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

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Number of papers included: **120**

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

1. Lee et al. (2015). **Subject-dependent classification for robust idle state detection using multi-modal neuroimaging and data-fusion techniques in BCI**

Abstract: Brain–computer interfaces (BCIs) allow users to control external devices by their intentions. Currently, most BCI systems are synchronous. They rely on cues or tasks to which a subject has to react. In order to design an asynchronous BCI one needs to be able to robustly detect an idle class. In this study, we examine whether multi-modal neuroimaging, based on simultaneous EEG and near-infrared spectroscopy (NIRS) measurements, can assist in the robust detection of the idle class within a sensory motor rhythm-based BCI paradigm. We propose two types of subject-dependent classification strategies to combine the information of both modalities. Our results demonstrate that not only idle-state decoding can be significantly improved by exploiting the complementary information of multi-modal recordings, but also it is possible to minimize the delay of the system, caused by the slow inherent hemodynamic response of the NIRS signal.

2. Dewey et al. (2015). **Cortical cross-modal plasticity following deafness measured using functional near-infrared spectroscopy**

Abstract: Evidence from functional neuroimaging studies suggests that the auditory cortex can become more responsive to visual and somatosensory stimulation following deafness, and that this occurs predominately in the right hemisphere. Extensive cross-modal plasticity in prospective cochlear implant recipients is correlated with poor speech outcomes following implantation, highlighting the potential impact of central auditory plasticity on subsequent aural rehabilitation. Conversely, the effects of hearing restoration with a cochlear implant on cortical plasticity are less well understood, since the use of most neuroimaging techniques in CI recipients is either unsafe or problematic due to the electromagnetic artefacts generated by CI stimulation. Additionally, techniques such as functional magnetic resonance imaging (fMRI) are confounded by acoustic noise produced by the scanner that will be perceived more by hearing than by deaf individuals. Subsequently it is conceivable that auditory responses to acoustic noise produced by the MR scanner may mask auditory cortical responses to non-auditory stimulation, and render inter-group comparisons less significant. Uniquely, functional near-infrared spectroscopy (fNIRS) is a silent neuroimaging technique that is non-invasive and completely unaffected by the presence of a CI. Here, we used fNIRS to study temporal-lobe responses to auditory, visual and somatosensory stimuli in thirty profoundly-deaf participants and thirty normally-hearing controls. Compared with silence, acoustic noise stimuli elicited a significant group fNIRS response in the temporal region of normally-hearing individuals, which was not seen in profoundly-deaf participants. Visual motion elicited a larger group response within the right temporal lobe of profoundly-deaf participants, compared with normally-hearing controls. However, bilateral temporal lobe fNIRS activation to somatosensory stimulation was comparable in both groups. Using fNIRS these results confirm that auditory deprivation is associated with cross-modal plasticity of visual inputs to auditory cortex. Although we found no evidence for plasticity of somatosensory inputs, it is possible that our recordings may have included activation of somatosensory cortex that masked any group differences in auditory cortical responses due to the limited spatial resolution associated with fNIRS.

3. Racek et al. (2015). **Different Brain Responses to Pain and Its Expectation in the Dental Chair**

Abstract: A dental appointment commonly prompts fear of a painful experience, yet we have never fully understood how our brains react to the expectation of imminent tooth pain once in a dental chair. In our study, 21 patients with hypersensitive teeth were tested using nonpainful and painful stimuli in a clinical setting. Subjects were tested in a dental chair using functional near-infrared spectroscopy to measure cortical activity during a stepwise cold stimulation of a hypersensitive tooth, as well as nonpainful control stimulation on the same tooth. Patients' sensory-discriminative and emotional-cognitive cortical regions were studied through the transition of a neutral to a painful stimulation. In the putative somatosensory cortex contralateral to the stimulus, 2 well-defined hemodynamic peaks were detected in the homuncular orofacial region: the first peak during the nonpainful phase and a second peak after the pain threshold was reached. Moreover, in the upper-left and lower-right prefrontal cortices, there was a significant active hemodynamic response in only the first phase, before the pain. Subsequently, the same prefrontal cortical areas deactivated after a painful experience had been reached. Our study indicates for the first time that pain perception and expectation elicit different hemodynamic cortical responses in a dental clinical setting.

4. Ono et al. (2015). **Reduced prefrontal activation during performance of the Iowa Gambling Task in patients with bipolar disorder**

Abstract: The Iowa Gambling Task (IGT) is a complex decision-making task in which monetary wins and losses guide the development of strategies. The objective of this study was to evaluate hemodynamic responses of patients with bipolar disorder (BD) during performance of the IGT using near-infrared spectroscopy (NIRS). Participants comprised 13 patients and 15 healthy control subjects who were matched for age, sex, handedness, and intelligence quotient. Relative changes in oxygenated and deoxygenated hemoglobin (oxy-Hb and deoxy-Hb) levels in the frontal region were measured using a 46-channel NIRS system. All subjects were evaluated using NIRS during a verbal fluency task (VFT) and the IGT. During performance of the IGT, BD patients showed significantly decreased oxy-Hb levels in the bilateral orbitofrontal cortex (OFC) and left prefrontal cortex (PFC) compared with normal control subjects. However, during the VFT, patients with BD showed no significant changes in oxy-Hb levels compared with control subjects. Changes in oxy-Hb levels in the bilateral OFC and the PFC during the IGT were negatively correlated with total scores on the Hamilton Rating Scale for Depression (HAM-D). Although the IGT was useful for differentiating patients with BP from control subjects, no significant differences in autonomic activity were observed.

5. Harmat et al. (2015). **Physiological correlates of the flow experience during computer game playing**

Abstract: Flow is the subjective experience of effortless attention, reduced self-awareness, and enjoyment that typically occurs during optimal task performance. Previous studies have suggested that flow may be associated with a non-reciprocal coactivation of the sympathetic and parasympathetic systems and, on a cortical level, with a state of hypofrontality and implicit processing. Here, we test these hypotheses, using the computer game TETRIS as model task. The participants (n = 77) played TETRIS under three conditions that differed in difficulty (Easy < Optimal < Difficult). Cardiac and respiratory activities, and the average oxygenation changes of the prefrontal cortex were measured continuously with functional near infrared spectroscopy (fNIRS) during performance. The Optimal condition was characterized by the highest levels of state flow, positive affect, and effortless attention. The associations between self-reported psychological flow and physiological measures were investigated using a series of repeated measures linear mixed model analyses. The results showed that higher flow was associated with larger respiratory depth and lower LF. The higher respiratory depth during high flow is indicative of a more relaxed state with an increased parasympathetic activity, and thus provides partial support for the main hypotheses. There was no association between frontal cortical oxygenation and flow, even at liberal thresholds; i.e. we found no support that flow is related to a state of hypofrontality.

6. Schudlo et al. (2015). **Single-trial classification of near-infrared spectroscopy signals arising from multiple cortical regions**

Abstract: Near-infrared spectroscopy (NIRS) brain–computer interface (BCI) studies have primarily made use of measurements taken from a single cortical area. In particular, the anterior prefrontal cortex has been the key area used for detecting higher-level cognitive task performance. However, mental task execution typically requires coordination between several, spatially-distributed brain regions. We investigated the value of expanding the area of interrogation to include NIRS measurements from both the prefrontal and parietal cortices to decode mental states. Hemodynamic activity was monitored at 46 locations over the prefrontal and parietal cortices using a continuous-wave near-infrared spectrometer while 11 able-bodied adults rested or performed either the verbal fluency task (VFT) or Stroop task. Offline classification was performed for the three possible binary problems using 25 iterations of bagging with a linear discriminant base classifier. Classifiers were trained on a 10 dimensional feature set. When all 46 measurement locations were considered for classification, average accuracies of 80.4 ± 7.0%, 82.4 ± 7.6%, and 82.8 ± 5.9% in differentiating VFT vs rest, Stroop vs rest and VFT vs Stroop, respectively, were obtained. Relative to using measurements from the anterior PFC alone, an overall average improvement of 11.3% was achieved. Utilizing NIRS measurements from the prefrontal and parietal cortices can be of value in classifying mental states involving working memory and attention. NIRS-BCI accuracies may be improved by incorporating measurements from several, distinct cortical regions, rather than a single area alone. Further development of an NIRS-BCI supporting combinations of VFT, Stroop task and rest states is also warranted.

7. Dreckhahn et al. (2015). **A validation study of the use of near-infrared spectroscopy imaging in primary and secondary motor areas of the human brain**

Abstract: The electroencephalographically measured Bereitschafts (readiness)-potential in the supplementary motor area (SMA) serves as a signature of the preparation of motor activity. Using a multichannel, noninvasive near-infrared spectroscopy (NIRS) imager, we studied the vascular correlate of the readiness potential.
Sixteen healthy subjects performed a self-paced or externally triggered motor task in a single or repetitive pattern, while NIRS simultaneously recorded the task-related responses of deoxygenated hemoglobin (HbR) in the primary motor area (M1) and the SMA.
Right-hand movements in the repetitive sequence trial elicited a significantly greater HbR response in both the SMA and the left M1 compared to left-hand movements. During the single sequence condition, the HbR response in the SMA, but not in the M1, was significantly greater for self-paced than for externally cued movements. Nonetheless, an unequivocal temporal delay was not found between the SMA and M1.
Near-infrared spectroscopy is a promising, noninvasive bedside tool for the neuromonitoring of epileptic seizures or cortical spreading depolarizations (CSDs) in patients with epilepsy, stroke, or brain trauma because these pathological events are associated with typical spatial and temporal changes in HbR. Propagation is a characteristic feature of these events which importantly supports their identification and characterization in invasive recordings. Unfortunately, the present noninvasive study failed to show a temporal delay during self-paced movements between the SMA and M1 as a vascular correlate of the readiness potential. Although this result does not exclude, in principle, the possibility that scalp-NIRS can detect a temporal delay between different regions during epileptic seizures or CSDs, it strongly suggests that further technological development of NIRS should focus on both improved spatial and temporal resolution.

8. Furian et al. (2015). **Cerebral oxygenation in highlanders with and without high-altitude pulmonary hypertension**

Abstract: High-altitude pulmonary hypertension (HAPH), a chronic altitude-related illness, causes hypoxaemia and impaired exercise performance. We evaluated the hypothesis that haemodynamic limitation and hypoxaemia in patients with HAPH are associated with impaired cerebral tissue oxygenation (CTO) compared

with healthy highlanders (HH) and lowlanders (LL). We studied 36 highlanders with HAPH and 54 HH at an altitude of 3250 m, and 34 LL at 760 m. Mean(±SD) pulmonary artery pressures were 34(±3), 22(±5) and 16(±4) mmHg, respectively ($P < 0.05$, all comparisons). The CTO was monitored by near-infrared spectroscopy along with pulse oximetry (peripheral arterial oxygen saturation, inline image) during quiet breathing of room air (RA) and oxygen for 20 min each, and during hyperventilation with RA and oxygen, respectively. In HAPH, HH and LL breathing RA, inline image was 88(±4), 92(±2) and 95(±2)%, respectively ($P < 0.001$, all comparisons), and CTO was similar in the three groups, at 68(±3), 68(±4) and 69(±4)%, respectively (n.s., all comparisons). Breathing oxygen increased inline image and CTO significantly more in HAPH than in HH and LL. Hyperventilation (RA) did not reduce CTO in HAPH but did in HH and LL; hyperventilation (oxygen) increased CTO in HAPH only. Highlanders with and without HAPH studied at 3250 m had a similar CTO to healthy lowlanders at 760 m even though highlanders were hypoxaemic. The physiological response to hyperoxia and hypocapnia assessed by cerebral near-infrared spectroscopy suggests that healthy highlanders and even highlanders with HAPH effectively maintain an adequate CTO. This adaptation may be of particular relevance because adequate cerebral oxygenation is essential for vital brain functions.

9. Hassanpour et al. (2015). **Mapping cortical responses to speech using high-density diffuse optical tomography**

Abstract: The functional neuroanatomy of speech processing has been investigated using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) for more than 20 years. However, these approaches have relatively poor temporal resolution and/or challenges of acoustic contamination due to the constraints of echoplanar fMRI. Furthermore, these methods are contraindicated because of safety concerns in longitudinal studies and research with children (PET) or in studies of patients with metal implants (fMRI). High-density diffuse optical tomography (HD-DOT) permits presenting speech in a quiet acoustic environment, has excellent temporal resolution relative to the hemodynamic response, and provides noninvasive and metal-compatible imaging. However, the performance of HD-DOT in imaging the brain regions involved in speech processing is not fully established. In the current study, we use an auditory sentence comprehension task to evaluate the ability of HD-DOT to map the cortical networks supporting speech processing. Using sentences with two levels of linguistic complexity, along with a control condition consisting of unintelligible noise-vocoded speech, we recovered a hierarchically organized speech network that matches the results of previous fMRI studies. Specifically, hearing intelligible speech resulted in increased activity in bilateral temporal cortex and left frontal cortex, with syntactically complex speech leading to additional activity in left posterior temporal cortex and left inferior frontal gyrus. These results demonstrate the feasibility of using HD-DOT to map spatially distributed brain networks supporting higher-order cognitive faculties such as spoken language.

10. Lague-Beauvais et al. (2015). **Shedding light on the effect of priority instructions during dual-task performance in younger and older adults: A fNIRS study**

Abstract: Age-related differences in the ability to perform two tasks simultaneously (or dual-task) have become a major concern in aging neurosciences and have often been assessed with two distinct paradigms; the Psychological Refractory Period (PRP) and the Dual-Task (DT) paradigms. PRP studies assess participants when they give Priority to one task over the other (complete A then B), whereas in DT studies participants give Equal priority to both tasks (complete A and B). The Equal condition could be viewed as adding an executive control component to the task since the participants must spontaneously monitor attention between tasks. In the current study, we assessed the effect of priority instructions (Priority vs. Equal) on the dual-task performance and brain activity of younger (n = 16) and older adults (n = 19) with functional near infra-red spectroscopy (fNIRS). In younger adults, the Priority condition showed right-sided activation in the prefrontal cortex during DT execution. Older adults showed bilateral frontal activation, yet restrained to specific areas. They showed increased activation in DT vs. single task condition in the left dorsolateral prefrontal cortex (DLPFC) and the bilateral ventrolateral prefrontal cortex (VLPFC). In the Equal condition, the DT condition showed isolated left

DLPFC and VLPFC activation in younger adults and widespread bilateral DLPFC activation in older adults. These results suggest that for both older and younger adults, priority effects are associated with distinct patterns of prefrontal activation. Age-related differences also exist in these patterns such that prefrontal activation seems to be more spread out at different sites in older adults when they are instructed to give Equal priority to both tasks.

11. Massaro et al. (2015). **Impaired cerebral autoregulation and brain injury in newborns with hypoxic-ischemic encephalopathy treated with hypothermia**

Abstract: Impaired cerebral autoregulation may contribute to secondary injury in newborns with hypoxic-ischemic encephalopathy (HIE). Continuous, noninvasive assessment of cerebral pressure autoregulation can be achieved with bedside near-infrared spectroscopy (NIRS) and systemic mean arterial blood pressure (MAP) monitoring. This study aimed to evaluate whether impaired cerebral autoregulation measured by NIRS-MAP monitoring during therapeutic hypothermia and rewarming relates to outcome in 36 newborns with HIE. Spectral coherence analysis between NIRS and MAP was used to quantify changes in the duration [pressure passivity index (PPI)] and magnitude (gain) of cerebral autoregulatory impairment. Higher PPI in both cerebral hemispheres and gain in the right hemisphere were associated with neonatal adverse outcomes [death or detectable brain injury by magnetic resonance imaging (MRI), $P < 0.001$]. NIRS-MAP monitoring of cerebral autoregulation can provide an ongoing physiological biomarker that may help direct care in perinatal brain injury.

12. Singh-Moon et al. (2015). **Near-infrared spectroscopy integrated catheter for characterization of myocardial tissues: preliminary demonstrations to radiofrequency ablation therapy for atrial fibrillation**

Abstract: Effects of radiofrequency ablation (RFA) treatment of atrial fibrillation can be limited by the ability to characterize the tissue in contact. Parameters obtained by conventional catheters, such as impedance and temperature can be insufficient in providing physiological information pertaining to effective treatment. In this report, we present a near-infrared spectroscopy (NIRS)-integrated catheter capable of extracting tissue optical properties. Validation experiments were first performed in tissue phantoms with known optical properties. We then apply the technique for characterization of myocardial tissues in swine and human hearts, ex vivo. Additionally, we demonstrate the recovery of critical parameters relevant to RFA therapy including contact verification, and lesion transmurality. These findings support the application of NIRS for improved guidance in RFA therapeutic interventions.

13. Grant et al. (2015). **Hemodynamic changes in the prefrontal cortex during working memory in essential hypertension**

Abstract: Behavioral performance and hemodynamic changes in the prefrontal cortex (PFC) represent cerebrovascular reserve and may indicate functional deficits related to essential hypertension. Fifteen stage 1 hypertensive and normotensive males (19–55 years) were compared on four tests of working memory (digit span and auditory consonant trigrams), and accompanying hemodynamic changes measured by functional near infrared spectroscopy (fNIRS). With participants blindfolded, the four tests were randomized while fNIRS was used to monitor bilateral PFC changes in oxyhemoglobin (O2Hb), deoxyhemoglobin (HHb), total hemoglobin (tHb), and hemoglobin difference. The hypertensive group demonstrated significant impairment in performance on the working memory tests with a trend of decreased efficiency performance scores (tests score/O2Hb and tHb changes). Significant correlations were noted in the hypertensive group between test performance and changes in O2Hb and tHb in both the left and right PFC. These findings suggest that fNIRS combined with cognitive testing may provide important measures of cerebrovascular reserve in essential hypertension.

