial pressure (ICP) monitoring was used in all the 31 institutions. Cerebral perfusion pressure was used in 30 of the 31 units and a Cerebral perfusion pressure target of 60 to 70 mm Hg was the most widely used target (25 of 31 units). Transcranial Doppler was used in 12 units (39%); brain tissue oxygen (PbtO2) was used in 8 (26%); cerebral microdialysis was used in 4 (13%); jugular bulb oximetry in 1 unit; and near-infrared spectrometry was not used in any unit. Continuous capnometry was used in 28 (91%) units for mechanically ventilated patients. Mannitol was the most commonly used agent for osmotherapy to treat intracranial hypertension.

Conclusions: We identified that there was no clear consensus and considerable variation in practice in the management of TBI patients in UK neurocritical care units. A protocol-based management has been shown to improve outcome in sepsis patients. Given the magnitude of the problem, we conclude that there is an urgent need for international consensus guidelines for management of TBI patients in critical care units.

100. Du et al. (2014). **A study of the relationship between image quality and Cerebral Blood Flow**

Abstract: In this paper we examine the relationship between Cerebral Blood Flow and image quality using Near-Infrared Spectroscopy (NIRS). We measured data of cerebral blood flow and applied it to image quality assessment. To prove that test subjects acknowledged the quality degradation of test images, we performed subjective assessment tests through questionnaires. Results showed that all subjects acknowledged quality degradation. We found that Oxy-Hb in the frontal lobe increased when a subject was watching a moving image and change in blood flow was higher when image quality was degraded. We argue that NIRS can be effectively applied in the field of image quality assessment.

101. Ito et al. (2014). **Visual Perception of Incomplete Human-Like Body Postures: A Near-Infrared Spectroscopy Study**

Abstract: Previous studies have reported that the mirror neuron system plays a crucial role in social cognition. We examined whether the higher-order cognitive functions are involved in the activations in the mirror neuron area when we perceive simplified pseudo-postures. We measured 14 participants' brain activation during the posture-recognition task using near-infrared spectroscopy. The participants' task was to observe five sequentially presented target pseudo-postures and judge whether a test pseudo-posture was identical to one of the preceding five target pseudo-postures. The results in the majority of participants (n = 10/14) revealed that the activity in the inferior frontal mirror neuron area is modulated by perception of human-likeness, but not in the remaining four participants (n = 4/14). These results suggest that the degree of the activation of higher-order cognitive functions, which may be engaged in the inhibitory and/or facilitative processing of human body or bodily movement, leads to the distinctive activities in the inferior frontal mirror neuron area.

102. Suzuki et al. (2014). **Measurement of maternal cerebral tissue hemoglobin on near-infrared time-resolved spectroscopy in the peripartum period**

Abstract: Aim: To measure cerebral tissue hemoglobin in uncomplicated and complicated pregnant women during the peripartum period.
Methods: Time-resolved spectroscopy (TRS-20) can measure absolute concentration of oxygenated, deoxygenated, and total tissue hemoglobin based on the transit time of individual photons. Therefore, we used TRS-20 to measured tissue hemoglobin in the hemi-prefrontal lobes of normotensive pregnant women with (n = 51) or without (n = 19) epidural anesthesia, hypertensive pregnant women with pre-eclampsia (n = 10), a pregnant woman with acute onset of hypertension soon after delivery, and a hypertensive woman after hemorrhagic stroke in delivery.
Results: Cyclic labor concomitant with intra-abdominal pressure caused synergistic elevation in cerebral tissue hemoglobin. In contrast, epidural anesthesia reduced the amplitude of the cyclic increase of cerebral tissue hemoglobin in normotensive pregnant women. Hypertension in labor due to pre-eclampsia increased the amplitude of synergistic elevation of cerebral tissue hemoglobin caused by cyclic labor and intra-abdominal pressure. A prolonged high basal level of cerebral tissue hemoglobin was observed in a case of acute onset of hypertension soon after delivery. A decrease in cerebral tissue hemoglobin in the hemi-prefrontal lobe was observed in a woman 2 h after the onset of hemorrhagic stroke in labor.

Conclusions: TRS-20 can detect specific changes in maternal cerebral tissue hemoglobin level in response to physiological and pathophysiological changes in delivery. Thus, it represents a promising new conventional tool for maternal cerebral monitoring in the peripartum period.

