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

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Number of papers included: **110**

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

1. An et al. (2013). **An efficient GP approach to recognizing cognitive tasks from fNIRS neural signals**

Abstract: This paper presents a new genetic programming (GP) approach to accurately classifying cognitive tasks from non-stationary and noisy fNIRS neural signals. To this end, a new GP that effectively handles multiclass problems is developed. In accordance with multi-tree structure, GP operators are innovated: crossover exchanges every subtree of parents without suffering from any incongruity problem and mutation fine-tunes candidate solutions by a less destructive process. Experimental results verifies the effectiveness of the proposed GP classifier over existing references.

2. Grossmann et al. (2013). **Brain responses reveal young infants' sensitivity to when a social partner follows their gaze**

Abstract: Infants' ability to follow another person's eye gaze has been studied extensively and is considered to be an important and early emerging social cognitive skill. However, it is not known whether young infants detect when a social partner follows their gaze to an object. This sensitivity might help infants in soliciting information from others and serve as an important basis for social learning. In this study, we used functional near-infrared spectroscopy (fNIRS) to measure 5-month-old infants' frontal and temporal cortex responses during social interactions in which a social partner (virtual agent) either followed the infants' gaze to an object (congruent condition) or looked to an object that the infant had not looked at before (incongruent condition). The fNIRS data revealed that a region in the left prefrontal cortex showed an increased response when compared to baseline during the congruent condition but not during the incongruent condition, suggesting that infants are sensitive to when someone follows their gaze. The findings and their implications for the development of early social cognition are discussed in relation to what is known about the brain processes engaged by adults during these kinds of social interactions.

3. Tupak et al. (2013). **Implicit emotion regulation in the presence of threat: Neural and autonomic correlates**

Abstract: Efficient emotion regulation is essential for social interaction and functioning in human society and often happens without direct intention and conscious awareness. Cognitive labeling of stimuli based on certain characteristics has been assumed to represent an effective strategy of implicit emotional regulation whereas processing based on simple perceptual characteristics (e.g., matching) has not. Evidence exists that the ventrolateral prefrontal cortex (VLPFC) might be of functional relevance during labeling by down-regulating limbic activity in the presence of threatening stimuli. However, it remained unclear whether this VLPFC activation was particularly specific to threat because previous studies focused exclusively on threatening stimuli. In the current study, 35 healthy participants labeled or matched both threatening and neutral pictures while undergoing 52-channel functional near-infrared spectroscopy. Results showed increased VLPFC activation during labeling of threatening but not neutral pictures. No increase in prefrontal activation was detected during

matching. Moreover, skin conductance increased equally for both valence conditions during initial phases of labeling whereas during matching stronger increases were found for threatening stimuli. Although a general inverse relationship between VLPFC function and skin conductance was not confirmed, both were negatively correlated during matching of threatening pictures in subjects with high state anxiety. It was concluded that the VLPFC plays an essential role during implicit emotion regulation. Further, even simple perceptual processing seems to engage regulatory top-down activation in anxious individuals.

4. Lee et al. (2013). **Brain responses reveal young infants' sensitivity to when a social partner follows their gaze**

Abstract: Pain and itch are closely related sensations, yet qualitatively quite distinct. Despite recent advances in brain imaging techniques, identifying the differences between pain and itch signals in the brain cortex is difficult due to continuous temporal and spatial changes in the signals. The high spatial resolution of positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) has substantially advanced research of pain and itch, but these are uncomfortable because of expensiveness, importability and the limited operation in the shielded room. Here, we used near infrared spectroscopy (NIRS), which has more conventional usability. NIRS can be used to visualize dynamic changes in oxygenated hemoglobin and deoxyhemoglobin concentrations in the capillary networks near activated neural circuits in real-time as well as fMRI. We observed distinct activation patterns in the frontal cortex for acute pain and histamine-induced itch. The prefrontal cortex exhibited a pain-related and itch-related activation pattern of blood flow in each subject. Although it looked as though that activation pattern for pain and itching was different in each subject, further cross correlation analysis of NIRS signals between each channels showed an overall agreement with regard to prefrontal area involvement. As a result, pain-related and itch-related blood flow responses (delayed responses in prefrontal area) were found to be clearly different between pain (τ = +18.7 sec) and itch (τ = +0.63 sec) stimulation. This is the first pilot study to demonstrate the temporal and spatial separation of a pain-induced blood flow and an itch-induced blood flow in human cortex during information processing.

5. Kanthack et al. (2013). **Equal prefrontal cortex activation between males and females in a motor tasks and different visual imagery perspectives: A functional near-infrared spectroscopy (fNIRS) study**

Abstract: The purpose of this study was to compare the prefrontal cortex (PFC) blood flow variation and time on in males and females while performing a motor task and imagery perspectives. Eighteen right handed subjects (11 males and 7 females) were volunteers to this study. All subjects went through three randomly conditions, a motor task condition (MT) in which they had to do a simple finger tap. The other conditions included practicing imagery in first and third views. During all the conditions, the fNIRS device was attached to the subject forehead to obtain the blood flow; the total time in each task which was measured with a chronometer. No difference had been found in any condition for both sexes in the PFC and time, nor for all subjects integrated in the PFC. Therefore, we conclude that both imageries can be used to mentally train a motor task, and probably both sexes can be benefited.

6. Shimokawa et al. (2013). **Extended hierarchical Bayesian diffuse optical tomography for removing scalp artifact**

Abstract: Functional near-infrared spectroscopy (fNIRS) can non-invasively measure hemodynamic responses in the cerebral cortex with a portable apparatus. However, the observation signal in fNIRS measurements is contaminated by the artifact signal from the hemodynamic response in the scalp. In this paper, we propose a method to separate the signals from the cortex and the scalp by estimating both hemodynamic changes by diffuse optical tomography (DOT). In the inverse problem of DOT, we introduce smooth regularization to the

hemodynamic change in the scalp and sparse regularization to that in the cortex based on the nature of the hemodynamic responses. These appropriate regularization models, with the spatial information of optical paths of many measurement channels, allow three-dimensional reconstruction of both hemodynamic changes. We validate our proposed method through two-layer phantom experiments and MRI-based head-model simulations. In both experiments, the proposed method simultaneously estimates the superficial smooth activity in the scalp area and the deep localized activity in the cortical area.

7. Ferrari et al. (2013). **Prefrontal Cortex Activated Bilaterally by a Tilt Board Balance Task: A Functional Near-Infrared Spectroscopy Study in a Semi-Immersive Virtual Reality Environment**

Abstract: The aim of this study was to assess the prefrontal cortex (PFC) oxygenation response to a 5-min incremental tilt board balance task (ITBBT) in a semi-immersive virtual reality (VR) environment driven by a depth-sensing camera. It was hypothesized that the PFC would be bilaterally activated in response to the increase of the ITBBT difficulty, given the PFC involvement in the allocation of the attentional resources to maintain postural control. Twenty-two healthy male subjects were asked to use medial–lateral postural sways to maintain their equilibrium on a virtual tilt board (VTB) balancing over a pivot. When the subject was unable to maintain the VTB angle within ±35° the VTB became red (error). An eight-channel fNIRS system was employed for measuring changes in PFC oxygenated-deoxygenated hemoglobin (O2Hb-HHb, respectively). Results revealed that the number of the performed board sways and errors augmented with the increasing of the ITBBT difficulty. A PFC activation was observed with a tendency to plateau for both O2Hb-HHb changes within the last 2 min of the task. A significant main effect of the level of difficulty was found in O2Hb and HHb ($p < 0.001$). The study has demonstrated that the oxygenation increased over the PFC while the subject was performing an ITBBT in a semi-immersive VR environment. This increase was modulated by the task difficulty, suggesting that the PFC is bilaterally involved in attention-demanding tasks. This task could be considered useful for diagnostic testing and functional neurorehabilitation given its adaptability in elderly and in patients with movement disorders.

8. Arlt et al. (2013). **A study of pile-up in integrated time-correlated single photon counting system**

Abstract: Recent demonstration of highly integrated, solid-state, time-correlated single photon counting (TCSPC) systems in CMOS technology is set to provide significant increases in performance over existing bulky, expensive hardware. Arrays of single photon single photon avalanche diode (SPAD) detectors, timing channels, and signal processing can be integrated on a single silicon chip with a degree of parallelism and computational speed that is unattainable by discrete photomultiplier tube and photon counting card solutions. New multi-channel, multi-detector TCSPC sensor architectures with greatly enhanced throughput due to minimal detector transit (dead) time or timing channel dead time are now feasible. In this paper, we study the potential for future integrated, solid-state TCSPC sensors to exceed the photon pile-up limit through analytic formula and simulation. The results are validated using a 10% fill factor SPAD array and an 8-channel, 52 ps resolution time-to-digital conversion architecture with embedded lifetime estimation. It is demonstrated that pile-up insensitive acquisition is attainable at greater than 10 times the pulse repetition rate providing over 60 dB of extended dynamic range to the TCSPC technique. Our results predict future CMOS TCSPC sensors capable of live-cell transient observations in confocal scanning microscopy, improved resolution of near-infrared optical tomography systems, and fluorescence lifetime activated cell sorting.

9. Ferreri et al. (2013). **Music improves verbal memory encoding while decreasing prefrontal cortex activity: an fNIRS study**

Abstract: Listening to music engages the whole brain, thus stimulating cognitive performance in a range of non-purely musical activities such as language and memory tasks. This article addresses an ongoing debate on the link between music and memory for words. While evidence on healthy and clinical populations suggests that music listening can improve verbal memory in a variety of situations, it is still unclear what specific memory process is affected and how. This study was designed to explore the hypothesis that music specifically benefits the encoding part of verbal memory tasks, by providing a richer context for encoding and therefore less demand on the dorsolateral prefrontal cortex (DLPFC). Twenty-two healthy young adults were subjected to functional near-infrared spectroscopy (fNIRS) imaging of their bilateral DLPFC while encoding words in the presence of either a music or a silent background. Behavioral data confirmed the facilitating effect of music background during encoding on subsequent item recognition. fNIRS results revealed significantly greater activation of the left hemisphere during encoding (in line with the HERA model of memory lateralization) and a sustained, bilateral decrease of activity in the DLPFC in the music condition compared to silence. These findings suggest that music modulates the role played by the DLPFC during verbal encoding, and open perspectives for applications to clinical populations with prefrontal impairments, such as elderly adults or Alzheimer's patients.

10. Tempest & Parfitt (2013). **Imagery use and affective responses during exercise: an examination of cerebral hemodynamics using near-infrared spectroscopy**

Abstract: Imagery, as a cognitive strategy, can improve affective responses during moderate-intensity exercise. The effects of imagery at higher intensities of exercise have not been examined. Further, the effect of imagery use and activity in the frontal cortex during exercise is unknown. Using a crossover design (imagery and control), activity of the frontal cortex (reflected by changes in cerebral hemodynamics using near-infrared spectroscopy) and affective responses were measured during exercise at intensities 5% above the ventilatory threshold (VT) and the respiratory compensation point (RCP). Results indicated that imagery use influenced activity of the frontal cortex and was associated with a more positive affective response at intensities above VT, but not RCP to exhaustion ($p < .05$). These findings provide direct neurophysiological evidence of imagery use and activity in the frontal cortex during exercise at intensities above VT that positively impact affective responses.

11. Crespi (2013). **Parallel Effect of Nicotine and MK-801 on Brain Metabolism: An In vivo Non Invasive Near-Infrared Spectroscopy Analysis in Rats**

Abstract: Oxygenated haemoglobin, deoxyhaemoglobin and total blood volume are measured with our recently developed Near-Infrared Spectroscopy [NIRS] apparatus allowing in vivo non invasive real time monitoring of brain metabolism in anaesthetized rats. These measurements are indicative of the state of vascular activity and the state of the oxygen saturation, thus of the level of metabolism in the living tissue.
Nicotine is a natural alkaloid derived from tobacco that has been implicated in various effects ranging from addiction to toxic effects and neuro-protective actions. Here we analyse the influence of nicotine as well as that of the non competitive NMDA receptor antagonist MK-801 [(+)-5-methyl-10,11-dihydro-5H-dibenzo[a,d] cyclohepten-5,10-imine maleate)] upon brain metabolism in anaesthetized rats.
In the first 30min after treatment, nicotine decreases significantly although in a transient manner oxygenated haemoglobin and total blood volume while increasing significantly deoxyhaemoglobin. In addition, MK-801 performed in another group of rats was followed by changes in these three parameters that were similar to those monitored in nicotine treated rats.
The NIRS methodology appears to be apt to analyzing non-invasively and in real time the influence of systemic pharmacological treatments upon brain metabolism. In particular the data gathered show similarity of action of the two chemicals studied on influencing metabolic brain "behaviour" proposing that their central protective action may pass via the observed similar changes in brain metabolism. These changes could be a common mechanism of adaptation and protection towards neurotoxicity: mechanism that should be also considered in the intent of developing new pharmaceutical approaches for neuro-protective treatments.

12. Gehricke et al. (2013). **Prefrontal hemodynamic changes during cigarette smoking in young adult smokers with and without ADHD**

Abstract: Individuals with attention-deficit/hyperactivity disorder (ADHD) have elevated smoking prevalence and reduced cessation rates compared to the general population. However, the effects of cigarette smoking on underlying brain activity in smokers with ADHD are not well characterized. Non-invasive near-infrared spectroscopy (NIRS) was used to characterize how cigarette smoking affects prefrontal brain hemodynamics in smokers with and without ADHD. Prefrontal changes of oxy- and deoxyhemoglobin (HbO_2 and HHb) were measured in six male adult smokers with ADHD and six age- and gender-matched control smokers. NIRS measurements were separated into four sequential time intervals, i.e., before smoking, during smoking, after smoking, and during a breath hold. Prefrontal HbO_2 was lower during smoking in smokers with ADHD compared to control smokers. More specifically, smokers with ADHD showed decreased prefrontal HbO_2 during smoking compared to breath hold, before and after smoking periods. In contrast, control smokers showed increased prefrontal HbO_2 from before smoking to breath hold. Decreased prefrontal HbO_2 in smokers with ADHD may reflect a smoking-induced change in prefrontal brain activity and microvasculature, which is not found in smokers without ADHD. The lower prefrontal HbO_2 may be a biomarker for increased susceptibility to tobacco smoke in smokers with ADHD. Smoking in individuals with ADHD may increase vasoconstriction of cerebral arteries in the prefrontal cortex, which may contribute to a reduction in HbO_2. The findings highlight the importance of smoking cessation, in particular in those smokers who use nicotine to self-medicate ADHD symptoms.

13. Fassoulaki et al. (2013). **Cesarean delivery under spinal anesthesia is associated with decreases in cerebral oxygen saturation as assessed by NIRS: an observational study**

Abstract: Objectives: To investigate the effect of spinal anesthesia on cerebral rSO_2 during elective cesarean delivery (CD). Methods: Thirty-four women scheduled for elective CD under spinal anesthesia were recruited. In the operating room rSO2 of the left and right frontal area and right thigh was recorded using three disposable sensors. A combination of 1.8–2.0 ml of 0.75% ropivacaine plus 10 μg of fentanyl were injected intrathecally. Systolic and diastolic blood pressure, heart rate, SpO2 as well as rSO2 of the left and right forehead areas and right thigh were recorded before, 5, 10, and 25 to 50 minutes after spinal injection, after uterine incision and placenta delivery, and analyzed with ANOVA repeated measures. The study was approved by the Aretaieio Hospital Institutional Review Board and registered with ClinicalTrials.gov (ID: NCT01669135). Results: The rSO2 left and right frontal area values decreased significantly from baseline ($p = 0.0001$ and $p = 0.0001$ respectively), with most remarkable decreases 5 and 10 minutes after spinal injection, from 65 (SD 8.7) % to 56 (SD 9.3) % and 56 (SD 9.5) % ($p = 0.0001$ and $p = 0.0001$) for the left and from 63 (SD 7.7) % to 55 (SD 9.3) % and 56 (SD 8.9) % ($p = 0{,}0001$ and $p = 0.0001$) for the right frontal area respectively. The rSO2 right thigh values increased significantly during the study period ($p = 0.0001$). Conclusions: Women undergoing CD under spinal anesthesia may present decreases in cerebral rSO_2. The clinical impact of these results remains to be determined.

