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

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

1. Pu et al. (2016). The association between cognitive deficits and prefrontal hemodynamic responses during performance of working memory task in patients with schizophrenia

Abstract: Schizophrenia-associated cognitive deficits are resistant to treatment and thus pose a lifelong burden. The Brief Assessment of Cognition in Schizophrenia (BACS) provides reliable and valid assessments across cognitive domains. However, because the prefrontal functional abnormalities specifically associated with the level of cognitive deficits in schizophrenia have not been examined, we explored this relationship. Patients with schizophrenia (N = 87) and matched healthy controls (N = 50) participated in the study. Using near-infrared spectroscopy (NIRS), we measured the hemodynamic responses in the prefrontal and superior temporal cortical surface areas during a working memory task. Correlation analyses revealed a relationship between the hemodynamics and the BACS composite and domain scores. Hemodynamic responses of the left dorsolateral prefrontal cortex (DLPFC) and left frontopolar cortex (FPC) in the higher-level-of-cognitive-function schizophrenia group were weaker than the responses of the controls but similar to those of the lower-level-of-cognitive-function schizophrenia group. However, hemodynamic responses in the right DLPFC, bilateral ventrolateral PFC (VLPFC), and right temporal regions decreased with increasing cognitive deficits. In addition, the hemodynamic response correlated positively with the level of cognitive function (BACS composite scores) in the right DLPFC, bilateral VLPFC, right FPC, and bilateral temporal regions in schizophrenia. The correlation was driven by all BACS domains. Our results suggest that the linked functional deficits in the right DLPFC, bilateral VLPFC, right FPC, and bilateral temporal regions may be related to BACS-measured cognitive impairments in schizophrenia and show that linking the neurocognitive deficits and brain abnormalities can increase our understanding of schizophrenia pathophysiology.

2. Dadgostar et al. (2016). Functional connectivity of the PFC via partial correlation

Abstract: Functional near-infrared spectroscopy (fNIRS) has been applied to study of brain oxygenation and metabolism. In this study, we aimed to investigate the partial correlation (PC) in fNIRS signals on functional connectivity in the prefrontal cortex (PFC) during a modified version of the color-word matching Stroop task. A continuous wave 16 channels near-infrared spectroscopy device (ARGES Cerebro, Hemosoft Inc., Turkey) was used to measure the changes in HbO2 and Hb concentrations from 12 healthy volunteers. Partial correlation (PC) values were computed for each stimulus condition. The results of ANOVA test (p < 0.05) in HbO2 and Hb signals indicate the bilateral connections between two brain hemispheres. The partial correlation analysis, by removing the common effect of channel interference, offers a suitable measure to evaluate the performance of the prefrontal cortex. Also, the results of partial correlation showed that compared to Hb signal, HbO2 signal is more sensitive to brain activities. This study suggests that fNIRS is a valuable tool for demonstrating the relationship between cortical function in complex cognitive activities.
3. Iwashiro et al. (2016). Association between impaired brain activity and volume at the sub-region of Broca's area in ultra-high risk and first-episode schizophrenia: A multi-modal neuroimaging study

Abstract: Recent studies have suggested that functional abnormalities in Broca’s area, which is important in language production (speech and thoughts before speech), play an important role in the pathophysiology of schizophrenia. While multi-modal approaches have proved useful in revealing the specific pathophysiology of psychosis, the association of functional abnormalities with gray matter volume (GMV) here in subjects with an ultra-high risk (UHR) of schizophrenia, those with first-episode schizophrenia (FES), and healthy controls has yet to be clarified. Therefore, the relationship between cortical activity measured using functional near-infrared spectroscopy (fNIRS) during a verbal fluency task, and GMV in the Broca’s area assessed using a manual tracing in magnetic resonance imaging (MRI), which considers individual structural variation, was examined for 57 subjects (23 UHR/18 FES/16 controls). The UHR and FES group showed significantly reduced brain activity compared to control group in the left pars triangularis (PT) (P = .036, .003, respectively). Furthermore in the FES group, the reduced brain activity significantly positively correlated with the volume in the left PT (B = 0.29, P = .027), while significant negative association was evident for all subjects (B = − 0.18, P = .010). This correlation remained significant after adjusting for antipsychotics dosage, and voxel-wise analysis could not detect any significant correlation between impaired cortical activity and volume. The significant relationship between neural activity and GMV in the left PT may reflect a specific pathophysiology related to the onset of schizophrenia.

4. Vannasing et al. (2016). Distinct hemispheric specializations for native and non-native languages in one-day-old newborns identified by fNIRS

Abstract: This study assessed whether the neonatal brain recruits different neural networks for native and non-native languages at birth. Twenty-seven one-day-old full-term infants underwent functional near-infrared spectroscopy (fNIRS) recording during linguistic and non-linguistic stimulation. Fourteen newborns listened to linguistic stimuli (native and non-native language stories) and 13 newborns were exposed to non-linguistic conditions (native and non-native stimuli played in reverse). Comparisons between left and right hemisphere oxyhemoglobin (HbO2) concentration changes over the temporal areas revealed clear left hemisphere dominance for native language, whereas non-native stimuli were associated with right hemisphere lateralization. In addition, bilateral cerebral activation was found for non-linguistic stimulus processing. Overall, our findings indicate that from the first day after birth, native language and prosodic features are processed in parallel by distinct neural networks.