103. Murphy et al. (2014). **Utility of near infrared light to determine tissue oxygenation during hepato-biliary surgery**

Abstract: Near-infrared spectrophotometry assesses cerebral oxygen saturation (ScO2) based on the absorption spectra of oxygenated and deoxygenated hemoglobin, and the translucency of biological tissue, in the near-infrared band. There is increasing evidence that optimising cerebral oxygenation, guided by ScO2, is associated with improved outcomes in a variety of high risk surgical settings. However, in patients with liver disease, bilirubin can potentially render cerebral oximetry inaccurate. As a result, measurement of cerebral oxygen saturation is rarely undertaken in patients undergoing hepatobiliary surgery. We prospectively measured baseline and intraoperative cerebral oxygen saturation in patients undergoing major pancreatic surgery. Indices including bilirubin, sodium, platelets and maximum amplitude on thromboelastography were associated with low baseline ScO2. However, those patients with low ScO2 (≤51 %) maintained a similar trend in cerebral oximetry values both at induction and intraoperatively to those with a normal ScO2. We conclude that the pattern of cerebral oximetry is similar in patients undergoing major pancreatic surgery regardless of their underlying liver dysfunction. Therefore, cerebral oximetry may have a role in monitoring neurological function in this high risk group of patients.

104. Lee et al. (2014). **Cortical activities during a stand to sit movement using fNIRS**

Abstract: Recently, a functional near-infrared spectroscopy (fNIRS) is frequently reported optical brain imaging method from the standpoint of clinical feasibility. This paper was aimed at examining whether fNIRS can be an appropriate brain imaging modality for checking the progress of rehabilitation treatments or not. Two healthy adults performed the given task. Stand to sit task was offered in this study. The results showed that stand to sit movement commonly activated the medial primary motor cortex and primary sensory motor cortex. A fNIRS accurately pointed the brain activity coincided with neurophysiological evidences which were commonly accepted. The results from this study we saw the possibility of the utilizing NIRS into the field of rehabilitation medicine and may contribute to better understanding how motor executions can be expressed into cortical activations.

105. Khan et al. (2014). **A hybrid EEG-fNIRS BCI: Motor imagery for EEG and mental arithmetic for fNIRS**

Abstract: In this paper, we have combined electroencephalography (EEG) and functional near-infrared spectroscopy (fNRIS) to make a hybrid EEG-NIRS based system for brain-computer interface (BCI). The EEG electrodes were placed on the motor cortex region and the NIRS optodes were set on the prefrontal region. The data of four subjects was acquired using mental arithmetic tasks and motor imageries of the left- and right-hand. The EEG data were band-pass filtered to obtain the activity (8~18 Hz). The modified Beer-Lambert law (MBLL) was used to convert the fNIRS data into oxy- and deoxy-hemoglobin (HbO and HbR), respectively. A common threshold between the two modalities was established to define a common resting state. The support vector machines (SVM) was used for data classification. Three control commands were generated using the prefrontal and motor cortex data. The results show that EEG and fNIRS can be combined for better brain signal acquisition and classification for BCI.

106. Bigliassi et al. (2014). **Music and cortical blood flow: A functional near-infrared spectroscopy (fNIRS) study**

Abstract: The function of the prefrontal cortex (PFC) appears to be more activated in men than in women when it is conditioned to emotional situations via external stimuli. The aim of the present study was to investigate the effects of different music genres on PFC oxygenation according to gender. Eighteen healthy volunteers (10 males and 8 females), aged 20-28 years (mean: 22.25 ± 2.34 years), participated in the study. They remained in silence, and hemoglobin levels in a linear scattering were recorded (O2Hb [oxyhemoglobin] and HHb [deoxyhemoglobin]). When this procedure was finished, music was played for 1.5 min. The results showed that different genres of music might change cortical oxygenation in several ways, and such modulation may be related to gender. We conclude that music modulated cortical oxygenation in the PFC in both the right and left hemispheres, and differences in cortical oxygenation were highly related to gender. Furthermore, preferred and motivational songs can be considered the most important for increasing blood flow in the listening process.