14. Yamasaki et al. (2013). **Rapid maturation of voice and linguistic processing systems in preschool children: A near-infrared spectroscopic study**

Abstract: To better understand how voice and linguistic processing systems develop during the preschool years, changes in cerebral oxygenation were measured bilaterally from temporal areas using multi-channel near-infrared spectroscopy (NIRS). NIRS was recorded while children listened to their mothers' voice (MV), an unfamiliar female voice (UV) and environmental sound (ES) stimuli. Twenty typical children (aged 3–6 years) were divided into younger (Y) ($n = 10$, male = 5; aged 3–4.5 years) and older (O) ($n = 10$, male = 5; aged 4.5–6 years) groups. In the Y group, while MV stimuli significantly activated anterior temporal areas with a right

predominance compared to ES stimuli, they significantly activated left mid-temporal areas compared to UV stimuli. These temporal activations were significantly higher in the Y group compared to the O group. Furthermore, only the O group exhibited significant habituation and gender differences in the left mid-temporal area during MV perception. These findings suggest that the right voice-related and the left language-related temporal areas already exist in the Y group, and that MV stimuli modulate these areas differently in the two age groups. Therefore, we conclude that a mother's voice plays an important role in the maturation of the voice and linguistic processing systems, particularly during the first half of the preschool-aged period. This role may decrease during the latter half of the preschool-aged period due to rapid development of these systems as children age.

15. Aksun et al. (2013). **Cerebral oximetry monitoring method for the evaluation of the need of shunt placement during carotid endarterectomy**

Abstract: The primary objective of anesthetic and surgical approach in carotid surgery is to protect the heart and brain from an ischemic damage. As a result, a shunt application which carries the blood from the common carotid artery to the internal carotid artery may be required during surgery. Shunt is usually used in patients with contralateral carotid artery stenosis or circle of Willis disease. Several monitoring methods are available to identify the need for intraoperative shunting. In this article, we aimed to present our clinical experience related to the use of cerebral oximetry monitoring method in the decision of shunt usage in carotid surgery. We believe that NIRS monitoring is a valuable tool which provides beneficial information that can be used to determine whether a shunt is needed in carotid surgery. Furthermore, it can help prevent possible potential risks because of its noninvasive nature and ease of application. In addition, it provides current data and can be employed as a trend monitor. Our findings determined that NIRS monitoring is an indispensable method that can be used for patients undergoing CEA surgery, and in the future, we believe that it will be offered routinely in centers everywhere.

16. Ikeda et al. (2013). **Prefrontal dysfunction in remitted depression at work reinstatement using near-infrared spectroscopy**

Abstract: A long-term and/or recurrent sickness absence from work due to depression has been an important health problem in industrial countries. In addition, previous sick leave is a risk factor of recurrence. However, many characteristics, especially biological aspects, have not been investigated in remitted depressive patients who were ready to return to work from sickness absence. Therefore, the purpose of this study is to clarify the pathophysiological characteristics of patients who were at risk for recurrence of sickness absence. We recruited 21 patients and 16 healthy control subjects. All patients were ready to return to work within one month from long-term sickness absence. All subjects were examined for prefrontal function represented by oxyHb changes during the verbal fluency task (VFT) and the Stroop task using near-infrared spectroscopy. Suppressed prefrontal reaction during the VFT and increased prefrontal reaction during the Stroop task were observed in the patient group compared with the control group. Significantly lengthened reaction time was observed in the incongruent condition in the patient group during the Stroop task. Depressive patients showed impaired executive function measured by the Stroop task and had prefrontal dysfunction despite clinical remission. Residual prefrontal dysfunction may be one biological reason for repetitive sickness absence.

17. Sato et al. (2013). **Dialectal differences in hemispheric specialization for Japanese lexical pitch accent**

Abstract: Language experience can alter perceptual abilities and the neural specialization for phonological contrasts. Here we investigated whether dialectal differences in the lexical use of pitch information lead to differences in functional lateralization for pitch processing. We measured cortical hemodynamic responses to

pitch pattern changes in native speakers of Standard (Tokyo) Japanese, which has a lexical pitch accent system, and native speakers of 'accentless' dialects, which do not have any lexical tonal phenomena. While the Standard Japanese speakers showed left-dominant responses in temporal regions to pitch pattern changes within words, the accentless dialects speakers did not show such left-dominance. Pitch pattern changes within harmonic-complex tones also elicited different brain activation patterns between the two groups. These results indicate that the neural processing of pitch information differs depending on the listener's native dialect, and that listeners' linguistic experiences may further affect the processing of pitch changes even for non-linguistic sounds.

18. Pichler et al. (2013). **Leukocytes influence peripheral tissue oxygenation and perfusion in neonates**

Abstract: Background. Leukocyte counts may influence peripheral (micro) circulation due to changes in rheology. The aim of this study was to investigate a possible association between leukocyte counts and peripheral tissue oxygenation/perfusion measured with near infrared spectroscopy (NIRS) in term and preterm neonates. Methods. In this observational study we included term and preterm neonates within the first 2 months of life, in whom peripheral tissue NIRS measurements were performed and blood samples (leukocytes and C reactive protein (CRP)) taken to investigate clinical signs of infection. Tissue-oxygenation index (TOI), fractional oxygen extraction (FTEO), oxygen delivery (DO2), oxygen consumption (VO TOI, FTOE, DO2, VO22) and vascular resistance (VR) were measured by NIRS and venous occlusion method. and VR were correlated to leukocyte counts on the same day and maximal CRP levels within 24 hours (CRP max). Results. In 180 infants, with a mean gestational age of 35.5±3.3 weeks, leukocyte counts were 16546± 8830/l (median 14830; range 1790 to 67840) and CRP max was 8.0± 19.0 mg/l (median 0.0; range 0.0 to 110.0mg/l). TOI was 71.1±5.5%, FTOE 28.5±6.1%, DO2 46.7±19.7, VO2 12.5±4.4 and VR 11.7±6.4. Leukocyte counts correlated negatively (r= -0.21; p= 0.005) with TOI and positively (r=0.17; p=0.029) with VR. Correlations with CRP max did not reach significance. Conclusion. We demonstrated that peripheral tissue oxygen consumption decreases and vascular resistance increases with increasing leukocyte counts.

19. Yuan (2013). **Spatiotemporal and time-frequency analysis of functional near infrared spectroscopy brain signals using independent component analysis**

Abstract: Functional near infrared spectroscopy (fNIRS) is a noninvasive method to capture brain activities according to the measurements of changes in both oxyhemoglobin and deoxyhemoglobin concentrations. However, fNIRS recordings are the hemodynamic signals that come from the latent neural sources that are spatially and temporally mixed across the brain. The purpose of this work is to extract the temporal and frequency characteristics as well as the spatial activation patterns in the brains using independent component analysis (ICA). In this study, the filtered fNIRS recordings were processed and the time-frequency and spatiotemporal domain independent components (ICs) were identified by ICA. We found that multiple task-related components can be separated by ICA in time-frequency domain, and distinct spatial patterns of brain activity can be derived from ICs that are well correlated with the specific neural events, such as finger tapping tasks.

20. Toronov et al. (2013). **Dynamics of the brain: Mathematical models and non-invasive experimental studies**

Abstract: Dynamics is an essential aspect of the brain function. In this article we review theoretical models of neural and haemodynamic processes in the human brain and experimental non-invasive techniques developed to study brain functions and to measure dynamic characteristics, such as neurodynamics, neurovascular coupling, haemodynamic changes due to brain activity and autoregulation, and cerebral metabolic rate of oxygen. We focus on emerging theoretical biophysical models and experimental functional neuroimaging results, obtained mostly

by functional magnetic resonance imaging (fMRI) and near-infrared spectroscopy (NIRS). We also included our current results on the effects of blood pressure variations on cerebral haemodynamics and simultaneous measurements of fast processes in the brain by near-infrared spectroscopy and a very novel functional MRI technique called magnetic resonance encephalography. Based on a rapid progress in theoretical and experimental techniques and due to the growing computational capacities and combined use of rapidly improving and emerging neuroimaging techniques we anticipate during next decade great achievements in the overall knowledge of the human brain.

21. Harrivel et al. (2013). **Monitoring attentional state with fNIRS**

Abstract: The ability to distinguish between high and low levels of task engagement in the real world is important for detecting and preventing performance decrements during safety-critical operational tasks. We therefore investigated whether functional Near Infrared Spectroscopy (fNIRS), a portable brain neuroimaging technique, can be used to distinguish between high and low levels of task engagement during the performance of a selective attention task. A group of participants performed the multi-source interference task (MSIT) while we recorded brain activity with fNIRS from two brain regions. One was a key region of the "task-positive" network, which is associated with relatively high levels of task engagement. The second was a key region of the "task-negative" network, which is associated with relatively low levels of task engagement (e.g., resting and not performing a task). Using activity in these regions as inputs to a multivariate pattern classifier, we were able to predict above chance levels whether participants were engaged in performing the MSIT or resting. We were also able to replicate prior findings from functional magnetic resonance imaging (fMRI) indicating that activity in task-positive and task-negative regions is negatively correlated during task performance. Finally, data from a companion fMRI study verified our assumptions about the sources of brain activity in the fNIRS experiment and established an upper bound on classification accuracy in our task. Together, our findings suggest that fNIRS could prove quite useful for monitoring cognitive state in real-world settings.

22. Loomba et al. (2013). **Effect of Fontan Fenestration on Regional Venous Oxygen Saturation During Exercise: Further Insights Into Fontan Fenestration Closure**

Abstract: Fontan fenestration closure is a topic of great debate. The body of data regarding the risks and benefits of fenestration closure is limited yet growing. Previous studies have demonstrated that Fontan patients have less exercise capacity than those with normal cardiovascular anatomy. Differences also have been noted within various subgroups of Fontan patients such as whether Fontan is fenestrated or not. This study aimed to compare trends in regional oxygen saturations using near-infrared spectroscopy (NIRS) in patients with Fontan circulations during ramping exercise to further delineate differences between patients with and without a fenestration. It was hypothesized that Fontan patients with fenestrations have better exercise times, higher absolute regional oxygen venous saturations, and smaller arteriovenous differences than Fontan patients without fenestrations. For this study, 50 consecutive Fontan patients and 51 consecutive patients with normal cardiovascular anatomy were recruited. Placement of NIRS probes was performed to obtain regional oxygen saturations from the brain and the kidney. Readings were obtained at 1-min intervals during rest, exercise, and recovery. A standard Bruce protocol was used with a 5-min recovery period. Absolute regional tissue oxygenation values (rSO_2) and arterial-venous oxygen saturation differences ($AVDO_2$) calculated as arterial oxygen saturation (SPO_2)—rSO_2 for normal versus Fontan patients and for fenestrated versus unfenestrated Fontan patients were compared using independent t tests. When normal and Fontan patients were compared, the Fontan patients had a significantly shorter duration of exercise (9.3 vs 13.2 min; $p < 0.001$). No statistically significant difference in rSO_2 change or $AVDO_2$ was evident at the time of peak exercise, at 2 min into the recovery, or at 5 min into the recovery. A small oxygen debt also was paid back to the brain in the Fontan patients after exercise, as evidenced by a narrower $AVDO_2$ than at baseline. The comparison of Fontan patients with and without fenestration showed no statistically significant difference in exercise time, rSO_2 change, or $AVDO_2$. The Fontan patients were noted to have shorter exercise times than the normal patients and also

appeared to have an alteration in postexertional regional blood flow. However, when the various Fontan subtypes were compared by presence or absence of a fenestration, no significant differences were noted with regard to change in regional oxygen saturation or arteriovenous oxygen saturation. Thus, for patients with Fontan physiology, closure of the fenestration does not seem to have an impact on the dynamics of regional oxygen extraction during exercise or recovery.

23. Yuan (2013). **Combining independent component analysis and Granger causality to investigate brain network dynamics with fNIRS measurements**

Abstract: In this study a new strategy that combines Granger causality mapping (GCM) and independent component analysis (ICA) is proposed to reveal complex neural network dynamics underlying cognitive processes using functional near infrared spectroscopy (fNIRS) measurements. The GCM-ICA algorithm implements the following two procedures: (i) extraction of the region of interests (ROIs) of cortical activations by ICA, and (ii) estimation of the direct causal influences in local brain networks using Granger causality among voxels of ROIs. Our results show that the use of GCM in conjunction with ICA is able to effectively identify the directional brain network dynamics in time-frequency domain based on fNIRS recordings.

24. Koike et al. (2013). **Near-infrared spectroscopy in schizophrenia: a possible biomarker for predicting clinical outcome and treatment response**

Abstract: Functional near-infrared spectroscopy (fNIRS) is a relatively new technique that can measure hemoglobin changes in brain tissues, and its use in psychiatry has been progressing rapidly. Although it has several disadvantages (e.g., relatively low spatial resolution and the possibility of shallow coverage in the depth of brain regions) compared with other functional neuroimaging techniques (e.g., functional magnetic resonance imaging and positron emission tomography), fNIRS may be a candidate instrument for clinical use in psychiatry, as it can measure brain activity in naturalistic position easily and non-invasively. fNIRS instruments are also small and work silently, and can be moved almost everywhere including schools and care units. Previous fNIRS studies have shown that patients with schizophrenia have impaired activity and characteristic waveform patterns in the prefrontal cortex during the letter version of the verbal fluency task, and part of these results have been approved as one of the Advanced Medical Technologies as an aid for the differential diagnosis of depressive symptoms by the Ministry of Health, Labor and Welfare of Japan in 2009, which was the first such approval in the field of psychiatry. Moreover, previous studies suggest that the activity in the frontopolar prefrontal cortex is associated with their functions in chronic schizophrenia and is its next candidate biomarker. Future studies aimed at exploring fNIRS differences in various clinical stages, longitudinal changes, drug effects, and variations during different task paradigms will be needed to develop more accurate biomarkers that can be used to aid differential diagnosis, the comprehension of the present condition, the prediction of outcome, and the decision regarding treatment options in schizophrenia. Future fNIRS researches will require standardized measurement procedures, probe settings, analytical methods and tools, manuscript description, and database systems in an fNIRS community.

25. Mehta (2013). **Effects of Mental Fatigue on the Development of Physical Fatigue A Neuroergonomic Approach**

Abstract: Objective: The present study used a neuroergonomic approach to examine the interaction of mental and physical fatigue by assessing prefrontal cortex activation during submaximal fatiguing handgrip exercises.
Background: Mental fatigue is known to influence muscle function and motor performance, but its contribution to the development of voluntary physical fatigue is not well understood.
Method: A total of 12 participants performed separate physical (control) and physical and mental fatigue (concurrent) conditions at 30% of their maximal handgrip strength until exhaustion. Functional near infrared

spectroscopy was employed to measure prefrontal cortex activation, whereas electromyography and joint steadiness were used simultaneously to quantify muscular effort.
Results: Compared to the control condition, blood oxygenation in the bilateral prefrontal cortex was significantly lower during submaximal fatiguing contractions associated with mental fatigue at exhaustion, despite comparable muscular responses.
Conclusion: The findings suggest that interference in the prefrontal cortex may influence motor output during tasks that require both physical and cognitive processing.
Application: A neuroergonomic approach involving simultaneous monitoring of brain and body functions can provide critical information on fatigue development that may be overlooked during traditional fatigue assessments.

26. Kreplin & Fairclough (2013). **Activation of the rostromedial prefrontal cortex during the experience of positive emotion in the context of esthetic experience. An fNIRS study**

Abstract: The contemplation of visual art requires attention to be directed to external stimulus properties and internally generated thoughts. It has been proposed that the medial rostral prefrontal cortex (rPFC; BA10) plays a role in the maintenance of attention on external stimuli whereas the lateral area of the rPFC is associated with the preservation of attention on internal cognitions. An alternative hypothesis associates activation of medial rPFC with internal cognitions related to the self during emotion regulation. The aim of the current study was to differentiate activation within rPFC using functional near infrared spectroscopy (fNIRS) during the viewing of visual art selected to induce positive and negative valence, which were viewed under two conditions: (1) emotional introspection and (2) external object identification. Thirty participants (15 female) were recruited. Sixteen pre-rated images that represented either positive or negative valence were selected from an existing database of visual art. In one condition, participants were directed to engage in emotional introspection during picture viewing. The second condition involved a spot-the-difference task where participants compared two almost identical images, a viewing strategy that directed attention to external properties of the stimuli. The analysis revealed a significant increase of oxygenated blood in the medial rPFC during viewing of positive images compared to negative images. This finding suggests that the rPFC is involved during positive evaluations of visual art that may be related to judgment of pleasantness or attraction. The fNIRS data revealed no significant main effect between the two viewing conditions, which seemed to indicate that the emotional impact of the stimuli remained unaffected by the two viewing conditions.

27. Kim (2013). ***In-vivo* Optical Measurement of Neural Activity in the Brain**

Abstract: The optical neural recording techniques are promising tools in recent years. Compared to the traditional electrophysiological recording, the optical means offer several advantages including no inclusion of electrical noise, simultaneous imaging of a large number of neurons, or selective recording from genetically-targeted neurons. Overall the optical neural recording technique comprises the intrinsic and the extrinsic optical recordings. The methods for intrinsic neural recording employ the change of optical properties in brains such as blood flow/oxygenation, cellular volume change, or refractive index change without addition of external indicators. Those properties can be detected using various optical techniques including laser Doppler flowmetry (LDF), near-infrared (NIR) spectrometer, functional optical coherence tomography (fOCT), and surface plasmon resonance (SPR). The extrinsic monitoring techniques use fluorescence signals reflecting neuronal activity via chemical or genetic modification of the neuronal cells. Two most popular activity-dependent fluorescent probes, calcium indicators and voltage-sensitive fluorescent proteins will be examined in this review. The principles, the instrumentations and *in vivo* applications of those optical signal measurements are described.