14. Huang et al. (2015). **Effects of Synchronization during Noninvasive Intermittent Mandatory Ventilation in Preterm Infants with Respiratory Distress Syndrome Immediately after Extubation**

Abstract: Background: Noninvasive ventilation is increasingly used in very-low-birth-weight infants (VLBWI) to reduce complications that occur with invasive ventilation. However, the physiological effects of synchronization during noninvasive nasal intermittent mandatory ventilation (IMV) have not been tested in VLBWI immediately after extubation. Objective: We aimed to study the short-term effects of synchronized nasal IMV (S-NIMV) compared to nonsynchronized nasal IMV (NIMV) on breathing effort as measured by phasic esophageal pressure (Pe) deflection, spontaneous respiratory rate (RR), gas exchange, cerebral tissue oxygen saturation (StO2) and intermittent episodes of bradycardia or hypoxemia in VLBWI recovering from respiratory distress syndrome (RDS). Methods: Fourteen VLBWI recovering from RDS were studied using a randomized cross-over design during both S-NIMV and NIMV (of 2 h each) immediately after extubation. Results: Phasic Pe deflection, spontaneous RR and transcutaneous PCO2 decreased significantly while transcutaneous PO2 and synchrony rate (defined as peak ventilator pressure delivered within the first half of spontaneous inspiration) increased significantly during S-NIMV compared to during NIMV. There was no difference in blood pressure, average arterial oxygen saturation (SpO2), cerebral StO2, fractional tissue oxygen extraction of the brain and severe bradycardia (defined as time with a heart rate <100 beats/min lasting ≥10 s) and in hypoxemic episodes (SpO2 <80%) between the two modes. Conclusion: Synchronization during nasal ventilation immediately after extubation in VLBWI recovering from RDS improved gas exchange and decreased the respiratory effort, and it could therefore be considered to provide a more efficient respiratory support and synchrony.

15. Ravicz et al. (2015). **Infants' neural responses to facial emotion in the prefrontal cortex are correlated with temperament: a functional near-infrared spectroscopy study**

Abstract: Accurate decoding of facial expressions is critical for human communication, particularly during infancy, before formal language has developed. Different facial emotions elicit distinct neural responses within the first months of life. However, there are broad individual differences in such responses, so that the same emotional expression can elicit different brain responses in different infants. In this study, we sought to investigate such differences in the processing of emotional faces by analyzing infants's cortical metabolic responses to face stimuli and examining whether individual differences in these responses might vary as a function of infant temperament. Seven-month-old infants (N = 24) were shown photographs of women portraying happy expressions, and neural activity was recorded using functional near-infrared spectroscopy (fNIRS). Temperament data were collected using the Revised Infant Behavior Questionnaire Short Form, which assesses the broad temperament factors of Surgency/Extraversion (S/E), Negative Emotionality (NE), and Orienting/Regulation (O/R). We observed that oxyhemoglobin (oxyHb) responses to happy face stimuli were negatively correlated with infant temperament factors in channels over the left prefrontal cortex (uncorrected for multiple comparisons). To investigate the brain activity underlying this association, and to explore the use of fNIRS in measuring cortical asymmetry, we analyzed hemispheric asymmetry with respect to temperament groups. Results showed preferential activation of the left hemisphere in low-NE infants in response to smiling faces. These results suggest that individual differences in temperament are associated with differential prefrontal oxyHb responses to faces. Overall, these analyses contribute to our current understanding of face processing during infancy, demonstrate the use of fNIRS in measuring prefrontal asymmetry, and illuminate the neural correlates of face processing as modulated by temperament.

16. Broxterman et al. (2015). **Influence of blood flow occlusion on the development of peripheral and central fatigue during small muscle mass handgrip exercise**

Abstract: The influence of the muscle metabolic milieu on peripheral and central fatigue is currently unclear. Moreover, the relationships between peripheral and central fatigue and the curvature constant (W′) have not

been investigated. Six men (age: 25 ± 4 years, body mass: 82 ± 10 kg, height: 179 ± 4 cm) completed four constant power handgrip tests to exhaustion under conditions of control exercise (Con), blood flow occlusion exercise (Occ), Con with 5 min post-exercise blood flow occlusion (Con + Occ), and Occ with 5 min post-exercise blood flow occlusion (Occ + Occ). Neuromuscular fatigue measurements and W′ were obtained for each subject. Each trial resulted in significant peripheral and central fatigue. Significantly greater peripheral (79.7 ± 5.1% vs. 22.7 ± 6.0%) and central (42.6 ± 3.9% vs. 4.9 ± 2.0%) fatigue occurred for Occ than for Con. In addition, significantly greater peripheral (83.0 ± 4.2% vs. 69.0 ± 6.2%) and central (65.5 ± 14.6% vs. 18.6 ± 4.1%) fatigue occurred for Occ + Occ than for Con + Occ. W′ was significantly related to the magnitude of global (r = 0.91) and peripheral (r = 0.83) fatigue. The current findings demonstrate that blood flow occlusion exacerbated the development of both peripheral and central fatigue and that post-exercise blood flow occlusion prevented the recovery of both peripheral and central fatigue. Moreover, the current findings suggest that W′ may be determined by the magnitude of fatigue accrued during exercise.

17. Shidoh et al. (2015). **The process of change in hemodynamics after revascularization in the ischemic brain**

Abstract: In patients with a high-degree of internal carotid artery stenosis, cerebral hemodynamics and metabolism are compromised during ischemia. Revascularization improves cortical hemodynamics and oxygen metabolism during functional activity, but the process by which it occurs is still controversial. Therefore, using functional near-infrared spectroscopy (fNIRS), we investigated the process by which cerebral hemodynamics improve after revascularization surgery. Eight patients with severe carotid artery stenosis were examined using fNIRS during a motor task before and after surgery. We evaluated postoperative changes in total hemoglobin and deoxyhemoglobin (HbR), at 2 weeks after surgery, and again at 3 months after surgery. Parameters measured were the TTP (time to peak) value, defined as the time taken to reach 70% of the maximum total hemoglobin concentration, and the increase in HbR during the motor task. TTP was higher in four patients preoperatively, but this was no longer evident in two of the patients at 2 weeks after surgery. An increase in HbR during the task was observed in six patients before surgery, and was maintained at 2 weeks after surgery. However, in three of these patients, this increase was no longer evident 3 months later. These changes observed using fNIRS suggest that the increase in cerebral blood flow after revascularization surgery is followed by improvement in parenchymal vasodilation and neuronal oxygen metabolism.

18. Sood et al. (2015). **Anterior temporal artery tap to identify systemic interference using short-separation NIRS measurements: A NIRS/EEG-tDCS study**

Abstract: Transcranial direct current stimulation (tDCS) has been shown to modulate neural activity. Neural activity has been shown to be closely related, spatially and temporally, to cerebral blood flow (CBF) that supplies glucose via neurovascular coupling. Therefore, noninvasive and continuous monitoring of neural activity is possible with a measure of cerebral hemoglobin oxygenation using near-infrared spectroscopy (NIRS). In principal accordance, NIRS can capture the hemodynamic response to tDCS but the challenge remains in removing the systemic interference occurring in the superficial layers of the head that are also affected by tDCS. An approach may be to use short optode separations to measure systemic hemodynamic fluctuations occurring in the superficial layers which can then be used as regressors to remove the systemic contamination. Here, we demonstrate that temporal artery tap may be used to better identify systemic interference using this short-separation NIRS. Moreover, NIRS-EEG joint-imaging during anodal tDCS was used to measure changes in mean cerebral haemoglobin oxygen saturation (rSO2) along with changes in the log-transformed mean-power of EEG within 0.5 Hz-11.25 Hz. We found that percent change in the mean rSO2 better correlated with the corresponding percent change in log-transformed mean-power of EEG within 0.5 Hz-11.25 Hz frequency band after removing the systemic contamination using the temporal artery tap method. Based on our findings, we propose that anterior temporal artery tap technique presented in this paper may be able to classify carotid stenosis, external carotid artery stenosis, and internal carotid artery stenosis patients using the laterality in the

hemodynamic response evoked by anodal tDCS both at the brain as well as at the superficial layers. These findings may have important implications for both prognosis and rehabilitation of patients with intracranial stenosis.

19. Sugiura et al. (2015). **Effects of sex and proficiency in second language processing as revealed by a large-scale fNIRS study of school-aged children**

Abstract: Previous neuroimaging studies in adults have revealed that first and second languages (L1/L2) share similar neural substrates, and that proficiency is a major determinant of the neural organization of L2 in the lexical-semantic and syntactic domains. However, little is known about neural substrates of children in the phonological domain, or about sex differences. Here, we conducted a large-scale study (n = 484) of school-aged children using functional near-infrared spectroscopy and a word repetition task, which requires a great extent of phonological processing. We investigated cortical activation during word processing, emphasizing sex differences, to clarify similarities and differences between L1 and L2, and proficiency-related differences during early L2 learning. L1 and L2 shared similar neural substrates with decreased activation in L2 compared to L1 in the posterior superior/middle temporal and angular/supramarginal gyri for both sexes. Significant sex differences were found in cortical activation within language areas during high-frequency word but not during low-frequency word processing. During high-frequency word processing, widely distributed areas including the angular/supramarginal gyri were activated in boys, while more restricted areas, excluding the angular/supramarginal gyri were activated in girls. Significant sex differences were also found in L2 proficiency-related activation: activation significantly increased with proficiency in boys, whereas no proficiency-related differences were found in girls. Importantly, cortical sex differences emerged with proficiency. Based on previous research, the present results indicate that sex differences are acquired or enlarged during language development through different cognitive strategies between sexes, possibly reflecting their different memory functions.

20. Messere et al. (2015). **Local and remote thermoregulatory changes affect NIRS measurement in forearm muscles**

Abstract: Purpose: Near infrared spectroscopy (NIRS) assessment in skeletal muscle is potentially affected by circulatory changes occurring in superficial tissues. The aim of this study was to separately assess the interference from skin microcirculation and large vein blood flow by investigating the effect of selective local and remote warming-induced vasodilation, respectively.
Methods: Blood volume and oxygenation changes were investigated in the forearm muscles of healthy subjects in two experimental series (ES) during selective forearm (ES1, n = 12) or hand warming (ES2, n = 10). In ES1, the response to muscle contraction (10 s, 70 % MVC) and occlusion before and after warming was also investigated, while in ES2 two NIRS probes were expressly positioned over a visible vein and over a vein-free area.
Results: Local warming increased the modified Beer–Lambert (BL) blood volume indicator, tHb, by 5.3 ± 3.6 μmol/L cm to an extent comparable to post-contraction hyperemia (6.8 ± 2.9 μmol/L cm, $p < 0.01$). Remote warming increased skin blood flow at the hand and tHb at both forearm sites (on average: 5.4 ± 4.8 μmol/L cm, $p < 0.01$). Conversely, indicators of blood volume and oxygenation, based on spatially resolved spectroscopy (SRS), were not affected by any of the warming stimuli.
Conclusions: These results demonstrate for the first time that: (1) blood drained by superficial veins may affect BL measurement; (2) it is difficult to exclude veins from the measurement by simple visual inspection of the cutaneous surface; (3) SRS effectively rejects artifacts from superficial hemodynamic changes in both cutaneous microcirculation and large veins. These results bear implications to conditions in which thermoregulatory adjustments cannot be excluded.

21. Sørensen et al. (2015). **Near-infrared spectroscopy assessed cerebral oxygenation during open abdominal aortic aneurysm repair: relation to end-tidal CO_2 tension**

Abstract: During open abdominal aortic aneurism (AAA) repair cerebral blood flow is challenged. Clamping of the aorta may lead to unintended hyperventilation as metabolism is reduced by perfusion of a smaller part of the body and reperfusion of the aorta releases vasodilatory substances including CO2. We intend to adjust ventilation according end-tidal CO2 tension (EtCO2) and here evaluated to what extent that strategy maintains frontal lobe oxygenation (ScO2) as determined by near infrared spectroscopy. For 44 patients [5 women, aged 70 (48–83) years] ScO2, mean arterial pressure (MAP), EtCO2, and ventilation were obtained retrospectively from the anesthetic charts. By clamping the aorta, ScO2 and EtCO2 were kept stable by reducing ventilation (median, −0.8 l min−1; interquartile range, −1.1 to −0.4; P < 0.001). During reperfusion of the aorta a reduction in MAP by 8 mmHg (−15 to −1; P < 0.001) did not prevent an increase in ScO2 by 2 % (−1 to 4; P < 0.001) as EtCO2 increased 0.5 kPa (0.1–1.0; P < 0.001) despite an increase in ventilation by 1.8 l min−1 (0.9–2.7; P < 0.001). Changes in ScO2 related to those in EtCO2 (r = 0.41; P = 0.0001) and cerebral deoxygenation (−15 %) was noted in three patients while cerebral hyperoxygenation (+15 %) manifests in one patient. Thus changes in ScO2 were kept within acceptable limits (±15 %) in 91 % of the patients. For the majority of the patients undergoing AAA repair ScO2 was kept within reasonable limits by reducing ventilation by approximately 1 l min−1 upon clamping of the aorta and increasing ventilation by approximately 2 l min−1 when the lower body is reperfused.

22. Miyata et al. (2015). **Impaired cortical oxygenation is related to mood disturbance resulting from three nights of sleep restriction**

Abstract: Chronic sleep restriction adversely effects cognitive performance and mood, resulting in accidents and economic loss. We examined the effects of three nights of sleep restriction on cortical oxygenation, cognitive performance and mood. We studied 14 young adults. All subjects spent ≥8 h/night in bed prior to the study day (sufficient sleep), followed by <4 h/night in bed for 3 days (insufficient sleep). Oxyhemoglobin (oxyHb) levels were measured with near-infrared spectroscopy during a word fluency task, and subjects underwent a continuous performance test-identical pairs version (CPT-IP) and filled out the Profile of Mood States (POMS) questionnaire. Peak oxyHb levels after the first and third insufficient sleep nights were significantly lower than that after the sufficient sleep night. Sustained reaction time after the first and third insufficient sleep nights was significantly shorter than that after the sufficient sleep night. Correct response on the CPT-IP after the first and third insufficient sleep nights was significantly less than after the sufficient sleep night. POMS vigor scores after the first and third insufficient sleep nights were both significantly lower than that after the sufficient sleep night. Fatigue and total mood disturbance scores of POMS were significantly higher after the third insufficient sleep night than those after the sufficient sleep night. Three nights of sleep restriction reduced the cortical oxygenation response, and might impair cognitive performance and promote mood disturbance.

23. Gorman et al. (2015). **Effects of ibuprofen on cerebral and somatic regional tissue oxygenation, using near-infrared spectroscopy in preterm infants <1500g with a patent ductus arteriosus**

Abstract: Background: Patent ductus arteriosus (PDA) is a common finding in premature infants, and there are conflicting studies about the indications and benefits for medical or surgical intervention. Near-infrared spectroscopy (NIRS) allows bedside, noninvasive monitoring of tissue perfusion or oxygenation of underlying organs. Objectives: The objective of this study was to investigate the impact of ibuprofen on regional tissue oxygenation in the cerebral and somatic circulation using NIRS in infants medically treated for an hemodynamically significant PDA. Materials and Methods: This was a prospective observational study in the Neonatal Intensive Care Unit of Rotunda Maternity Hospital from May 2011 to April 2012. All infants <34 weeks and <1500 g with a PDA confirmed on echocardiogram were enrolled in the study. NIRS sensor was applied at least 1 h pre-treatment and at least 9 h during treatment after the first dose of ibuprofen. Nontreatment patients were infants who met the above criteria, but did not receive ibuprofen. Results: There are

a total of 20 recordings for 18 infants; 10 infants received ibuprofen and 10 infants who were not treated. In the treatment group, 1 infant received ibuprofen on two occasions. One infant was initially in the nontreatment group and later received ibuprofen therapy. The mean (standard deviation [SD]) cerebral regional oxygenation (CrO 2 %) pretreatment was 68.1 (±6.28) % and during treatment was 68.56 (±6.43) %. The mean (SD) somatic regional oxygenation (SrO2 %) pretreatment was 40.9 (+/25.3) % and during treatment was 48.6 (±20.4) %. In the nontreatment group, the mean (SD) CrO 2 was 66.8 (±8.75) % and SrO 2 was 45.7 (23.75) %. Conclusion: This study highlights the equipoise and clinical dilemma surrounding managing preterm babies with PDAs. NIRS does not seem to be a helpful adjunct in stratifying those high-risk babies who may benefit from ductal closure, that is, babies where PDA is affecting tissue oxygenation. However, in the one baby who had a significant complication necrotizing enterocolitis, NIRS did identify early a significant change in the somatic oxygenation, 30% drop from baseline. Even when a PDA is considered hemodynamically significant by a Consultant Paediatric Cardiologist, it appears to have little or no effect on CrO 2 and SrO 2 saturation. In comparison to indomethacin, ibuprofen had little or no effect on CrO 2 and SrO 2 .

24. Dong et al. (2015). **Deep Tissue Hemodynamic Monitoring Using Diffuse Optical Probes**

Abstract: To see what is happening under our skin using light would have been a dream, as there are many strong absorbers and scatterers that act as hindrances for imaging purpose. Although light penetrates the skin a little and it is possible to image and monitor superficial blood flow using light illumination, it remains as a challenge to probe deep tissue (roughly 0.1 ~ 3.0 cm) using light alone. In this chapter, we describe the challenges and recent achievements of diffuse optical methods to probe deep tissue, running the gamut from diffuse optical spectroscopy (DOS) and diffuse optical tomography (DOT) to recently developed diffuse speckle contrast analysis (DSCA). Diffuse optics has opened up a new possibility of non-invasive diagnosis of lesions in deep tissue. In addition, the usage of light makes diffuse optics-based device compatible with other conventional medical devices such as CT and MRI as well as some implanted device such as pace maker. Moreover, diffuse optics-based device is relatively cost-effective and portable. These merits could limitlessly extend its application to primary care unit, bedside monitoring, and operation theater as an optimal modality for probing hemodynamic parameters in microvasculature in deep tissue.

25. Inoue et al. (2015). **Differences in the Pattern of Hemodynamic Response to Self-Face and Stranger-Face Images in Adolescents with Anorexia Nervosa: A Near-Infrared Spectroscopic Study**

Abstract: There have been no reports concerning the self-face perception in patients with anorexia nervosa (AN). The purpose of this study was to compare the neuronal correlates of viewing self-face images (i.e. images of familiar face) and stranger-face images (i.e. images of an unfamiliar face) in female adolescents with and without AN. We used near-infrared spectroscopy (NIRS) to measure hemodynamic responses while the participants viewed full-color photographs of self-face and stranger-face. Fifteen females with AN (mean age, 13.8 years) and 15 age- and intelligence quotient (IQ)-matched female controls without AN (mean age, 13.1 years) participated in the study. The responses to photographs were compared with the baseline activation (response to white uniform blank). In the AN group, the concentration of oxygenated hemoglobin (oxy-Hb) significantly increased in the right temporal area during the presentation of both the self-face and stranger-face images compared with the baseline level. In contrast, in the control group, the concentration of oxy-Hb significantly increased in the right temporal area only during the presentation of the self-face image. To our knowledge the present study is the first report to assess brain activities during self-face and stranger-face perception among female adolescents with AN. There were different patterns of brain activation in response to the sight of the self-face and stranger-face images in female adolescents with AN and controls.