5. Watanabe et al. (2016). NIRS-Based Language Learning BCI System

Abstract: This paper describes a non-invasive, less restrictive, stable measurement system for a brain-computer interface (BCI) for second-language (L2) learning. The system outputs the arousal of the Yerkes-Dodson law. We employ non-invasive near-infrared spectroscopy (NIRS) as a basic device to measure the blood volume. However, the blood volume measured by NIRS includes base-line drift and is not stable. Here, we introduce a new drift-free variable defined as blood flow, which is the time derivative of the blood volume. Problems to be considered are: 1) Can the blood flow represent brain activity? 2) Where are the fewest brain areas strongly influenced by the language listening? 3) What parameter expresses arousal? We also present a measurement system. To verify the system, we carried out experiments with 40 listeners (10 advanced, 15 intermediate, and 15 novice listeners). When advanced L2 listeners were listening to the first and second languages, the distribution patterns of the root mean squares of the blood flow in the prefrontal regions were close to the correlation coefficient of 0.89, which shows that blood flow can represent brain activity in language processing. The center of BA10 and the right and left BA46 in the prefrontal regions were sufficient to detect language processing. The root mean squares of the differences of the left and right BA46 from BA10 peaked at a certain L2 readability level for all L2
listeners; they can be the parameter that expresses arousal. Thus, the measurement system can function as an input measurement device for BCI.


Abstract: Background: Optimal cerebral oxygenation is considered fundamental to cerebral protection in cardiac arrest (CA) patients. Hypercapnia increases cerebral blood flow and may also improve cerebral oxygenation. It is uncertain, however, whether this effect occurs in mechanically ventilated early survivors of CA.

Methods: We enrolled mechanically ventilated resuscitated patients within 36 h of their cardiac arrest. We performed a prospective double cross-over physiological study comparing the impact of normocapnia (PaCO$_2$ 35–45 mmHg) vs. mild hypercapnia (PaCO$_2$ 45–55 mmHg) on regional cerebral tissue oxygen saturation (SctO$_2$) assessed by near infrared spectroscopy (NIRS).

Results: We studied seven adult CA patients with a median time to return of spontaneous circulation of 28 min at a median of 26 h and 30 min after CA. During normocapnia (median EtCO$_2$ of 32 mmHg [30–41 mmHg] and PaCO$_2$ of 37 mmHg [32–45 mmHg]) the median NIRS-derived left frontal SctO$_2$ was 61% [52–65%] and the right frontal SctO$_2$ was 61% [54–68%]. However, during mild hypercapnia (median EtCO$_2$ of 49 mmHg [40–57 mmHg] and PaCO$_2$ of 52 mmHg [43–55 mmHg]) the median left frontal SctO$_2$ increased to 69% [59–78%] and the right frontal SctO$_2$ increased to 73% [61–76%](p = 0.001, for all comparisons).

Conclusion: During the early post-resuscitation period, in mechanically ventilated CA patients, mild hypercapnia increases cerebral oxygenation as assessed by NIRS. Further investigations of the effect of prolonged mild hypercapnia on cerebral oxygenation and patient outcomes appear justified.

7. Chernomordik et al. (2016). Abnormality of low frequency cerebral hemodynamics oscillations in TBI population

Abstract: Functional Near Infrared Spectroscopy (fNIRS) can non-invasively capture dynamic cognitive activation and underlying physiological processes by measuring changes in oxy- and deoxy-hemoglobin levels, correlated to brain activation. It is a portable, inexpensive and user-friendly device which is easily adapted to the outpatient setting for the assessment of cognitive functions after Traumatic Brain Injury (TBI). Low frequency oscillations in hemodynamic signal, attributed in the literature to cerebral autoregulation, were assessed using recently introduced metrics, Oxygenation Variability (OV Index), obtained from oxy/deoxy-hemoglobin variations in response to mental tasks for a group of healthy control (HC, n=14) and TBI (n=29). Participants responded to an action complexity judgment task (evaluating the complexity of daily life activities by classifying the number of steps as “few” or “many”) with a varying degree of cognitive load to produce brain activation. During the task, we measured blood variations with fNIRS and analyzed OV Index changes. Mean OV indices, corresponding to high complexity tasks, are higher than that of low complexity tasks in the HC group, revealing strong parametric effect (0.039±0.017 for low, 0.057±0.036 for high, p-value=0.069). However, no significant difference has been recorded for the OV indexes for two different loads in the TBI group (0.055±0.033 for low, 0.054±0.035 for high, p=0.9). OV index metrics proves to be sensitive to chronic TBI and can potentially be used to separate subpopulations TBI vs. HC. Noticeable differences in OV index spatial distributions between subpopulations have been observed.

8. Nosrati et al. (2016). Event-related changes of the prefrontal cortex oxygen delivery and metabolism during driving measured by hyperspectral fNIRS

Abstract: Recent technological advancements in optical spectroscopy allow for the construction of hyperspectral (broadband) portable tissue oximeters. In a series of our recent papers we have shown that hyperspectral NIRS (hNIRS) has similar or better capabilities in the absolute tissue oximetry as frequency-domain NIRS, and that
hNIRS is also very efficient in measuring temporal changes in tissue hemoglobin concentration and oxygenation. In this paper, we extend the application of hNIRS to the measurement of event-related hemodynamic and metabolic functional cerebral responses during simulated driving. In order to check if hNIRS can detect event-related changes in the brain, we measured the concentration changes of oxygenated (HbO2) and deoxygenated (HHb) hemoglobin and of the oxidized state of cytochrome c oxidase, on the right and left prefrontal cortices (PFC) simultaneously during simulated driving on sixteen healthy right-handed participants (aged between 22–32). We used our in-house hNIRS system based on a portable spectrometer with cooled CCD detector and a driving simulator with a fully functional steering wheel and foot pedals. Each participant performed different driving tasks and participants were distracted during some driving conditions by asking general knowledge true/false questions. Our findings suggest that more complex driving tasks (non-distracted) deactivate PFC while distractions during driving significantly activate PFC, which is in agreement with previous fMRI results. Also, we found the changes in the redox state of the cytochrome C oxidase to be very consistent with those in the concentrations of HbO2 and HHb. Overall our findings suggest that in addition to the suitability of absolute tissue oximetry, hyperspectral NIRS may also offer advantages in functional brain imaging. In particular, it can be used to measure the metabolic functional brain activity during actual driving.