107. Cristia et al. (2014). **Responses to Vocalizations and Auditory Controls in the Human Newborn Brain**

Abstract: In the adult brain, speech can recruit a brain network that is overlapping with, but not identical to, that involved in perceiving non-linguistic vocalizations. Using the same stimuli that had been presented to human 4-month-olds and adults, as well as adult macaques, we sought to shed light on the cortical networks engaged when human newborns process diverse vocalization types. Near infrared spectroscopy was used to register the response of 40 newborns' perisylvian regions when stimulated with speech, human and macaque emotional vocalizations, as well as auditory controls where the formant structure was destroyed but the long-term spectrum was retained. Left fronto-temporal and parietal regions were significantly activated in the comparison of stimulation versus rest, with unclear selectivity in cortical activation. These results for the newborn brain are qualitatively and quantitatively compared with previous work on newborns, older human infants, adult humans, and adult macaques reported in previous work.

108. Chaddad et al. (2014). **Low-noise transimpedance amplifier dedicated to biomedical devices: Near infrared spectroscopy system**

Abstract: This paper concerns the design and the implementation of a transimpedance amplifier (TIA) dedicated to detector of Near Infrared spectroscopy (NIRS). To reduce the effect of the input capacitance on the bandwidth, a bias circuit with low input impedance is connected to input stage. A single ended common source common gate input stage based on a cascode structure is used to get a higher gain bandwidth closed loop transimpedance amplifier. In addition, a higher open loop gain is got by adding second active load. To increase noise circuit performance, a feedback single transistor technique is considered. The TIA is implemented in 0.18 µm CMOS process. Simulation results show a transimpedance gain of 104.2 dBΩ, -3dB bandwidth of 19 MHz and an equivalent input noise current spectral density of 446 fA/√Hz. A comparative study confirms the feasibility of our proposal.

109. Phillip et al. (2014). **Spontaneous Low Frequency Oscillations in Acute Ischemic Stroke - A Near Infrared Spectroscopy (NIRS) Study**

Abstract: Background and purpose: Continuous wave near infrared spectroscopy (NIRS) is a non-invasive bed-side optical method to detect changes in oxygenated (oxyHb) and deoxygenated hemoglobin (deoxyHb) in the outermost layers of the cerebral cortex. Cortical oxyHb low frequency oscillations (LFOs) in the 0.09-0.11 Hz range are affected by changes in cerebral autoregulation (CA), which is altered following stroke. We examined

oxyHb LFOs at bed-side as a marker of CA in the subacute phase in stroke patients with or without recombinant tissue plasminogen activator thrombolytic therapy.
Methods: We recruited 29 patients admitted to the stroke unit with symptoms of ischemic stroke. 11/29 patients received thrombolytic therapy. NIRS examination was conducted 2 days (median time) from stroke onset. NIRS optodes were placed on each side of the head with a 3 cm source-detector distance. Using transfer function analysis, inter-hemispheric phase shift and amplitude ratio of the oxyHb oscillations in the 0.09-0.11 Hz range were assessed.
Results: The correlation between NIHSS scores at admission and oxyHb parameters revealed a significant positive correlation between stroke severity at admission and inter-hemispheric phase shift (P=0.028). The oxyHb absolute inter-hemispheric phase shift was significantly less in patients receiving thrombolytic therapy compared to non-thrombolytic therapy patients (3° vs. 23°, P=0.005).
Conclusions: Stroke severity correlates with the degree of impaired cortical CA and stroke patients receiving thrombolytic therapy might have less severely impaired CA. NIRS detects alteration in cortical oxyHb LFOs between hemispheres in stroke patients in the subacute phase and may be a feasible method to explore changes at bed-side in a stroke unit.

110. Hirao (2014). **Two-channel Near-infrared Spectroscopic Analysis of Association of Paranoia Symptoms with Prefrontal Activation**

Abstract: OBJECTIVE: The relationship between paranoia symptoms and underlying prefrontal cortex mechanisms among healthy subjects was analyzed using near-infrared spectroscopy.
METHODS: Seventy-eight healthy subjects were assessed for paranoia symptoms using the Japanese version of the Paranoia Checklist. Changes in hemoglobin concentrations were assessed using 2-channel near-infrared spectroscopy on the surface of the prefrontal cortex while subjects performed a verbal fluency test.
RESULTS: Changes in the concentration of oxygenated hemoglobin in the prefrontal cortex during a verbal fluency test did not correlate with the Japanese version of the Paranoia Checklist.
CONCLUSION: Our findings show that the symptoms of paranoia do not negatively affect the prefrontal cortex function among healthy subjects.