28. Mohamed et al. (2013). **Brain activity and Emotional Responses of the Japanese People Toward Trees Pruned using Sukashi Technique**

Abstract: Several studies on people–plant interactions have shown that viewing plants had positive influences on human being. The objective of this study was to investigate how plant shape of Pine (*Pinus thunbergii*) trees pruned using the Sukashi technique, which is an important component of natural style Japanese garden and trees without pruning influenced the brain activity and emotions response. The physiological responses of 32 university students (20 males and 12 females) were measured by multi channel infrared spectroscopy (NIRS, OMM-2001, Shimadzu, Co., Ltd. Japan). Furthermore, fifteen pairs of adjectives on the semantic differential scale were used to record subjects' psychological reactions. Based on the results, visual impact of plantscape evoked different psycho-physiological responses. The results revealed that the Sukashi pruned trees had a relaxing effect as evidenced by decreased cerebral blood flow (CBF) at the feeling area compared to the unpruned trees that diminished skin and body sensations. The results also suggested that the Sukashi pruned trees provided positive impressions for both gender. In conclusion, findings of this study indicated that these visual cognitive characteristics of Japanese individuals with respect to Sukashi pruning technique suggested an association among aesthetic consciousness, thought and the natural style Japanese garden.

29. Wiyor & Ntuen (2013). **Empirical Evaluation of Visual Fatigue from Display Alignment Errors Using Cerebral Hemodynamic Responses**

Abstract: Several The purpose of this study was to investigate the effect of stereoscopic display alignment errors on visual fatigue and prefrontal cortical tissue hemodynamic responses. We collected hemodynamic data and perceptual ratings of visual fatigue while participants performed visual display tasks on 8 ft x 6 ft NEC LT silver screen with NEC LT 245 DLP projectors. There was statistical significant difference between subjective measures of visual fatigue before air traffic control task (BATC) and after air traffic control task (ATC 3), ($p < 0.05$). Statistical significance was observed between left dorsolateral prefrontal cortex oxygenated hemoglobin (l DLPFC-HbO2), left dorsolateral prefrontal cortex deoxygenated hemoglobin (l DLPFC-Hbb), and right dorsolateral prefrontal cortex deoxygenated hemoglobin (r DLPFC-Hbb) on stereoscopic alignment errors ($p < 0.05$). Thus, cortical tissue oxygenation requirement in the left hemisphere indicates that the effect of visual fatigue is more pronounced in the left dorsolateral prefrontal cortex.

30. Zhang et al. (2013). **A New Approach to Separate Haemodynamic Signals for Brain-Computer Interface Using Independent Component Analysis and Least Squares**

Abstract: Brain-computer interface (BCI) is one technology that allows a user to communicate with external devices through detecting brain activity. As a promising noninvasive technique, functional near-infrared spectroscopy (fNIRS) has recently earned increasing attention in BCI studies. However, in practice fNIRS measurements can suffer from significant physiological interference, for example, arising from cardiac contraction, breathing, and blood pressure fluctuations, thereby severely limiting the utility of the method. Here, we apply the multidistance fNIRS method, with short-distance and long-distance optode pairs, and we propose the combination of independent component analysis (ICA) and least squares (LS) with the fNIRS recordings to reduce the interference. The short-distance fNIRS measurement is treated as the virtual channel and the long-distance fNIRS measurement is treated as the measurement channel. Least squares is used to optimize the reconstruction value for brain activity signal. Monte Carlo simulations of photon propagation through a five-layered slab model of a human adult head were implemented to evaluate our methodology. The results demonstrate that the ICA method can separate the brain signal and interference; the further application of least squares can significantly recover haemodynamic signals contaminated by physiological interference from the fNIRS-evoked brain activity data.

31. Abramo (2013). **Cerebral oximetry and cerebral blood flow monitoring in 2 pediatric survivors with out-of-hospital cardiac arrest**

Abstract: – not Abstract available –

32. Radak et al. (2013). **Practical Use of Near-Infrared Spectroscopy in Carotid Surgery**

Abstract: Carotid endarterectomy (CEA) is the gold standard for the treatment of symptomatic patients with atherosclerotic carotid disease. However, benefit of the CEA procedure depends on the rate of peri- and postoperative adverse neurological events. Therefore, brain monitoring is important in detecting cerebral ischemia during and after CEA and also allows to prompt appropriate action. Traditional methods of cerebral monitoring are being replaced by novel, easy-to-use techniques that allow continued monitoring of regional cerebral oxygen saturation. In this review, we present the recent literature data related to the mechanism of cerebral oximetry and its practical use during and after CEA.

33. Tsang (2013). **Hemodynamic Monitoring in the Cardiac Intensive Care Unit**

Abstract: Hemodynamic monitoring is central to the management of critically ill patients in the cardiac intensive care unit (CICU). The goals of hemodynamic monitoring are to anticipate threats and complications before they arise, to gauge the effectiveness of interventions, and to avoid progression to a decompensated shock state. Although there are numerous modalities of hemodynamic monitoring in the CICU, discordance exists between assessments based on physical exam and standard hemodynamic parameters and those based on measurements of cardiac output. This article will review both the standard and advanced hemodynamic monitoring strategies employed in the CICU.

34. Leocani et al. (2013). **Non Invasive Neuromodulation in Motor Recovery after Stroke: State of the Art, Open Questions and Future Perspectives**

Abstract: Stroke is the leading cause of adult disability. Unfortunately, less than 40% of stroke survivors completely recover, despite intensive acute care and rehabilitation training. Non invasive brain stimulation (NIBS) techniques have been recognized as a promising intervention to improve motor recovery after stroke. Repeated sessions of repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation (tDCS) can, indeed, induce changes in cortical excitability and long term plasticity. Several protocols of stimulation have been already tested and proven efficient in modulating the lesioned as well as the unlesioned hemisphere after stroke. However, not all patients can be considered as responder to NIBS. We provide an overview of the rationale, open questions and future perspectives for NIBS after stroke.

35. Kirilina et al. (2013). **Identifying and quantifying main components of physiological noise in functional near infrared spectroscopy on the prefrontal cortex**

Abstract: Functional Near-Infrared Spectroscopy (fNIRS) is a promising method to study functional organization of the prefrontal cortex. However, in order to realize the high potential of fNIRS, effective discrimination between physiological noise originating from forehead skin haemodynamic and cerebral signals is required. Main sources of physiological noise are global and local blood flow regulation processes on multiple time scales. The goal of the present study was to identify the main physiological noise contributions in fNIRS forehead signals and to develop a method for physiological de-noising of fNIRS data. To achieve this goal we combined concurrent time-domain fNIRS and peripheral physiology recordings with wavelet coherence analysis (WCA). Depth selectivity was achieved by analyzing moments of photon time-of-flight distributions provided by

time-domain fNIRS. Simultaneously, mean arterial blood pressure (MAP), heart rate (HR), and skin blood flow (SBF) on the forehead were recorded. WCA was employed to quantify the impact of physiological processes on fNIRS signals separately for different time scales. We identified three main processes contributing to physiological noise in fNIRS signals on the forehead. The first process with the period of about 3 s is induced by respiration. The second process is highly correlated with time lagged MAP and HR fluctuations with a period of about 10 s often referred as *Mayer waves*. The third process is local regulation of the facial SBF time locked to the task-evoked fNIRS signals. All processes affect oxygenated haemoglobin concentration more strongly than that of deoxygenated haemoglobin. Based on these results we developed a set of physiological regressors, which were used for physiological de-noising of fNIRS signals. Our results demonstrate that proposed de-noising method can significantly improve the sensitivity of fNIRS to cerebral signals.

36. Murphy et al. (2013). **Bedside Monitoring of Vascular Mechanisms in CNS Trauma: The Use of Near-Infrared Spectroscopy (NIRS) and Transcranial Doppler (TCD)**

Abstract: Ischemia and adequacy of regional and global cerebral blood flow are important determinants of outcome in traumatic brain injury (TBI). Although brain ischemia may be a major common pathway of secondary brain damage following TBI, hyperemia and reperfusion injury may also occur and lead to elevated intracranial pressure and decreased cerebral perfusion pressure. Bedside monitors of cerebral ischemia include near-infrared spectroscopy (NIRS), transcranial Doppler ultrasound (TCD), continuous electroencephalography, and brain tissue microdialysis. This chapter will describe how NIRS and TCD enhance our understanding of vascular pathology following a brain injury and their potential applications in the acute management of TBI.

37. Hartley & Slater (2013). **Neurophysiological measures of nociceptive brain activity in the newborn infant – the next steps**

Abstract: Infants within neonatal intensive care units can receive multiple medically essential painful procedures per day. How they respond to these events, how best to alleviate the negative effects, and the long-term consequences for the infant are all significant questions that have yet to be fully answered. In recent years, several studies have examined cortical responses to noxious stimuli in the neonate through the use of near-infrared spectroscopy (NIRS) and electroencephalography (EEG). These investigations dispel any notion that the newborn infant does not process noxious stimuli at a cortical level and open the way for future research. In this Viewpoint Article, we review these studies and discuss key clinical challenges which may be elucidated with the use of these techniques.

38. Ma et al. (2013). **Left Prefrontal Activity Reflects the Ability of Vicarious Fear Learning: A Functional Near-infrared Spectroscopy Study**

Abstract: Fear could be acquired indirectly via social observation. However, it remains unclear which cortical substrate activities are involved in vicarious fear transmission. The present study was to examine empathy-related processes during fear learning by-proxy and to examine the activation of prefrontal cortex by using functional near-infrared spectroscopy. We simultaneously measured participants' hemodynamic responses and skin conductance responses when they were exposed to a movie. In this movie, a demonstrator (i.e., another human being) was receiving a classical fear conditioning. A neutral colored square paired with shocks (CS_shock) and another colored square paired with no shocks (CS_no-shock) were randomly presented in front of the demonstrator. Results showed that increased concentration of oxygenated hemoglobin in left prefrontal cortex was observed when participants watched a demonstrator seeing CS_shock compared with that exposed to CS_non-shock. In addition, enhanced skin conductance responses showing a demonstrator's aversive experience during learning object-fear association were observed. The present study suggests that left prefrontal cortex, which may reflect speculation of others' mental state, is associated with social fear transmission.

39. Khan et al. (2013). **Functional near-infrared spectroscopy maps cortical plasticity underlying altered motor performance induced by transcranial direct current stimulation**

Abstract: Transcranial direct current stimulation (tDCS) of the human sensorimotor cortex during physical rehabilitation induces plasticity in the injured brain that improves motor performance. Bi-hemispheric tDCS is a noninvasive technique that modulates cortical activation by delivering weak current through a pair of anodal–cathodal (excitation–suppression) electrodes, placed on the scalp and centered over the primary motor cortex of each hemisphere. To quantify tDCS-induced plasticity during motor performance, sensorimotor cortical activity was mapped during an event-related, wrist flexion task by functional near-infrared spectroscopy (fNIRS) before, during, and after applying both possible bi-hemispheric tDCS montages in eight healthy adults. Additionally, torque applied to a lever device during isometric wrist flexion and surface electromyography measurements of major muscle group activity in both arms were acquired concurrently with fNIRS. This multiparameter approach found that hemispheric suppression contralateral to wrist flexion changed resting-state connectivity from intra-hemispheric to inter-hemispheric and increased flexion speed ($p<0.05$). Conversely, exciting this hemisphere increased opposing muscle output resulting in a decrease in speed but an increase in accuracy ($p<0.05$ for both). The findings of this work suggest that tDCS with fNIRS and concurrent multimotor measurements can provide insights into how neuroplasticity changes muscle output, which could find future use in guiding motor rehabilitation.

40. Sanchez-de-Toledo et al. (2013). **Cerebral Regional Oxygen Saturation and Serum Neuromarkers for the Prediction of Adverse Neurologic Outcome in Pediatric Cardiac Surgery**

Abstract: Background: The aim of this study is to determine the utility of non-invasive bedside neuromonitoring, including cerebral regional oxygen saturation (rSO2) measured by near-infrared spectroscopy and serum biomarkers, in identifying children at risk from adverse neurological outcome after heart surgery.
Methods: Prospective observational study including 39 consecutive children undergoing heart surgery with cardiopulmonary bypass (CPB) and normal neurologic exam prior to surgery. Cerebral rSO2 was measured at baseline (prior to surgery) and then continuously during surgery and for the first 16 h post-operatively. Neuromarkers [neuron-specific enolase (NSE), S100β, glial fibrillary acidic protein (GFAP), and brain-derived neurotrophic factor (BDNF)] were measured in serum at baseline, immediately after CPB and at 16 h post-operatively. Adverse neurological outcome was defined as an abnormal pediatric cerebral performance category (PCPC) scale score at 12 months after surgery.
Results: Sixteen children (41 %) had an abnormal PCPC scale score at the 12-month evaluation after surgery. In children with unfavorable neurological outcomes, mean cerebral rSO2 values were lower and the area-under-the-curve below a threshold of 40 and 20 % below baseline were also increased. No significant differences were found in serum neuromarkers between groups at the time points that were assessed.
Conclusions: Bedside determination of cerebral rSO2 may have some utility in identifying children at risk for adverse neurological outcome after heart surgery in children. Additional studies that are sufficiently powered to control for the many covariates in this patient population will be required to fully interrogate this important question. The role of serum neuromarkers in the immediate post-operative period do not appear to be helpful in this question, though more thorough interrogation of delayed periods may ultimately demonstrate some utility in answering this question.

41. Miranda et al. (2013). **Breast phantom for mammary tissue characterization by near infrared spectroscopy**

Abstract: Breast cancer is a disease associated to a high morbidity and mortality in the entire world. In the study of early detection of breast cancer the development of phantom is so important. In this research we fabricate a breast phantom using a ballistic gel with special modifications to simulate a normal and abnormal human breast. Optical properties of woman breast in the near infrared region were modelled with the phantom

we developed. The developed phantom was evaluated with near infrared spectroscopy in order to study its relation with breast tissue. A good optical behaviour was achieved with the model fabricated.

42. Xu et al. (2013). **Static Magnetic Field Effects on Impaired Peripheral Vasomotion in Conscious Rats**

Abstract: We investigated the SMF effects on hemodynamics in the caudal artery-ligated rat as an in vivo ischemia model using noninvasive near-infrared spectroscopy (NIRS) combined with power spectral analysis by fast Fourier transform. Male Wistar rats in the growth stage (10 weeks old) were randomly assigned into four groups: (i) intact and nonoperated cage control (n = 20); (ii) ligated alone (n = 20); (iii) ligated and implanted with a nonmagnetized rod (sham magnet; n = 22); and (vi) ligated and implanted with a magnetized rod (n = 22). After caudal artery ligation, a magnetized or unmagnetized rod (maximum magnetic flux density of 160 mT) was implanted transcortically into the middle diaphysis of the fifth caudal vertebra. During the experimental period of 7 weeks, NIRS measurements were performed in 3- , 5- , and 7-week sessions and the vasomotion amplitude and frequency were analyzed by fast Fourier transform. Exposure for 3–7 weeks to the SMF significantly contracted the increased vasomotion amplitude in the ischemic area. These results suggest that SMF may have a regulatory effect on rhythmic vasomotion in the ischemic area by smoothing the vasomotion amplitude in the early stage of the wound healing process.

43. Babiloni et al. (2013). **Hypercapnia affects the functional coupling of resting state electroencephalographic rhythms and cerebral haemodynamics in healthy elderly subjects and in patients with amnestic mild cognitive impairment**

Abstract: Objective: Cerebral vasomotor reactivity (VMR) and coherence of resting state electroencephalographic (EEG) rhythms are impaired in Alzheimer's disease (AD) patients. Here we tested the hypothesis that these two variables could be related.
Methods: We investigated VMR and coherence of resting state EEG rhythms in nine normal elderly (Nold) and in 10 amnesic mild cognitive impairment (MCI) subjects. Resting state eyes-closed EEG data were recorded at baseline pre-CO_2 (ambient air, 2 min), during 7% CO_2/air mixture inhalation (hypercapnia, 90 s) and post-CO_2 (ambient air, 2 min) conditions. Simultaneous frontal bilateral near-infrared spectroscopy (NIRS) was performed to assess VMR by cortical oxy- and deoxy-haemoglobin concentration changes. EEG coherence across all electrodes was computed at delta (2–4 Hz), theta (4–8 Hz), alpha 1 (8–10.5 Hz), alpha 2 (10.5–13 Hz), beta 1 (13–20 Hz), beta 2 (20–30 Hz) and gamma (30–40 Hz) bands.
Results: In Nold subjects, 'total coherence' of EEG across all frequency bands and electrode pairs decreased during hypercapnia, with full recovery during post-CO_2. Total coherence resulted lower in pre-CO_2 and post-CO_2 and presented poor reactivity during CO_2 inhalation in MCI patients compared with Nold subjects. Hypercapnia increased oxy-haemoglobin and decreased deoxy-haemoglobin concentrations in both groups. Furthermore, the extent of changes in these variables during CO_2 challenge was correlated with the EEG coherence, as a reflection of neurovascular coupling.
Conclusions: Hypercapnia induced normal frontal VMR that was detected by NIRS in both Nold and amnesic MCI groups, while it produced a reactivity of global functional coupling of resting state EEG rhythms only in the Nold group.
Significance: In amnesic MCI patients, global EEG functional coupling is basically low in amplitude and does not react to hypercapnia.