26. Seong et al. (2015). **A fiber optic probe coupled low-cost CMOS-camera-based system for simultaneous measurement of oxy-, deoxyhemoglobin, and blood flow**

Abstract: Appropriate oxygen supply and blood flow are important in coordination of body functions and maintaining a life. To measure both oxygen supply and blood flow simultaneously, we developed a system that combined near-infrared spectroscopy (NIRS) and diffuse speckle contrast analysis (DSCA). Our system is more cost effective and compact than such combined systems as diffuse correlation spectroscopy (DCS)-NIRS or DCS flow oximeter, and also offers the same quantitative information. In this article, we present the configuration of DSCA-NIRS and preliminary data from an arm cuff occlusion and a repeated gripping exercise. With further investigation, we believe that DSCA-NIRS can be a useful tool for the field of neuroscience, muscle physiology and metabolic diseases such as diabetes.

27. Muthalib et al. (2015). **Effects of Increasing Neuromuscular Electrical Stimulation Current Intensity on Cortical Sensorimotor Network Activation: A Time Domain fNIRS Study**

Abstract: Neuroimaging studies have shown neuromuscular electrical stimulation (NMES)-evoked movements activate regions of the cortical sensorimotor network, including the primary sensorimotor cortex (SMC), premotor cortex (PMC), supplementary motor area (SMA), and secondary somatosensory area (S2), as well as regions of the prefrontal cortex (PFC) known to be involved in pain processing. The aim of this study, on nine healthy subjects, was to compare the cortical network activation profile and pain ratings during NMES of the right forearm wrist extensor muscles at increasing current intensities up to and slightly over the individual maximal tolerated intensity (MTI), and with reference to voluntary (VOL) wrist extension movements. By exploiting the capability of the multi-channel time domain functional near-infrared spectroscopy technique to relate depth information to the photon time-of-flight, the cortical and superficial oxygenated (O2Hb) and deoxygenated (HHb) hemoglobin concentrations were estimated. The O2Hb and HHb maps obtained using the General Linear Model (NIRS-SPM) analysis method, showed that the VOL and NMES-evoked movements significantly increased activation (i.e., increase in O2Hb and corresponding decrease in HHb) in the cortical layer of the contralateral sensorimotor network (SMC, PMC/SMA, and S2). However, the level and area of contralateral sensorimotor network (including PFC) activation was significantly greater for NMES than VOL. Furthermore, there was greater bilateral sensorimotor network activation with the high NMES current intensities which corresponded with increased pain ratings. In conclusion, our findings suggest that greater bilateral sensorimotor network activation profile with high NMES current intensities could be in part attributable to increased attentional/pain processing and to increased bilateral sensorimotor integration in these cortical regions.

28. Monden et al. (2015). **Individual classification of ADHD children by right prefrontal hemodynamic responses during a go/no-go task as assessed by fNIRS**

Abstract: While a growing body of neurocognitive research has explored the neural substrates associated with attention deficit hyperactive disorder (ADHD), an objective biomarker for diagnosis has not been established. The advent of functional near-infrared spectroscopy (fNIRS), which is a noninvasive and unrestrictive method of functional neuroimaging, raised the possibility of introducing functional neuroimaging diagnosis in young ADHD children. Previously, our fNIRS-based measurements successfully visualized the hypoactivation pattern in the right prefrontal cortex during a go/no-go task in ADHD children compared with typically developing control children at a group level. The current study aimed to explore a method of individual differentiation between ADHD and typically developing control children using multichannel fNIRS, emphasizing how spatial distribution and amplitude of hemodynamic response are associated with inhibition-related right prefrontal dysfunction. Thirty ADHD and thirty typically developing control children underwent a go/no-go task, and their cortical hemodynamics were assessed using fNIRS. We explored specific regions of interest (ROIs) and cut-off amplitudes for cortical activation to distinguish ADHD children from control children. The ROI located on the

border of inferior and middle frontal gyri yielded the most accurate discrimination. Furthermore, we adapted well-formed formulae for the constituent channels of the optimized ROI, leading to improved classification accuracy with an area under the curve value of 85% and with 90% sensitivity. Thus, the right prefrontal hypoactivation assessed by fNIRS would serve as a potentially effective biomarker for classifying ADHD children at the individual level.

29. Zaidi et al. (2015). **Simultaneous epidural functional near-infrared spectroscopy and cortical electrophysiology as a tool for studying local neurovascular coupling in primates**

Abstract: Simultaneous measurements of intra-cortical electrophysiology and hemodynamic signals in primates are essential for relating human neuroimaging studies with intra-cortical electrophysiology in monkeys. Previously, technically challenging and resourcefully demanding techniques such as fMRI and intrinsic-signal optical imaging have been used for such studies. Functional near-infrared spectroscopy is a relatively less cumbersome neuroimaging method that uses near-infrared light to detect small changes in concentrations of oxy-hemoglobin (HbO), deoxy-hemoglobin (HbR) and total hemoglobin (HbT) in a volume of tissue with high specificity and temporal resolution. FNIRS is thus a good candidate for hemodynamic measurements in primates to acquire local hemodynamic signals during electrophysiological recordings. To test the feasibility of using epidural fNIRS with concomitant extracellular electrophysiology, we recorded neuronal and hemodynamic activity from the primary visual cortex of two anesthetized monkeys during visual stimulation. We recorded fNIRS epidurally, using one emitter and two detectors. We performed simultaneous cortical electrophysiology using tetrodes placed between the fNIRS sensors. We observed robust and reliable responses to the visual stimulation in both [HbO] and [HbR] signals, and quantified the signal-to-noise ratio of the epidurally measured signals. We also observed a positive correlation between stimulus-induced modulation of [HbO] and [HbR] signals and strength of neural modulation. Briefly, our results show that epidural fNIRS detects single-trial responses to visual stimuli on a trial-by-trial basis, and when coupled with cortical electrophysiology, is a promising tool for studying local hemodynamic signals and neurovascular coupling.

30. Rodrigo et al. (2015). **Linking trait-based phenotypes to prefrontal cortex activation during inhibitory control**

Abstract: Inhibitory control is subserved in part by discrete regions of the prefrontal cortex whose functionality may be altered according to specific trait-based phenotypes. Using a unified model of normal range personality traits, we examined activation within lateral and medial aspects of the prefrontal cortex during a manual go/no-go task. Evoked hemodynamic oxygenation within the prefrontal cortex was measured in 106 adults using a 16-channel continuous-wave functional near-infrared spectroscopy system. Within lateral regions of the prefrontal cortex, greater activation was associated with higher trait levels of extraversion, agreeableness and conscientiousness, and lower neuroticism. Higher agreeableness was also related to more activation in the medial prefrontal cortex during inhibitory control. These results suggest that personality traits reflecting greater emotional stability, extraversion, agreeableness and conscientiousness may be associated with more efficient recruitment of control processes subserved by lateral regions of the prefrontal cortex. These findings highlight key links between trait-based phenotypes and neural activation patterns in the prefrontal cortex underlying inhibitory control.

31. Tang et al. (2015). **Disturbance elimination in near-infrared spectroscopy by correlated empirical mode decomposition**

Abstract: Near-infrared spectroscopy (NIRS) is a noninvasive measurement method used to gain the information regarding brain activities through the scalp. Near-infrared light can penetrate several centimeters into the scalp tissue and indicate the oxygen concentration in the outer part of the cerebral cortex. Three major

disturbances of NIRS are respiratory, the heartbeat, and Mayer waves. The nonlinear coupling between signals and noise can lead to the loss of meaningful information when linear noise-removal methods are applied. To resolve this problem, correlated empirical mode decomposition (CEMD), a new algorithm used to extract the common modes between two correlated signals, was adopted to separate the signal and disturbance. Public NIRS data were used as a pure input signal, and respiratory and electrocardiogram signals were added to it. The correlated intrinsic mode functions associated with the known disturbances were eliminated through the CEMD screening process. The spectrum results indicated that the energy of the additional signals can be eliminated. The CEMD method can eliminate the disturbances and thus reduce their effects on signal analyses.

32. Iwata et al. (2015). **Application of Functional Near-infrared Spectroscopy to Ophthalmology**

Abstract: In recent years, functional near-infrared spectroscopy (fNIRS) has come to be widely used in the field of medicine. fNIRS may also possibly be applied to objective visual acuity testing, and other areas. Here, we describe fNIRS, which is relatively unknown in the field of ophthalmology. fNIRS can be used to easily and non-invasively measure the localization of brain function under a low-degree restraint by using near-infrared light. However, fNIRS has some disadvantages such as its measurements revealing relative, and not absolute, values. fNIRS additionally faces a variety of problems in applications for objective visual acuity testing in daily clinical ophthalmology. However, given the remarkable rate of modern technology development, fNIRS may well grow to fill this role in the future.

33. Zhang et al. (2015). **Multiregional functional near-infrared spectroscopy reveals globally symmetrical and frequency-specific patterns of superficial interference**

Abstract: Linear regression with short source-detector separation channels (S-channels) as references is an efficient way to overcome significant physiological interference from the superficial layer for functional near-infrared spectroscopy (fNIRS). However, the co-located configuration of S-channels and long source-detector separation channels (L-channels) is difficult to achieve in practice. In this study, we recorded superficial interference with S-channels in multiple scalp regions. We found that superficial interference has overall frequency-specific and globally symmetrical patterns. The performance of linear regression is also dependent on these patterns, indicating the possibility of simplifying the S-channel configurations for multiregional fNIRS imaging.

34. Dutta et al. (2015). **Bidirectional interactions between neuronal and hemodynamic responses to transcranial direct current stimulation (tDCS): challenges for brain-state dependent tDCS**

Abstract: Transcranial direct current stimulation (tDCS) has been shown to modulate cortical neural activity. During neural activity, the electric currents from excitable membranes of brain tissue superimpose in the extracellular medium and generate a potential at scalp, which is referred as the electroencephalogram (EEG). Respective neural activity (energy demand) has been shown to be closely related, spatially and temporally, to cerebral blood flow (CBF) that supplies glucose (energy supply) via neurovascular coupling. The hemodynamic response can be captured by near-infrared spectroscopy (NIRS), which enables continuous monitoring of cerebral oxygenation and blood volume. This neurovascular coupling phenomenon led to the concept of neurovascular unit (NVU) that consists of the endothelium, glia, neurons, pericytes, and the basal lamina. Here, recent works suggest NVU as an integrated system working in concert using feedback mechanisms to enable proper brain homeostasis and function where the challenge remains in capturing these mostly nonlinear spatiotemporal interactions within NVU for brain-state dependent tDCS. In principal accordance, we propose EEG-NIRS-based whole-head monitoring of tDCS-induced neuronal and hemodynamic alterations during tDCS.

35. Bembich et al. (2015). **Pain activates a defined area of the somatosensory and motor cortex in newborn infants**

Abstract: not available

36. Almajidy et al. (2015). **Novel near infrared sensors for hybrid BCI applications**

Abstract: This study's goal is to develop a low cost, portable, accurate and comfortable NIRS module that can be used simultaneously with EEG in a dual modality system for brain computer interface (BCI). The sensing modules consist of electroencephalography (EEG) electrodes (at the positions Fp1, Fpz and Fp2 in the international 10-20 system) with eight custom made functional near infrared spectroscopy (fNIRS) channels, positioned on the prefrontal cortex area with two extra channels to measure and eliminate extra-cranial oxygenation. The NIRS sensors were designed to guarantee good sensor-skin contact, without causing subject discomfort, using springs to press them to the skin instead of pressing them by cap fixture. Two open source software packages were modified to carry out dual modality hybrid BCI experiments. The experimental paradigm consisted of a mental task (arithmetic task or text reading) and a resting period. Both oxygenated hemoglobin concentration changes (HbO), and EEG signals showed an increase during the mental task, but the onset, period and amount of that increase depends on each modality's characteristics. The subject's degree of attention played an important role especially during online sessions. The sensors can be easily used to acquire brain signals from different cerebral cortex parts. The system serves as a simple technological test bed and will be used for stroke patient rehabilitation purposes.

37. Pifferi et al. (2015). **Design and construction of a solid switchable phantom for diffuse optical imaging**

Abstract: We propose a simple and reliable solid phantom for mimicking realistic localized absorption changes within a diffusive medium. The phantom is based on a solid matrix holding a movable black inclusion embedded in a rod. Translating the rod parallel to the phantom surface, the inhomogeneity can be positioned beneath the source-detector pair (perturbed case) or far from it (unperturbed case). Examples of time-resolved transmittance measurements and time-resolved reflectance scans are shown to demonstrate the properties and the versatility of the phantom.

38. Lange et al. (2015). **A hyperspectral time resolved DOT system to monitor physiological changes of the human brain activity**

Abstract: Diffuse optical tomography (DOT) is a growing area of research in the field of biomedical optics and neurosciences. Over the past 20 years, technical development allowed a more and more accurate detection of the brain activation, both spatially and in the calculation of the variations of chromophores's concentrations such as Hemoglobin, cytochrome c oxidase, etc. In particular, time resolved systems are able to distinguish between superficial layers (skin, skull) and deep layers (brain) allowing the differentiation between the systemic response and the response of the brain. In order to increase the accuracy of the brain's activation detection, we have developed a Hyperspectral Time Resolved DOT system. It is composed of a compact supercontinuum laser within the picosecond range for the source part and of an ICCD camera coupled with an imaging spectrometer for the detection part. This allows a simultaneous detection of the spatial and spectral dimension, as well as the time of flight of photons. Through the information acquired by our system, we've been able to retrieve, to our knowledge, the first spectrum of the physiology of the human brain activity as function as depth. Here we present the instrument and show our first in-vivo results that are demonstrating its capabilities to distinguish between the skin's response and the brain's responses during a cognitive task. We are also focused on the detection of the Fast Optical Signal.

39. Wu et al. (2015). **Efficient method for near real-time diffuse optical tomography of the human brain**

Abstract: Previous studies have showed only regions with a sensitivity higher that 1% of the maximum value can affect the recovery result for diffuse optical tomography (DOT). Two methods of efficient sensitivity map generation based on Finite Element Models (FEM) are developed based on (1) reduced sensitivity matrix and (2) parallelisation process. Time and memory efficiency of these processes are evaluated and compared with conventional methods. It is shown that the computational time for a full head model containing 200k nodes is reduced from 3 hours to 48 minutes and the required memory is reduced from 5.5 GB to 0.5 GB. For a range of mesh densities up to 320k nodes, the required memory is improved by ~1000% and computational time by ~400% to allow near real-time image recovery.

40. Contini et al. (2015). **Time-domain diffuse optics: towards next generation devices**

Abstract: Diffuse optics is a powerful tool for clinical applications ranging from oncology to neurology, but also for molecular imaging, and quality assessment of food, wood and pharmaceuticals. We show that ideally time-domain diffuse optics can give higher contrast and a higher penetration depth with respect to standard technology. In order to completely exploit the advantages of a time-domain system a distribution of sources and detectors with fast gating capabilities covering all the sample surface is needed. Here, we present the building block to build up such system. This basic component is made of a miniaturised source-detector pair embedded into the probe based on pulsed Vertical-Cavity Surface-Emitting Lasers (VCSEL) as sources and Single-Photon Avalanche Diodes (SPAD) or Silicon Photomultipliers (SiPM) as detectors. The possibility to miniaturized and dramatically increase the number of source detectors pairs open the way to an advancement of diffuse optics in terms of improvement of performances and exploration of new applications. Furthermore, availability of compact devices with reduction in size and cost can boost the application of this technique.

41. Wabnitz et al. (2015). **Non-contact scanning time-domain functional optical imaging of the adult human brain**

Abstract: We developed a novel scanning system that relies on gated detection of late photons at short source-detector separation, enabling the recording of absorption changes in deep tissue compartments. The tissue was scanned by a galvanometer scanner from a distance of more than 10 cm, with a fixed separation of the illumination and the detection spot of a few mm. The light source was a supercontinuum laser with an acousto-optic tunable filter that was used to rapidly switch between two wavelength bands centered at 760 nm and 860 nm. A fast-gated single-photon avalanche diode was employed to eliminate the intense early part of the diffusely remitted signal and to detect photons with long times of flight with improved signal-to-noise ratio. A second detection channel contained a non-gated detector. The gated and non-gated time-of-flight distributions of photons were recorded by imaging time-correlated single photon counting synchronized with the movement of the scanner. A tissue area with dimensions of several cm was scanned with 32×32 pixels within a frame time of 1 s. Sensitivity and spatial resolution of the system were characterized by phantom measurements. In-vivo tests included functional brain activation by various tasks and demonstrated the feasibility of non-contact imaging of hemodynamic changes in the cerebral cortex.

42. Baskak et al. (2015). **Effect of a social defeat experience on prefrontal activity in schizophrenia**

Abstract: The social defeat (SD) hypothesis of schizophrenia posits that repeated experiences of SD may lead to sensitization of the mesolimbic dopaminergic system and to precipitation of psychosis. Based on previous definitions adapted to a human experimental paradigm, we prepared a computer simulation of SD to mimic this subjective experience. We measured prefrontal cortex (PFC) activity in subjects with schizophrenia and healthy

controls during exposure to a single SD experience with functional near infrared spectroscopy. PFC activity declined in both groups. Compared with the control condition, SD exposure was associated with a broader decline in left ventromedial, right medial and right lateral PFC activity in healthy controls (n=25), and a sharper decline in right ventrolateral PFC activity in subjects with schizophrenia (n=25). The activity in the right ventrolateral PFC, was significantly lower in patients compared with controls. This may be due to a deficiency in emotion regulation or self-control, or it may be related to impaired empathy in schizophrenia. Different patterns of brain activity during the SD experience in subjects with schizophrenia versus healthy controls may provide indirect evidence regarding the SD hypothesis of schizophrenia.

43. Di Sieno et al. (2015). **Time-resolved diffuse optical tomography for non-invasive flap viability assessment: pre-clinical tests on rats**

Abstract: We present a new setup for time-resolved diffuse optical tomography based on multiple source-detector acquisitions analysed by means of the Mellin-Laplace transform. The proposed setup has been used to perform pre-clinical measurements on rats in order to show its suitability for non-invasive assessment of flap viability.

44. Re et al. (2015). **Validation of time domain near infrared spectroscopy in muscle measurements: effect of a superficial layer**

Abstract: In reflectance spectroscopy, a major concern is the possibility to discriminate signals coming from different layers of the investigated medium. In this work, the case of time-domain near infrared spectroscopy of muscle is studied with particular attention in the estimation of the pathlength in the different tissue's layers and its impact in the calculation of chromophores concentration.