111. Matsuura al. (2014). **Distribution of Cerebral Blood Flow during Biofeedback Training**

Abstract: Near-infrared spectroscopy (NIRS) is less restrictive for examinees than other brain function imaging methods such as positron emission tomography or functional magnetic resonance imaging. In addition, fixation of the head and recumbence on a special device during measurement are unnecessary with NIRS. Biofeedback training (BFT) elucidates the importance of mental training, and monitors and encourages the learning of psycho-physiological control necessary for peak performance. Electromyography of examinees' rectus femoris muscles and nearinfrared spectroscopy were simultaneously conducted to investigate the relationship between BFT and local cerebral blood flow. The influence of a kicking motion on brain functioning was confirmed. These findings suggest that BFT is effective in activating working memory.

112. Hiroyasu et al. (2014). **Gender classification of subjects from cerebral blood flow changes using Deep Learning**

Abstract: In this study, using Deep Learning, the gender of subjects is classified the cerebral blood flow changes that are measured by fNIRS. It is reported that cerebral blood flow changes are triggered by brain activities. Thus, if this classification has a high searching accuracy, gender classification should be related to brain activities. In the experiment, fNIRS data are derived from subjects who perform a memory task in white noise environment. From the results, it is confirmed that the learning classifier exhibits high accuracy. This fact suggests that there exists a relation between cerebral blood flow changes and biological information.

113. Okubo et al. (2014). **Analysis of Brain Activities due to Differences in Running Shoe Properties**

Abstract: Many of the ever-growing elderly population require exercise, such as running, for health management. One important element of a runner's training is the choice of shoes for exercise; shoes are important because they provide the interface between the feet and road. When we purchase shoes, we may instinctively choose a pair after trying on many different pairs of shoes. Selecting the shoes instinctively may work, but it does not guarantee a suitable fit for running activities. Therefore, if we could select suitable shoes for each runner from the viewpoint of brain activities, it would be helpful for validating shoe selection. In this paper, we describe how brain activities show different characteristics during particular task, corresponding to different properties of shoes. Using five subjects, we performed a verification experiment, applying weight, softness, and flexibility as shoe properties. In order to affect the shoe property's differences to the brain, subjects run for 10 min. Before and after running, subjects conducted a paced auditory serial addition task (PASAT) as the particular task; and the subjects' brain activities during the PASAT are evaluated based on oxyhemoglobin and deoxyhemoglobin relative concentration changes, measured by near-infrared spectroscopy (NIRS). When the brain works actively, oxihemoglobin and deoxyhemoglobin concentration drastically changes; therefore, we calculate the maximum values of concentration changes. In order to normalize relative concentration changes after running, the maximum value are divided by before running maximum value as evaluation parameters. The classification of the groups of shoes is expressed on a self-organizing map (SOM). As a result, deoxyhemoglobin can make clusters for two of the three types of shoes.

114. Okubo et al. (2014). **Analysis of Brain Activities due to Differences in Running Shoe Properties**

Abstract: Mild traumatic brain injury (mTBI) is a significant public health care burden in the United States. However, we lack a detailed understanding of the pathophysiology following mTBI and its relation to symptoms and recovery. With advanced magnetic resonance imaging (MRI), we can investigate brain perfusion and oxygenation in regions known to be implicated in symptoms, including cortical gray matter and subcortical structures. In this study, we assessed 14 mTBI patients and 18 controls with susceptibility weighted imaging and mapping (SWIM) for blood oxygenation quantification. In addition to SWIM, 7 patients and 12 controls had cerebral perfusion measured with arterial spin labeling (ASL). We found increases in regional cerebral blood flow (CBF) in the left striatum, and in frontal and occipital lobes in patients as compared to controls ($p = 0.01, 0.03, 0.03$ respectively). We also found decreases in venous susceptibility, indicating increases in venous oxygenation, in the left thalamostriate vein and right basal vein of Rosenthal ($p = 0.04$ in both). mTBI patients had significantly lower delayed recall scores on the standardized assessment of concussion, but neither susceptibility nor CBF measures were found to correlate with symptoms as assessed by neuropsychological testing. The increased CBF combined with increased venous oxygenation suggests an increase in cerebral blood flow that exceeds the oxygen demand of the tissue, in contrast to the regional hypoxia seen in more severe TBI. This may represent a neuroprotective response following mTBI, which warrants further investigation.