9. Frie et al. (2016). Extremely Preterm-Born Infants Demonstrate Different Facial Recognition Processes at 6-10 Months of Corrected Age

Abstract: Objectives: To compare cortical hemodynamic responses to known and unknown facial stimuli between infants born extremely preterm and term-born infants, and to correlate the responses of the extremely preterm-born infants to regional cortical volumes at term-equivalent age.

Study design: We compared 27 infants born extremely preterm (<28 gestational weeks) with 26 term-born infants. Corrected age and chronological age at testing were between 6 and 10 months, respectively. Both groups were exposed to a gray background, their mother's face, and an unknown face. Cerebral regional concentrations of oxygenated and deoxygenated hemoglobin were measured with near-infrared spectroscopy. In the preterm group, we also performed structural brain magnetic resonance imaging and correlated regional cortical volumes to hemodynamic responses.

Results: The preterm-born infants demonstrated different cortical face recognition processes than the term-born infants. They had a significantly smaller hemodynamic response in the right frontotemporal areas while watching their mother's face (0.13 μmol/L vs 0.63 μmol/L; P < .001). We also found a negative correlation between the magnitude of the oxygenated hemoglobin increase in the right frontotemporal cortex and regional gray matter volume in the left fusiform gyrus and amygdala (voxels, 25; r = 0.86; P < .005).

Conclusion: At 6-10 months corrected age, the preterm-born infants demonstrated a different pattern in the maturation of their cortical face recognition process compared with term-born infants.

10. Gervain et al. (2016). The neural correlates of processing scale-invariant environmental sounds at birth

Abstract: Sensory systems are thought to have evolved to efficiently represent the full range of sensory stimuli encountered in the natural world. The statistics of natural environmental sounds are characterized by scale-invariance: the property of exhibiting similar patterns at different levels of observation. The statistical structure of scale-invariant sounds remains constant at different spectro-temporal scales. Scale-invariance plays a fundamental role in how efficiently animals and human adults perceive acoustic signals. However, the developmental origins and brain correlates of the neural encoding of scale-invariant environmental sounds remain unexplored. Here, we investigate whether the human brain extracts the statistical property of scale-invariance. Synthetic sounds generated by a mathematical model to respect scale-invariance or violate it were presented to newborns. In alternating blocks, the two sound types were presented together in an alternating fashion, whereas in non-alternating blocks, only one type of sound was presented. Newborns' brain responses were measured using near-infrared spectroscopy. We found that scale-invariant and variable-scale sounds were
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discriminated by the newborn brain, as suggested by differential activation in the left frontal and temporal areas to alternating vs. non-alternating blocks. These results indicate that newborns already detect and encode scale-invariance as a characteristic feature of acoustic stimuli. This suggests that the mathematical principle of efficient coding of information guides the auditory neural code from the beginning of human development, a finding that may help explain how evolution has prepared the brain for perceiving the natural world.

11. Tak et al. (2016). Sensor space group analysis for fNIRS data

Abstract: Background: Functional near-infrared spectroscopy (fNIRS) is a method for monitoring hemoglobin responses using optical probes placed on the scalp. fNIRS spatial resolution is limited by the distance between channels defined as a pair of source and detector, and channel positions are often inconsistent across subjects. These challenges can lead to less accurate estimate of group level effects from channel-specific measurements.

New method: This paper addresses this shortcoming by applying random-effects analysis using summary statistics to interpolated fNIRS topographic images. Specifically, we generate individual contrast images containing the experimental effects of interest in a canonical scalp surface. Random-effects analysis then allows for making inference about the regionally specific effects induced by (potentially) multiple experimental factors in a population.

Results: We illustrate the approach using experimental data acquired during a colour-word matching Stroop task, and show that left frontopolar regions are significantly activated in a population during Stroop effects. This result agrees with previous neuroimaging findings.

Compared with existing methods: The proposed methods (i) address potential misalignment of sensor locations between subjects using spatial interpolation; (ii) produce experimental effects of interest either on a 2D regular grid or on a 3D triangular mesh, both representations of a canonical scalp surface; and (iii) enables one to infer population effects from fNIRS data using a computationally efficient summary statistic approach (random-effects analysis). Significance of regional effects is assessed using random field theory.

Conclusions: In this paper, we have shown how fNIRS data from multiple subjects can be analysed in sensor space using random-effects analysis.