44. Saiko et al. (2013). **Optical Detection of a Capillary Grid Spatial Pattern in Epithelium by Spatially Resolved Diffuse Reflectance Probe: Monte Carlo Verification**

Abstract: We performed a large scale Monte Carlo verification of possibility of detecting the capillary grid spatial pattern in surface tissues such as mucosal epithelium or epidermis with very thin (optically nonsignificant) stratum corneum by a spatially resolved diffuse reflectance probe. Our results confirm the hypothesis that a spatially resolved, steady-state, diffuse reflectance spectroscopy can potentially identify absorption inhomogeneities located at the depth of 0.5-1.0 of the transport mean free path $l_s' = 1/\mu_s'$, which is the range of capillary loops locations within epithelium. The modulation depth depends significantly on an inhomogeneity's absorption, depth of the inhomogeneity, a bulk reduced scattering coefficient, and the size of the defect. The optical clearing technique can be used to lower the scattering in surface tissues and subsequently increase the transport mean free path, which can lead to increase in the sensitivity of the method.

45. Barati et al. (2013). **Functional data analysis view of functional near infrared spectroscopy data**

Abstract: Functional near infrared spectroscopy (fNIRS) is a powerful tool for the study of oxygenation and hemodynamics of living tissues. Despite the continuous nature of the processes generating the data, analysis of fNIRS data has been limited to discrete-time methods. We propose a technique, namely functional data analysis (fDA), that converts discrete samples to continuous curves. We used fNIRS data collected on forehead during a cold pressor test (CPT) from 20 healthy subjects. Using functional principal component analysis, oxyhemoglobin (HbO2) and deoxyhemoglobin (Hb) curves were decomposed into several components based on variability across the subjects. Each component corresponded to an experimental condition and provided qualitative and quantitative information of the shape and weight of that component. Furthermore, we applied functional canonical correlation analysis to investigate the interaction between Hb and HbO2 curves. We showed that the variation of Hb and HbO2 was positively correlated during the CPT, with a "far" channel on right forehead showing a smaller and faster HbO2 variation than Hb. This research suggests the fDA platform for the analysis of fNIRS data, which solves problem of high dimensionality, enables study of response dynamics, enhances characterization of the evoked response, and may improve design of future fNIRS experiments.

46. Muthalib et al. (2013). **Comparison between electrically-evoked and voluntary wrist movements on sensorimotor and prefrontal cortical activation : A multi-channel time domain fNIRS study**

Abstract: Neuromuscular electrical stimulation (NMES) has been consistently demonstrated to improve skeletal muscle function in neurological populations with movement disorders, such as poststroke and incomplete spinal cord injury (Vanderthommen and Duchateau, 2007). Recent research has documented that rapid, supraspinal central nervous system reorganisation/neuroplastic mechanisms are also implicated during NMES (Chipchase et al., 2011). Functional neuroimaging studies have shown NMES to activate a network of sub-cortical and cortical brain regions, including the sensorimotor (SMC) and prefrontal (PFC) cortex (Blickenstorfer et al., 2009; Han et al., 2003; Muthalib et al., 2012). A relationship between increase in SMC activation with increasing NMES current intensity up to motor threshold has been previously reported using functional MRI (Smith et al., 2003). However, since clinical neurorehabilitation programmes commonly utilise NMES current intensities above the motor threshold and up to the maximum tolerated current intensity (MTI), limited research has determined the cortical correlates of increasing NMES current intensity at or above MTI (Muthalib et al., 2012). In our previous study (Muthalib et al., 2012), we assessed contralateral PFC activation using 1-channel functional near infrared spectroscopy (fNIRS) during NMES of the elbow flexors by increasing current intensity from motor threshold to greater than MTI and showed a linear relationship between NMES current intensity and the level of PFC activation. However, the relationship between NMES current intensity and activation of the motor cortical network, including SMC and PFC, has not been clarified. Moreover, it is of scientific and clinical relevance to know how NMES affects the central nervous system, especially in comparison

to voluntary (VOL) muscle activation. Therefore, the aim of this study was to utilise multi-channel time domain fNIRS to compare SMC and PFC activation between VOL and NMESevoked wrist extension movements.

47. Zucchelli et al. (2013). **Method for the discrimination of superficial and deep absorption variations by time domain fNIRS**

Abstract: A method for the discrimination of superficial and deep absorption variations by time domain functional near infrared spectroscopy is presented. The method exploits the estimate of the photon time-dependent pathlength in different domains of the sampled medium and makes use of an approach based on time-gating of the photon distribution of time-of-flights. Validation of the method is performed in the two-layer geometry to focus on muscle and head applications. Numerical simulations varied the thickness of the upper layer, the interfiber distance, the shape of the instrument response function and the photon counts. Preliminary results from *in vivo* data are also shown.

48. Sultan et al. (2013). **3D Numerical modeling and its experimental verifications for an inhomogeneous head phantom using broadband fNIR system**

Abstract: Modeling behavior of broadband (30–1000 MHz) frequency modulated near infrared photons through a multilayer phantom is of interest to optical bio-imaging research. Photon dynamics in phantom are predicted using three-dimension (3D) finite element numerical simulation and are related to the measured insertion loss and phase for a given human head geometry in this paper based on three layers of phantom each with distinct optical parameter properties. Simulation and experimental results are achieved for single, two, and three layers solid phantoms using COMSOL (COMSOL AB, Tegnérgatan 23, SE-111 40, Stockholm, Sweden) (for FEM) simulation and custom-designed broadband free space optical transmitter (Tx) and receiver (Rx) modules that are developed for photon migration at wavelengths of 680, 795, and 850 nm. Standard error is used to compute error between two-dimension and 3D FE modeling along with experimental results by fitting experimental data to the functional form of $a\sqrt{frequency}+b$. Error results are shown at narrowband and broadband frequency modulation. Confidence in numerical modeling of the photonic behavior using 3D FEM for human head has been established here by comparing the reflection mode's experimental results with the predictions made by COMSOL for known commercial solid brain phantoms.

49. Bressan et al. (2013). **The use of handheld near-infrared device (Infrascanner) for detecting intracranial haemorrhages in children with minor head injury**

Abstract: Objective: A handheld device using near-infrared technology (Infrascanner) has shown good accuracy for detection of traumatic intracranial haemorrhages in adults. This study aims to determine the feasibility of use of Infrascanner in children with minor head injury (MHI) in the Emergency Department (ED). Secondary aim was to assess its potential usefulness to reduce CT scan rate.
Methods: Prospective pilot study conducted in two paediatric EDs, including children at high or intermediate risk for clinically important traumatic brain injury (ciTBI) according to the adapted PECARN rule in use. Completion of Infrascanner measurements and time to completion were recorded. Decision on CT scan and CT scan reporting were performed independently and blinded to Infrascanner results.
Results: Completion of the Infrascanner measurement was successfully achieved in 103 (94 %) of 110 patients enrolled, after a mean of 4.4 ± 2.9 min. A CT scan was performed in 18 (17.5 %) children. Only one had an intracranial haemorrhage that was correctly identified by the Infrascanner. The exploratory analysis showed a specificity of 93 % (95 % CI, 86.5–96.6) and a negative predictive value of 100 % (95 % CI, 81.6–100) for ciTBI. The use of Infrascanner would have led to avoid ten CT scan, reducing the CT scan rate by 58.8 %.

Conclusions: Infrascanner seems an easy-to-use tool for children presenting to the ED following a MHI, given the high completion rate and short time to completion. Our preliminary results suggest that Infrascanner is worthy of further investigation as a potential tool to decrease the CT scan rate in children with MHI.

50. Shaharin et al. (2013). **Muscle tissue saturation in humans studied with two non-invasive optical techniques: a comparative study**

Abstract: Muscle tissue saturation (StO_2) has been measured with two non–invasive optical techniques and the results were compared. One of the techniques is widely used in the hospitals – the CW-NIRS technique. The other is the photon timeofflight spectrometer (pTOFS) developed in the Group of Biophotonics, Lund University, Sweden. The wavelengths used in both the techniques are 730 nm and 810 nm. A campaign was arranged to perform measurements on 21 (17 were taken for comparison) healthy adult volunteers (8 women and 13 men). Oxygen saturations were measured at the right lower arm of each volunteer. To observe the effects of different provocations on the oxygen saturation a blood pressure cuff was attached in the upper right arm. For CW-NIRS, the tissue saturation values were in the range from 70-90%, while for pTOFS the values were in the range from 55-60%.

51. Azuma et al. (2013). **Changes in Cerebral Blood Flow during Olfactory Stimulation in Patients with Multiple Chemical Sensitivity: A Multi-Channel Near-Infrared Spectroscopic Study**

Abstract: Multiple chemical sensitivity (MCS) is characterized by somatic distress upon exposure to odors. Patients with MCS process odors differently from controls. This odor-processing may be associated with activation in the prefrontal area connecting to the anterior cingulate cortex, which has been suggested as an area of odorant-related activation in MCS patients. In this study, activation was defined as a significant increase in regional cerebral blood flow (rCBF) because of odorant stimulation. Using the well-designed card-type olfactory test kit, changes in rCBF in the prefrontal cortex (PFC) were investigated after olfactory stimulation with several different odorants. Near-infrared spectroscopic (NIRS) imaging was performed in 12 MCS patients and 11 controls. The olfactory stimulation test was continuously repeated 10 times. The study also included subjective assessment of physical and psychological status and the perception of irritating and hedonic odors. Significant changes in rCBF were observed in the PFC of MCS patients on both the right and left sides, as distinct from the center of the PFC, compared with controls. MCS patients adequately distinguished the non-odorant in 10 odor repetitions during the early stage of the olfactory stimulation test, but not in the late stage. In comparison to controls, autonomic perception and negative affectivity were poorer in MCS patients. These results suggest that prefrontal information processing associated with odor-processing neuronal circuits and memory and cognition processes from past experience of chemical exposure play significant roles in the pathology of this disorder.

52. Southern et al. (2013). **Reproducibility of near infrared spectroscopy measurements of oxidative function and post-exercise recovery kinetics in the medial gastrocnemius muscle**

Abstract: The purpose of this study was to assess the reproducibility of resting blood flow, resting oxygen consumption, and mitochondrial capacity in skeletal muscle using near infrared spectroscopy (NIRS). We also determined the influence of two exercise modalities (ergometer and rubber exercise bands) on the NIRS measurements. Fifteen young, healthy participants (5 female, 10 male) were tested on two non-consecutive occasions within an 8-day period. The NIRS device was placed on the medial gastrocnemius. Venous and arterial occlusions were performed to obtain blood flow and oxygen consumption. A series of repeated arterial occlusions was used to measure the recovery kinetics of muscle oxygen consumption after ~7-10 seconds of voluntary plantar flexion exercise. Resting blood flow had mean coefficients of variation (CV) of 42% and 38% for bands and ergometer respectively, and resting metabolism had mean CVs of 17% and 12% for bands and ergometer

respectively. The recovery time constant of oxygen consumption (day 1 bands and ergometer: 23.2 ± 3.7 s, 27.6 ± 6.5 s respectively; day 2 bands and ergometer: 25.5 ± 5.4 s, 25.0 ± 4.9 s respectively) had mean CVs of 10% and 11% for bands and ergometer respectively. We conclude that measurements of oxygen consumption and mitochondrial capacity using NIRS can be obtained with good reproducibility.

53. Carp et al. (2013). **Hemodynamic signature of breast cancer under fractional mammographic compression using a dynamic diffuse optical tomography system**

Abstract: Near infrared dynamic diffuse optical tomography measurements of breast hemodynamics during fractional mammographic compression offer a novel contrast mechanism for detecting breast cancer and monitoring chemotherapy. Tissue viscoelastic relaxation during the compression period leads to a slow reduction in the compression force and reveals biomechanical and metabolic differences between healthy and lesion tissue. We measured both the absolute values and the temporal evolution of hemoglobin concentration during 25-35 N of compression for 22 stage II and III breast cancer patients scheduled to undergo neoadjuvant chemotherapy. 17 patients were included in the group analysis (average tumor size 3.2 cm, range: 1.3-5.7 cm). We observed a statistically significant differential decrease in total and oxy-hemoglobin, as well as in hemoglobin oxygen saturation in tumor areas vs. healthy tissue, as early as 30 seconds into the compression period. The hemodynamic contrast is likely driven by the higher tumor stiffness and different viscoelastic relaxation rate, as well as the higher tumor oxygen metabolism rate.

54. Ghosh et al. (2013). **Normobaric Hyperoxia Does Not Change Optical Scattering or Pathlength but Does Increase Oxidised Cytochrome *c* Oxidase Concentration in Patients with Brain Injury**

Abstract: We report the use of a novel hybrid near-infrared spectrometer for the measurement of optical scattering, pathlength and chromophore concentration in critically ill patients with brain injury. Ten mechanically ventilated patients with acute brain injury were studied. In addition to standard neurointensive care monitoring, middle cerebral artery flow velocity, brain lactate–pyruvate ratio (LPR) and brain tissue oxygen tension were monitored. The patients were subjected to graded normobaric hyperoxia (NBH), with the inspired fraction of oxygen increased from baseline to 60% then 100%. NBH induced significant changes in the concentrations of oxyhaemoglobin, deoxyhaemoglobin and oxidised–reduced cytochrome *c* oxidase; these were accompanied by a corresponding reduction in brain LPR and increase in brain tissue oxygen tension. No significant change in optical scattering or pathlength was observed. These results suggest that the measurement of chromophore concentration in the injured brain is not confounded by changes in optical scattering or pathlength and that NBH induces an increase in cerebral aerobic metabolism.

55. Grocott & Davie (2013). **Future uncertainties in the development of clinical cerebral oximetry**

Abstract: – no abstract available –

56. Scott & Hoffman (2013). **Near-infrared spectroscopy: exposing the dark (venous) side of the circulation**

Abstract: The safety of anesthesia has improved greatly in the past three decades. Standard perioperative monitoring, including pulse oximetry, has practically eliminated unrecognized arterial hypoxia as a cause for perioperative injury. However, most anesthesia-related cardiac arrests in children are now cardiovascular in origin, and standard monitoring is unable to detect many circulatory abnormalities. Near-infrared spectroscopy provides noninvasive continuous access to the venous side of regional circulations that can approximate organ-

specific and global measures to facilitate the detection of circulatory abnormalities and drive goal-directed interventions to reduce end-organ ischemic injury.

57. Divya & Kumar (2013). **Design and Development of Low-Cost, Handheld Near Infrared Spectroscopy (NIRS) Device for Neonatal Brain Functional Analysis with Phantom Studies**

Abstract: Near infrared spectroscopy (NIRS) is an emerging optical modality to analyze biological tissues non-invasively within the near infrared window (700-1000 nm). Since this technology uses non-ionizing light photon, it facilitates the physician for repeated diagnosis on specific regions of tissue continuously. A recent literature on clinical studies proves that some of the newborns especially premature babies have a high risk of potential brain injuries like intra ventricular haemorrhages and hypoxic-ischemia which can affect their mental growth. Therefore, there is a need for continuous monitoring of their brain function to identify and prevent any such abnormalities and it should not interfere with intensive care of the newborn as well. In this paper we depict the design, development and calibration of low-cost, handheld, dual wavelength, reflectance type continuous wave near infrared spectroscopy system for neonatal brain functional monitoring. The hardware component of the device includes the sensor patch with 2 LEDs of different wavelengths and 14 photo detectors together forming the dual octal geometry, ARDUINO AT MEGA 2560 with operating voltage of 5V and with clock speed of 16 MHz acts as the master controller, the pre- processing unit and the NI-DAQ card interfaced with PC. The software component includes LabVIEW for data analysis and an Arduino IDE which relies on java programming language and it is flexible to run on any platforms/operating system. The special features of the proposed device are its low cost, portability, low power consumption, less heat dissipation unlike laser systems, faster access, and controllability, provide optimal results and hence better accuracy.