45. Huang et al. (2015). **Noncontact diffuse optical assessment of blood flow changes in head and neck free tissue transfer flaps**

Abstract: Knowledge of tissue blood flow (BF) changes after free tissue transfer may enable surgeons to predict the failure of flap thrombosis at an early stage. This study used our recently developed noncontact diffuse correlation spectroscopy to monitor dynamic BF changes in free flaps without getting in contact with the targeted tissue. Eight free flaps were elevated in patients with head and neck cancer; one of the flaps failed. Multiple BF measurements probing the transferred tissue were performed during and post the surgical operation. Postoperative BF values were normalized to the intraoperative baselines (assigning "1") for the calculation of relative BF change (rBF). The rBF changes over the seven successful flaps were 1.89±0.151.89±0.15, 2.26±0.132.26±0.13, and 2.43±0.132.43±0.13 (mean±standard errormean±standard error), respectively, on postoperative days 2, 4, and 7. These postoperative values were significantly higher than the intraoperative baseline values ($p<0.001p<0.001$), indicating a gradual recovery of flap vascularity after the tissue transfer. By contrast, rBF changes observed from the unsuccessful flaps were 1.14 and 1.34, respectively, on postoperative days 2 and 4, indicating less flow recovery. Measurement of BF recovery after flap anastomosis holds the potential to act early to salvage ischemic flaps.

46. Emberson et al. (2015). **Top-down modulation in the infant brain: Learning-induced expectations rapidly affect the sensory cortex at 6 months**

Abstract: Although infants are excellent learners, it is unclear whether infants use neural strategies similar to those of adults to track changes in their environment. One adult neural strategy is to use feedback connections to modulate sensory cortices based on their expectations. The current study provides, to our knowledge, the first

evidence that the fundamental architecture required for sensory feedback is already in place in infancy. This top-down modulation is especially impressive because the study employs an audiovisual task that requires the flexible use of long-range neural connections, and the infant brain is dominated by short-range neural connections with weak (e.g., unmyelinated) long-range connections. These results suggest that learners can use sophisticated top-down feedback neural strategies from an early age.

47. Binzoni et al. (2015). **Near-infrared photons: a non-invasive probe for studying bone blood flow regulation in humans**

Abstract: The study of bone blood flow regulation in humans has always represented a difficult task for the clinician and the researcher. Classical measurement techniques imply the presence of ionizing radiation or contrast agents, or they are slow or cannot be repeated too often in time. In the present review, we would like to give a perspective on how the optical approach might overcome some of these problems and give unique solutions to the study of bone blood flow regulation. We hope that the present contribution will encourage the scientific community to put a greater attention on this approach.

48. Guo et al. (2015). **Development of a Multi-Channel Compact-Size Wireless Hybrid sEMG/NIRS Sensor System for Prosthetic Manipulation**

Abstract: It is evident that surface electromyography (sEMG)-based approaches have inherent difficulty in coping with modern dominant applications of clinical diagnosis and human machine interface such as prosthetic manipulation. This paper presents a hybrid sensor to attentively overcome the difficulty with a clinical purpose of simultaneously acquiring electrophysiological, hemodynamic, and oxidative metabolic information of muscle activity, also with front-end conditioning circuit and Bluetooth module integrated and packaged. A multi-channel compact-size wireless hybrid sEMG/near-infrared spectroscopy (NIRS) acquisition system is developed, forming a platform to demonstrate individual sEMG and NIRS measurement capabilities, and their combination. Extensive experiments are carried out to explore sensor functionality based on the sEMG, NIRS, and their combination, convincingly addressing the capabilities meeting their commercial or state-of-the-art counterparts. Future work is targeted to extract the sEMG/NIRS sensor-based muscular fatigue which plays a crucial role in biomedical and clinical applications.

49. Tang et al. (2015). **Interpersonal brain synchronization in the right temporo-parietal junction during face-to-face economic exchange**

Abstract: In daily life, interpersonal interactions are influenced by uncertainty about other people's intentions. Face-to-face (FF) interaction reduces such uncertainty by providing external visible cues such as facial expression or body gestures and facilitates shared intentionality to promote belief of cooperative decisions and actual cooperative behaviors in interaction. However, so far little is known about interpersonal brain synchronization between two people engaged in naturally occurring FF interactions. In this study, we combined an adapted ultimatum game with functional near-infrared spectroscopy (fNIRS) hyperscanning to investigate how FF interaction impacts interpersonal brain synchronization during economic exchange. Pairs of strangers interacted repeatedly either FF or face-blocked (FB), while their activation was simultaneously measured in the right temporo-parietal junction (rTPJ) and the control region, right dorsolateral prefrontal cortex (rDLPFC). Behaviorally, FF interactions increased shared intentionality between strangers, leading more positive belief of cooperative decisions and more actual gains in the game. FNIRS results indicated increased interpersonal brain synchronizations during FF interactions in rTPJ (but not in rDLPFC) with greater shared intentionality between partners. These results highlighted the importance of rTPJ in collaborative social interactions during FF economic exchange and warrant future research that combines FF interactions with fNIRS hyperscanning to study social brain disorders such as autism.

50. Da Costa et al. (2015). **Is near-infrared spectroscopy clinically useful in the preterm infant?**

Abstract: Near-infrared spectroscopy (NIRS) has been used to study cerebral haemodynamics and oxygenation in the preterm infant for many years, but its use as a clinical tool has remained elusive. This has partly been due to the challenges of providing a continuous quantitative measurement that is valid and reliable, as well as demonstrating that interventions based on NIRS measurements improve clinical outcome. Recent studies investigating cerebral oxygenation targeted treatment, and defining optimal blood pressure based on an assessment of cerebrovascular reactivity, suggest ways in which this technology may yet be clinically useful.

51. Balconi et al. (2015). **Transitive and intransitive gesture execution and observation compared to resting state: the hemodynamic measures (fNIRS)**

Abstract: The present study explored cortical correlates of gesture execution and observation in peripersonal space, using functional near-infrared spectroscopy (fNIRS). Moreover, a direct comparison was realized between resting state condition and execution/observation. Meaningful gestures produced in the presence (transitive action) or in the absence (intransitive action) of the object were considered in a real context (situated representation of gestures). Subjects were required to execute or observe transitive versus intransitive gestures during fNIRS registration. Gesture execution was related to higher brain activity (increased oxygenated hemoglobin levels) with respect to observation in motor areas (premotor cortex, PMC; supplementary motor cortex, SM1). In contrast, the posterior parietal cortex was similarly activated in case of both execution and observation task. Moreover, both tasks showed increased brain activity within these areas compared to resting state. Finally, it was shown that action execution and observation of transitive gestures was supported by similar parietal posterior areas. These findings support the hypothesis of a partial common network for observation and execution of gestures within peripersonal space, mainly in transitive condition.

52. Liu et al. (2015). **Near-infrared spectroscopy as a tool for driving research**

Abstract: Driving a motor vehicle requires various cognitive functions to process surrounding information, to guide appropriate actions, and especially to respond to or integrate with numerous contextual and perceptual hindrances or risks. It is, thus, imperative to examine driving performance and road safety from a perspective of cognitive neuroscience, which considers both the behaviour and the functioning of the brain. However, because of technical limitations of current brain imaging approaches, studies have primarily adopted driving games or simulators to present participants with simulated driving environments that may have less ecological validity. Near-infrared spectroscopy (NIRS) is a relatively new, non-invasive brain-imaging technique allowing measurement of brain activations in more realistic settings, even within real motor vehicles. This study reviews current NIRS driving research and explores NIRS' potential as a new tool to examine driving behaviour, along with various risk factors in natural situations, promoting our understanding about neural mechanisms of driving safety.

53. Murata et al. (2015). **Artifact robust estimation of cognitive load by measuring cerebral blood flow**

Abstract: Cognitive load reflects the strength of efforts and difficulties in learning. It is known that cognitive load can be estimated by measuring the cerebral blood flow around prefrontal area. This study aims utilizing for the remote skill education service (e-learning) where trainee's psychological status is difficult to be guessed from his/her trainees via an internet communication. In previous study, artifact robust estimation method of cognitive load was proposed. First, in order to investigate relation between activation level of cerebral blood flow and types of the learning tasks without body motion, cerebral blood flow on performing some mathematical tasks was measured and analyzed. As a result, it was found that the subtraction task evoked brain activity. Next, other

cerebral blood flow during performing the subtraction task on walking was measured by cooperating with two participants to obtain the data disturbed with an artifact caused by body motion. Comparing the two cases of cerebral blood flow data, a robust method to estimate cognitive load was found by the spectral and correlation analysis. It was significantly confirmed that the presented method could distinguish the trainee's cognitive load even when he/she moved the body involving the skill learning. In this study, an effectivity of proposal method was verified by increasing participants. The same experiment was performed by cooperating with five participants, and obtained data was analyzed with proposal method to estimate cognitive load. In conclusion, it was confirmed that proposal method using spectral and correlation analysis was effective significantly to estimate cognitive load against body motion.

54. Abeln et al. (2015). **Electrocortical and Hemodynamic Changes within the Brain during Incremental Bicycle Exercise in Normoxia and Hypoxia—A Combined EEG/NIRS Study**

Abstract: The correlation of NIRS (near-infrared spectroscopy) and EEG (electro-cortical activity) in exercise studies has never been shown. Eight sport students performed an incremental bicycle exercise test under normoxic and hypoxic (12.7% O2) conditions respectively. EEG and NIRS recordings of the prefrontal cortex (PFC, Brodmann area 10. 46) were performed synchronously to shed light on their correlation. ANOVA revealed a higher absolute workload (231.3 ± 37.2 W), and relative PFC oxygenation under normoxic conditions, whereas hypoxic conditions resulted in earlier exhaustion (200 ± 26.7 W) and reduced PFC oxygenation. NIRS parameters increased remarkably with exercise intensity ($P < 0.001$) and differed between conditions (O2Hb: $P < 0.001$; HHb: $P = 0.023$; tHb: $P = 0.016$) and hemispheres (O2Hb: $P = 0.023$). For EEG, higher prefrontal cortical current density during compared to pre and post exercise was revealed for both conditions ($P < 0.001$). No difference between conditions and hemispheres were found. In conclusion, brain cortical activity is not impaired by hypoxia. No correlation between NIRS and EEG, but a moderate correlation between EEG and cardio-vascular parameters and a moderate to high correlation between NIRS and cardio-vascular parameters were found. The results emphasize that the transfer of EEG and NIRS results need to be done with caution.

55. Ohdaira et al. (2015). **fNIRS-based analysis of brain activation with knee extension induced by functional electrical stimulation**

Abstract: Patients suffering from paralysis due to aging, accidents, or brain injuries are increasing worldwide. Conse-quently, there is a compelling need for effective methods for the recovery of motor functions. The involvement of brain plasticity has been suggested effective and previous studies have reported that lost motor function and efficiency due to brain damage can be regained by repeatedly increasing and decreasing brain activation. Functional electrical stimulation (FES) has shown its effectiveness in the recovery of motor function. Brain activity usually decreases with the improve-ment of muscle control by FES. This study investigated the generality of brain responses during rehabilitation with FES in order to elucidate the recovery mechanism. We monitored the brain activity of one healthy subject with fNIRS over a ten-day period (one experiment per day) during which the knee joint movement was induced by FES with different parameters. The subject was seated in the chair of a leg extension device (Fig.1). The measurement regions covered the primary motor cortex and the somatosensory cortex with transmitters and receivers shown in the right of Fig. 1. Receiver No. 5 in Fig. 1 was posi-tioned on the Cz of the international 10-20 system. We stimu-lated his left quadriceps muscle with the FES device for 4 sec-onds. The results suggest that the observed increases and decreases of brain activity induced by FES are common (Fig.2). It is suggested that increasing and decreasing brain activation was evoked by long-term FES stimulation. Further research is needed to examine greater numbers of healthy subjects and patients suffering from paralysis to determine the optimum stimulation parameters for brain activation to involve brain plasticity.

56. Asano et al. (2015). **Objective Evaluation of Likes and Dislikes by Prefrontal Blood Flows**

Abstract: It is difficult to know the emotion of likes and dislikes. Questionnaire is the only method to know likes and dislikes, and has low reliability because it is not objective evaluation method. In this paper, we reported about a technique to distinguish the likes and dislikes objectively by measuring prefrontal blood flows, because emotions were based on pre-frontal activity. We show images of selected solid colors which were red, blue, orange, indigo, yellow, purple, green, black, and white, and we measured the blood flows of the subject, using near infra-red spectroscopy (NIRS). In addition, we asked subjects about likes and dislikes with the color by the order after the experiment. By the way, artifacts based on the body motion or change of the blood pressure are included the signal of the NIRS. Therefore, we obtained the approximation of the artifact using polynomial approximation algorithm. Then we subtract the approximation from the original signal. As the result of the subtraction, we confirmed the artifact was reduced. As the result of the experiment, the level of the oxyhemoglobin when the subject answered "I don't like" was relatively high, compared with the level of the oxyhemoglobin when the subject answered "I like". We consider that undesirable stimulus is more impressed than desirable stimulus. Furthermore, we consider that we will distinguish that likes and dislikes by measuring the cerebral blood flows in the future.

57. Arimitsu et al. (2015). **Assessment of Developing Speech Perception in Preterm Infants Using Near-Infrared Spectroscopy**

Abstract: Despite improved survival rates of infants, higher brain dysfunction in surviving infants remains a considerable problem. Most infants with higher brain dysfunctions are born preterm. Magnetic resonance imaging (MRI) is a useful tool to detect structural brain damage and provides important information to evaluate the neurologic sequelae of such preterm infants. Although MRI can reveal detailed brain structure, it is not the best option to assess brain function in preterm infants because of various restrictions. To overcome this difficulty, a new imaging technique, called functional near infrared spectroscopy (fNIRS), can be used to evaluate brain function in preterm infants. fNIRS is a suitable method to examine infants because, unlike MRI, it is not necessary to restrict movement and it is silent. In this review, we focus on language function, an important higher human brain function and one of the most prominent difficulties among grown preterm infants. We describe the development of speech perception in infants from preterm to age 1 year. First, we discuss the development of the brain hemodynamic response to speech stimulation in full-term infants, imaged using fNIRS. Second, we discuss the functional specialization in full-term infants for speech processing in the cerebral cortex as revealed by fNIRS. Third, we discuss potential interpretations of developmental changes in brain activation during speech perception in preterm infants. We present data that reveal the development of speech processing in full-term and preterm infants. We conclude that fNIRS can aid in the anticipation of language delay in preterm infants and may facilitate early intervention and treatment of such dysfunctions.

58. Nishiyori et al. (2015). **Motor Cortex Activity During Functional Motor Skills: An fNIRS Study**

Abstract: Assessments of brain activity during motor task performance have been limited to fine motor movements due to technological constraints presented by traditional neuroimaging techniques, such as functional magnetic resonance imaging. Functional near-infrared spectroscopy (fNIRS) offers a promising method by which to overcome these constraints and investigate motor performance of functional motor tasks. The current study used fNIRS to quantify hemodynamic responses within the primary motor cortex in twelve healthy adults as they performed unimanual right, unimanual left, and bimanual reaching, and stepping in place. Results revealed that during both unimanual reaching tasks, the contralateral hemisphere showed significant activation in channels located approximately 3 cm medial to the C3 (for right-hand reach) and C4 (for left-hand reach) landmarks. Bimanual reaching and stepping showed activation in similar channels, which were located bilaterally across the primary motor cortex. The medial channels, surrounding Cz, showed significantly higher activations during stepping when compared to bimanual reaching. Our results extend the viability of

fNIRS to study motor function and build a foundation for future investigation of motor development in infants during nascent functional behaviors and monitor how they may change with age or practice.

59. Kuriyama et al. (2015). **Prefrontal Brain Activity of Goal Keeper when Penalty Kick**

Abstract: Penalty kick is the special play which influences a result of the game in the football. A goalkeeper should react to the ball instantaneously at the penalty kick, we estimated that the state of the reaction is different in a trained football player and an inexperienced person. Therefore, we got a hypothesis from which a cerebral reaction may be different by the trained football player and an inexperienced person. To inspect this hypothesis, we measured prefrontal activity of the trained and inexperienced subjects when they watch the video of penalty kick, using NIRS. As the result of the experiment, we found that specific region of prefrontal area reacts strongly in a trained football player. Therefore, we suggest that prefrontal activity will be an index for state of training in the football.

60. Maghwry et al. (2015). **Cerebral oxygen saturation monitoring: a comparative study between bolus doses of ephedrine and phenylephrine in elective cesarean section**

Abstract: Background: Maternal hypotension is suspected to occur during cesarean section, especially under spinal anesthesia. Ephedrine and phenylephrine are the most common drugs used to treat this phenomenon. Phenylephrine has been claimed to decrease cerebral oxygen saturation (ScO 2) under general anesthesia but it is unclear whether it has the same effect in spinal anesthesia.
Patients and methods
A randomized double-blinded study was conducted that included 42 pregnant women for elective cesarean section under spinal anesthesia. A bolus dose of ephedrine (10 mg) or phenylephrine (0.1 mg) was given for treatment of hypotension. Frontal lobe oxygenation (ScO 2), mean arterial blood pressure (MAP), and heart rate (HR) were recorded, besides standard monitoring of other vitals.
Results: There was a significant decrease in left ScO 2 in the phenylephrine group after bolus treatment in response to hypotension when compared with the ephedrine group (rate of change -6 ± 2 vs. +2 ± 1; P < 0.001), as well as in right ScO 2 (-8.65 ± 0.81 vs. +2.38 ± 0.9; P < 0.001). HR was significantly lower in the phenylephrine group than in the ephedrine group after the bolus dose (60 ± 7.3 vs. 71.1 ± 4.8; P < 0.001). There was no significant difference between the two groups as regards fetal outcome.
Conclusion: Bolus dose of phenylephrine for treatment of spinal anesthesia-induced hypotension in elective cesarean section causes more decrease in ScO 2 and maternal HR in comparison with a bolus dose of ephedrine, but both are effective in maintaining mean arterial blood pressure, with satisfactory fetal outcome.