Abstract: Objective. In the last few years, the interest in applying virtual reality systems for neurorehabilitation is increasing. Their compatibility with neuroimaging techniques, such as functional near-infrared spectroscopy (fNIRS), allows for the investigation of brain reorganization with multimodal stimulation and real-time control of the changes occurring in brain activity. The present study was aimed at testing a novel semi-immersive visuo-motor task (VMT), which has the features of being adopted in the field of neurorehabilitation of the upper limb motor function. Approach. A virtual environment was simulated through a three-dimensional hand-sensing device (the LEAP Motion Controller), and the concomitant VMT-related prefrontal cortex (PFC) response was monitored non-invasively by fNIRS. Upon the VMT, performed at three different levels of difficulty, it was hypothesized that the PFC would be activated with an expected greater level of activation in the ventrolateral PFC (VLPFC), given its involvement in the motor action planning and in the allocation of the attentional resources to generate goals from current contexts. Twenty-one subjects were asked to move their right hand/forearm with the purpose of guiding a virtual sphere over a virtual path. A twenty-channel fNIRS system was employed for measuring changes in PFC oxygenated–deoxygenated hemoglobin (O2Hb/HHb, respectively). Main results. A VLPFC O2Hb increase and a concomitant HHb decrease were observed during the VMT performance, without any difference in relation to the task difficulty. Significance. The present study has revealed a particular involvement of the VLPFC in the execution of the novel proposed semi-immersive VMT adoptable in the neurorehabilitation field.
13. Li et al. (2016). An upgraded camera-based imaging system for mapping venous blood oxygenation in human skin tissue

**Abstract:** A camera-based imaging system was previously developed for mapping venous blood oxygenation in human skin. However, several limitations were realized in later applications, which could lead to either significant bias in the estimated oxygen saturation value or poor spatial resolution in the map of the oxygen saturation. To overcome these issues, an upgraded system was developed using improved modeling and image processing algorithms. In the modeling, Monte Carlo (MC) simulation was used to verify the effectiveness of the ratio-to-ratio method for semi-infinite and two-layer skin models, and then the relationship between the venous oxygen saturation and the ratio-to-ratio was determined. The improved image processing algorithms included surface curvature correction and motion compensation. The curvature correction is necessary when the imaged skin surface is uneven. The motion compensation is critical for the imaging system because surface motion is inevitable when the venous volume alteration is induced by cuff inflation. In addition to the modeling and image processing algorithms in the upgraded system, a ring light guide was used to achieve perpendicular and uniform incidence of light. Cross-polarization detection was also adopted to suppress surface specular reflection. The upgraded system was applied to mapping of venous oxygen saturation in the palm, opisthenar and forearm of human subjects. The spatial resolution of the oxygenation map achieved is much better than that of the original system. In addition, the mean values of the venous oxygen saturation for the three locations were verified with a commercial near-infrared spectroscopy system and were consistent with previously published data.


**Abstract:** Tinnitus is the phantom perception of sound in the absence of an acoustic stimulus. To date, the purported neural correlates of tinnitus from animal models have not been adequately characterized with translational technology in the human brain. The aim of the present study was to measure changes in oxyhemoglobin concentration from regions of interest (ROI; auditory cortex) and non-ROI (adjacent nonauditory cortices) during auditory stimulation and silence in participants with subjective tinnitus appreciated equally in both ears and in nontinnitus controls using functional near-infrared spectroscopy (fNIRS). Control and tinnitus participants with normal/near-normal hearing were tested during a passive auditory task. Hemodynamic activity was monitored over ROI and non-ROI under episodic periods of auditory stimulation with 750 or 8000 Hz tones, broadband noise, and silence. During periods of silence, tinnitus participants maintained increased hemodynamic responses in ROI, while a significant deactivation was seen in controls. Interestingly, non-ROI activity was also increased in the tinnitus group as compared to controls during silence. The present results demonstrate that both auditory and select nonauditory cortices have elevated hemodynamic activity in participants with tinnitus in the absence of an external auditory stimulus, a finding that may reflect basic science neural correlates of tinnitus that ultimately contribute to phantom sound perception.

15. Tgavalekos et al. (2016). Blood-pressure-induced oscillations of deoxy- and oxyhemoglobin concentrations are in-phase in the healthy breast and out-of-phase in the healthy brain

**Abstract:** We present a near-infrared spectroscopy (NIRS) study of local hemodynamics in the breast and the brain (prefrontal cortex) of healthy volunteers in a protocol involving periodic perturbations to the systemic arterial blood pressure. These periodic perturbations were achieved by cyclic inflation (to a pressure of 200 mmHg) and deflation (at frequencies of 0.046, 0.056, 0.063, 0.071, and 0.083 Hz) of two pneumatic cuffs wrapped around the subject’s thighs. As a result of these systemic perturbations, the concentrations of deoxy- and oxyhemoglobin in tissue (D and O, respectively) oscillate at the set frequency. We found that the oscillations of D and O in breast tissue are in-phase at all frequencies considered, a result that we attribute to dominant contributions from blood volume oscillations. In contrast, D and O oscillations in brain tissue feature a frequency-dependent phase difference, which we attribute to significant contributions from cerebral blood flow
oscillations. Frequency-resolved measurements of D and O oscillations are exploited by the technique of coherent hemodynamics spectroscopy for the assessment of cerebrovascular parameters and cerebral autoregulation. We show the relevant physiological information content of NIRS measurements of oscillatory hemodynamics, which have qualitatively distinct features in the healthy breast and healthy brain.