58. Heger et al. (2013). **Continuous Recognition of Affective States by Functional Near Infrared Spectroscopy Signals**

Abstract: Functional near infrared spectroscopy (fNIRS) is becoming more and more popular as an innovative imaging modality for brain computer interfaces. A continuous (i.e. asynchronous) affective state monitoring system using fNIRS signals would be highly relevant for numerous disciplines, including adaptive user interfaces, entertainment, biofeedback, and medical applications. However, only stimulus-locked emotion recognition systems have been proposed by now. fNRIS signals of eight subjects at eight prefrontal locations have been recorded in response to three different classes of affect induction by emotional audio-visual stimuli and a neutral class. Our system evaluates short windows of five seconds length to continuously recognize affective states. We analyze hemodynamic responses, present a careful evaluation of binary classification tasks and investigate classification accuracies over the time.

59. Yoshino et al. (2013). **Functional brain imaging using near-infrared spectroscopy during actual driving on an expressway**

Abstract: The prefrontal cortex is considered to have a significant effect on driving behavior, but little is known about prefrontal cortex function in actual road driving. Driving simulation experiments are not the same, because the subject is in a stationary state, and the results may be different. Functional near-infrared spectroscopy (fNIRS) is advantageous in that it can measure cerebral hemodynamic responses in a person driving an actual vehicle. We mounted fNIRS equipment in a vehicle to evaluate brain functions related to various actual driving operations while the subjects drove on a section of an expressway that was not yet open to the public. Measurements were recorded while parked, and during acceleration, constant velocity driving (CVD), deceleration, and U-turns, in the daytime and at night. Changes in cerebral oxygen exchange (ΔCOE) and cerebral blood volume were calculated and imaged for each part of the task. Responses from the prefrontal cortex and the parietal cortex were highly reproducible in the daytime and nighttime experiments. Significant

increases in ΔCOE were observed in the frontal eye field (FEF), which has not been mentioned much in previous simulation experiments. In particular, significant activation was detected during acceleration in the right FEF, and during deceleration in the left FEF. Weaker responses during CVD suggest that FEF function was increased during changes in vehicle speed. As the FEF contributes to control of eye movement in three-dimensional space, FEF activation may be important in actual road driving. fNIRS is a powerful technique for investigating brain activation outdoors, and it proved to be sufficiently robust for use in an actual highway driving experiment in the field of intelligent transport systems (ITS).

60. Nakao et al. (2013). **Resting state low-frequency fluctuations in prefrontal cortex reflect degrees of harm avoidance and novelty seeking: an exploratory NIRS study**

Abstract: Harm avoidance (HA) and novelty seeking (NS) are temperament dimensions defined by Temperament and Character Inventory (TCI), respectively, reflecting a heritable bias for intense response to aversive stimuli or for excitement in response to novel stimuli. High HA is regarded as a risk factor for major depressive disorder and anxiety disorder. In contrast, higher NS is linked to increased risk for substance abuse and pathological gambling disorder. A growing body of evidence suggests that patients with these disorders show abnormality in the power of slow oscillations of resting-state brain activity. It is particularly interesting that previous studies have demonstrated that resting state activities in medial prefrontal cortex (MPFC) are associated with HA or NS scores, although the relation between the power of resting state slow oscillations and these temperament dimensions remains poorly elucidated. This preliminary study investigated the biological bases of these temperament traits by particularly addressing the resting state low-frequency fluctuations in MPFC. Regional hemodynamic changes in channels covering MPFC during 5-min resting states were measured from 22 healthy participants using near-infrared spectroscopy (NIRS). These data were used for correlation analyses. Results show that the power of slow oscillations during resting state around the dorsal part of MPFC is negatively correlated with the HA score. In contrast, NS was positively correlated with the power of resting state slow oscillations around the ventral part of MPFC. These results suggest that the powers of slow oscillation at rest in dorsal or ventral MPFC, respectively, reflect the degrees of HA and NS. This exploratory study therefore uncovers novel neural bases of HA and NS. We discuss a neural mechanism underlying aversion-related and reward-related processing based on results obtained from this study.

61. Xuxan et al. (2013). **Software Digital Lock-in Amplifier in the Application of fNIRS System**

Abstract: Lock-in amplifier is particularly important in the fNIRS-based system, because the lock-in amplifier can recover the low-level signals buried in significant amounts of noise. But the price of lock-in amplifier is very expensive. This paper presented a software method for designing digital lock-in amplifier. Compared with analogue lock-in amplifier, results show that software lock-in amplifier is feasible for experimental research and can replace the expensive analogue lock-in amplifier.

62. Philip et al. (2013). **Altered low frequency oscillations of cortical vessels in patients with cerebrovascular occlusive disease – a NIRS study**

Abstract: Analysis of cerebral autoregulation by measuring spontaneous oscillations in the low frequency spectrum of cerebral cortical vessels might be a useful tool for assessing risk and investigating different treatment strategies in carotid artery disease and stroke. Near infrared spectroscopy (NIRS) is a non-invasive optical method to investigate regional changes in oxygenated (oxyHb) and deoxygenated hemoglobin (deoxyHb) in the outermost layers of the cerebral cortex. In the present study we examined oxyHb low frequency oscillations, believed to reflect cortical cerebral autoregulation, in 16 patients with both symptomatic carotid occlusive disease and cerebral hypoperfusion in comparison to healthy controls. Each hemisphere was examined with two NIRS channels using a 3 cm source detector distance. Arterial blood pressure (ABP) was measured via

a finger plethysmograph. Using transfer function analysis ABP-oxyHb phase shift and gain as well as inter-hemispheric phase shift and amplitude ratio were assessed. We found that inter-hemispheric amplitude ratio was significantly altered in hypoperfusion patients compared to healthy controls (P = 0.010), because of relatively lower amplitude on the hypoperfusion side. The inter-hemispheric phase shift showed a trend (P = 0.061) toward increased phase shift in hypoperfusion patients compared to controls. We found no statistical difference between hemispheres in hypoperfusion patients for phase shift or gain values. There were no differences between the hypoperfusion side and controls for phase shift or gain values. These preliminary results suggest an impairment of autoregulation in hypoperfusion patients at the cortical level detected by NIRS.

63. Yücel et al. (2013). **Target principle component analysis: A new motion artifact correction approach for near-infrared spectroscopy**

Abstract: As near-infrared spectroscopy (NIRS) broadens its application area to different age and disease groups, motion artifacts in the NIRS signal due to subject movement is becoming an important challenge. Motion artifacts generally produce signal fluctuations that are larger than physiological NIRS signals, thus it is crucial to correct for them before obtaining an estimate of stimulus evoked hemodynamic responses. There are various methods for correction such as principle component analysis (PCA), wavelet-based filtering and spline interpolation. Here, we introduce a new approach to motion artifact correction, targeted principle component analysis (tPCA), which incorporates a PCA filter only on the segments of data identified as motion artifacts. It is expected that this will overcome the issues of filtering desired signals that plagues standard PCA filtering of entire data sets. We compared the new approach with the most effective motion artifact correction algorithms on a set of data acquired simultaneously with a collodion-fixed probe (low motion artifact content) and a standard Velcro probe (high motion artifact content). Our results show that tPCA gives statistically better results in recovering hemodynamic response function (HRF) as compared to wavelet-based filtering and spline interpolation for the Velcro probe. It results in a significant reduction in mean-squared error (MSE) and significant enhancement in Pearson's correlation coefficient to the true HRF. The collodion-fixed fiber probe with no motion correction performed better than the Velcro probe corrected for motion artifacts in terms of MSE and Pearson's correlation coefficient. Thus, if the experimental study permits, the use of a collodion-fixed fiber probe may be desirable. If the use of a collodion-fixed probe is not feasible, then we suggest the use of tPCA in the processing of motion artifact contaminated data.

64. Messere & Roatta (2013). **Influence of cutaneous and muscular circulation on spatially resolved versus standard Beer–Lambert near-infrared spectroscopy**

Abstract: The potential interference of cutaneous circulation on muscle blood volume and oxygenation monitoring by near-infrared spectroscopy (NIRS) remains an important limitation of this technique. Spatially resolved spectroscopy (SRS) was reported to minimize the contribution of superficial tissue layers in cerebral monitoring but this characteristic has never been documented in muscle tissue monitoring. This study aims to compare SRS with the standard Beer–Lambert (BL) technique in detecting blood volume changes selectively induced in muscle and skin. In 16 healthy subjects, the biceps brachii was investigated during isometric elbow flexion at 70% of the maximum voluntary contractions lasting 10 sec, performed before and after exposure of the upper arm to warm air flow. From probes applied over the muscle belly the following variables were recorded: total hemoglobin index (THI, SRS-based), total hemoglobin concentration (tHb, BL-based), tissue oxygenation index (TOI, SRS-based), and skin blood flow (SBF), using laser Doppler flowmetry. Blood volume indices exhibited similar changes during muscle contraction but only tHb significantly increased during warming (+5.2 ± 0.7 μmol/L·cm, an effect comparable to the increase occurring in postcontraction hyperemia), accompanying a 10-fold increase in SBF. Contraction-induced changes in tHb and THI were not substantially affected by warming, although the tHb tracing was shifted upward by (5.2 ± 3.5 μmol/L·cm, $P < 0.01$). TOI was not affected by cutaneous warming. In conclusion, SRS appears to effectively reject interference by SBF in both

muscle blood volume and oxygenation monitoring. Instead, BL-based parameters should be interpreted with caution, whenever changes in cutaneous perfusion cannot be excluded.

65. Ito et al. (2013). **Brain machine interface using portable Near-InfraRed spectroscopy — Improvement of classification performance based on ICA analysis and self-proliferating LVQ**

Abstract: Recently, the Brain-Machine Interface (BMI) has been expected to be applied to robotics and medical science field as a new intuitive interface. BMI measures human cerebral activities and uses them directly as an input signal to various instruments. The future goal of our research is to design a practical BMI system that can be used reliably in daily lives. In this paper, we will discuss a design method of a BMI system using a portable Near-InfraRed Spectroscopy (NIRS) device and then we will consider improving the performance of the learning vector quantization (LVQ) classifier by using the independent component analysis (ICA) and the self-proliferating function of neurons. The effectiveness of the proposed method is investigated in human imagery classification experiments.

66. Yamazaki et al. (2013). **A preliminary analysis of light blue backgrounds on the scores of Web-based tests using NIRS**

Abstract: In this study, the authors conducted an experiment to see how a background color of Web-based tests (WBTs) can affect the performance of Web-based test takers and their brain activities. Twenty one subjects in their twenties took Web-based English grammar tests and also performed circle-counting tasks on a computer screen with white and light blue backgrounds. Two dimensional images of hemoglobin (Hb) concentration changes in the brain of each subject were recorded by using near-infrared spectroscopy (NIRS). On average, the subjects scored higher on both the English tests and the counting tasks with the light blue background when texts and symbols were presented in black. The NIRS images obtained in the experiment showed that areas in the brain associated with linguistic tasks tended to have higher Hb concentrations for the light blue background than the white background. Also, the brain areas related to eye movements showed higher Hb concentration changes while the subjects were looking at the screen with the white background. Even though the NIRS signals were not analyzed in details, these results suggest that white color may not be the best choice for a background color of a WBT.

67. Yoshino et al. (2013). **Correlation of prefrontal cortical activation with changing vehicle speeds in actual driving: a vector-based functional near-infrared spectroscopy study**

Abstract: Traffic accidents occur more frequently during deceleration than during acceleration. However, little is known about the relationship between brain activation and vehicle acceleration because it has been difficult to measure the brain activation of drivers while they drive. In this study, we measured brain activation during actual driving using vector-based functional near-infrared spectroscopy. Subjects decelerated from 100 to 50 km/h (speed reduction task) and accelerated from 50 to 100 km/h (speed increase task) while driving on an expressway, in the daytime and at night. We examined correlations between average vehicle acceleration in each task and five hemodynamic indices: changes in oxygenated hemoglobin (ΔoxyHb), deoxygenated hemoglobin (ΔdeoxyHb), cerebral blood volume (ΔCBV), and cerebral oxygen exchange (ΔCOE); and the phase angle k (degrees) derived from the other hemoglobin (Hb) indices. ΔoxyHb and ΔCBV reflect changes in cerebral blood flow, whereas ΔdeoxyHb, ΔCOE, and k are related to variations in cerebral oxygen metabolism. Most of the resulting correlations with specific brain sites, for all the indices, appeared during deceleration rather than during acceleration. Faster deceleration resulted in greater increases in ΔdeoxyHb, ΔCOE, and k in the prefrontal cortex ($r < -0.5$, $p < 0.01$), in particular, in the frontal eye field, and at night, it also resulted in greater decreases in ΔoxyHb and ΔCBV in the prefrontal cortex and in the parietal lobe ($r > 0.4$, $p < 0.01$), suggesting oxygen metabolism associated with transient ischemic changes. Our results suggest that vehicle deceleration

requires more brain activation, focused in the prefrontal cortex, than does acceleration. From the standpoint of the indices used, we found that simultaneous analysis of multiple hemodynamic indices was able to detect not only the blood flow components of hemodynamic responses, but also more localized frontal lobe activation involving oxygen metabolism.

68. Hansen et al. (2013). **Impact of afterload reduction strategies on regional tissue oxygenation after the Norwood procedure for hypoplastic left heart syndrome**

Abstract: OBJECTIVES Low cerebral tissue oxygenation saturations have been observed by near-infrared spectroscopy (NIRS) after the Norwood procedure. Altered cerebral vascular resistance and pharmacological afterload reduction redirecting blood flow away from the cerebral circulation are possible mechanisms.
METHODS Two different afterload reduction strategies were evaluated in patients with hypoplastic left heart syndrome or variants after the Norwood procedure. In patients of Group 1 (n = 34), afterload reduction was controlled with sodium nitroprusside or with the α-blocker phentolamine. In addition, a phosphodiesterase-III inhibitor was administered. Patients of Group 2 (n = 34) received a phosphodiesterase-III inhibitor only. Cerebral and somatic tissue oxygenation saturations and routine intensive care monitoring data were recorded for 24 h before and 48 h after the Norwood procedure. Mean values of the last 4 preoperative (baseline) and of the first and last 4 postoperative hours (early and late course) were calculated.
RESULTS Baseline, early and late cerebral saturations were 58 ± 7, 52 ± 9 and 60 ± 6% for Group 1 and 58 ± 7, 52 ± 12 and 61 ± 7% for Group 2 and somatic saturations were 59 ± 8, 76 ± 10 and 67 ± 9% and 58 ± 9, 78 ± 8 and 69 ± 10%, respectively. Regional saturations were not different between groups. The postoperative cerebral tissue oxygen saturation was below 40% for 50 (0–1040) min in Group 1 and for 45 (0–720) min in Group 2 (P = 1.00). Preoperative cerebral NIRS values (OR 0.85 [0.76–0.96], P = 0.007), age at operation (OR 1.39 [1.02–1.88], P = 0.034) and early postoperative diastolic blood pressure (OR 0.88 [0.78–0.99], P = 0.038) were associated with cerebral tissue oxygen saturations below 40% for more than 60 min. Patients with a prolonged period of low cerebral tissue oxygen saturation had longer duration of mechanical ventilation (69 (37–192) vs 60 (33–238) h, P = 0.039) and afterload reduction therapy was terminated later (95 (47–696) vs 74 (39–650) h, P = 0.006). Early mortality was 9.4% (3 of 32) compared with 2.8% (1 of 36) in the remainder (P = 0.336).
CONCLUSIONS The postoperative decline of cerebral tissue oxygen saturation was observed with both afterload reduction strategies. The difference between cerebral and somatic NIRS values may indicate a mismatch between cerebral and splanchnic oxygenation. Other strategies to improve cerebral tissue oxygenation are warranted.

69. Ullman et al. (2013). **Usefulness of cerebral NIRS in detecting the effects of pediatric sleep apnea**

Abstract: Background Children with sleep apnea have increased morbidity if the sleep apnea is untreated. Polysomnography (PSG) is used to detect sleep apnea, but in children, there are technical difficulties that make the diagnosis more difficult. Cerebral near infrared spectroscopy (NIRS) has the ability to detect tissue hypoxia by measuring regional oxygen saturation (rSO_2). We hypothesized that when used as an adjunct to PSG testing, cerebral NIRS would better detect the effects of sleep apnea in children than arterial pulse oximetry (SpO_2). Specifically, we aimed to show that the apnea/hypopnea index (AHI) calculated with rSO_2 from the NIRS would be greater than that calculated with SpO_2.
Methods Forty-seven patients under 18 years of age who underwent PSG testing for sleep apnea were evaluated. Cerebral NIRS was utilized in addition to PSG. The AHI was calculated using SpO_2 and compared to the AHI calculated using the rSO_2. A pediatric pulmonologist who was unaware of the NIRS data evaluated each patient for sleep apnea. Data are median (interquartile range).
Results The median AHI(rSO_2) was 2.4(1.2,5.1), significantly greater ($P < 0.0001$) than the AHI(SpO_2) of 0.7(0.4,1.2). Four patients were diagnosed with sleep apnea; however, only one had an AHI(SpO_2) ≥ 5, a typical threshold for the diagnosis of sleep apnea. All 4 subjects had an AHI(rSO_2) ≥ 5 but 10 patients without sleep

apnea had a value ≥5. The sensitivity and specificity for using the AHI(rSO_2) to diagnose sleep apnea was 100% and 76.7%, respectively.
Conclusion Consistent with the ability of NIRS to detect tissue hypoxia, we found that the AHI calculated with rSO_2 was greater than that using SpO_2. We conclude that NIRS has potential as a valuable adjunct to PSG in evaluating patients for sleep apnea and warrants further investigation for this purpose.