61. Guerin et al. (2015). **Randomized control trial comparing physiologic effects in preterm infants during treatment with nasal continuous positive airway pressure (NCPAP) generated by Bubble NCPAP and Ventilator NCPAP: a pilot study**

Abstract: Objectives: Nasal continuous positive airway pressure (NCPAP) is an accepted form of non-invasive ventilation in preterm infants. Few, if any, studies have shown an advantage of one type of NCPAP over another. It has been theorized that bubble-generated NCPAP may be advantageous for the preterm neonate versus traditionally used ventilator-generated NCPAP. The aim of this study was to examine for any short-term differences in physiologic parameters in preterm subjects receiving these two different methods of NCPAP.
Methods: We conducted a randomized, prospective, cross-over pilot study of preterm infants being treated with NCPAP in the neonatal intensive care unit. Subjects were continuously monitored for several physiologic parameters including heart rate, respiratory rate, oxygen saturation, cerebral tissue oxygen saturation and cerebral fractional oxygen extraction using routine neonatal monitors and near-infrared spectroscopy (NIRS) while on 2 h of bubble NCPAP and 2 h of ventilator NCPAP. Subjects were randomized to be monitored while

either starting on bubble NCPAP and then switching to ventilator NCPAP or starting on ventilator NCPAP and switching to bubble NCPAP.
Results: Eighteen subjects were included. We found no statistically significant difference in any of the physiologic parameters while subjects were receiving bubble NCPAP versus ventilator NCPAP during the monitoring time periods. While on bubble NCPAP, subjects showed a trend toward decreasing respiratory rate and decreasing cerebral fractional oxygen extraction over time, but this did not reach statistical significance.
Conclusion: There appears to be no difference in immediate physiologic effects between bubble NCPAP and ventilator NCPAP. This does not preclude the possibility of potential long-term differences, but any differences seen would likely be based on mechanisms that take more time to develop. A larger prospective trial is warranted to confirm our findings.

62. Matsuo et al. (2015). **Eyelid Opening with Trigeminal Proprioceptive Activation Regulates a Brainstem Arousal Mechanism**

Abstract: Eyelid opening stretches mechanoreceptors in the supratarsal Müller muscle to activate the proprioceptive fiber supplied by the trigeminal mesencephalic nucleus. This proprioception induces reflex contractions of the slow-twitch fibers in the levator palpebrae superioris and frontalis muscles to sustain eyelid and eyebrow positions against gravity. The cell bodies of the trigeminal proprioceptive neurons in the mesencephalon potentially make gap-junctional connections with the locus coeruleus neurons. The locus coeruleus is implicated in arousal and autonomic function. Due to the relationship between arousal, ventromedial prefrontal cortex, and skin conductance, we assessed whether upgaze with trigeminal proprioceptive evocation activates sympathetically innervated sweat glands and the ventromedial prefrontal cortex. Specifically, we examined whether 60° upgaze induces palmar sweating and hemodynamic changes in the prefrontal cortex in 16 subjects. Sweating was monitored using a thumb-mounted perspiration meter, and prefrontal cortex activity was measured with 45-channel, functional near-infrared spectroscopy (fNIRS) and 2-channel NIRS at Fp1 and Fp2. In 16 subjects, palmar sweating was induced by upgaze and decreased in response to downgaze. Upgaze activated the ventromedial prefrontal cortex with an accumulation of integrated concentration changes in deoxyhemoglobin, oxyhemoglobin, and total hemoglobin levels in 12 subjects. Upgaze phasically and degree-dependently increased deoxyhemoglobin level at Fp1 and Fp2, whereas downgaze phasically decreased it in 16 subjects. Unilateral anesthetization of mechanoreceptors in the supratarsal Müller muscle used to significantly reduce trigeminal proprioceptive evocation ipsilaterally impaired the increased deoxyhemoglobin level by 60° upgaze at Fp1 or Fp2 in 6 subjects. We concluded that upgaze with strong trigeminal proprioceptive evocation was sufficient to phasically activate sympathetically innervated sweat glands and appeared to induce rapid oxygen consumption in the ventromedial prefrontal cortex and to rapidly produce deoxyhemoglobin to regulate physiological arousal. Thus, eyelid opening with trigeminal proprioceptive evocation may activate the ventromedial prefrontal cortex via the mesencephalic trigeminal nucleus and locus coeruleus.

63. De Joux et al. (2015). **The effects of a transition between local and global processing on vigilance performance**

Abstract: Sixty participants performed a sustained attention task in which they were required to perform either global or local feature discrimination. Two groups required just one type of discrimination, while the remaining two groups started on one type of discrimination before transitioning to the other type halfway through. A transition resulted in worse performance when compared to no transition. It was also found that the local discrimination group showed improved performance over time compared to the global discrimination group. Functional near-infrared spectroscopy (fNIRS) was used to measure blood oxygenation during the task and was used as an index of cerebral hemodynamic activity. Total oxygenation was found to increase more in global discrimination tasks. It was also found that the left prefrontal cortex showed little change in nontransition tasks while in transition tasks it followed the same trend as the right prefrontal cortex. Combined with performance

data, it suggests that an increased utilization of bilateral resources may in some cases improve performance over time.

64. Witte et al. (2015). **Neuronal Correlates of Cognitive Control during Gaming Revealed by Near-Infrared Spectroscopy**

Abstract: In everyday life we quickly build and maintain associations between stimuli and behavioral responses. This is governed by rules of varying complexity and past studies have identified an underlying fronto-parietal network involved in cognitive control processes. However, there is only limited knowledge about the neuronal activations during more natural settings like game playing. We thus assessed whether near-infrared spectroscopy recordings can reflect different demands on cognitive control during a simple game playing task. Sixteen healthy participants had to catch falling objects by pressing computer keys. These objects either fell randomly (RANDOM task), according to a known stimulus-response mapping applied by players (APPLY task) or according to a stimulus-response mapping that had to be learned (LEARN task). We found an increased change of oxygenated and deoxygenated hemoglobin during LEARN covering broad areas over right frontal, central and parietal cortex. Opposed to this, hemoglobin changes were less pronounced for RANDOM and APPLY. Along with the findings that fewer objects were caught during LEARN but stimulus-response mappings were successfully identified, we attribute the higher activations to an increased cognitive load when extracting an unknown mapping. This study therefore demonstrates a neuronal marker of cognitive control during gaming revealed by near-infrared spectroscopy recordings.

65. Conforti et al. (2015). **Effects of ventilation modalities on near-infrared spectroscopy in surgically corrected CDH infants**

Abstract: Background: Near-infrared spectroscopy (NIRS) is a noninvasive technique for monitoring tissue oxygenation and perfusion. The aim of this study was to evaluate cerebral and splanchnic NIRS changes in CDH operated infants enrolled into the VICI trial and therefore randomized for ventilatory modalities.
Materials and methods: CDH newborns enrolled into the VICI trial (Netherlands Trial Register, NTR 1310) were randomized at birth for high-frequency oscillatory ventilation (HFOV) or conventional mechanical ventilation (CMV) according to the trial. Cerebral oxygenation (rSO2C) and splanchnic oxygenation (rSO2S) were obtained by NIRS (INVOS 5100; Somanetics, Troy, MI) before and after surgery. Variations in rSO2C and rSO2S were evaluated. Mann–Whitney test and one-way ANOVA were used as appropriate. $p < 0.05$ was considered significant.
Results: Thirteen VICI trial patients underwent surgical repair between March 2011 and December 2012, and were enrolled in the study. Seven patients were assigned to HFOV and six to CMV group respectively. During surgery, a significant reduction in rSO2C ($p = 0.0001$) and rSO2S ($p = 0.005$) were observed. HFOV patients experienced prolonged reduction in rSO2C value ($p = 0.003$) while rSO2S did not vary between HFOV and CMV ($p = 0.94$).
Conclusions: Surgical CDH repair was associated with decrease of cerebral and splanchnic oxygenation, regardless of ventilation. Patients ventilated by HFOV need a longer time interval to recovery normal rSO2C values, than those ventilated by CMV. This may be owing to a different impact of HFOV on patients' hemodynamic status with a higher impairment on total venous return and its negative consequences on cardiac output.

66. Kuwajima et al. (2015). **Role of Near-Infrared Spectroscopy in Neuroanesthesia**

Abstract: Near-infrared spectroscopy (NIRS) provides information on regional tissue oxygen saturation (rSO2) by measuring absorption of near-infrared light. Values of rSO2 reflect the balance between oxygen supply and demand in the monitored region. The clinical application of NIRS has been frequently studied in the context of

neuroanesthesia, such as assessment of cerebral ischemia during carotid endarterectomy or early detection of cerebral hyperperfusion. In addition, when a bolus of indocyanine green is injected and analyzed using specific NIRS software, blood flow index can be calculated, which indicates the relative measurement of cerebral blood flow. While NIRS has technical limitations and requires further development, it is noninvasive and relatively simple, thus providing advantages over other modalities. It has the potential to provide helpful information on cerebral function and improve perioperative outcomes in neuroanesthesia.

67. Stark et al. (2015). **Intrauterine inflammation, cerebral oxygen consumption and susceptibility to early brain injury in very preterm newborns**

Abstract: Background In utero exposure to inflammation results in elevated cerebral oxygen consumption. This increased metabolic demand may contribute to the association between chorioamnionitis and intraventricular haemorrhage (P/IVH). We hypothesised that intrauterine inflammation imposes an elevated cerebral metabolic load and increased fractional oxygen extraction (cFTOE) with cFTOE further increased in the presence of early P/IVH.
Methods Eighty-three infants ≤30 weeks gestation were recruited. Exposure to intrauterine inflammation was determined by placental histology. Total internal carotid blood flow (Doppler ultrasound) and near infrared spectroscopy were measured and cerebral oxygen delivery (mcerbDO2), consumption (mcerbVO2) and cFTOE were calculated on days 1 and 3 of life. Primary outcome was defined as death or P/IVH >grade II (cranial sonograph) by day 3.
Results Infants exposed to intrauterine inflammation had higher total internal carotid blood flow (92 vs 63 mL/kg/min) and mcerbDO2 (13.7 vs 10.1 mL/kg/min) than those not exposed to inflammation. Newborns with P/IVH had both higher oxygen consumption and extraction compared with those without sonographic injury regardless of exposure to intrauterine inflammation. Further, in preterms exposed to inflammation, those with P/IVH had higher consumption (6.1 vs 4.8 mL/kg/min) and extraction than those without injury. These differences were observed only on day 1 of life.
Conclusions Although P/IVH is multifactorial in preterm newborns, it is likely that cerebral hypoxic-ischaemia plays a central pathophysiological role. These data provide a mechanistic insight into this process and suggests that the increased cerebral metabolic load imposed by the presence of inflammation results in a higher risk of critical hypoxic ischaemia in the preterm with increased susceptibility to significant P/IVH.

68. Vanutelli et al. (2015). **Perceiving emotions in human–human and human–animal interactions: Hemodynamic prefrontal activity (fNIRS) and empathic concern**

Abstract: In the last years social neuroscience research attempted to identify the neural networks underlying the human ability to perceive others' emotions, a core process in establishing meaningful social bonds. A large amount of papers arose and identified common and specific empathy-based networks with respect to stimulus type and task. Despite the great majority of studies focused on human–human contexts, we do not establish relations with only other humans, but also with non-human animals. The aim of the present work was to explore the brain mechanisms involved in empathic concern for people who interacts with both peers and other species. Participants have been assessed by functional near-infrared spectroscopy (fNIRS) while viewing pictures depicting humans interacting with both other men and women (human–human condition: HH), or with dogs and cats (human–animal: HA). Results showed that aggressive HH interactions elicited greater prefrontal activity (PFC) than HA ones while, when considering HA interactions, friendly ones were related to higher cortical activity. Finally, oxy (O2Hb) and deoxyhemoglobin (HHb) increasing related to the processing of aggressive interactions positively correlated with different empathic measures, within more specific brain regions. Results were elucidated with respect to available evidence on emotion perception, empathic neural mechanisms and their functional meaning for human–animal contexts.

69. Gorshkov et al. (2015). **Acceleration of Monte Carlo simulation of photon migration in complex heterogeneous media using Intel many-integrated core architecture**

Abstract: Over two decades, the Monte Carlo technique has become a gold standard in simulation of light propagation in turbid media, including biotissues. Technological solutions provide further advances of this technique. The Intel Xeon Phi coprocessor is a new type of accelerator for highly parallel general purpose computing, which allows execution of a wide range of applications without substantial code modification. We present a technical approach of porting our previously developed Monte Carlo (MC) code for simulation of light transport in tissues to the Intel Xeon Phi coprocessor. We show that employing the accelerator allows reducing computational time of MC simulation and obtaining simulation speed-up comparable to GPU. We demonstrate the performance of the developed code for simulation of light transport in the human head and determination of the measurement volume in near-infrared spectroscopy brain sensing.

70. Francis et al. (2015). **NIR light propagation in a digital head model for traumatic brain injury (TBI)**

Abstract: Near infrared spectroscopy (NIRS) is capable of detecting and monitoring acute changes in cerebral blood volume and oxygenation associated with traumatic brain injury (TBI). Wavelength selection, source-detector separation, optode density, and detector sensitivity are key design parameters that determine the imaging depth, chromophore separability, and, ultimately, clinical usefulness of a NIRS instrument. We present simulation results of NIR light propagation in a digital head model as it relates to the ability to detect intracranial hematomas and monitor the peri-hematomal tissue viability. These results inform NIRS instrument design specific to TBI diagnosis and monitoring.

71. Lankford et al. (2015). **Cerebral blood flow during HUTT in young patients with orthostatic intolerance**

Abstract: Purpose: To investigate patterns of change in cerebral perfusion during head-up tilt testing (HUTT) in children and young adults with autonomic dysfunction.
Methods: We utilized near-infrared spectroscopy (NIRS) to estimate bilateral cerebral perfusion patterns during HUTT in 71 adolescents and young adults with a diagnosis of autonomic dysfunction. In addition, we used transthoracic impedance to measure cardiac stroke volume and thus infer autonomic tone, heart rate, and blood pressure during the test. Cerebral blood-flow wave-patterns were then visually analyzed and associated with clinical symptoms and measures of cardiovascular and autonomic function.
Results: Visual analysis of contour changes in head NIRS values during phases of HUTT revealed variable patterns of cerebral blood flow, some specifically associated with severe symptomatology (i.e., syncope). We also observed an inequality in blood flow of the cerebral hemispheres in many patients. Finally, we observed changes in cardiac stroke volume during HUTT, as previously reported, that related to changes in head NIRS.
Conclusion: These results confirm a decrease in cerebral blood flow during HUTT as assessed by head NIRS in patients with autonomic dysfunction. Specifically, we have profiled the cerebral blood flow contours throughout the phases of HUTT, which add insight into the clinical spectrum of the disorder and may correlate with clinical severity.

72. Dalmis et al. (2015). **Similarity analysis of functional connectivity with functional near-infrared spectroscopy**

Abstract: One of the remaining challenges in functional connectivity (FC) studies is investigation of the temporal variability of FC networks. Recent studies focusing on the dynamic FC mostly use functional magnetic resonance imaging as an imaging tool to investigate the temporal variability of FC. We attempted to quantify

this variability via analyzing the functional near-infrared spectroscopy (fNIRS) signals, which were recorded from the prefrontal cortex (PFC) of 12 healthy subjects during a Stroop test. Mutual information was used as a metric to determine functional connectivity between PFC regions. Two-dimensional correlation based similarity measure was used as a method to analyze within-subject and intersubject consistency of FC maps and how they change in time. We found that within-subject consistency (0.61±0.090.61±0.09) is higher than intersubject consistency (0.28±0.130.28±0.13). Within-subject consistency was not found to be task-specific. Results also revealed that there is a gradual change in FC patterns during a Stroop session for congruent and neutral conditions, where there is no such trend in the presence of an interference effect. In conclusion, we have demonstrated the between-subject, within-subject, and temporal variability of FC and the feasibility of using fNIRS for studying dynamic FC.

73. Tellis et al. (2015). **Near Infrared Spectroscopy (NIRS): A Pilot Study to Measure Hemoglobin Concentration Changes in the Brains of Persons who Stutter and Typically Fluent Speakers**

Abstract: Near infrared spectroscopy (NIRS) is a diffuse optical technique that has been used to measure oxy-, de-oxy, and total hemoglobin concentration changes in real-time at the surface of the brain. NIRS relies on neuro-vascular coupling—Blood-Oxygenation–Level-Dependent (BOLD) response—and measures hemoglobin concentration changes through the use of a light source (infra-red) in a safe region of the electromagnetic spectrum. We conducted a pilot study with NIRS to determine whether there were hemoglobin concentration changes in the brains of persons who stutter and typically fluent speakers during reading, counting, and free speech. Results indicate that as the complexity of the task increased, the magnitude of the hemoglobin concentration change increased. Overall, these three speech tasks caused hemoglobin concentration changes in Broca's area, Wernicke's area, and other areas of the brain.

74. Li et al. (2015). **Bedside monitoring of patients with shock using a portable spatially-resolved near-infrared spectroscopy**

Abstract: Clinical monitoring of shock mainly depends on blood-oxygen-indices obtained from invasive blood sample tests. The central internal jugular central vein oxygenation level (ScvO2) has been considered as a gold standard indicator for shock prediction. We developed a noninvasive spatially-resolved near-infrared spectroscopy (SR-NIRS) to measure tissue blood oxygen saturation (StO2) surrounding the region of taking blood sample for the ScvO2 test in 25 patients with shock. StO2 values were found to be highly correlated ($r = 0.84$, $p < 0.001$) with ScvO2 levels and the concordance coefficient of 0.80 is high. The results suggest the potential of noninvasive SR-NIRS for bedside shock monitoring.

75. Tan et al. (2015). **Frequency-specific functional connectivity revealed by wavelet-based coherence analysis in elderly subjects with cerebral infarction using NIRS method**

Abstract: Purpose: Resting-state functional connectivity in subjects with cerebral infarction (CI) was assessed using wavelet-based coherence analysis of near-infrared spectroscopy (NIRS) signals.
Methods: Continuous recordings of NIRS signals were measured from the prefrontal cortex and sensorimotor cortical areas of 12 subjects with CI (CI group) and 16 healthy subjects (healthy group) during the resting state. The channels in these areas were divided into four connection types: homologous connectivity, frontoposterior connectivity, contralateral connectivity, and homolateral connectivity. Wavelet coherence (WCO) and wavelet phase coherence (WPCO) were calculated in six frequency intervals in each channel pair: I, 0.6–2 Hz; II, 0.145–0.6 Hz; III, 0.052–0.145 Hz; IV, 0.021–0.052 Hz; V, 0.0095–0.021 Hz; and VI, 0.005–0.0095 Hz.
Results: WCO in the six frequency intervals was significant for all channels in the healthy group. By contrast, WCO in frequency intervals II–VI showed weakened connectivity in the CI group, especially in terms of frontoposterior connectivity. WCO was significantly lower in the CI group than in the healthy group in the

following connectivities and frequency intervals: front-posterior, IV–VI ($p < 0.05$); homologous, III–V ($p < 0.01$); motor-contralateral, III–V ($p < 0.05$); and motor-homolateral, III–V ($p < 0.05$). WPCO in frequency intervals III ($F = 5.032$, $p = 0.033$) and IV ($F = 11.95$, $p = 0.002$) in frontoposterior connectivity, as well as in intervals III–V in homologous, motor-contralateral and motor-homolateral connectivities were significantly lower ($p < 0.05$) in the CI group than in the healthy group. However, WPCO in interval I showed significantly higher levels in motor-homolateral connectivity in the CI group than in the healthy group ($F = 4.241$, $p = 0.049$).
Conclusions: The authors' results suggest that CI causes a frequency-specific disruption in resting-state connectivity. This may be useful for assessing the effectiveness of functional recovery after CI.