115. Wang et al. (2014). **Observation on the effect of acupoint stimulation on regional cerebral blood flow using near-infrared spectroscopy technology**

Abstract: Objective: To observe the effect of acupuncture at Kngzuì (LU 6), Sānyīnjião (SP 6) and Zúānl (ST 36) on cerebral blood oxygenation level and explore the relevance between acupuncture and cerebral blood oxygenation level using near-infrared spectroscopy (NIRS).
Methods: Quasi-randomized design (random test sequence) was used. In clinical trial , placebo acupuncture was applied at Bǎihuì (GV 20) of 18 adults. In clinical trial , 54 adults were divided into three groups with 18 each in which acupuncture was applied at LU 6, SP 6 and ST 36 respectively. Before and after acupuncture, verbal fluency test (VFT) was performed and the blood oxygenation level of cerebral cortex was measured using NIRS. Quantized data was processed with JMP10.0.2 software and SPSS software.

Results: In clinical trial , the mean integral values of cerebral blood oxygenation level were 10.8 mMcm·s and 9.2 mMcm·s respectively before and after acupuncture at GV 20 in placebo acupuncture group. There was no significant difference in the cerebral blood oxygenation level after acupuncture. In clinical trial , the mean integral values of cerebral blood oxygen level were 18.1 mMcm·s and 8.6 mMcm·s respectively before and after acupuncture at LU 6 in [LU 6] acupuncture group, the cerebral blood oxygenation level was significantly decreased after acupuncture (P = 0.001). The mean integral values of cerebral blood oxygenation level were 16.1 mMcm·s and 17.4 mMcm·s respectively before and after acupuncture at SP 6 in [SP 6] acupuncture group, the cerebral blood oxygenation level was slightly increased after acupuncture, but the increase was not statistically significant. The mean integral values of cerebral blood oxygenation level were 13.8 mMcm·s and 10.1 mMcm·s respectively before and after acupuncture at ST 36 in [ST 36] acupuncture group, the cerebral blood oxygenation level was slightly deceased after acupuncture, but the increase was not statistically significant.
Conclusion: The cerebral blood oxygenation level of frontal head was decreased by acupuncture at LU 6, the cerebral blood oxygenation level of frontal head was intended to decrease by acupuncture at ST 36. The cerebral blood oxygenation level of frontal head is intended to increase by acupuncture at SP 6.

116. Alaniz et al. (2014). **Design and Validation of a One Channel Near-Infrared Spectroscopy System for Applications in Medicine**

Abstract: Near-infrared spectroscopy (NIRS) is a noninvasive and portable technique to quantify changes of oxy- and deoxy-hemoglobin concentration in tissue. In this paper the development of a continuous wave NIRS instrument is presented. The instrument was designed using a LED emitting light at 750 and 850 nm, that are wavelengths at which the oxy- and deoxy-hemoglobin specifically respond, and a photodetector with an integrated transimpedance amplifier; to complete the prototype, a professional digital acquisition card is used. All the data processing is performed offline. The instrument was tested by measuring total occlusion and total flow in muscle; and in frontal cortex while performing a mental task. All recorded an processed signals show the expected physiological behavior. The optical and electronic components commercially available today allow to build inexpensive NIRS systems for application in medicine.

117. Yuan et al. (2014). **Light-emitting diode-based multiwavelength diffuse optical tomography system guided by ultrasound**

Abstract: Laser diodes are widely used in diffuse optical tomography (DOT) systems but are typically expensive and fragile, while light-emitting diodes (LEDs) are cheaper and are also available in the near-infrared (NIR) range with adequate output power for imaging deeply seated targets. In this study, we introduce a new low-cost DOT system using LEDs of four wavelengths in the NIR spectrum as light sources. The LEDs were modulated at 20 kHz to avoid ambient light. The LEDs were distributed on a hand-held probe and a printed circuit board was mounted at the back of the probe to separately provide switching and driving current to each LED. Ten optical fibers were used to couple the reflected light to 10 parallel photomultiplier tube detectors. A commercial ultrasound system provided simultaneous images of target location and size to guide the image reconstruction. A frequency-domain (FD) laser-diode-based system with ultrasound guidance was also used to compare the results obtained from those of the LED-based system. Results of absorbers embedded in intralipid and inhomogeneous tissue phantoms have demonstrated that the LED-based system provides a comparable quantification accuracy of targets to the FD system and has the potential to image deep targets such as breast lesions.