70. Desebbe et al. (2013). **Tissue Hemoglobin Monitoring Is Unable to Follow Variations of Arterial Hemoglobin During Transitions From Pulsatile to Constant Flow in Cardiac Surgery**

Abstract: Objective: To test whether the variations of tissue hemoglobin concentration (Δ_THb) measured by the FORE-SIGHT™ cerebral oximeter can accurately detect changes in arterial hemoglobin concentration (Δ_AHb) before, during, and after cardiopulmonary bypass. Design: A prospective clinical study. Setting Cardiac surgery operating room. Participants: Thirty patients scheduled for cardiac surgery.
Interventions: Tissue hemoglobin concentration ($_T$Hb) was recorded continuously via 2 sensors applied on the forehead and connected to the cerebral oximeter. Arterial hemoglobin concentration ($_A$Hb) was measured in a hematology analyzer laboratory. Hemodynamic and respiratory parameters as well as epidemiologic data also were noted. Data were collected at 3 perioperative times: After induction of anesthesia, 10 minutes after cardioplegia, and at the end of the surgery.
Measurements and Main Results: Ninety pairs of data were collected. The coefficient of linear regression between Δ_THb and Δ_AHb was 0.4 ($p<0.001$). After exclusion of Hb variations<5%, the trending ability of $_T$Hb to predict Δ_AHb was 87%. However, the Bland and Altman plot graph for $_T$Hb and $_A$Hb showed major limits of agreement (2.4 times the standard deviation). Central venous pressure and carbon dioxide tension were linked independently and positively with $_T$Hb ($p = 0.03$).
Conclusions: Continuous monitoring of $_T$Hb cannot accurately track variations of $_A$Hb during the transition from pulsatile to continuous flow and vice versa in cardiac surgery. Local hemodynamic factors such as $PaCO_2$ and vasodilation significantly impact $_T$Hb. In this setting, $_T$Hb monitoring should not be used to guide eventual blood transfusion management.

71. Beken et al. (2013). **Cerebral Hemodynamic Changes and Pain Perception During Venipuncture Is Glucose Really Effective?**

Abstract: Newborns are exposed to a considerable number of painful stimuli. This study is aimed to investigate the effects of 30% glucose solution and nonnutritive sucking on pain perception during venipuncture. Twenty-five term infants were randomized as receiving 30% dextrose (group 1) or sterile water (group 2). Neonatal Infant Pain Scale scores, skin conductance algesimeter recordings, and near-infrared spectroscopy measurements were recorded during the procedure. Neonatal Infant Pain Scale and skin conductance algesimeter results were decreased in both groups from that during venipuncture to after the procedure. Group 1 had lower Neonatal Infant Pain Scale scores compared with group 2 after venipuncture, different from the skin conductance algesimeter, where no difference was observed between groups. In group 1, cerebral blood volume increased after venipuncture. Glucose does not attenuate the Neonatal Infant Pain Scale score and skin conductance algesimeter index during venipuncture, but it leads to a lower Neonatal Infant Pain Scale score after venipuncture unlike the skin conductance algesimeter index, which was not lowered.

72. Viola et al. (2013). **New brain reperfusion rehabilitation therapy improves cognitive impairment in mild Alzheimer's disease: a prospective, controlled, open-label 12-month study with NIRS correlates**

Abstract: Background and aims: A large body of evidence indicates that cerebral hypoperfusion is one of the earliest signs in the development of Alzheimer's disease (AD). The aim of our study was to evaluate whether the

brain reperfusion rehabilitation therapy (BRRT) would improve verbal memory and learning and/or global cognitive impairment in mild AD.
Methods: Using a prospective, controlled, open-label 12-month study, we enrolled 15 patients with mild AD, who underwent BRRT program (BRRT group), and 10 age–sex-matched mild AD patients, who received no treatment (control group). At baseline (T0), and at the end of the 3 months (T3), 6 months (T6) and 12 months (T12) participants from both groups were given an evaluation, using Mini-Mental State Examination (MMSE) and Rey Auditory Verbal Learning Test (RAVLT). In both groups by using near-infrared spectroscopy, at T0 and T12, we measured tissue oxygen saturation (TOI) on temporal–parietal and frontal cortex of both sides.
Results: Ten patients from the BRRT group and 10 from the control group completed the 12-month follow-up. At the end of rehabilitation protocol, a significant improvement of MMSE and RAVLT was observed in the BRRT group as compared to control group. At T12 compared to T0, a significant improvement of TOI on frontal cortex of both sides was observed in the BRRT group as compared to control group.
Conclusion: BRRT improves verbal memory–learning and global cognitive impairment which are associated with increased TOI values on frontal cortex of both sides.

73. Blokland et al. (2013). **Combined EEG-fNIRS Decoding of Motor Attempt and Imagery for Brain Switch Control: An Offline Study in Patients With Tetraplegia**

Abstract: Combining electrophysiological and hemodynamic features is a novel approach for improving current performance of brain switches based on sensorimotor rhythms (SMR). This study was conducted with a dual purpose: to test the feasibility of using a combined EEG-fNIRS SMR-based brain switch in patients with tetraplegia, and to examine the performance difference between motor imagery and motor attempt for this user group. A general improvement was found when using both EEG and fNIRS features for classification as compared to using the single-modality EEG classifier, with average classification rates of 79% for attempted movement and 70% for imagined movement. For the control group, rates of 87% and 79% were obtained, respectively, where the 'attempted movement' condition was replaced with 'actual movement'. A combined EEG-fNIRS system might be especially beneficial for users who lack sufficient control of current EEG-based brain switches. The average classification performance in the patient group for attempted movement was significantly higher than for imagined movement using the EEG-only as well as the combined classifier, arguing for the case of a paradigm shift in current brain switch research.

74. Basso Moro et al. (2013). **Prefrontal cortex activation during story encoding/retrieval: a multi-channel functional near-infrared spectroscopy study**

Abstract: Encoding, storage and retrieval constitute three fundamental stages in information processing and memory. They allow for the creation of new memory traces, the maintenance and the consolidation of these traces over time, and the access and recover of the stored information from short or long-term memory. Functional near-infrared spectroscopy (fNIRS) is a non-invasive neuroimaging technique that measures concentration changes of oxygenated-hemoglobin (O_2Hb) and deoxygenated-hemoglobin (HHb) in cortical microcirculation blood vessels by means of the characteristic absorption spectra of hemoglobin in the near-infrared range. In the present study, we monitored, using a 16-channel fNIRS system, the hemodynamic response during the encoding and retrieval processes (EP and RP, respectively) over the prefrontal cortex (PFC) of 13 healthy subjects (27.2 ± 2.6 years) while were performing the "Logical Memory Test" (LMT) of the Wechsler Memory Scale. A LMT-related PFC activation was expected; specifically, it was hypothesized a neural dissociation between EP and RP. The results showed a heterogeneous O_2Hb/HHb response over the mapped area during the EP and the RP, with a O_2Hb progressive and prominent increment in ventrolateral PFC (VLPFC) since the beginning of the EP. During the RP a broader activation, including the VLPFC, the dorsolateral PFC and the frontopolar cortex, was observed. This could be explained by the different contributions of the PFC regions in the EP and the RP. Considering the fNIRS applicability for the hemodynamic monitoring during the LMT performance, this study has demonstrated that fNIRS could be utilized as a valuable clinical diagnostic

tool, and that it has the potential to be adopted in patients with cognitive disorders or slight working memory deficits.

75. Mesquita et al. (2013). **Optical Monitoring and Detection of Spinal Cord Ischemia**

Abstract: Spinal cord ischemia can lead to paralysis or paraparesis, but if detected early it may be amenable to treatment. Current methods use evoked potentials for detection of spinal cord ischemia, a decades old technology whose warning signs are indirect and significantly delayed from the onset of ischemia. Here we introduce and demonstrate a prototype fiber optic device that directly measures spinal cord blood flow and oxygenation. This technical advance in neurological monitoring promises a new standard of care for detection of spinal cord ischemia and the opportunity for early intervention. We demonstrate the probe in an adult Dorset sheep model. Both open and percutaneous approaches were evaluated during pharmacologic, physiological, and mechanical interventions designed to induce variations in spinal cord blood flow and oxygenation. The induced variations were rapidly and reproducibly detected, demonstrating direct measurement of spinal cord ischemia in real-time. In the future, this form of hemodynamic spinal cord diagnosis could significantly improve monitoring and management in a broad range of patients, including those undergoing thoracic and abdominal aortic revascularization, spine stabilization procedures for scoliosis and trauma, spinal cord tumor resection, and those requiring management of spinal cord injury in intensive care settings.

76. Belegar et al. (2013). **Early Cerebral Oxygen Extraction and the Risk of Death or Sonographic Brain Injury in Very Preterm Infants**

Abstract: Objective: To evaluate the relationship between cerebral fractional tissue oxygen extraction (cFTOE), a measure of oxygen delivery–consumption equilibrium, and the risk of early poor outcome in very preterm infants. Study design: Cerebral blood flow, tissue oxygenation index (by near-infrared spectroscopy), and arterial oxygen content were measured, and cerebral oxygen delivery, consumption, and cFTOE were calculated at 3 intervals in the first 72 hours of life in infants ≤30 weeks gestational age (GA). A receiver operating characteristic curve was derived with an a priori defined dichotomized outcome of good or poor, defined as death or sonographic brain injury (grade ≥II intraventricular hemorrhage) by day 7.
Results: Seventy-one infants were enrolled, with a mean (SD) GA of 27 (2) weeks. cFTOE demonstrated better discrimination for the study outcome at <24 hours of age than at 48 or 72 hours of age (P = .01). The area under the curve for cFTOE at the initial measurement was no different from that for GA alone (0.87; 95% CI, 0.77-0.95 vs 0.81; 95% CI, 0.69-0.92), but the combined measure of cFTOE and GA had better discrimination (0.96; 95% CI, 0.91-1.0) than either cFTOE (P = .03) or GA (P = .016) alone. A cFTOE of 0.4 had a sensitivity of 82% and specificity of 75% for risk of early poor outcome.
Conclusion: Elevated cFTOE values are associated with increased risk of early poor outcome in very preterm infants. Its predictive value is further improved with the addition of GA.

77. Thang et al. (2013). **State-space modeling based on principal component analysis and oxygenated-deoxygenated correlation to improve near-infrared spectroscopy signals**

Abstract: Near infrared spectroscopy (NIRS) is currently becoming an effective technique for noninvasive functional brain imaging. Therefore, the methods to improve the quality of measured NIRS signals play an important role to make NIRS broadly accepted in practical applications. Previously, there have been approaches using state-space modeling to recover the NIRS signals from basic component signals to eliminate the artifacts presented in the NIRS measurements. However, the proposed approach requires us an onset vector to determine the starting position of stimulus that is not always available in practical situation. In this work, we provide a new way to find the basic components for efficient implementations of the state-space modeling. We apply principal component analysis to estimate eigenvector-based basis that presents the compact information of the

whole signals. We utilize the oxygenated-deoxygenated correlation to find another set of basic components to enhance the quality of NIRS signals. The state-space modeling based on Kalman filter is used to reconstruct the NIRS signals from these basic components. We tested the proposed algorithm with actual data and showed significant improvements of the contrast-to-noise (CNR) of the NIRS signals after filtered by our proposed approach.

78. Blohm et al. (2013). **Effect of cerebral circulatory arrest on cerebral near-infrared spectroscopy in pediatric patients**

Abstract: Background/Aims: The aim was to investigate whether cerebral transcutaneous near-infrared spectroscopy (NIRS) or two-site NIRS is a suitable monitoring tool to detect or confirm a cerebral circulatory arrest in pediatric intensive care unit (PICU) patients.
Methods: Prospective single-center pediatric observational study. Simultaneous NIRS measurements over forehead (cNIRS, crS02) and kidney (rNIRS, rrSO2), at the same time, the cardiac output were determined by transthoracic echocardiography. Area under the curve (AUC) in the receiver-operating curve (ROC) was analyzed for NIRS regarding cerebral circulatory arrest.
Results: There were two groups of patients (weight 2.1–73 kg): Group A: patients with intact cerebral perfusion ($n = 36$). Group B: patients with cerebral circulatory arrest ($n = 8$) proven by Doppler ultrasound scan or perfusion scintigraphy. There was no difference in cardiac output between the groups. PICU mortality for Group A was 3/36 (8.3%), for Group B 8/8, (100%). Mean cNIRS values were significantly higher with 68.92 (sem = 2.54, sd = 15.25) in Group A compared with 34.63 (sem = 5.36, sd = 15.15) in Group B ($P < 0.001$). ROC analysis for cNIRS detecting cerebral circulatory arrest was significant (AUC 0.948, 95% confidence interval 0.876–1.000, se = 0.037, $P < 0.001$). Discrimination was optimal at 46 for cNIRS, at 36.5 for the difference rNIRS-cNIRS and at 0.5646 for the quotient cNIRS/rNIRS. The probability of a cerebral circulatory arrest was 77.8% (cNIRS) and 87.5% (combinations of cNIRS and rNIRS) at these cutoffs.
Conclusions: cNIRS did detect cerebral circulatory arrest with high sensitivity. Specificity was, however, not high enough to confirm a cerebral circulatory arrest.

79. Oudegeest-Sander et al. (2013). **Assessment of dynamic cerebral autoregulation and cerebrovascular CO_2 reactivity in aging by measurements of cerebral blood flow and cortical oxygenation**

Abstract: With aging cerebral blood flow velocity (CBFV) decreases. However, to what extent dynamic cerebral autoregulation and cerebrovascular carbon dioxide (CO_2) reactivity are influenced by aging is unknown. The aim was to examine the dynamic responses of CBFV and cortical oxygenation to changes in blood pressure (BP) and arterial CO_2 across different ages. Eighty-five participants in three age groups were included: young (n = 20, 24 ± 2 years), elderly (n = 20, 66 ± 1 years), and older elderly (n = 18, 78 ± 3 years). CBFV was measured using transcranial Doppler, simultaneously with oxyhemoglobin (O_2Hb) using near-infrared spectroscopy and beat-to-beat BP measurements using Finapres. Postural maneuvers were performed to induce hemodynamic fluctuations. Cerebrovascular CO_2 reactivity was tested with hyperventilation and CO_2-inhalation.
With age, CBFV decreased (young 59 ± 12 cm/s, elderly 48 ± 7 cm/s, older elderly 42 ± 9 cm/s, $p < 0.05$) and cerebrovascular resistance increased (1.46 ± 0.58 mmHg/cm/s, 1.81 ± 0.36 mmHg/cm/s, 1.98 ± 0.52 mmHg/cm/s, $p < 0.05$). Normalized gain (autoregulatory damping) increased with age for BP-CBFV (0.88 ± 0.18, 1.31 ± 0.30, 1.06 ± 0.34, $p < 0.05$) and CBFV-O_2Hb (0.10 ± 0.09, 0.12 ± 0.04, 0.17 ± 0.08, $p < 0.05$) during the repeated sit-stand maneuver at 0.05Hz. Even though the absolute changes in CBFV and CVRi during the cerebrovascular CO_2 reactivity were higher in the young group, the percentage changes in CBFV, CVRi and O_2Hb were similar in all age groups.
In conclusion, there was no decline in dynamic cerebral autoregulation and cerebrovascular CO_2 reactivity with increasing age up to 86 years. Despite the decrease in cerebral blood flow velocity and increase in

cerebrovascular resistance with advancing age, CBFV and cortical oxygenation were not compromised in these elderly during maneuvers that mimic daily life activities.