76. Qiu et al. (2015). **Optical imaging of the prefrontal activity in joint attention experience**

Abstract: Functional near-infrared spectroscopy (fNIRS) was used to measure the prefrontal activity in joint attention experience. 16 healthy adults participated in the experiment in which 42 optical channels were fixed over the anterior prefrontal cortex (aPFC), dorsolateral prefrontal cortex (DLPFC), inferior frontal gyrus (IFG) and a small anterior portion of the superior temporal gyrus (STG). Video stimuli were used to engender joint or non-joint attention experience in observers. Cortical hemodynamic response and functional connectivity were measured and averaged across all subjects for each stimulus condition. Our data showed the activation in joint attention located in the aPFC and DLPFC bilaterally, but dominantly in the left hemisphere. This observation, together with the previous findings on infants and children, provides a clear developmental scenario on the prefrontal activation associated with joint attention process. In the case of non-joint attention condition, only a small region of the right DLPFC was activated. Functional connectivity was observed to be enhanced, but differently in joint and non-joint attention condition.

77. Brunetti et al. (2015). **Potential determinants of efficacy of mirror therapy in stroke patients--A pilot study**

Abstract: BACKGROUND: Mirror therapy (MT) was found to improve motor function after stroke. However, there is high variability between patients regarding motor recovery.
OBJECTIVES: The following pilot study was designed to identify potential factors determining this variability between patients with severe upper limb paresis, receiving MT.
METHODS: Eleven sub-acute stroke patients with severe upper limb paresis participated, receiving in-patient rehabilitation. After a set of pre-assessments (including measurement of brain activity at the primary motor cortex and precuneus during the mirror illusion, using near-infrared spectroscopy as described previously), four weeks of MT were applied, followed by a set of post-assessments. Discriminant group analysis for MT responders and non-responders was performed.
RESULTS: Six out of eleven patients were defined as responders and five as non-responders on the basis of their functional motor improvement. The initial motor function and the activity shift in both precunei (mirror index) were found to discriminate significantly between responders and non-responders.
CONCLUSIONS: In line with earlier results, initial motor function was confirmed as crucial determinant of motor recovery. Additionally, activity response to the mirror illusion in both precunei was found to be a candidate for determination of the efficacy of MT.

78. Vitale et al. (2015). **Near-Infrared Spectroscopy Technology in Typically Fluent Speakers and Persons who Stutter**

Abstract: Near-infrared spectroscopy (NIRS) is a biomedical optical imaging technique that is used to measure real-time functional brain activity. NIRS uses non-invasive infrared light to measure oxy-, de-oxy, and total hemoglobin concentration at the surface of the cerebral cortex. Hemoglobin concentration is monitored through the use of light scattering and tissue absorption. NIRS is advantageous over other techniques (e.g., EEG, MRI,

PET etc.) because it does not utilize harmful radiation or an extrinsic contrast agent. It is also portable and is a low cost technology to administer. NIRS can also be used with infants, young children, and adults. Since its discovery, NIRS has been used to study Alzheimer's disease, verbal fluency, language processing, epilepsy, frontal lateralization in speech tasks, cerebral hemodynamics, visual stimulation, odor stimulation, chronic schizophrenia, and other conditions. We have used NIRS to measure hemoglobin changes in typically fluent speakers (TFS) and persons who stutter (PWS). Our NIRS device has 16 sources and 24 detectors to measure haemoglobin concentration changes during speech and non-speech tasks for TFS and PWS. Our participants ranged in age from 10 to young adulthood. Measurements were taken during three conditions: Speakers were asked to read out loud, to engage in spontaneous speech, and to sit for a rest period. The purpose of this study was to determine whether there were haemoglobin concentration changes in TFS and PWS while they engaged in speech and non-speech tasks. Initial results indicate that speech tasks caused hemoglobin concentration changes. A more in-depth analysis of our technology and pilot data will be presented.

79. Kerz et al. (2015). **Continuous-wave near-infrared spectroscopy is not related to brain tissue oxygen tension**

Abstract: Near-infrared spectroscopy (NIRS) has gained acceptance for cerebral monitoring, especially during cardiac surgery, though there are few data showing its validity. We therefore aimed to correlate invasive brain tissue oxygen measurements (PtiO2) with the corresponding NIRS-values (regional oxygen saturation, rSO2). We also studied whether NIRS was able to detect ischemic events, defined as a PtiO2-value of <15 mmHg. Eleven patients were studied with invasive brain tissue oxygen monitoring and continuous-wave NIRS. PtiO2-correlation with corresponding NIRS-values was calculated. We found no correlation between PtiO2- and NIRS-readings. Measurement of rSO2 was no better than flipping a coin in the detection of cerebral ischemia when a commonly agreed ischemic PtiO2 cut-off value of <15 mmHg was chosen. Continuous-wave-NIRS was unable to reliably detect ischemic cerebral episodes, defined as a PtiO2 value <15 mmHg. Displayed NIRS-values did not correlate with invasively measured PtiO2-values. CW-NIRS should not be used for the detection of cerebral ischemia.

80. Kerz et al. (2015). **Near-Infrared Spectroscopy for the Evaluation of Anesthetic Depth**

Abstract: The standard-of-care guidelines published by the American Society of Anesthesiologists (ASA) recommend monitoring of pulse oximetry, blood pressure, heart rate, and end tidal CO2 during the use of anesthesia and sedation. This information can help to identify adverse events that may occur during procedures. However, these parameters are not specific to the effects of anesthetics or sedatives, and therefore they offer little, to no, real time information regarding the effects of those agents and do not give the clinician the lead-time necessary to prevent patient “awareness.” Since no “gold-standard” method is available to continuously, reliably, and effectively monitor the effects of sedatives and anesthetics, such a method is greatly needed. Investigation of the use of functional near-infrared spectroscopy (fNIRS) as a method for anesthesia or sedation monitoring and for the assessment of the effects of various anesthetic drugs on cerebral oxygenation has started to be conducted. The objective of this paper is to provide a thorough review of the currently available published scientific studies regarding the use of fNIRS in the fields of anesthesia and sedation monitoring, comment on their findings, and discuss the future work required for the translation of this technology to the clinical setting.

81. Höller et al. (2015). **Peripheral Muscle Near-Infrared Spectroscopy in Neonates: Ready for Clinical Use? A Systematic Qualitative Review of the Literature**

Abstract: Background: Peripheral muscle near-infrared spectroscopy (NIRS) measurements are of increasing interest especially in the care of critically ill patients. Objective: The aim was to perform a systematic qualitative review on peripheral muscle NIRS measurements in the clinical care of term and preterm neonates. Methods: A

systematic search of PubMed and Ovid Embase was performed using the following terms: neonate, neonates, newborn, newborns, infant, infants, near-infrared spectroscopy, NIRS, oxygenation, perfusion, oxygen extraction, peripheral, tissue, muscle, calf, forearm and thigh. Additional articles were identified by a manual search of the cited references. Only human studies were included. Results: Twenty-one studies were identified to use peripheral muscle NIRS measurements as a single method, 17 studies combined cerebral and peripheral muscle NIRS measurements and 1 study used multi-site NIRS measurements in human neonates. Two randomized studies were identified. Two additional publications were included because they provided important general information about peripheral muscle NIRS measurements. Conclusion: In the care of critically ill neonates peripheral muscle NIRS measurements alone or in combination with cerebral or multi-site NIRS measurements provide useful additional information about peripheral circulation and oxygenation. This method is a promising tool in the recognition of early states of centralization (compensated shock) in this vulnerable group of patients. However, before this method can be used in the clinical routine it has to be tested as monitoring to guide interventions in further studies.

82. Greenberg et al. (2015). **Extracranial contamination in the INVOS 5100C *versus* the FORE-SIGHT ELITE cerebral oximeter: a prospective observational crossover study in volunteers**

Abstract: Purpose: Previous studies have found that most cerebral oximeters are subject to inaccuracies secondary to extracranial contamination of the cerebral oximetric signals. We hypothesized that the more advanced second-generation FORE-SIGHT ELITE cerebral oximeter would be significantly less affected by extracranial tissue hypoxemia than the more widely used first-generation INVOS™ 5100C monitor.
Methods: Twenty healthy volunteers aged 18-45 yr had the INVOS and FORE-SIGHT probes placed on their forehead in a random sequence while in the supine position. A pneumatic head cuff was then placed around each volunteer's head just below both the oximeter and a concomitantly placed scalp forehead pulse oximeter probe. The subjects' scalp cerebral oxygen saturation (SctO2) values were measured and compared using the two different devices in sequence, both before and after scalp tissue ischemia was induced by the pneumatic cuff.
Results: Extracranial ischemia resulted in a significant reduction in SctO2 values from baseline in both devices. The INVOS 5100C recorded a median [interquartile range] decrease in SctO2 from baseline at five minutes of 15.1% [12.6 - 17.6], while that recorded by the FORESIGHT ELITE device was 8.6% [4.0 -12.3] at five minutes (median difference, 7.9%; 99% confidence interval, 1.9 to 16.5; P = 0.002).
Conclusion: Updated technological algorithms employed in the FORE-SIGHT ELITE cerebral oximeter may be responsible for less extracranial contamination than was observed in the previous-generation INVOS 5100C device. The impact that this extracranial contamination may have on the clinical use of these devices remains to be determined.

83. Schwaberger et al. (2015). **Transitional Changes in Cerebral Blood Volume at Birth**

Abstract: Background: Near-infrared spectroscopy (NIRS) enables non-invasive measurements of changes in the concentration of oxygenated (ΔHbO2) and reduced (ΔHbR) haemoglobin. Changes in total haemoglobin (ΔHbT = ΔHbO2 + ΔHbR) provide information on changes in cerebral blood volume (CBV). Objective: The aim was to evaluate the behaviour of CBV during immediate postnatal transition in term infants. Design: This observational study was conducted at the Medical University of Graz. NIRS measurements were carried out in term infants without need for respiratory support by using 'NIRO 200-NX' (Hamamatsu) over the first 15 min after birth. Results: 109 infants with a mean gestational age of 38 + 6 weeks (±7 days) and birth weight of 3,242 g (±481) were included. Related to a reference value at minute 15, a significant decrease of HbT was observed for each minute within the study period. The mean (±SD) decrease of HbT of 17 (±40) μmol/l from minutes 2 to 15 represents a decrease of CBV of 1.0 ml/100 g brain (±2.2). Conclusions: In healthy newborns, CBV decreased over the whole study period. This likely reflects a physiological process. The impact and clinical relevance of different CBV behaviour during immediate transition needs to be investigated in further studies.

84. Cerbo et al. (2015). **Cerebral Oxygenation, Superior Vena Cava Flow, Severe Intraventricular Hemorrhage and Mortality in 60 Very Low Birth Weight Infants**

Abstract: Background: Brain vulnerability in the critically ill preterm newborn may be related to the burden of cerebral hypoxygenation and hypoperfusion during the immediate postnatal period. Objective: We determined the association between adverse outcomes [death or high grade intraventricular hemorrhage (IVH)] and continuous cerebral tissue oxygen saturation (rSO2), superior vena cava flow (SVCf) and cerebral fractional oxygen extraction (CFOE) in very low birth weight (VLBW) infants during the first 48 h of life. Methods: We studied a prospective cohort of 60 VLBW infants admitted to our neonatal intensive care unit within the first 6 h of life between March 2010 and June 2012. rSO2 (expressed as a number of summary measures) was continuously monitored with near-infrared spectroscopy (INVOS 5100 Somanetic) during the first 48 h of life, SCVf was measured at 4-6, 12, 24 and 48 h after birth, and CFOE was calculated. Results: The mean gestational age was 27.9 (SD 2.39); 8 infants died (13.3%) and 7 developed IVH grade III-IV: 1 in the alive group and 6 in the deceased group ($p < 0.001$). The odds ratio for death was 1.08 (95% CI: 1.015-1.15, $p = 0.016$) for each 10 periods of rSO2 values <40% in the first 48 h, and 4.2 (95% CI: 1.27-14.05, $p = 0.019$) for SVCf values <40 ml/kg/min. Among alive babies, mean CFOE decreased at 24, 36 and 48 h; among deceased babies it did not ($p < 0.001$). In the multivariate analyses, these results retained significance. Conclusions: Both rSO2 ≤40% and SVCf <40 ml/kg/min independently increase the risk of death. The trend in CFOE supports the ischemic-hypoperfusion hypothesis as a mechanism for cerebral damage.

85. Nguyen et al. (2015). **Optimizing a hemodynamic model in the human motor cortex**

Abstract: The paper presents a method for reconstructing the impulse hemodynamic response (HR) of functional near-infrared spectroscopy (fNIRS) data measured in the motor cortex of a human brain. The empirical impulse HRs are averaged across the most active channels of nineteen healthy volunteers. The impulse HR is modeled by a state space equation in which the optimal order of this model is computed by using the Akaike information criterion. The subspace method is utilized to estimate the parameter matrices in the state space model based on the obtained fNIRS-HR to an impulse stimulus. The stability of the reconstructed HR to an impulse stimulus will be investigated. It is worthy to note that the third-order state-space equation can be utilized to describe the impulse HR of the motor cortex in generating the predicted HR to an arbitrary stimulus sequence in an online imaging.

86. Lee et al. (2015). **Neuro-feedback using real-time near infrared spectroscopy enhances brain plasticity during treadmill walking: A pilot study**

Abstract: Despite of the findings that motor imagery and motor execution are supposed to share common neural networks, previous studies using motor imagery based rehabilitation have revealed inconsistent results. In this study, we implemented a real-time neuro-feedback system based on near infrared spectroscopy (NIRS), and investigate the effect of neuro-feedback for gait rehabilitation. Four healthy volunteers performed individually given tasks. In the non-feedback task, subjects were performed treadmill walking without feedback. In the feedback task was used in subjects to evaluate whether real-time cortical oxygenated hemoglobin signal feedback during treadmill walking task. Results demonstrated that neuro-feedback induced significantly greater activation of the premotor area and supplementary motor area compare with non-feedback treadmill walking. This result suggested the feasibility of NIRS based real-time neuro-feedback system on gait rehabilitation.

87. Xu et al. (2015). **FC-NIRS: A Functional Connectivity Analysis Tool for Near-Infrared Spectroscopy Data**

Abstract: Functional near-infrared spectroscopy (fNIRS), a promising noninvasive imaging technique, has recently become an increasingly popular tool in resting-state brain functional connectivity (FC) studies. However, the corresponding software packages for FC analysis are still lacking. To facilitate fNIRS-based human functional connectome studies, we developed a MATLAB software package called "functional connectivity analysis tool for near-infrared spectroscopy data" (FC-NIRS). This package includes the main functions of fNIRS data preprocessing, quality control, FC calculation, and network analysis. Because this software has a friendly graphical user interface (GUI), FC-NIRS allows researchers to perform data analysis in an easy, flexible, and quick way. Furthermore, FC-NIRS can accomplish batch processing during data processing and analysis, thereby greatly reducing the time cost of addressing a large number of datasets. Extensive experimental results using real human brain imaging confirm the viability of the toolbox. This novel toolbox is expected to substantially facilitate fNIRS-data-based human functional connectome studies.

88. Gagnon et al. (2015). **Effect of persistent pulmonary hypertension on brain oxygenation in asphyxiated term newborns treated with hypothermia**

Abstract: Objective: To better understand the impact of persistent pulmonary hypertension (PPHN) on brain oxygenation in term asphyxiated newborns treated with hypothermia.
Methods: The regional cerebral oxygenation saturation (rSO2) measured by near-infrared spectroscopy was compared to pre/post-ductal oxygen saturation and mean arterial blood pressure in three term asphyxiated newborns with documented PPHN during their first 4 days of life while they were being treated with hypothermia.
Results: The cerebral oxygen saturation remained relatively stable when oxygen saturation was more than 92% and when there was no difference between pre- and post-ductal oxygen saturations. Episodes of desaturations with a difference between pre- and post-ductal saturations, as well as episodes of hypotension, caused a significant decrease in rSO2 in these newborns.
Conclusion: This case series demonstrates that PPHN has a profound impact on brain oxygenation in term asphyxiated newborns treated with hypothermia during the first days of life after birth. PPHN may represent an additional risk factor for brain injury in these newborns during the first days of life.

89. Balconi et al. (2015). **Emotions and BIS/BAS components affect brain activity (ERPs and fNIRS) in observing intra-species and inter-species interactions**

Abstract: Affective response to observation of intra-species and inter-species interactions was considered in the present research. The brain activity (optical imaging: functional Near-Infrared Spectroscopy, fNIRS; and event-related potentials, ERPs, N200) was monitored when subjects observed interactive situations (human-human, HH; human-animal, HA) with a positive (cooperative), negative (uncooperative) or neutral (no emotional) content. In addition, cortical lateralization (more left or right prefrontal activity) and personality component (Behavioral Activation System, BAS; Behavioral Inhibition System, BIS) effects were explored. Both ERP and fNIRS showed significant brain activity increasing in response to positive and negative compared with neutral interactions for HH and HA. However, some differences were found between HH (more "negative valence" effect) and HA (more "positive valence" effect). Finally BAS and BIS were related respectively to more left (positive conditions) or right (negative conditions) hemispheric activity. These results supported the significance of affective behavior differentiating the species-specific and species-aspecific relationships.

90. Metzger et al. (2015). **Effects of cholinesterase inhibitor on brain activation in Alzheimer's patients measured with functional near-infrared spectroscopy**

Abstract: RATIONALE: Neurobiological effects of neuropsychiatric medication can contribute to the understanding of mechanisms of action and to the evaluation of target medication effects. Cholinesterase inhibitors (ChEI) have been used in patients with Alzheimer's disease (AD) for years with only small knowledge about the underlying neurobiological effects. The measurement of brain activation links neurobiological and functional aspects but is challenging in the group of demented patients; here, an alternative method, functional near-infrared spectroscopy (fNIRS), is introduced to measure those medication effects.
OBJECTIVES: The current study investigated the influence of ChEI on cortical activation of patients with AD measured using fNIRS during a verbal fluency task (VFT).
METHODS: In this study, 24 probable AD patients were investigated three times using fNIRS: before medication with rivastigmine was given (t0), when the medication was at the target dose after 4 weeks (t1), and after the target dose was kept constant for a further 8 weeks (t2).
RESULTS: The results show a concentration increase of oxygenated hemoglobin as measured with fNIRS from t0 to t2 in speech relevant areas and a general decrease in prefrontal areas. Behaviorally, an improvement was found for the VFT used to measure cortical activation during fNIRS. In the neuropsychological test battery, no significant changes were found, yet high effect sizes for the mini mental status examination, immediate and delayed word list recall were found.
CONCLUSIONS: The results indicate a positive effect of ChEI on cognitive function. The underlying cortical changes can be imaged using fNIRS.