118. Jones et al. (2014). **Underwater near-infrared spectroscopy measurements of muscle oxygenation: laboratory validation and preliminary observations in swimmers and triathletes**

Abstract: The purpose of this research was to waterproof a near-infrared spectroscopy device (PortaMon, Artinis Medical Systems) to enable NIR measurement during swim exercise. Candidate materials were initially tested

for waterproof suitability by comparing light intensity values during phantom-based tissue assessment. Secondary assessment involved repeated isokinetic exercises ensuring reliability of the results obtained from the modified device. Tertiary assessment required analysis of the effect of water immersion and temperature upon device function. Initial testing revealed that merely covering the PortaMon light sources with waterproof materials considerably affected the NIR light intensities. Modifying a commercially available silicone covering through the addition of a polyvinyl chloride material (impermeable to NIR light transmission) produces an acceptable compromise. Bland–Altman analysis indicated that exercise-induced changes in tissue saturation index (TSI %) were within acceptable limits during laboratory exercise. Although water immersion had a small but significant effect upon NIR light intensity, this resulted in a negligible change in the measured TSI (%). We then tested the waterproof device in vivo illustrating oxygenation changes during a 100 m freestyle swim case study. Finally, a full study compared club level swimmers and triathletes. Significant changes in oxygenation profiles when comparing upper and lower extremities for the two groups were revealed, reflecting differences in swim biomechanics.

119. Bale et al. (2014). **A new broadband near-infrared spectroscopy system for in-vivo measurements of cerebral cytochrome-c-oxidase changes in neonatal brain injury**

Abstract: We present a novel lens-based broadband near-infrared spectroscopy system to simultaneously measure cerebral changes in tissue oxygenation and haemodynamics via estimation of the changes in haemoglobin concentration; in addition to oxygen utilization via the measurement of the oxidation state of cytochrome-c-oxidase (CCO). We demonstrate the use of the system in a cohort of 6 newborn infants with neonatal encephalopathy in the Neonatal Intensive Care Unit for continuous measurement periods of up to 5 days. NIRS data was collected from above the frontal lobe on the left and right hemispheres simultaneously with systemic data to allow multimodal data analysis. This allowed us to study the NIRS variables in response to global pathophysiological events and we focused our analysis to spontaneous oxygen desaturations. We identified changes from the NIRS variables during 236 oxygen desaturations from over 212 hours of data with a change from the baseline to nadir of −12 ± 3%. There was a consistent negative change in the Δ[HbD] (= oxygenated – deoxygenated haemoglobin) and Δ[oxCCO] measurements, mean decreases were 3.0 ± 1.7μM and 0.22 ± 0.11μM, and a positive change in the Δ[HbT] (= oxygenated + deoxygenated haemoglobin) measurements across all subjects, mean increase was 0.85 ± 0.58μM. We have shown with a feasibility study that the relationship between haemoglobin oxygenation changes and CCO oxidation changes during these desaturation events was significantly associated with a magnetic resonance spectroscopy (MRS)-measured biomarker of injury severity ($r = 0.91$, $p<0.01$).

120. Kainerstorfer et al. (2014). **Coherent hemodynamics spectroscopy in a single step**

Abstract: Coherent Hemodynamics Spectroscopy (CHS) is a technique based on inducing cerebral hemodynamic oscillations at multiple frequencies, measuring them with near-infrared spectroscopy (NIRS), and analyzing them with a hemodynamic model to obtain physiological information such as blood transit times in the microvasculature and the autoregulation cutoff frequency. We have previously demonstrated that such oscillations can be induced one frequency at a time. Here we demonstrate that CHS can be performed by a single inflation of two pneumatic thigh cuffs (duration: 2 min; pressure: 200 mmHg), whose sudden release produces a step response in systemic arterial blood pressure that lasts for ~20 s and induces cerebral hemodynamics that contain all the frequency information necessary for CHS. Following a validation study on simulated data, we performed measurements on human subjects with this new method based on a single occlusion/release of the thigh cuffs and with the previous method based on sequential sets of cyclic inflation/deflation one frequency at a time, and demonstrated that the two methods yield the same CHS spectra and the same physiological parameters (within measurement errors). The advantages of the new method presented here are that CHS spectra cover the entire bandwidth of the induced hemodynamic response, they are measured over ~20 s thus

better satisfying the requirement of time invariance of physiological conditions, and they can be measured every ~2.5 min thus achieving finer temporal sampling in monitoring applications.