16. Jeong et al. (2016). **Nonverbal auditory working memory: Can music indicate the capacity?**

**Abstract:** Different working memory (WM) mechanisms that underlie words, tones, and timbres have been proposed in previous studies. In this regard, the present study developed a WM test with nonverbal sounds and compared it to the conventional verbal WM test. A total of twenty-five, non-music major, right-handed college students were presented with four different types of sounds (words, syllables, pitches, timbres) that varied from two to eight digits in length. Both accuracy and oxygenated hemoglobin (oxyHb) were measured. The results showed significant effects of number of targets on accuracy and sound type on oxyHb. A further analysis showed prefrontal asymmetry with pitch being processed by the right hemisphere (RH) and timbre by the left hemisphere (LH). These findings suggest a potential for employing musical sounds (i.e., pitch and timbre) as a complementary stimuli for conventional nonverbal WM tests, which can additionally examine its asymmetrical roles in the prefrontal regions.

17. Yamamuro et al. (2016). **Reduced Prefrontal Cortex Hemodynamic Response in Adults with Methamphetamine Induced Psychosis: Relevance for Impulsivity**

**Abstract:** Patients with methamphetamine abuse/dependence often exhibit high levels of impulsivity, which may be associated with the structural abnormalities and functional hypactivities observed in the frontal cortex of these subjects. Although near-infrared spectroscopy (NIRS) is a simple and non-invasive method for characterizing the clinical features of various psychiatric illnesses, few studies have used NIRS to directly investigate the association between prefrontal cortical activity and inhibitory control in patients with methamphetamine-induced psychosis (MAP). Using a 24-channel NIRS system, we compared hemodynamic responses during the Stroop color-word task in 14 patients with MAP and 21 healthy controls matched for age, sex and premorbid IQ. In addition, we used the Barrett Impulsivity Scale-11 (BIS-11) to assess impulsivity between subject groups. The MAP group exhibited significantly less activation in the anterior and frontopolar prefrontal cortex accompanied by lower Stroop color-word task performance, compared with controls. Moreover, BIS-11 scores were significantly higher in the MAP group, and were negatively correlated with the hemodynamic responses in prefrontal cortex. Our data suggest that reduced hemodynamic responses in the prefrontal cortex might reflect higher levels of impulsivity in patients with MAP, providing new insights into disrupted inhibitory control observed in MAP.


**Abstract:** Background: Recent evidence of obesity-related changes in the prefrontal cortex during cognitive and seated motor activities has surfaced; however, the impact of obesity on neural activity during ambulation remains unclear. The purpose of this study was to determine obesity-specific neural cost of simple and complex ambulation in older adults.

Methods: Twenty non-obese and obese individuals, 65 years and older, performed three tasks varying in the types of complexity of ambulation (simple walking, walking + cognitive dual-task, and precision walking). Maximum oxygenated hemoglobin, a measure of neural activity, was measured bilaterally using a portable functional near infrared spectroscopy system, and gait speed and performance on the complex tasks were also obtained.
Findings: Complex ambulatory tasks were associated with ~2–3.5 times greater cerebral oxygenation levels and ~30–40% slower gait speeds when compared to the simple walking task. Additionally, obesity was associated with three times greater oxygenation levels, particularly during the precision gait task, despite obese adults demonstrating similar gait speeds and performances on the complex gait tasks as non-obese adults.

Interpretation: Compared to existing studies that focus solely on biomechanical outcomes, the present study is one of the first to examine obesity-related differences in neural activity during ambulation in older adults. In order to maintain gait performance, obesity was associated with higher neural costs, and this was augmented during ambulatory tasks requiring greater precision control. These preliminary findings have clinical implications in identifying individuals who are at greater risk of mobility limitations, particularly when performing complex ambulatory tasks.


Abstract: We tested the COVIS-based prediction that activation in dorsolateral prefrontal cortex (DLPFC) should remain higher during information-integration category learning than unidimensional rule-based category learning. This effect was expected to be stronger when learners use a unidimensional rule with information-integration categories. We replicated conditions from prior neuroimaging studies (Cincotta & Seger, 2007; Filoteo, et al, 2005) but measured BOLD response in DLPFC using functional near-infrared spectroscopy (fNIRS). The categorization task was made up of two conditions, rule based and information integration, that presented 2D line stimuli with immediate feedback following response. The rule based task requires that participants utilize only 1 dimension while the information integration necessitates both dimensions be utilized to obtain maximum accuracy. Most participants performed above chance in the learning tasks, and we found that oxy-hemoglobin levels were indeed often higher across blocks in the information-integration condition. Decision-bound modeling analyses indicated that in many cases – during information-integration category learning – participants responded according to a unidimensional rule rather than a more appropriate rule combining information from the two stimulus dimensions, supporting our hypothesis.

This research has practical implications in the areas of training and education in both a professional and academic setting. Understanding whether an individual is employing optimal decision strategies is crucial towards maximizing learning and overall performance. Future research will look at the effects of aging on these neural responses associated with implicit and explicit learning.

20. Hoshi et al. (2016). Hemodynamic signals in fNIRS

Abstract: Near-infrared spectroscopy (NIRS) was originally designed for clinical monitoring of tissue oxygenation, and it has also been developed into a useful tool in neuroimaging studies, with the so-called functional NIRS (fNIRS). With NIRS, cerebral activation is detected by measuring the cerebral hemoglobin (Hb), where however, the precise correlation between NIRS signal and neural activity remains to be fully understood. This can in part be attributed to the situation that NIRS signals are inherently subject to contamination by signals arising from extracerebral tissue. In recent years, several approaches have been investigated to distinguish between NIRS signals originating in cerebral tissue and signals originating in extracerebral tissue. Selective measurements of cerebral Hb will enable a further evolution of fNIRS. This chapter is divided into six sections: first a summary of the basic theory of NIRS, NIRS signals arising in the activated areas, correlations between NIRS signals and fMRI signals, correlations between NIRS signals and neural activities, and the influence of a variety of extracerebral tissue on NIRS signals and approaches to this issue are reviewed. Finally, future prospects of fNIRS are described.