91. Iliopolos et al. (2015). **Mesenteric near-infrared spectroscopy and risk of gastrointestinal complications in infants undergoing surgery for congenital heart disease**

Abstract: We hypothesised that lower mesenteric near-infrared spectroscopy values would be associated with a greater incidence of gastrointestinal complications in children weighing <10 kg who were recovering from cardiac surgery. We evaluated mesenteric near-infrared spectroscopy, central venous oxygen saturation, and arterial blood gases for 48 hours post-operatively. Enteral feeding intake, gastrointestinal complications, and markers of organ dysfunction were monitored for 7 days. A total of 50 children, with median age of 16.7 (3.2–31.6) weeks, were studied. On admission, the average mesenteric near-infrared spectroscopy value was 71±18%, and the systemic oxygen saturation was 93±7.5%. Lower admission mesenteric near-infrared spectroscopy correlated with longer time to establish enteral feeds ($r=-0.58$, $p<0.01$) and shorter duration of feeds at 7 days ($r=0.48$, $p<0.01$). Children with gastrointestinal complications had significantly lower admission mesenteric near-infrared spectroscopy (58±18% versus 73±17%, $p=0.01$) and higher mesenteric arteriovenous difference of oxygen at admission [39 (23–47) % versus 19 (4–27) %, $p=0.02$]. Based on multiple logistic regression, admission mesenteric near-infrared spectroscopy was independently associated with gastrointestinal complications (Odds ratio, 0.95; 95% confidence interval, 0.93–0.97; $p=0.03$). Admission mesenteric near-infrared spectroscopy showed an area under the receiver operating characteristic curve of 0.76 to identify children who developed gastrointestinal complications, with a suggested cut-off value of 72% (78% sensitivity, 68% specificity). In this pilot study, we conclude that admission mesenteric near-infrared spectroscopy is associated with gastrointestinal complications and enteral feeding tolerance in children after cardiac surgery.

92. Clancy et al. (2015). **Comparison of neurological NIRS signals during standing Valsalva maneuvers, pre and post vasoconstrictor injection**

Abstract: Near infrared spectroscopy (NIRS) has potential to offer a fast and non-invasive method of assessing cerebral saturation in a clinical setting, however, there are concerns that NIRS brain measures suffer contamination from superficial tissues. This study used the Valsalva manoeuver (VM) to determine whether NIRS could differentiate between superficial (from somatic tissue) and neurological changes in the context of

traumatic brain injury. A potent vasopressor was used to assess the effect of reducing total haemoglobin concentration in the superficial regions of the forehead. Frequency domain NIRS measurements during the VM pre and post vasoconstrictor injection, combined with simulation data, conclusively show that NIRS can detect neurological changes, in both haemoglobin content and saturation, when positioned on the forehead. The effect of superficial contamination in this instance appeared to be insignificant, with no statistically significant change in saturation over 8 patients, even with a drop in superficial haemoglobin concentration due to the vasoconstrictor, confirmed by laser Doppler. Nevertheless, simulations indicated that the absolute values of the recovered NIRS parameters are not quantitatively accurate; however a direct comparison with invasive measures is needed to confirm this.

93. Olsson et al. (2015). **Skin-to-skin contact reduces near-infrared spectroscopy pain responses in premature infants during blood sampling**

Abstract: Aim: This study investigated if skin-to-skin contact could provide pain relief, measured with near-infrared spectroscopy (NIRS), during venepuncture in premature infants.
Methods: Ten infants born at 26–35 weeks of gestation were examined during a blood-sampling procedure with venepuncture under two different conditions: in skin-to-skin contact with their mother or lying in their incubator or crib. A double-channel NIRS device was used, and oxygen saturation and heart rate were measured using pulse oximetry. The infant's face and the pulse oximetry values were videotaped throughout the procedures, so that we could carry out a pain assessment using the Premature Infant Pain Profile-Revised (PIPP-R).
Results: We found a significantly smaller increase in oxygenated haemoglobin on the contralateral side during venepuncture when the infants were in skin-to-skin contact with their mothers, compared to when they were laying in their incubator or crib. When venepuncture was compared with a sham procedure, oxygenated haemoglobin increased significantly more with the infant in the incubator or crib than held skin-to-skin, but no significant differences could be seen in the PIPP-R results between the two groups.
Conclusion: This study showed that skin-to-skin contact between premature infants and their mothers during venepuncture had a pain-relieving effect.

94. Anuardi et al. (2015). **An Analysis of Emotions in Reversed Japanese Sentences and Malay Sentences with NIRS**

Abstract: Effective communication relies on the smooth exchange of information, and involves a good understanding of emotions behind the information. Emotions play an important role in language communication. In this study, the authors conducted experiments to understand whether emotional context in language sounds activates what areas of the brain. Twenty-seven Japanese subjects listened to a recording of five reversed Japanese sentences and five Malay sentences: both with emotional intonation and without emotional intonation. A near-infrared spectroscopy (NIRS) system was used to observe the relative changes of blood Hb concentrations in the brain while the subjects were listening to the sentences with and without emotions. The results of the experiments showed that the areas related to working memory tended to be more activated when they were listening to the sentences without emotions for reversed Japanese sentences. However, for Malay sentences, working memory were more activated when the subjects were listening to the sentences with emotions.

95. Tanino et al. (2015). **The Analysis of the Brain State Measuring by NIRS-based BMI in Answering yes-no Questions**

Abstract: In recent years, Brain-Machine Interface (BMI) has been improved with the rapid development of the cerebral function measurement technologies. BMI is used for measuring the brain activity of the subjects and inferring his/her intention. These measuring results can control the devices such as the electric wheelchair or the electric arm directly. Previous studies have such problems that BMI device is not portable, and it takes much

time to attach a lot of sensor nodes on the head of the subject. Therefore, we use portable NIRS, because it is easy for the subjects to mount it and their burden is low. This paper describes the analytical method for cerebral blood flow during imagining affirmative or negative answers to the questions. It was verified whether it is possible to use the NIRS as BMI to discriminate the yes answer or no without voice and gesture.
In our study, a subject keeps watching the display which shows a yes-no question, he/she imagines affirmative or negative answer to the questions. In the experiment, one test trial is in 30 seconds and it includes 10 seconds task between 10 seconds rests. Each test set consists of 10 trials. One subject has five test set. In our study, we used Wearable Optical Topography WOT-100 as measurement device of NIRS which has 10 channels (ch7-16) of prefrontal cortex. The NIRS data analysis procedure is as follows; in the first step, we used a band-pass filter to select the data of frequencies from 0.02 Hz up to 0.1 Hz. In the second step, measured NIRS data of each task set is divided into 10 blocks which are included 5 seconds data before the task and 10 seconds data after the task. In the third step, we calculated baseline of measured data from 5 seconds of the beginning and the end of the task blocks, and this baseline fitting is applied to the original data. In the last step, the neural network learned the important elements of the training data and classified the test data. Our method can discriminate between imagining affirmative or negative answers with 70% accuracy. At result, NIRS is useful to discriminate the yes-no answer of the questions.

96. Wood et al. (2015). **Brain Tissue Oxygenation in Patients with Septic Shock: a Feasibility Study**

Abstract: Background: Delirium is common in critically ill patients and its presence is associated with increased mortality and increased likelihood of poor cognitive function among survivors. However, the cause of delirium is unknown. The purpose of this study was to demonstrate the feasibility of using near-infrared spectroscopy (NIRS) to assess brain tissue oxygenation in patients with septic shock, who are at high risk of developing delirium. Methods : This prospective observational study was conducted in a 33-bed general medical surgical intensive care unit (ICU). Patients with severe sepsis or septic shock were eligible for recruitment. The FORESIGHT NIRS monitor was used to assess brain tissue oxygenation in the frontal lobes for the first 72 hours of ICU admission. Physiological data was also recorded. We used the Confusion Assessment Method-ICU to screen for delirium. Results : From March 1st 2014-September 30th 2014, 10 patients with septic shock were recruited. The NIRS monitor captured 81% of the available data. No adverse events were recorded. Brain tissue oxygenation demonstrated significant intra- and inter-individual variability in the way it correlated with physiological parameters, such as mean arterial pressure, heart rate, and peripheral oxygen saturation. Mean brain tissue oxygen levels were significantly lower in patients who were delirious for the majority of their ICU stay. Conclusion: It is feasible to record brain tissue oxygenation with NIRS in patients with septic shock. This study provides the infrastructure necessary for a larger prospective observational study to further examine the relationship between brain tissue oxygenation, physiological parameters, and acute neurological dysfunction.

97. Tempest et al. (2015). **Self-reported tolerance influences prefrontal cortex hemodynamics and affective responses**

Abstract: The relationship between cognitive and sensory processes in the brain contributes to the regulation of affective responses (pleasure–displeasure). Exercise can be used to manipulate sensory processes (by increasing physiological demand) in order to examine the role of dispositional traits that may influence an individual's ability to cognitively regulate these responses. With the use of near infrared spectroscopy, in this study we examined the influence of self-reported tolerance upon prefrontal cortex (PFC) hemodynamics and affective responses. The hemodynamic response was measured in individuals with high or low tolerance during an incremental exercise test. Sensory manipulation was standardized against metabolic processes (ventilatory threshold [VT] and respiratory compensation point [RCP]), and affective responses were recorded. The results showed that the high-tolerance group displayed a larger hemodynamic response within the right PFC above VT (which increased above RCP). The low-tolerance group showed a larger hemodynamic response within the left PFC above VT. The high-tolerance group reported a more positive/less negative affective response above VT.

These findings provide direct neurophysiological evidence of differential hemodynamic responses within the PFC that are associated with tolerance in the presence of increased physiological demands. This study supports the role of dispositional traits and previous theorizing into the underlying mechanisms (cognitive vs. sensory processes) of affective responses.

98. Abdullah et al. (2015). **A Novel Near-Infrared Spectroscopy Based Spatiotemporal Cognition Study of the Human Brain Using Clustering**

Abstract: In this study, we investigate how the two hemispheres of the brain are involved spatiotemporally in a cognitive-based setup when people relate different colors with different concepts (for example, the color 'blue' associated with the word 'dependable' or 'cheap') objectively or subjectively. We developed an experimental setup using a 17-channel near-infrared spectroscopy (NIRS) device to measure the changes in brain hemoglobin concentration during a concept–color association task in a block design paradigm. The channel-wise activation data were recorded for 10 male students; after cleansing, the data were clustered using an indigenous clustering technique to identify channels having similar spatiotemporal activity. Data mining was imperative because of the big data generated by NIRS (ca. 0.1+ MB textual data captured per sec involving high volume and veracity), for which the traditional statistical techniques for data analysis could have failed to discover the patterns of interest. The results showed that it was possible to associate brain activities in the two hemispheres to study the association among linguistic concepts and colors, with most neural activity taking place in the right hemisphere of the brain characterized with intuition, subjectivity, etc. Thus, the study suggests novel application areas of neural activity analysis, such as color as marketing cue, response of obese versus lean to food intake, traditional versus neural data validation.

99. Khan et al. (2015). **Passive BCI based on drowsiness detection: an fNIRS study**

Abstract: We use functional near-infrared spectroscopy (fNIRS) to discriminate the alert and drowsy states for a passive brain-computer interface (BCI). The passive brain signals for the drowsy state are acquired from the prefrontal and dorsolateral prefrontal cortex. The experiment is performed on 13 healthy subjects using a driving simulator, and their brain activity is recorded using a continuous-wave fNIRS system. Linear discriminant analysis (LDA) is employed for training and testing, using the data from the prefrontal, left- and right-dorsolateral prefrontal regions. For classification, eight features are tested: mean oxyhemoglobin, mean deoxyhemoglobin, skewness, kurtosis, signal slope, number of peaks, sum of peaks, and signal peak, in 0~5, 0~10, and 0~15 second time windows, respectively. The results show that the best performance for classification is achieved using mean oxyhemoglobin, the signal peak, and the sum of peaks as features. The average accuracies in the right dorsolateral prefrontal cortex (83.1, 83.4 and 84.9% in the 0~5, 0~10 and 0~15 second time windows, respectively) show that the proposed method has an effective utility for detection of drowsiness for a passive BCI.

100. Semyachkina-Glushkovskaya et al. (2015). **Optical monitoring of stress-related changes in the brain tissues and vessels associated with hemorrhagic stroke in newborn rats**

Abstract: Stress is a major factor for a risk of cerebrovascular catastrophes. Studying of mechanisms underlying stress-related brain-injures in neonates is crucial for development of strategy to prevent of neonatal stroke. Here, using a model of sound-stress-induced intracranial hemorrhages in newborn rats and optical methods, we found that cerebral veins are more sensitive to the deleterious effect of stress than arteries and microvessels. The development of venous insufficiency with decreased blood outflow from the brain accompanied by hypoxia, reduction of complexity of venous blood flow and high production of beta-arrestin-1 are possible mechanisms responsible for a risk of neonatal hemorrhagic stroke.

101. Ono et al. (2015). **Motor learning and modulation of prefrontal cortex: an fNIRS assessment**

Abstract: OBJECTIVE: Prefrontal hemodynamic responses are observed during performance of motor tasks. Using a dance video game (DVG), a complex motor task that requires temporally accurate footsteps with given visual and auditory cues, we investigated whether 20 h of DVG training modified hemodynamic responses of the prefrontal cortex in six healthy young adults.
APPROACH: Fronto-temporal activity during actual DVG play was measured using functional near-infrared spectroscopy (fNIRS) pre- and post-training. To evaluate the training-induced changes in the time-courses of fNIRS signals, we employed a regression analysis using the task-specific template fNIRS signals that were generated from alternate well-trained and/or novice DVG players. The HRF was also separately incorporated as a template to construct an alternate regression model. Change in coefficients for template functions at pre- and post- training were determined and compared among different models.
MAIN RESULTS: Training significantly increased the motor performance using the number of temporally accurate steps in the DVG as criteria. The mean oxygenated hemoglobin (ΔoxyHb) waveform changed from an activation above baseline pattern to that of a below baseline pattern. Participants showed significantly decreased coefficients for regressors of the ΔoxyHb response of novice players and HRF. The model using ΔoxyHb responses from both well-trained and novice players of DVG as templates showed the best fit for the ΔoxyHb responses of the participants at both pre- and post-training when analyzed with Akaike information criteria.
SIGNIFICANCE: These results suggest that the coefficients for the template ΔoxyHb responses of the novice players are sensitive indicators of motor learning during the initial stage of training and thus clinically useful to determine the improvement in motor performance when patients are engaged in a specific rehabilitation program.

102. Edwards et al. (2015). **Functional brain organization for number processing in pre-verbal infants**

Abstract: Humans are born with the ability to mentally represent the approximate numerosity of a set of objects, but little is known about the brain systems that sub-serve this ability early in life and their relation to the brain systems underlying symbolic number and mathematics later in development. Here we investigate processing of numerical magnitudes before the acquisition of a symbolic numerical system or even spoken language, by measuring the brain response to numerosity changes in pre-verbal infants using functional near-infrared spectroscopy (fNIRS). To do this, we presented infants with two types of numerical stimulus blocks: number change blocks that presented dot arrays alternating in numerosity and no change blocks that presented dot arrays all with the same number. Images were carefully constructed to rule out the possibility that responses to number changes could be due to non-numerical stimulus properties that tend to co-vary with number. Interleaved with the two types of numerical blocks were audio-visual animations designed to increase attention. We observed that number change blocks evoked an increase in oxygenated hemoglobin over a focal right parietal region that was greater than that observed during no change blocks and during audio-visual attention blocks. The location of this effect was consistent with intra-parietal activity seen in older children and adults for both symbolic and non-symbolic numerical tasks. A distinct set of bilateral occipital and middle parietal channels responded more to the attention-grabbing animations than to either of the types of numerical stimuli, further dissociating the specific right parietal response to number from a more general bilateral visual or attentional response. These results provide the strongest evidence to date that the right parietal cortex is specialized for numerical processing in infancy, as the response to number is dissociated from visual change processing and general attentional processing.

103. Binder-Heschl et al. (2015). **Borderline hypotension: how does it influence cerebral regional tissue oxygenation in preterm infants?**

Abstract: Aim: To monitor cerebral regional tissue oxygenation (crSO2) of preterm infants continuously and to analyze the influence of arterial hypotension on crSO2.

Methods: In this prospective, observational study crSO2, peripheral oxygen saturation (SpO2), heart rate (HR) and mean arterial blood pressure (MABP) were monitored continuously for 24 h, starting within the first 6 h after birth. Furthermore, cerebral fractional tissue oxygen extraction (cFTOE) was calculated. Preterm neonates with and without arterial hypotension (MABP below the gestational age in weeks) were compared to each other.
Results: Forty-six preterm infants could be analyzed, 17 with (33.4 ± 1.9 weeks, 2016.5 ± 548.5 g) and 29 without arterial hypotension (33.3 ± 1.3 weeks, 1924.7 ± 451.9 g). Altogether, we detected 30 episodes of hypotension, with a mean duration of 1.6 ± 1.2 h per infant and a mean decrease in MABP of 2.2 ± 0.9 mmHg. During hypotension mean crSO2 was 7 5 ± 11%, 2 h prior to that 76 ± 10% and 2 h after the hypotension 7 7 ± 10%, therefore no significant alterations could be observed. Moreover, there was no significant difference in mean 24-h crSO2, SpO2 and cFTOE between the two groups.
Conclusion: Mild short-term hypotensive episodes in preterm infants did not affect crSO2. This suggests that cerebral autoregulation is maintained in case of borderline-hypotension and may protect infants from cerebral injury.

104. Montgomery et al. (2015). **Data clustering methods for the determination of cerebral autoregulation functionality**

Abstract: Cerebral blood flow is regulated over a range of systemic blood pressures through the cerebral autoregulation (CA) control mechanism. The COx measure based on near infrared spectroscopy (NIRS) has been proposed as a suitable technique for the analysis of CA as it is non-invasive and provides a simpler acquisition methodology than other methods. The COx method relies on data binning and thresholding to determine the change between intact and impaired autoregulation zones. In the work reported here we have developed a novel method of differentiating the intact and impaired CA blood pressure regimes using clustering methods on unbinned data. K-means and Gaussian mixture model algorithms were used to analyse a porcine data set. The determination of the lower limit of autoregulation (LLA) was compared to a traditional binned data approach. Good agreement was found between the methods. The work highlights the potential application of using data clustering tools in the monitoring of CA function.