121. Hyttel-Sorensen et al. (2014). **A comparison between two NIRS oximeters (INVOS, OxyPrem) using measurement on the arm of adults and head of infants after caesarean section**

Abstract: Previously the NIRS oximeter OxyPrem was calibrated by comparison to the INVOS in a blood-lipid phantom. The aim of the present study was to test this calibration clinically. During vasculur occlusions in 10 adults and after birth in 25 term infants the relationship was OxyPrem = 1.24 x INVOS - 23.6% and OxyPrem = 1.15 x INVOS - 16.2% on the adult arm and infant head, respectively. The precsion during steady state was 4.0% (CI 3.4% to 4.6%) and 3.4% (CI 2.9% to 3.9%) on the arm, and 6.7% (CI 5.9% to 7.6%) and 4.7% (CI 3.5% to 5.9%) on the infant head for OxyPrem and INVOS, respectively. We conclude that the calibration on the blood-lipid phantom was unsuccessful in achieving agreement in clinical measurements.

122. Wu et al. (2014). **Shape-parameterized diffuse optical tomography holds promise for sensitivity enhancement of fluorescence molecular tomography**

Abstract: A fundamental approach to enhancing the sensitivity of the fluorescence molecular tomography (FMT) is to incorporate diffuse optical tomography (DOT) to modify the light propagation modeling. However, the traditional voxel-based DOT has been involving a severely ill-posed inverse problem and cannot retrieve the optical property distributions with the acceptable quantitative accuracy and spatial resolution. Although, with the aid of an anatomical imaging modality, the structural-prior-based DOT method with either the hard- or soft-prior scheme holds promise for in vivo acquiring the optical background of tissues, the low robustness of the hard-prior scheme to the segmentation error and inferior performance of the soft-prior one in the quantitative accuracy limit its further application. We propose in this paper a shape-parameterized DOT method for not only effectively determining the regional optical properties but potentially achieving reasonable structural amelioration, lending itself to FMT for comparably improved recovery of fluorescence distribution.

123. Wu et al. (2014). **Quantitative evaluation of atlas-based high-density diffuse optical tomography for imaging of the human visual cortex**

Abstract: Image recovery in diffuse optical tomography (DOT) of the human brain often relies on accurate models of light propagation within the head. In the absence of subject specific models for image reconstruction, the use of atlas based models are showing strong promise. Although there exists some understanding in the use of some limited rigid model registrations in DOT, there has been a lack of a detailed analysis between errors in geometrical accuracy, light propagation in tissue and subsequent errors in dynamic imaging of recovered focal activations in the brain. In this work 11 different rigid registration algorithms, across 24 simulated subjects, are evaluated for DOT studies in the visual cortex. Although there exists a strong correlation (R2 = 0.97) between geometrical surface error and internal light propagation errors, the overall variation is minimal when analysing recovered focal activations in the visual cortex. While a subject specific mesh gives the best results with a 1.2 mm average location error, no single algorithm provides errors greater than 4.5 mm. This work demonstrates that the use of rigid algorithms for atlas based imaging is a promising route when subject specific models are not available.

124. Bi et al. (2014). **Image Reconstruction for Diffuse Optical Tomography Based on Radiative Transfer Equation**

Abstract: Diffuse optical tomography is a novel molecular imaging technology for small animal studies. Most known reconstruction methods use the diffusion equation (DA) as forward model, although the validation of DA breaks down in certain situations. In this work, we use the radiative transfer equation as forward model which provides an accurate description of the light propagation within biological media and investigate the potential of sparsity constraints in solving the diffuse optical tomography inverse problem. The feasibility of the sparsity reconstruction approach is evaluated by boundary angular-averaged measurement data and internal angular-averaged measurement data. Simulation results demonstrate that in most of the test cases the reconstructions with sparsity regularization are both qualitatively and quantitatively more reliable than those with standard regularization. Results also show the competitive performance of the split Bregman algorithm for the DOT image reconstruction with sparsity regularization compared with other existing algorithms.