80. Ahn et al. (2013). **A feasibility study of cerebral oximetry monitoring during the post-resuscitation period in comatose patients following cardiac arrest**

Abstract: Background: One of the major causes of death and neurological injury after cardiac arrest is delayed ischemia combined with oxygen free radical mediated reperfusion injury. Consequently determining the optimal balance between oxygen delivery and uptake in the brain using a reliable non-invasive monitoring system during the post-resuscitation period is of importance. In this observational study, we evaluated the feasibility of using cerebral oximetry during the post-resuscitation period in order to identify changes in regional cerebral oxygen saturation (rSO_2) and its association with survival to discharge.
Methods: 21 consecutive patients admitted to the intensive care units following cardiac arrest had cerebral oximetry monitoring carried out for 48 h. Mean rSO_2 values were collected during the first 24 h and then again during the subsequent 24–48 h of the post-resuscitation period.
Results: 43% ($n = 9$) patients survived to hospital discharge and 57% ($n = 12$) died. Amongst all patients the median (IQR) rSO_2% was 65.5% (62.6–68.2) in the first 24-h following ROSC and increased to 72.1% (64.6–73.7) ($p = 0.11$) in the subsequent 24–48 h. The median (IQR) rSO_2% during the first 24 h in patients who survived to discharge compared to those who did not survive were significantly higher 68.2% (66.0–71.0) vs. 62.9% (56.5–66.0), $p = 0.01$). During the subsequent 24–48 h period, while a difference in the rSO_2 between survivors and non-survivors was noted, this did not achieve statistical significance (median (IQR): 73.7 (70.2–74.0) vs. 66.5 (58.2–72.1), $p = 0.11$).
Conclusions: Our study indicates that the use of cerebral oximetry is feasible during the post resuscitation period after cardiac arrest. Further studies are needed to determine whether cerebral oximetry may be used as a novel non-invasive monitoring system to evaluate changes in the balance between cerebral oxygen delivery and uptake during the post-resuscitation period.

81. Perdue & Diamond (2013). **Effects of Spatial Pattern Scale of Brain Activity on the Sensitivity of DOT, fMRI, EEG and MEG**

Abstract: The objective of this work is to quantify how patterns of cortical activity at different spatial scales are measured by noninvasive functional neuroimaging sensors. We simulated cortical activation patterns at nine different spatial scales in a realistic head model and propagated this activity to magnetoencephalography (MEG), electroencephalography (EEG), diffuse optical tomography (DOT), and functional magnetic resonance imaging (fMRI) sensors in arrangements that are typically used in functional neuroimaging studies. We estimated contrast transfer functions (CTF), correlation distances in sensor space, and the minimum resolvable spatial scale of cortical activity for each modality. We found that CTF decreases as the spatial extent of cortical activity decreases, and that correlations between nearby sensors depend on the spatial extent of cortical activity. For cortical activity on the intermediate spatial scale of 6.7 cm^2, the correlation distances (r>0.5) were 1.0 cm for fMRI, 2.0 cm for DOT, 12.8 for EEG, 9.5 cm for MEG magnetometers and 9.7 cm for MEG gradiometers. The resolvable spatial pattern scale was found to be 1.43 cm^2 for MEG magnetometers, 0.88 cm^2 for MEG gradiometers, 376 cm^2 for EEG, 0.75 cm^2 for DOT, and 0.072 cm^2 for fMRI. These findings show that sensitivity to cortical activity varies substantially as a function of spatial scale within and between the different imaging modalities. This information should be taken into account when interpreting neuroimaging data and when choosing the number of nodes for network analyses in sensor space.

82. Fallahi et al. (2013). **Lower limb peripheral NIRS parameters during a vascular occlusion test: An experimental study in healthy volunteers**

Abstract: Objectives: The aim of the study was to compare NIRS parameters in combination with a vascular occlusion test (VOT) at a proximal (leg) and a distal (foot) site in male and female.
Study design: A prospective experimental study in healthy subjects.
Patients and methods: Twenty volunteers (10 male, 10 female, 28 ± 4 years) were investigated during 4 experimental steps: baseline, ischemia, reperfusion, and baseline. For each volunteer, 3 NIRS optodes were placed on right and left calves and the left arch of the foot. Blood pressure, heart rate and peripheral pulse oxymetry were monitored.
Results: Significant differences were observed at baseline between regional oxygen saturation (rSO_2) values according to the site of measurement (proximal rSO_2 81 ± 9% vs distal rSO_2 60 ± 5%, $P < 0.001$) but not according to gender. Both decreases in proximal and distal rSO_2 during ischemia and increases over baseline values during reperfusion depended on group membership (male or female). NIRS parameters during the VOT were significantly higher in male when compared with female at the proximal site: desaturation rate 5.6% (IQR: 5.5) vs 2.5% (IQR: 0.8), $P = 0.001$; resaturation rate 40.7% (IQR: 6.6) vs 21.7% (IQR: 5.4), $P = 0.003$; and ΔrSO_2 10.0% (IQR: 7.0) vs 5.5% (IQR: 6.0), $P = 0.041$.
Conclusions: Values of rSO_2 at the lower limb varied according to the anatomical site of measurement. A VOT induced major changes in rSO_2 that differed between male and female. These results should be taken into account in further clinical studies.

83. Kucewicz et al. (2013). **Anaesthesiology and intensive care. Does the optimization of intra-operative cerebral regional oxygen saturation have an effect on neurological function in elderly patients undergoing cardiac surgery?**

Abstract: Background: The optimization of cerebral oxygen delivery variables by using noninvasive cerebral oximetry could reduce the incidence of stroke. The aim of the study was to evaluate the effect of the intraoperative management of oxygen delivery on neurological function during the early postoperative period in elderly patients undergoing cardiac surgery. Material and methods: This observational study included 257 patients, aged 75 and above, who underwent surgery in 2011. In the study group (119 patients), cerebral oxygen saturation was monitored and managed in order to maintain the oximetry values within individually assigned optimal levels. The control group (138 patients) underwent cardiac surgery without the intraoperative monitoring of cerebral oximetry. The two groups were dissimilar with regard to age, EuroSCORE risk factors, previous cerebral vascular accidents, and chronic kidney disease. More patients in the control group had preoperative NYHA class I. Results: There was no difference between the groups with regard to the incidence of permanent stroke. Total ventilation time was significantly shorter in the study group. Patients in the study group required shorter lung ventilation and a lower number of packed red blood cell units. The length of postoperative ward and hospital stay was longer among the patients with low values of baseline cerebral oximetry (< 50%). Conclusions: These findings suggest that intraoperative patient management based on cerebral oxygen monitoring may improve the postoperative course in elderly patients after cardiac surgery.

84. Cao et al. (2013). **Multispectral imaging in the extended near-infrared window based on endogenous chromophores**

Abstract: To minimize the problem with scattering in deep tissues while increasing the penetration depth, we explored the feasibility of imaging in the relatively unexplored extended near infrared (exNIR) spectral region at 900 to 1400 nm with endogenous chromophores. This region, also known as the second NIR window, is weakly dominated by absorption from water and lipids and is free from other endogenous chromophores with virtually no autofluorescence. To demonstrate the applicability of the exNIR for bioimaging, we analyzed the optical properties of individual components and biological tissues using an InGaAs spectrophotometer and a

multispectral InGaAs scanning imager featuring transmission geometry. Based on the differences in spectral properties of tissues, we utilized ratiometric approaches to extract spectral characteristics from the acquired three-dimensional "datacube". The obtained images of an exNIR transmission through a mouse head revealed sufficient details consistent with anatomical structures.

85. Cao et al. (2013). **Study on reflection of human skin with liquid paraffin as the penetration enhancer by spectroscopy**

Abstract: Optical clearing agents can improve tissue optical transmittance by reducing the diffuse reflection. The reflection on *in vivo* human skin before and after applying anhydrous glycerol and 30 to 50% liquid paraffin glycerol mixed solution are investigated in this paper. From their visible and near-infrared reflection spectroscopy, all of their diffuse reflections are reduced after applying the agents. It is found that the three mixed solutions show stronger effect than that of anhydrous glycerol. These results further prove liquid paraffin can enhance the percutaneous penetration of glycerol and take synergistically optical clearing effect with glycerol over visible and near-infrared wave bands.

86. Shang et al. (2013). **Noninvasive evaluation of electrical stimulation impacts on muscle hemodynamics via integrating diffuse optical spectroscopies with muscle stimulator**

Abstract: Technologies currently available for the monitoring of electrical stimulation (ES) in promoting blood circulation and tissue oxygenation are limited. This study integrated a muscle stimulator with a diffuse correlation spectroscopy (DCS) flow-oximeter to noninvasively quantify muscle blood flow and oxygenation responses during ES. Ten healthy subjects were tested using the integrated system. The muscle stimulator delivered biphasic electrical current to right leg quadriceps muscle, and a custom-made DCS flow-oximeter was used for simultaneous measurements of muscle blood flow and oxygenation in both legs. To minimize motion artifact of muscle fibers during ES, a novel gating algorithm was developed for data acquisition at the time when the muscle was relaxed. ES at 2, 10, and 50 Hz were applied for 20 min on each subject in three days sequentially. Results demonstrate that the 20-min ES at all frequencies promoted muscle blood flow significantly. However, only the ES at 10 Hz resulted in significant and persistent increases in oxy-hemoglobin concentration during and post ES. This pilot study supports the application of the integrated system to quantify tissue hemodynamic improvements for the optimization of ES treatment in patients suffering from diseases caused by poor blood circulation and low tissue oxygenation (e.g., pressure ulcer).

87. Maughan et al. (2013). **Monte Carlo simulation of near-infrared light propagation through homogeneous mixed media**

Abstract: Noninvasive blood analysis devices that can measure levels of small constituents of blood are of interest in the medical community. An important step in creating these devices is to understand the interaction of photons with human tissue in increasingly greater physiological detail. Models based on layered biological materials give excellent results for many applications but may not be as accurate as needed when those materials are finely intertwined to the point of resembling a homogeneous mixture. To explore the ramifications of treating materials as layers versus a mixture, we have modeled, using a Monte Carlo technique, the interaction of photons through epidermis, blood, and water arranged both in layers and in a homogeneous blend. We confirm the expected linear relation between photon attenuation and material volumetric percentage in two-layer models. However, when the materials are homogeneously mixed together and volumetric percentage is replaced with interaction volume percentage, this relationship becomes nonlinear. These nonlinearities become significant when the values of the interaction coefficient, μt, differ by an order of magnitude or more.

88. Ebihara et al. (2013). **Detection of cerebral ischemia using the power spectrum of the pulse wave measured by near-infrared spectroscopy**

Abstract: The diagnosis and medical treatment of cerebral ischemia are becoming more important due to the increase in the prevalence of cerebrovascular disease. However, conventional methods of evaluating cerebral perfusion have several drawbacks: they are invasive, require physical restraint, and the equipment is not portable, which makes repeated measurements at the bedside difficult. An alternative method is developed using near-infrared spectroscopy (NIRS). NIRS signals are measured at 44 positions (22 on each side) on the fronto-temporal areas in 20 patients with cerebral ischemia. In order to extract the pulse-wave component, the raw total hemoglobin data recorded from each position are band-pass filtered (0.8 to 2.0 Hz) and subjected to a fast Fourier transform to obtain the power spectrum of the pulse wave. The ischemic region is determined by single-photon emission computed tomography. The pulse-wave power in the ischemic region is compared with that in the symmetrical region on the contralateral side. In 17 cases (85%), the pulse-wave power on the ischemic side is significantly lower than that on the contralateral side, which indicates that the transmission of the pulse wave is attenuated in the region with reduced blood flow. Pulse-wave power might be useful as a noninvasive marker of cerebral ischemia.

89. Dunaev et al. (2013). **Substantiation of medical and technical requirements for noninvasive spectrophotometric diagnostic devices**

Abstract: A scientific approach to the formulation of medical and technical requirements (MTRs) for noninvasive spectrophotometric diagnostic devices using optical technologies such as laser Doppler flowmetry and absorption spectroscopy is proposed. The theoretical modeling framework, metrological certification, and testing of these devices are still in the early stages of development. The theoretical estimation of the received signal levels for wavelengths between 514 and 940 nm is highly dependent on the blood volume level in the subject tissue. The proposed approach allows, in particular, the calculation of technical and metrological performance constraints of the instruments, such as the ranges of the sensitivity and power-related signal-to-noise ratios for different spectral channels and different biomedical (biochemical and physiological) parameters. Substantiation of specialized MTRs for the noninvasive spectrophotometric diagnostic devices can enable them to develop to the level of standardized measurement techniques.

90. Strojnik & Paez (2013). **Spectral dependence of absorption sensitivity on concentration of oxygenated hemoglobin: pulse oximetry implications**

Abstract: The sensitivity analysis indicates that the effective absorption coefficient is most sensitive to the concentration of oxygenated hemoglobin in spectral bands centered at 700 and 960 nm. We find that the highest temporal modulation due to heart function for a thick sample, like an arm, is at 940 nm, a significant shift from 710 nm measured for a finger. The most favorable spectral region for a thick transmission sample, such as a forearm, is the domain defined by intervals [900 nm$\leq\lambda 1\leq$1000 nm] and [650 nm$\leq\lambda 2\leq$720 nm]. We evaluated five near-infrared light-emitting diodes (LEDs) for their potential applications in oximetry. The LED with peak emission at 930 nm emits well in this spectral region. Here the temporal noise is low, and the effective absorption coefficient is strongly dependent on the concentration of the oxygenated hemoglobin. High-quality saturation results are obtained through the forearm during a short measurement (30 s).

91. Abookasis et al. (2013). **Closed head injury-induced changes in brain pathophysiology assessed with near-infrared structured illumination in a mouse model**

Abstract: Use of near-infrared (NIR) structured illumination technique has recently received great interest in biomedical research and clinical studies because of its ability to perform wide-field imaging and quantitatively

map changes in tissue hemodynamic properties and morphological features in a noncontact and scan-free fashion. We report on the feasibility of using the same to quantitatively monitor and map changes in brain optical properties and physiological parameters pre- and post-closed head injury in a mouse model. Five anesthetized male mice underwent head injury by weight-drop model using a ~50-g cylindrical metal object falling from a height of 90 cm onto the intact scalp. During experiments, NIR structured illumination was projected on the mouse head at two spatial frequencies and six different NIR wavelengths. A CCD camera positioned perpendicular to the head recorded the diffuse-reflected light. Computer analysis performed off-line on the captured data reveals spatiotemporal changes in the distribution of brain tissue absorption and reduced scattering coefficients. Using Beer's law and Mie theory, hemodynamic (hemoglobin, oxygen saturation, and lipids) and morphological (scattering amplitude and power) changes up to 1-h post-trauma were observed in comparison with baseline measurements. Functional maps of different brain properties were also generated. Following injury, we found difference in both brain hemodynamic and morphologic properties with respect to baseline levels, where in some properties, this difference was considered statistically significant. Specifically, a *t*-test indicates a substantial decrease in oxyhemoglobin (HbO_2) concentration and tissue oxygen saturation (StO_2) post-injury ($p < 0.01$ and $p < 0.001$, respectively). Overall, our preliminary results demonstrate the potential application of NIR structured illumination technique to track and spatially map changes in intact mouse brain pathophysiological parameters following head injury.

92. Mazurenka et al. (2013). **Non-contact in vivo diffuse optical imaging using a time-gated scanning system**

Abstract: We report on the design and first *in vivo* tests of a novel non-contact scanning imaging system for time-domain near-infrared spectroscopy. Our system is based on a null source-detector separation approach and utilizes polarization-selective detection and a fast-gated single-photon avalanche diode to record late photons only. The *in-vivo* tests included the recording of hemodynamics during arm occlusion and two brain activation tasks. Localized and non-localized changes in oxy- and deoxyhemoglobin concentration were detected for motor and cognitive tasks, respectively. The tests demonstrate the feasibility of non-contact imaging of absorption changes in deeper tissues.

93. Mozumder et al. (2013). **Compensation of optode sensitivity and position errors in diffuse optical tomography using the approximation error approach**

Abstract: Diffuse optical tomography is highly sensitive to measurement and modeling errors. Errors in the source and detector coupling and positions can cause significant artifacts in the reconstructed images. Recently the approximation error theory has been proposed to handle modeling errors. In this article, we investigate the feasibility of the approximation error approach to compensate for modeling errors due to inaccurately known optode locations and coupling coefficients. The approach is evaluated with simulations. The results show that the approximation error method can be used to recover from artifacts in reconstructed images due to optode coupling and position errors.

94. Jha et al. (2013). **An ideal-observer framework to investigate signal detectability in diffuse optical imaging**

Abstract: With the emergence of diffuse optical tomography (DOT) as a non-invasive imaging modality, there is a requirement to evaluate the performance of the developed DOT systems on clinically relevant tasks. One such important task is the detection of high-absorption signals in the tissue. To investigate signal detectability in DOT systems for system optimization, an appropriate approach is to use the Bayesian ideal observer, but this observer is computationally very intensive. It has been shown that the Fisher information can be used as a surrogate figure of merit (SFoM) that approximates the ideal observer performance. In this paper, we present a

theoretical framework to use the Fisher information for investigating signal detectability in DOT systems. The usage of Fisher information requires evaluating the gradient of the photon distribution function with respect to the absorption coefficients. We derive the expressions to compute the gradient of the photon distribution function with respect to the scattering and absorption coefficients. We find that computing these gradients simply requires executing the radiative transport equation with a different source term. We then demonstrate the application of the SFoM to investigate signal detectability in DOT by performing various simulation studies, which help to validate the proposed framework and also present some insights on signal detectability in DOT.