105. Shibuya et al. (2015). **Complementary activation of the ipsilateral primary motor cortex during a sustained handgrip task**

Abstract: Purpose: Near-infrared spectroscopy (NIRS) can be used to examine bilateral motor cortex activation during a sustained motor task in brain areas where increased oxygenation reflects cortical activation. This study examines the time course of activation of the bilateral motor cortex during a moderate-intensity handgrip task.
Methods: Ten healthy right-handed male subjects participated in this study. Functional NIRS probes were placed over the cortex to measure motor cortical activations while the subjects performed a 180-s handgrip task incrementally [30–60 % of the maximal voluntary contraction (MVC) at 0.17 % increase/s]
Results: Contralateral primary motor cortex (ContraM1) oxygenation values significantly increased from baseline between 40 and 120 s after the start of the motor task ($p < 0.05$). Moreover, the ipsilateral primary motor cortex (IpsiM1) oxygenation values significantly increased from baseline between 140 and 180 s after the start of the motor task ($p < 0.05$). IpsiM1 oxygenation gradually increased from 140 to 180 s, whereas ContraM1 oxygenation gradually decreased from 120 to 180 s after the start of the motor task.
Conclusion: These results suggest that the complementary functions of IpsiM1 become activated in response to the working of the ContraM1 during a continuous handgrip task.

106. Rackebrandt et al. (2015). **Measuring different oxygenation levels in a blood perfusion model simulating the human head using NIRS**

Abstract: The oxygenation, perfusion and metabolism of the brain - segmented in both hemispheres - can be estimated from the oxygenation and hemoglobin levels of the venous blood in the cerebral efferent vessels.
We present a phantom based model to simulate the anatomical target region which was connected to hemodynamic perfusion circuit to provide different oxygenation rates inside of the simulated target vessel (measurement cell) reproducible. A triple-wavelength (770, 808 and 850 nm) multi-distance NIRS sensor (6 photodiodes, linearly arranged, separated 6 mm each) was used to detect these different saturation levels.
The results illustrate the capability to measure the optical property variation of hemoglobin due to oxygenation and deoxygenation processes in a specific vessel. Based on these first results a series of measurements is introduced to correlate the amount of reflected light to the actual oxygen saturation of the blood.

107. Hyde et al. (2015). **Human temporal-parietal junction spontaneously tracks others' beliefs: A functional near-infrared spectroscopy study**

Abstract: Humans have the unique capacity to actively reflect on the thoughts, beliefs, and knowledge of others, but do we also track mental states spontaneously when observing other people? We asked this question by monitoring brain activity in belief-sensitive cortex using functional near-infrared spectroscopy (fNIRS) during free-viewing of social videos. More specifically, we identified a portion of the right temporal-parietal junction (rTPJ) selective for mental state processing using an established, explicit theory of mind task, and then analyzed the brain response in that region of interest (ROI) during free-viewing of video clips involving people producing goal-directed actions. We found a significant increase in oxygenated hemoglobin concentration in our rTPJ ROI during free-viewing for all of our test videos. Activity in this region was further modulated by the extent to which the knowledge state, or beliefs, of the protagonist regarding the location of an object contrasted with the reality of where the object was hidden. Open-ended questioning suggested our participants were not explicitly focusing on belief states of the characters during free-viewing. Further analyses ruled out lower-level details of the video clips or general attentional differences between conditions as likely explanations for the results. As such, these results call into question the traditional characterization of theory of mind as a resource intensive, deliberate process, and, instead, support an emerging view of theory of mind as a foundation for, rather than the pinnacle of, human social cognition.

108. Mrachal-Crespo et al. (2015). **Detecting motion intention in stroke survivors using autonomic nervous system responses**

Abstract: Individuals with severe neurologic injuries often cannot participate in robotic rehabilitation because they do not retain sufficient residual motor control to initiate the robotic assistance. In these situations, brain- and body-computer interfaces have emerged as promising solutions to control robotic devices. In a previous experiment conducted with healthy subjects, we showed that detecting motor execution accurately was possible using only the autonomic nervous system (ANS) response. In this paper, we investigate the feasibility of such a body-machine interface to detect motion intention by monitoring the ANS response in stroke survivors. Four physiological signals were measured (blood pressure, breathing rate, skin conductance response and heart rate) while participants executed and imagined a grasping task with their impaired hand. The physiological signals were then used to train a classifier based on hidden Markov models. We performed an experiment with four chronic stroke survivors to test the effectiveness of the classifier to detect rest, motor execution and motor imagery periods. We found that motion execution can be accurately classified based only on peripheral autonomic signals with an accuracy of 72.4%. The accuracy of classifying motion imagery was 62.4%. Therefore, attempting to move was a more effective strategy than imagining the movement. These results are encouraging to perform further research on the use of the ANS response in body-machine interfaces.

109. Khan et al. (2015). **Hybrid EEG-NIRS based BCI for quadcopter control**

Abstract: In this paper, we have proposed a novel control strategy for a quadcopter control using brain signals. A brain-computer interface (BCI) technology is developed using hybrid electroencephalography - near-infrared spectroscopy (EEG-NIRS) system and two commands are used to operate the quadcopter. An active brain signal upon the user's own will is generated using a motor imagery task and a reactive brain signal is generated by visual flickering of light. The reactive command is used for the triggering control of the quadcopter and the active command is used to navigate the quadcopter in the forward direction. Linear discriminant analysis is used to classify the brain activity in offline environment. The results indicate that the proposed scheme is suitable for the BCI control applications.

110. Khan et al. (2015). **Motor imagery performance evaluation using hybrid EEG-NIRS for BCI**

Abstract: In this paper, we have evaluated the performance of motor imagery (MI), before and after training by a rehabilitation robot, for brain-computer interface (BCI). A hybrid electroencephalography and near-infrared spectroscopy (EEG-NIRS) system is used to detect the MI by placing the electrodes and optodes around the motor cortex region. Five healthy subjects have participated in the experiment. The subjects are assisted by a rehabilitation robot in an arm movement paradigm during the training session. The MI activity of the subjects is recorded before and after the training sessions. The brain signals from the motor cortex are recorded simultaneously using EEG-NIRS. We found a significant improvement in the MI performance after training. Linear discriminant analysis is used to classify the acquired activity in an offline analysis. The data analysis shows that the hybrid EEG-NIRS can detect better motor activity than individual modality. The average classification accuracy of the subjects has increased from 66% to 94% after training. We propose that the training of the motor cortex by a rehabilitation robot can improve the MI performance for BCI.

111. Jin et al. (2015). **An application of common spatial pattern algorithm for accuracy improvement in classification of cortical activation pattern according to finger movement**

Abstract: In this paper, we tried to suggest feature extraction method using CSP Algorithm to improve the accuracy of classifier according to finger movement to develop the Upper Limb Rehabilitation Robot System based on brain signal. Four subjects participated in the experiment and they conducted four kind of tasks in three times. The task is divided by two kind of movement(Digit Flexion/Extension, Thumb Flexion/Extension), and two kind of mode(Active, Passive). We measured brain signal according to finger movement using fNIRS(functional Near Infrared Spectroscopy, FOIRE-3000, Shimadzu, Japan). Also, sampling rate of measured sign is 7.6923Hz and there are 24 channels. We conducted preprocessing process using HRF(Hemodynamic Response Function) and Wavelet-MDL(minimum description length) to remove the noise and global bias in selected signal. After preprocessing process, we extracted feature using CSP(Common Spatial Pattern) Algorithm and calculated the accuracy of classification in each task using Support Vector Machine(SVM). There is accuracy of classification result by applying CSP Algorithm. Accuracy of classification using SVM is about 69.53% and after applying CSP Algorithm is about 71.82%. we can find that it improved 2.29%.

112. Mitsutaka et al. (2015). **Effect of neck and trunk rotation speeds on cerebral cortex activity and standing postural stability: a functional near-infrared spectroscopy study**

Abstract: The aim of the present study was to determine whether different neck and trunk rotation speeds influence standing postural stability or frontal and temporal cortical activity during rotation in healthy young adults. [Subjects and Methods] Twelve healthy volunteers participated in this study. A custom turn-table operated by one of the experimenters was placed on a platform to assess postural perturbation. Subjects were asked to stand barefoot on the turn-table in an upright position with their feet together, and measurements were

obtained during high- and low-speed rotations. Postural stability was tested using a force platform and a head sensor. Cerebral cortex activity was measured using functional near-infrared spectroscopy. Brain activity, center of pressure, and head perturbation were measured simultaneously for each subject. [Results] Significant differences were found in the center of pressure and the head angular velocity between high- and low-speed rotations. However, compared to baseline, oxygenated hemoglobin levels were not significantly different during high- or low-speed rotations. [Conclusion] Automatic postural responses to neck and trunk rotation while standing did not significantly activate the cerebral cortex. Therefore, the response to stimuli from the feet may be controlled by the spinal reflex rather than the cerebral cortex.

113. Liu et al. (2015). **fNIRS based color detection from human visual cortex**

Abstract: In this study, functional near-infrared spectroscopy (fNIRS) is used to measure the relative hemodynamic response changes in the visual cortex for 10 subjects (aged 22~34 years old), while they watch red, green, and blue (RGB) colors on a projection screen. The concentration changes of oxygenated and deoxygenated hemoglobin (HbO and HbR) are measured in 30 channels (i.e., 15 sources and 15 detectors combination). The data recorded using the RGB color stimuli show a significant increase in the HbO in the visual cortex. It is found that the HbO changes are more active in the left side of the human visual cortex than the right side. It was able to distinguish red, green and blue colors using the fNIRS technology. The results suggest that investigating the human visual cortex by monitoring the hemodynamic response patterns with fNIRS is a viable method in understanding the human brain.

114. He et al. (2015). **The Scalp Confounds Near-Infrared Signal from Rat Brain Following Innocuous and Noxious Stimulation**

Abstract: Functional near-infrared imaging (fNIRI) is a non-invasive, low-cost and highly portable technique for assessing brain activity and functions. Both clinical and experimental evidence suggest that fNIRI is able to assess brain activity at associated regions during pain processing, indicating a strong possibility of using fNIRI-derived brain activity pattern as a biomarker for pain. However, it remains unclear how, especially in small animals, the scalp influences fNIRI signal in pain processing. Previously, we have shown that the use of a multi-channel system improves the spatial resolution of fNIRI in rats (without the scalp) during pain processing. Our current work is to investigate a scalp effect by comparing with new data from rats with the scalp during innocuous or noxious stimulation (n = 6). Results showed remarkable stimulus-dependent differences between the no-scalp and intact-scalp groups. In conclusion, the scalp confounded the fNIRI signal in pain processing likely via an autonomic mechanism; the scalp effect should be a critical factor in image reconstruction and data interpretation.

115. Schwaberger et al. (2015). **Do Sustained Lung Inflations during Neonatal Resuscitation Affect Cerebral Blood Volume in Preterm Infants? A Randomized Controlled Pilot Study**

Abstract: Background: Sustained lung inflations (SLI) during neonatal resuscitation may promote alveolar recruitment in preterm infants. While most of the studies focus on respiratory outcome, the impact of SLI on the brain hasn't been investigated yet.
Objective: Do SLI affect cerebral blood volume (CBV) in preterm infants?
Methods: Preterm infants of gestation 28 weeks 0 days to 33 weeks 6 days with requirement for respiratory support (RS) were included in this randomized controlled pilot trial. Within the first 15 minutes after birth near-infrared spectroscopy (NIRS) measurements using 'NIRO-200-NX' (Hamamatsu, Japan) were performed to evaluate changes in CBV and cerebral tissue oxygenation. Two groups were compared based on RS: In SLI group RS was given by applying 1–3 SLI (30 cmH2O for 15 s) continued by respiratory standard care. Control group received respiratory standard care only.

Results: 40 infants (20 in each group) with mean gestational age of 32 weeks one day (±2 days) and birth weight of 1707 (±470) g were included. In the control group ΔCBV was significantly decreasing, whereas in SLI group ΔCBV showed similar values during the whole period of 15 minutes. Comparing both groups within the first 15 minutes ΔCBV showed a tendency toward different overall courses ($p = 0.051$).
Conclusion: This is the first study demonstrating an impact of SLI on CBV. Further studies are warranted including reconfirmation of the present findings in infants with lower gestational age. Future investigations on SLI should not only focus on respiratory outcome but also on the consequences on the developing brain.

116. Diop et al. (2015). **Development of a combined broadband near-infrared and diffusion correlation system for monitoring cerebral blood flow and oxidative metabolism in preterm infants**

Abstract: Neonatal neuromonitoring is a major clinical focus of near-infrared spectroscopy (NIRS) and there is an increasing interest in measuring cerebral blood flow (CBF) and oxidative metabolism (CMRO2) in addition to the classic tissue oxygenation saturation (StO2). The purpose of this study was to assess the ability of broadband NIRS combined with diffusion correlation spectroscopy (DCS) to measured changes in StO2, CBF and CMRO2 in preterm infants undergoing pharmaceutical treatment of patent ductus arteriosus. CBF was measured by both DCS and contrast-enhanced NIRS for comparison. No significant difference in the treatment-induced CBF decrease was found between DCS (27.9 ± 2.2%) and NIRS (26.5 ± 4.3%). A reduction in StO2 (70.5 ± 2.4% to 63.7 ± 2.9%) was measured by broadband NIRS, reflecting the increase in oxygen extraction required to maintain CMRO2. This study demonstrates the applicability of broadband NIRS combined with DCS for neuromonitoring in this patient population.

117. Genbrugge et al. (2015). **Regional Cerebral Oximetry During Cardiopulmonary Resuscitation: Useful or Useless?**

Abstract: Background: Approximately 375,000 people annually experience sudden cardiac arrest (CA) in Europe. Most patients who survive the initial hours and days after CA die of postanoxic brain damage. Current monitors, such as electrocardiography and end-tidal capnography, provide only indirect information about the condition of the brain during cardiopulmonary resuscitation (CPR). In contrast, cerebral near-infrared spectroscopy provides continuous, noninvasive, real-time information about brain oxygenation without the need for a pulsatile blood flow. It measures transcutaneous cerebral tissue oxygen saturation (rSO2). This information could supplement currently used monitors. Moreover, an evolution in rSO2 monitoring technology has made it easier to assess rSO2 in CA conditions.
Objective: We give an overview of the literature regarding rSO2 measurements during CPR and the current commercially available devices. We highlight the feasibility of cerebral saturation measurement during CPR, its role as a quality parameter of CPR, predictor of return of spontaneous circulation (ROSC) and neurologic outcome, and its monitoring function during transport.
Discussion: rSO2 is feasible in the setting of CA and has the potential to measure the quality of CPR, predict ROSC and neurologic outcome, and monitor post-CA patients during transport.
Conclusion: The literature shows that rSO2 has the potential to serve multiple roles as a neuromonitoring tool during CPR and also to guide neuroprotective therapeutic strategies.

118. Li et al. (2015). **Dynamic functional connectivity revealed by resting-state functional near-infrared spectroscopy**

Abstract: The brain is a complex network with time-varying functional connectivity (FC) and network organization. However, it remains largely unknown whether resting-state fNIRS measurements can be used to characterize dynamic characteristics of intrinsic brain organization. In this study, for the first time, we used the

whole-cortical fNIRS time series and a sliding-window correlation approach to demonstrate that fNIRS measurement can be ultimately used to quantify the dynamic characteristics of resting-state brain connectivity. Our results reveal that the fNIRS-derived FC is time-varying, and the variability strength (Q) is correlated negatively with the time-averaged, static FC. Furthermore, the Q values also show significant differences in connectivity between different spatial locations (e.g., intrahemispheric and homotopic connections). The findings are reproducible across both sliding-window lengths and different brain scanning sessions, suggesting that the dynamic characteristics in fNIRS-derived cerebral functional correlation results from true cerebral fluctuation.

119. Li et al. (2015). **Using functional near-infrared spectroscopy (fNIRS) to detect the prefrontal cortical responses to deception under different motivations**

Abstract: In this study, functional near-infrared spectroscopy (fNIRS) was adopted to investigate the prefrontal cortical responses to deception under different motivations. By using a feigned memory impairment paradigm, 19 healthy adults were asked to deceive under the two different motivations: to obtain rewards and to avoid punishments. Results indicated that when deceiving for obtaining rewards, there was greater neural activation in the right inferior frontal gyrus (IFG) than the control condition. When deceiving for avoiding punishments, there was greater activation in the right inferior frontal gyrus (IFG) and the left middle frontal gyrus (MFG) than the control condition. In addition, deceiving for avoiding punishments led to greater neural activation in the left MFG than when deceiving for obtaining rewards. Furthermore, the results showed a moderate hit rate in detecting deception under either motivation. These results demonstrated that deception with different motivations led to distinct responses in the prefrontal cortex. fNIRS could provide a useful technique for the detection of deception with strategy of feigning memory impairment under different motivations.

Publications from the BORL, Zurich

120. Vögeli et al. (2015). **Housing conditions influence cortical and behavioural reactions of sheep in response to videos showing social interactions of different valence**

Abstract: Mood, as a long-term affective state, is thought to modulate short-term emotional reactions in animals, but the details of this interplay have hardly been investigated experimentally. Apart from a basic interest in this affective system, mood is likely to have an important impact on animal welfare, as bad mood may taint all emotional experience. In the present study about mood - emotion interaction, 29 sheep were kept under predictable, stimulus-rich or unpredictable, stimulus-poor housing conditions, to induce different mood states. In an experiment, the animals were confronted with video sequences of social interactions of conspecifics showing agonistic interactions, ruminating or tolerantly co-feeding as stimuli of different valences. Emotional reactions were assessed by measuring frontal brain activity using functional near-infrared spectroscopy and by recording behavioral reactions. Attentiveness of the sheep decreased from videos showing agonistic interactions to ruminating sheep to those displaying co-feeding sheep. Seeing agonistic interactions was also associated with a deactivation of the frontal cortex, specifically in animals living under predictable, stimulus-rich housing conditions. These sheep generally showed less attentiveness and locomotor activity and they had their ears in a forward position less often and in a backward position more often than the sheep from the unpredictable, stimulus-poor conditions. Housing conditions influenced how the sheep behaved, which can either be thought to be mediated by mood or by the animals' previous experience with stimulus-richness in their housing conditions. Frontal cortical activity may not depend on valence only, but also on the perceptual channel through which the stimuli were perceived.