**Abstract:** This study proposes a methodology to objectively differentiate surgical skill for physical and virtual trainers by measuring functional activation between expert and novice surgeons. Results indicate that there is a significant increase in functional activation for novices in the right lateral prefrontal cortex, and decrease in the left medial primary motor cortex, and the supplementary motor area for the physical trainer (p<0.05). Results also indicate that there is a significant lower functional activation for novices compared to experts in the left medial primary motor cortex for the virtual skills trainer (p<0.05).

22. Vasta et al. (2016). **The movement time analyser task investigated with functional near infrared spectroscopy: an ecologic approach for measuring hemodynamic response in the motor system**

**Abstract:** Aims: Movement time analyzer (MTA) is an objective instrument to evaluate the degree of motor impairment as well as to investigate the dopaminergic drug effect in Parkinson’s disease patients. The aim of this study is to validate a new ecologic neuroimaging tool for quantifying MTA-related hemodynamic response of the cortical motor system by means of functional near-infrared spectroscopy (fNIRS).

Materials: 11 right-handed healthy volunteers (six male and five female, age range 27–64 years) were studied with fNIRS and functional magnetic resonance imaging (fMRI) while performing MTA task for each hand.

Results: MTA performance was better for the dominant hand and younger participants. Both fNIRS and fMRI analyses revealed MTA-related increase of haemoglobin levels in the primary motor and premotor cortices contralateral to the moving hand. This response progressively increased with aging.

Conclusion: These findings supported the translation of fNIRS-based MTA behavioural tool in clinical practice.

23. Sugai et al. (2016). **Quantitative and qualitative discrimination of task periods from non-task periods by recurrence plots**

**Abstract:** Recurrence plots are useful tools for visualizing the inner structure of a time series, and they have been applied to physiological data to examine brain activity. However, these studies have focused on qualitative analysis of the data. In this study, we used unthresholded recurrence plots of near-infrared spectroscopy (NIRS) data to detect the difference in brain activity between task periods and non-task periods. Histograms derived from the recurrence plots showed a statistical difference between the periods. Throughout the pre-task period, task period, and post-task period, the histogram kept its shape statistically and shifted horizontally according to the period. Therefore, the changes in dynamical systems describing brain activity were observed as changes in histograms derived from NIRS data.

24. Storm et al. (2016). **Good neurological outcome despite very low regional cerebral oxygen saturation during resuscitation—a prospective preclinical trial in 29 patients**

**Abstract:** Background: Noninvasive regional cerebral oxygen saturation (rSO2) measurement using near-infrared spectroscopy (NIRS) might inform on extent and duration of cerebral hypoxia during cardiopulmonary resuscitation (CPR). This information may be used to guide resuscitation efforts and may carry relevant early prognostic information.

Methods: We prospectively investigated non-traumatic out-of-hospital cardiac arrest (OHCA) patients on scene. NIRS was started either during CPR or shortly after (<2 min) return of spontaneous circulation (ROSC) by emergency medical service (EMS). Outcome was determined at intensive care unit (ICU) discharge and 6 months after cardiac arrest.

Results: A total of 29 OHCA patients were included. In 23 patients NIRS was started during CPR and in 6 patients immediately after ROSC. 18 (62.1 %) patients did not reach ROSC. Initial rSO2 during CPR was very
low (<50 % in all 23 patients, < 30 % in 19 of 23 patients) with no significant difference between patients achieving ROSC and those who did not. Of five patients with ROSC, in whom NIRS was recorded during CPR, two reached a good six-months outcome (initial rSO2 22 %) and three died during the ICU stay (initial rSO2 15, 16 and 46 %). In six patients with NIRS started immediately after ROSC (<2 min), rSO2 was substantially higher (54–85 %) than in patients during CPR (p = 0.006).

Discussion and conclusion: Initial frontal brain rSO2 determined by NIRS during CPR was generally very low and recovered rapidly after ROSC. Very low initial rSO2 during CPR was compatible with good neurological outcome in our limited cohort of patients. Further studies are needed to assess in larger cohorts and more detail the implications of very low initial rSO2 during CPR on scene.


Abstract: – not available –


Abstract: Near-infrared spectroscopy (NIRS) has been used to measure reactive hyperemia following a vascular occlusion. However, the procedures and methods of analysis used have varied. The purpose of the present study is to identify reproducible methods for measuring reactive hyperemia using HbO2 NIRS signals in the calf and foot. Healthy participants (10 male, 10 female) aged 19 to 28 years performed one of two tests: reproducibility trials or elevation protocol (30 and 60 cm limb elevation above the heart). The time to 50% reperfusion (T1/2) and the second (R2q) quartile rates of reperfusion were found to be the most reproducible parameters (coefficient of variation=7.12 to 14.1%). The time to 95% reperfusion (T95) was 12.7% more reproducible on average than the previously reported parameter of time to peak hyperemia. Measures of reperfusion time and rate slowed with increasing limb elevation. Correlations were identified between the calf and foot in the measurements of R2q (R2=0.713, p=0.021), T1/2 (R2=0.673, p=0.033), and T95 (R2=0.792, p=0.006). Half and 95% recovery times and second and third quartile rates expressed good reproducibility and sensitivity to change with reduced perfusion pressure. NIRS measures of reactive hyperemia have the potential to evaluate microvascular perfusion in clinical populations.