125. Bi et al. (2014). **Image Reconstruction for Diffuse Optical Tomography Based on Radiative Transfer Equation**

Abstract: Diffuse optical tomography is a novel molecular imaging technology for small animal studies. Most known reconstruction methods

Publications from the BORL, Zurich

126. Bontrager et al. (2014). **Physiological noise cancellation in fNIRS using an adaptive filter based on mutual information**

Abstract: Functional near-infrared spectroscopy (fNIRS) is a noninvasive optical method that measures cortical activity based on hemodynamics in the brain. Physiological signals (biosignals), such as blood pressure and respiration, are known to appear in cortical fNIRS recordings. Some biosignal components occupy the same frequency band as the cortical response, and respond to the subjects activity. To process an fNIRS signal in a brain-computer interface, it is desirable to know which components of the signal come from cortical response, and which come from biosignal interference. Numerous filtering methods have been proposed to this end with mixed success, possibly because they assume that the cortical and physiological signals combine linearly, or that biosignals do not correlate with subject behavior. Here, we propose an adaptive filter with a cost function based on mutual information to selectively remove information that correlates with blood pressure from the fNIRS signal. The filter was tested with real and simulated data. The real signals were measured on seven healthy subjects performing an isometric pinching task. Cross-correlation and mutual information were employed as performance measures. The filter successfully removed correlations between blood pressure and the fNIRS signal, by an equal or greater amount compared to a traditional recursive least squares adaptive filter. Blood pressure was found to be the most informative signal to classify rest and active periods using linear discriminant analysis. Any task information in the fNIRS signal was redundant to that expressed by blood pressure.

127. Holper & Murphy (2014). **Hemodynamic and affective correlates assessed during performance on the Columbia Card Task (CCT)**

Abstract: The study aimed to test the potential of functional near-infrared spectroscopy (fNIRS) in combination with electrodermal activity (EDA) in a decision paradigm by means of the Columbia Card Task (CCT). The CCT is a dynamic decision task characterized by assessing subjects' risk-taking via eliciting voluntary stopping points in a series of incrementally increasingly risky choices. Using the combined fNIRS-EDA approach, we aim to

examine the hemodynamic and affective correlates of both decision and outcome responses during performance on the CCT. Twenty healthy subjects completed the Cold and Hot CCT version while fNIRS over prefrontal cortex and EDA were recorded. Results showed that (1) in the decision phase fNIRS revealed larger total hemoglobin concentration changes [tHb] in the Cold as compared to the Hot CCT, whereas EDA revealed an opposite pattern with larger skin conductance responses (SCRs) to the Hot as compared to the Cold CCT. (2) No significant [tHb] signals or SCRs were found in the outcome phase. (3) Coherence calculations between fNIRS and EDA in the heart rate frequency showed a significant increase during the Hot as compared to the Cold CCT. Our findings designate fNIRS as suitable tool for monitoring decision-making processes. The combination of fNIRS and EDA demonstrates the potential of simultaneously assessing the interaction between hemodynamic and affective responses which can provide additional information concerning the relationship between these two physiological systems for various research areas.

128. Quandt et al. (2014). **Body-Monitoring and Health Supervision by Means of Optical Fiber-Based Sensing Systems in Medical Textiles**

Abstract: Long-term monitoring with optical fibers has moved into the focus of attention due to the applicability for medical measurements. Within this Review, setups of flexible, unobtrusive body-monitoring systems based on optical fibers and the respective measured vital parameters are in focus. Optical principles are discussed as well as the interaction of light with tissue. Optical fiber-based sensors that are already used in first trials are primarily selected for the section on possible applications. These medical textiles include the supervision of respiration, cardiac output, blood pressure, blood flow and its saturation with hemoglobin as well as oxygen, pressure, shear stress, mobility, gait, temperature, and electrolyte balance. The implementation of these sensor concepts prompts the development of wearable smart textiles. Thus, current sensing techniques and possibilities within photonic textiles are reviewed leading to multiparameter designs. Evaluation of these designs should show the great potential of optical fibers for the introduction into textiles especially due to the benefit of immunity to electromagnetic radiation. Still, further improvement of the signal-to-noise ratio is often necessary to develop a commercial monitoring system.