95. Yang et al. (2013). **Light transport in turbid media with non-scattering, low-scattering and high absorption heterogeneities based on hybrid simplified spherical harmonics with radiosity model**

Abstract: Modeling light propagation in the whole body is essential and necessary for optical imaging. However, non-scattering, low-scattering and high absorption regions commonly exist in biological tissues, which lead to inaccuracy of the existing light transport models. In this paper, a novel hybrid light transport model that couples the simplified spherical harmonics approximation (SP_N) with the radiosity theory (HSRM) was presented, to accurately describe light transport in turbid media with non-scattering, low-scattering and high absorption heterogeneities. In the model, the radiosity theory was used to characterize the light transport in non-scattering regions and the SP_N was employed to handle the scattering problems, including subsets of low-scattering and high absorption. A Neumann source constructed by the light transport in the non-scattering region and formed at the interface between the non-scattering and scattering regions was superposed into the original light source, to couple the SP_N with the radiosity theory. The accuracy and effectiveness of the HSRM was first verified with both regular and digital mouse model based simulations and a physical phantom based experiment. The feasibility and applicability of the HSRM was then investigated by a broad range of optical properties. Lastly, the influence of depth of the light source on the model was also discussed. Primary results showed that the proposed model provided high performance for light transport in turbid media with non-scattering, low-scattering and high absorption heterogeneities.

96. Carpet al. (2013). **Hemodynamic signature of breast cancer under fractional mammographic compression using a dynamic diffuse optical tomography system**

Abstract: Near infrared dynamic diffuse optical tomography measurements of breast hemodynamics during fractional mammographic compression offer a novel contrast mechanism for detecting breast cancer and monitoring chemotherapy. Tissue viscoelastic relaxation during the compression period leads to a slow reduction in the compression force and reveals biomechanical and metabolic differences between healthy and lesion tissue. We measured both the absolute values and the temporal evolution of hemoglobin concentration during 25-35 N of compression for 22 stage II and III breast cancer patients scheduled to undergo neoadjuvant chemotherapy. 17 patients were included in the group analysis (average tumor size 3.2 cm, range: 1.3-5.7 cm). We observed a statistically significant differential decrease in total and oxy-hemoglobin, as well as in hemoglobin oxygen saturation in tumor areas vs. healthy tissue, as early as 30 seconds into the compression period. The hemodynamic contrast is likely driven by the higher tumor stiffness and different viscoelastic relaxation rate, as well as the higher tumor oxygen metabolism rate.

97. Sorensen al. (2013). **A note on arterial to venous oxygen saturation as reference for NIRS-determined frontal lobe oxygen saturation in healthy humans**

Abstract: – no abstract available –

98. Moriguchi & Hiraki (2013). **Prefrontal cortex and executive function in young children: a review of NIRS studies**

Abstract: Executive function (EF) refers to the higher-order cognitive control process for the attainment of a specific goal. There are several subcomponents of EF, such as inhibition, cognitive shifting, and working memory. Extensive neuroimaging research in adults has revealed that the lateral prefrontal cortex plays an important role in EF. Developmental studies have reported behavioral evidence showing that EF changes significantly during preschool years. However, the neural mechanism of EF in young children is still unclear. This article reviews recent near-infrared spectroscopy (NIRS) research that examined the relationship between the development of EF and the lateral prefrontal cortex. Specifically, this review focuses on inhibitory control, cognitive shifting, and working memory in young children. Research has consistently shown significant prefrontal activation during tasks in typically developed children, but this activation may be abnormal in children with developmental disorders. Finally, methodological issues and future directions are discussed.

99. Doi al. (2013). **NIRS as a tool for assaying emotional function in the prefrontal cortex**

Abstract: Despite having relatively poor spatial and temporal resolution, near-infrared spectroscopy (NIRS) has several methodological advantages compared with other non-invasive measurements of neural activation. For instance, the unique characteristics of NIRS give it potential as a tool for investigating the role of the prefrontal cortex (PFC) in emotion processing. However, there are several obstacles in the application of NIRS to emotion research. In this mini-review, we discuss the findings of studies that used NIRS to assess the effects of PFC activation on emotion. Specifically, we address the methodological challenges of NIRS measurement with respect to the field of emotion research, and consider potential strategies for mitigating these problems. In addition, we show that two fields of research, investigating (i) biological predisposition influencing PFC responses to emotional stimuli and (ii) neural mechanisms underlying the bi-directional interaction between emotion and action, have much to gain from the use of NIRS. With the present article, we aim to lay the foundation for the application of NIRS to the above-mentioned fields of emotion research.

100. Ghosh al. (2013). **Reduction of Cytochrome *c* Oxidase During Vasovagal Hypoxia-Ischemia in Human Adult Brain: A Case Study**

Abstract: Near-infrared spectroscopy (NIRS)-derived measurement of oxidized cytochrome *c* oxidase concentration ([oxCCO]) has been used as an assessment of the adequacy of cerebral oxygen delivery. We report a case in which a reduction in conscious level was associated with a reduction in [oxCCO]. Hypoxaemia was induced in a 31-year-old, healthy male subject as part of an ongoing clinical study. Midway through the hypoxaemic challenge, the subject experienced an unexpected vasovagal event with bradycardia, hypotension and reduced cerebral blood flow (middle cerebral artery blood flow velocity decrease from 70 to 30 cm s^{-1}) that induced a brief reduction in conscious level. An associated decrease in [oxCCO] was observed at 35 mm (−1.6 μM) but only minimal change (−0.1 μM) at 20-mm source-detector separation. A change in optical scattering was observed, but path length remained unchanged. This unexpected physiological event provides an unusual example of a severe reduction in cerebral oxygen delivery and is the first report correlating change in clinical status with changes in [oxCCO].

101. Helmich al. (2013). **Hemispheric Differences of Motor Execution: A Near-Infrared Spectroscopy Study**

Abstract: Distal movements of the limbs are predominantly controlled by the contralateral hemisphere. However, functional neuroimaging studies do not unequivocally demonstrate a lateralization of the cerebral activation during hand movements. While some studies show a predominant activation of the contralateral

hemisphere, other studies provide evidence for a symmetrically distributed bihemispheric activation. However, the divergent results may also be due to methodological shortcomings. Therefore, the present study using functional near-infrared spectroscopy examines cerebral activation in both hemispheres during motor actions of the right and left hands. Twenty participants performed a flexion/extension task with the right- or left-hand thumb. Cerebral oxygenation changes were recorded from 48 channels over the primary motor, pre-motor, supplementary motor, primary somatosensory cortex, subcentral area, and the supramarginal gyrus of each hemisphere. A consistent increase of cerebral oxygenation was found for oxygenated and for total hemoglobin in the hemisphere contralateral to the moving hand, regardless of the laterality. These findings are in line with previous data from localization [1–3] and brain imaging studies [4–6]. The present data support the proposition that there is no hemispheric specialization for simple distal motor tasks. Both hemispheres are equally activated during movement of the contralateral upper limb.

102. Muthalib al. (2013). **Effects of Transcranial Direct Current Stimulation of the Motor Cortex on Prefrontal Cortex Activation During a Neuromuscular Fatigue Task: An fNIRS Study**

Abstract: This study investigated whether manipulation of motor cortex excitability by transcranial direct current stimulation (tDCS) modulates neuromuscular fatigue and functional near-infrared spectroscopy (fNIRS)-derived prefrontal cortex (PFC) activation. Fifteen healthy men (27.7 ± 8.4 years) underwent anodal (2 mA, 10 min) and sham (2 mA, first 30 s only) tDCS delivered to the scalp over the right motor cortex. Subjects initially performed a baseline sustained submaximal (30 % maximal voluntary isometric contraction, MVC) isometric contraction task (SSIT) of the left elbow flexors until task failure, which was followed 50 min later by either an anodal or sham treatment condition, then a subsequent posttreatment SSIT. Endurance time (ET), torque integral (TI), and fNIRS-derived contralateral PFC oxygenated (O_2Hb) and deoxygenated (HHb) hemoglobin concentration changes were determined at task failure. Results indicated that during the baseline and posttreatment SSIT, there were no significant differences in TI and ET, and increases in fNIRS-derived PFC activation at task failure were observed similarly regardless of the tDCS conditions. This suggests that the PFC neuronal activation to maintain muscle force production was not modulated by anodal tDCS.

103. Tachtsidis & Papaioannou (2013). **Investigation of Frontal Lobe Activation with fNIRS and Systemic Changes During Video Gaming**

Abstract: Frontal lobe activation caused by tasks such as videogames can be investigated using multichannel near-infrared spectroscopy (fNIRS), sometimes called optical topography. The aims of this study are to investigate the effects of video gaming (fighting and puzzle games) in the brain and the systemic physiology and to determine whether systemic responses during the gaming task are associated with the measurement of localised cerebral haemodynamic changes as measured by fNIRS. We used a continuous-wave 8-channel fNIRS system to measure the changes in concentration of oxy-haemoglobin (HbO_2) and deoxy-haemoglobin (HHb) and changes in total haemoglobin ($\Delta tHb = \Delta HbO_2 + \Delta HHb$) over the frontal lobe in 30 healthy volunteers. The Portapres system was used to measure mean blood pressure (MBP) and heart rate (HR), and a laser Doppler was employed to measure the changes in scalp blood flow (or flux). Even though we observed significant changes in systemic variables during gaming, in particular in scalp flow, we also managed to see localised activation patterns over the frontal polar (FP1) region. However, in some channels over the frontal lobe, we also observed significant correlations between the HbO_2 and systemic variables.

104. Tsubaki et al. (2013). **Effect of Valsalva Maneuver-Induced Hemodynamic Changes on Brain Near-Infrared Spectroscopy Measurements**

Abstract: Near-infrared spectroscopy (NIRS) is widely used to measure human brain activation on the basis of cerebral hemodynamic response. However, a limitation of NIRS is that systemic changes influence the measured

signals. The purpose of this study was to clarify the relationship between NIRS signals and blood pressure during the Valsalva maneuver. Nine healthy volunteers performed a 20-s Valsalva maneuver to change their blood pressure. Changes in oxyhemoglobin (O_2Hb) concentration were measured with 34 channels with an inter-optode distance of 30 mm for deep-penetration measurements (deepO_2Hb) and 9 channels with an inter-optode distance of 15 mm for shallow-penetration measurements (shallowO_2Hb). The difference value (diffO_2Hb) between deepO_2Hb and shallowO_2Hb was calculated. Mean arterial pressure (MAP) was recorded by volume clamping the finger pulse, and skin blood flow changes were measured at the forehead. Pearson's correlation coefficients between deepO_2Hb and MAP, shallowO_2Hb and MAP, and diffO_2Hb and MAP were 0.893 ($P < 0.01$), 0.963 ($P < 0.01$), and 0.831 ($P < 0.01$), respectively. The results suggest that regional and systemic changes in the cardiovascular state strongly influence NIRS signals.

105. Caicedo et al. (2013). **Effect of Maternal use of Labetalol on the Cerebral Autoregulation in Premature Infants**

Abstract: Hypertensive disorders of pregnancy (HDP) are normally treated to avoid maternal complications. In this study we aimed to investigate if there was an effect of maternal HDP treatment on the cerebral autoregulation of the neonates by analysing measurements of mean arterial blood pressure (MABP) and $rScO_2$ by means of correlation, coherence, and transfer function analysis. We found that these infants presented higher values of transfer function gain, which indicates impaired cerebral autoregulation, with a decreasing trend towards normality. We hypothesised that this trend was due to a vasodilation effect of the maternal use of labetalol due to accumulation, which disappeared by the third day after birth. Therefore, we investigated the values of pulse pressure in order to find evidence for a vasodilatory effect. We found that lower values of pulse pressure were present in these infants when compared with a control population, which, together with increased transfer function gain values, suggests an effect of the drug on the cerebral autoregulation.

106. Yagi et al. (2013). **Changes of Cerebral Oxygen Metabolism and Hemodynamics During ECPR with Hypothermia Measured by Near-Infrared Spectroscopy: A Pilot Study**

Abstract: The 2010 CPR Guidelines recommend that extracorporeal cardiopulmonary resuscitation (ECPR) using an emergency cardiopulmonary bypass (CPB) should be considered for patients with cardiac arrest. However, it is not yet clear whether this therapy can improve cerebral circulation and oxygenation in these patients. To clarify this issue, we evaluated changes of cerebral blood oxygenation (CBO) during ECPR using near-infrared spectroscopy (NIRS). (Methods) We employed NIRS to measure CBO in the bilateral frontal lobe in patients transported to the emergency room (ER) after out-of-hospital cardiac arrest between November 2009 and June 2011. (Results) Fifteen patients met the above criteria. The tissue oxygenation index (TOI) on arrival at the ER was 36.5 %. This increased to 67.8 % during ECPR ($P < 0.001$). The one patient whose TOI subsequently decreased had a favorable neurological outcome. (Conclusion) Increase of TOI during ECPR might reflect an improvement in cerebral blood flow, while decrease of TOI after ECPR might reflect oxygen utilization by the brain tissue as a result of neuronal cell survival. NIRS may be useful for monitoring cerebral hemodynamics and oxygen metabolism during CPR.

107. Grieger et al. (2013). **Analysis of NIRS-Based Muscle Oxygenation Parameters by Inclusion of Adipose Tissue Thickness**

Abstract: The assessment of muscle oxygenation by non-invasive near-infrared spectroscopy generally assumes a homogeneous medium, and this is flawed for large adipose tissue layers underneath the skin. Here we summarize the influence of the adipose tissue thickness on the oxygenation data, show that the adipose layer can be measured by NIRS and indicate a possible correction algorithm. Spectroscopic evidence suggests the usefulness of this algorithm, however, not in all subjects.

Publications from the BORL, Zurich

108. Scholkmann & Wolf (2013). **General equation for the differential pathlength factor of the frontal human head depending on wavelength and age**

Abstract: Continuous-wave near-infrared spectroscopy and near-infrared imaging enable the measurement of relative concentration changes in oxy- and deoxyhemoglobin and thus hemodynamics and oxygenation. The accuracy of determined changes depends mainly on the modeling of the light transport through the probed tissue. Due to the highly scattering nature of tissue, the light path is longer than the source–detector separation (d). This is incorporated in modeling by multiplying d by a differential pathlength factor (DPF) which depends on several factors such as wavelength, age of the subject, and type of tissue. In the present work, we derive a general DPF equation for the frontal human head, incorporating dependency on wavelength and age, based on published data. We validated the equation using different data sets of experimentally determined DPFs from six independent studies.

109. Holper & Murphy (2013). **Hemodynamic and affective correlates assessed during performance on the Columbia Card Task (CCT)**

Abstract: The study aimed to test the potential of functional near-infrared spectroscopy (fNIRS) in combination with electrodermal activity (EDA) in a decision paradigm by means of the Columbia Card Task (CCT). The CCT is a dynamic decision task characterized by assessing subjects' risk-taking via eliciting voluntary stopping points in a series of incrementally increasingly risky choices. Using the combined fNIRS-EDA approach, we aim to examine the hemodynamic and affective correlates of both decision and outcome responses during performance on the CCT. Twenty healthy subjects completed the Cold and Hot CCT version while fNIRS over prefrontal cortex and EDA were recorded. Results showed that (1) in the decision phase fNIRS revealed larger total hemoglobin concentration changes [tHb] in the Cold as compared to the Hot CCT, whereas EDA revealed an opposite pattern with larger skin conductance responses (SCRs) to the Hot as compared to the Cold CCT. (2) No significant [tHb] signals or SCRs were found in the outcome phase. (3) Coherence calculations between fNIRS and EDA in the heart rate frequency showed a significant increase during the Hot as compared to the Cold CCT. Our findings designate fNIRS as suitable tool for monitoring decision-making processes. The combination of fNIRS and EDA demonstrates the potential of simultaneously assessing the interaction between hemodynamic and affective responses which can provide additional information concerning the relationship between these two physiological systems for various research areas.

110. Scholkmann et al. (2013). **A new methodical approach in neuroscience: assessing inter-personal brain coupling using functional near-infrared imaging (fNIRI) hyperscanning**

Abstract: Since the first demonstration of how to simultaneously measure brain activity using functional magnetic resonance imaging (fMRI) on two subjects about 10 years ago, a new paradigm in neuroscience is emerging: measuring brain activity from two or more people simultaneously, termed "hyperscanning". The hyperscanning approach has the potential to reveal inter-personal brain mechanisms underlying interaction-mediated brain-to-brain coupling. These mechanisms are engaged during real social interactions, and cannot be captured using single-subject recordings. In particular, functional near-infrared imaging (fNIRI) hyperscanning is a promising new method, offering a cost-effective, easy to apply and reliable technology to measure inter-personal interactions in a natural context. In this short review we report on fNIRI hyperscanning studies published so far and summarize opportunities and challenges for future studies.

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