Abstract: In traditional brain–computer interface (BCI) studies, binary communication systems have generally been implemented using two mental tasks arbitrarily assigned to “yes” or “no” intentions (e.g., mental arithmetic calculation for “yes”). A recent pilot study performed with one paralyzed patient showed the possibility of a more intuitive paradigm for binary BCI communications, in which the patient’s internal yes/no intentions were directly decoded from functional near-infrared spectroscopy (fNIRS). We investigated whether such an “fNIRS-based direct intention decoding” paradigm can be reliably used for practical BCI communications. Eight healthy subjects participated in this study, and each participant was administered 70 disjunctive questions. Brain hemodynamic responses were recorded using a multichannel fNIRS device, while the participants were internally expressing “yes” or “no” intentions to each question. Different feature types, feature numbers, and time window sizes were tested to investigate optimal conditions for classifying the internal binary intentions. About 75% of the answers were correctly classified when the individual best feature set was employed (75.89% ±1.39 and 74.08% ±2.87 for oxygenated and deoxygenated hemoglobin responses, respectively), which was significantly higher than a random chance level (68.57% for p<0.001). The kurtosis feature showed the highest mean classification accuracy among all feature types. The grand-averaged hemodynamic responses showed that
wide brain regions are associated with the processing of binary implicit intentions. Our experimental results demonstrated that direct decoding of internal binary intention has the potential to be used for implementing more intuitive and user-friendly communication systems for patients with motor disabilities.

28. Dix et al. (2016). *Cerebral oxygenation and echocardiographic parameters in preterm neonates with a patent ductus arteriosus: an observational study*  

Abstract: Background: A haemodynamically significant patent ductus arteriosus (hsPDA) is clinically suspected and confirmed by echocardiographic examination. A hsPDA decreases cerebral blood flow and oxygen saturation by the ductal steal phenomenon.  
Aim: To determine the relationship between echocardiographic parameters, cerebral oxygenation and a hsPDA in preterm infants.  
Methods: 380 preterm infants (<32 weeks gestational age) born between 2008 and 2010 were included. Blinded echocardiographic examination was performed on the second, fourth and sixth day after birth. Examinations were deblinded when hsPDA was clinically suspected. Regional cerebral oxygen saturation (rScO2) was continuously monitored by near-infrared spectroscopy during 72 h after birth, and afterwards for at least 1 h before echocardiography. Echocardiographic parameters included ductal diameter, end-diastolic flow in the left pulmonary artery, left atrium/aorta ratio and ductal flow pattern.  
Results: rScO2 was significantly related only to ductal diameter over time. Mixed modelling analysed the course of rScO2 over time, where infants were divided into four groups: a closed duct, an open haemodynamically insignificant duct (non-sPDA), a hsPDA, which was successfully closed during study period (SC hsPDA) or a hsPDA, which was unsuccessfully closed during study period (UC hsPDA). SC hsPDA infants showed the highest rScO2 on day 6, while UC hsPDA infants had the lowest rScO2 values.  
Conclusions: Ductal diameter is the only echocardiographic parameter significantly related to cerebral oxygenation over time. Cerebral oxygenation takes a different course over time depending on the status of the duct. Low cerebral oxygenation may be suggestive of a hsPDA.


Abstract: Research of interpersonal neural synchronization (INS) using functional near-infrared spectroscopy (fNIRS) hyperscanning is an expanding nascent field. This field still requires the accumulation of findings and establishment of analytic standards. In this study, we therefore intend to extend fNIRS-based INS research in three directions: (1) verifying the enhancement of frontopolar INS by natural and unstructured verbal communication involving more than two individuals; (2) examining timescale dependence of the INS modulation; and (3) evaluating the effects of artifact reduction methods in capturing INS. We conducted an fNIRS hyperscanning study while 12 groups of four subjects were engaged in cooperative verbal communication. Corresponding to the three objectives, our analyses of the data (1) confirmed communication-enhanced frontopolar INS, as expected from the region's roles in social communication; (2) revealed the timescale dependency in the INS modulation, suggesting the merit of evaluating INS in fine timescale bins; and (3) determined that removal of the skin blood flow component engenders substantial improvement in sensitivity to communication-enhanced INS and segregation from artifactual synchronization, and that caution for artifact reduction preprocessing is needed to avoid excessive removal of the neural fluctuation component. Accordingly, this study provides a prospective technical basis for future hyperscanning studies during daily communicative activities.
Abstract: Background: Endogenous triggers such as voluntary breath-holding induce various cardiovascular responses typically including modification of blood CO2. During dynamic exercise these responses may have a negative impact on performance or may associate with cardiovascular risk subjects. Therefore, we hypothesized that voluntary breathing tests induce changes in cardiovascular (CV) oxygenation that lead to cardiovascular-functional changes, measured by a complex of integrated cardiovascular parameters and their interactions. So the aim of the study was to determine the impact of the voluntary breath-holding on changes and interplay of cardiac and peripheral parameters.

Method: 18 girls (average age: 23.4 ± 1.3 years) performed 2 voluntary breath-holdings to failure, with a 5 min rest. Cardiac functional parameters were recorded using the electrocardiogram (ECG) analysis system “Kaunas load”. The blood flow in the calf was determined by venous occlusion plethysmography. Near-infrared spectroscopy (NIRS) was used for non-invasive monitoring of oxygen saturation in tissues (StO2).

Results: Throughout the first breath-holding, heart rate (HR) increased from 89.5 ± 3.9 bpm to 107.6 ± 4.2 bpm (P<0.05). The ECG JT interval decreased at the onset of breath-holdings, the intervals ratio (JT/RR) increased (P<0.05), and the ST-segment depression was not altered significantly. Arterial blood flow (ABF) was reduced from 3.5 ± 0.47 mL/100 mL/min to 1.64 ± 0.38 mL/100 mL/min (P<0.05) at the end of the first breath-holding. The StO2 of the calf muscles decreased during both breath-holdings. Within 60 s of recovery time, StO2 exceeded baseline 9.5% (P<0.05).

Conclusion: Breath-holding impact changes in the systemic (central) circulation and caused significant peripheral changes, i.e., decrease in arterial blood flow and oxygen saturation. The most essential alteration occurred between the HR and arterial blood pressure (ABP) parameters. The strongest interaction observed between HR and ABP, and in calf muscles - between ABF and StO2.

Abstract: Single bout of exercise can improve the performance on cognitive tasks. However, cognitive responses may be controversial due to different type, intensity, and duration of exercise. In addition, the mechanism of the effect of acute exercise on brain is still unclear. This study was aimed to investigate the effects of supramaximal exercise on cognitive tasks by means of brain oxygenation monitoring. The brain oxygenation of Prefrontal cortex (PFC) was measured on 35 healthy male volunteers via functional near infrared spectroscopy (fNIRS) system. Subjects performed 2-Back test before and after the supramaximal exercise wingate anerobic test (WAnT) lasting 30-s on cycle ergometer. The PFC oxygenation change evaluation revealed that PFC oxygenation rise during post-exercise 2-Back task was considerably higher than those in pre-exercise 2-Back task. In order to describe the relationship between oxygenation change and exercise performance, subjects were divided into two groups as high performers (HP) and low performers (LP) according to their peak power values (PP) obtained from the supramaximal test. The oxy-hemoglobin (oxy-Hb) values were compared between pre- and post-exercise conditions within subjects and also between subjects according to peak power. When performers were compared, in the HP group, the oxy-Hb values in post-exercise 2-Back test were significantly higher than those in pre-exercise 2-Back test. HP had significantly higher post-exercise oxy-Hb change (Δ) than those of LP. In addition, PP of the total group were significantly correlated with Δoxy-Hb. The key findings of the present study revealed that acute supramaximal exercise has an impact on the brain oxygenation during a cognitive task. Also, the higher the anerobic PP describes the larger the oxy-Hb response in post-exercise cognitive task. The current study also demonstrated a significant correlation between peak power (exercise load) and post-exercise hemodynamic responses (oxy-, deoxy- and total-Hb). The magnitude of this impact might be related with the physical performance capacities of the individuals. This can become a valuable parameter for future studies on human factor.
32. Uchida et al. (2016). Craniofacial tissue oxygen saturation is associated with blood pH using an examiner's finger-mounted tissue oximetry in mice

**Abstract:** Although fetal scalp blood sampling is an examination to assess fetal acidosis during the intrapartum period, it has not been widely used by obstetricians because of its invasiveness. We have developed a small, portable oximetry with a sensor attached to the examiner’s finger. Our previous report using this oximetry concluded that fetal head tissue oxygen saturation (StO2) correlated with umbilical cord artery blood pH. We investigated whether the association between StO2 and blood pH in mice could be validated using this oximetry. Eleven the Institute for Cancer Research (ICR) mice were measured using a near-infrared spectroscopy probe at the craniofacial site in a closed polyethylene bag while changing the oxygen concentration. A total of nine blood samples were collected and analyzed for pH. The StO2 and tissue blood pH showed a strong positive correlation (r=0.90 and P=0.0009). The StO2 and total hemoglobin index also showed a positive correlation (r=0.84 and P=0.0049). Thus, the results of the present study support those of our previous report on clinical cases and allow examiners to easily check the status of fetal acidosis. Fetal management using this oximetry might gain popularity with obstetricians in the near future.

33. McKay et al. (2016). Connectivity in Language Areas of the Brain in Cochlear Implant Users as Revealed by fNIRS

**Abstract:** Many studies, using a variety of imaging techniques, have shown that deafness induces functional plasticity in the brain of adults with late-onset deafness, and in children changes the way the auditory brain develops. Cross modal plasticity refers to evidence that stimuli of one modality (e.g. vision) activate neural regions devoted to a different modality (e.g. hearing) that are not normally activated by those stimuli. Other studies have shown that multimodal brain networks (such as those involved in language comprehension, and the default mode network) are altered by deafness, as evidenced by changes in patterns of activation or connectivity within the networks. In this paper, we summarise what is already known about brain plasticity due to deafness and propose that functional near-infra-red spectroscopy (fNIRS) is an imaging method that has potential to provide prognostic and diagnostic information for cochlear implant users. Currently, patient history factors account for only 10% of the variation in post-implantation speech understanding, and very few post-implantation behavioural measures of hearing ability correlate with speech understanding. As a non-invasive, inexpensive and user-friendly imaging method, fNIRS provides an opportunity to study both pre- and post-implantation brain function. Here, we explain the principle of fNIRS measurements and illustrate its use in studying brain network connectivity and function with example data.

34. Emberson et al. (2016). Isolating the effects of surface vasculature in infant neuroimaging using short-distance optical channels: a combination of local and global effects

**Abstract:** Functional near-infrared spectroscopy (fNIRS) records hemodynamic changes in the cortex arising from neurovascular coupling. However, (noninvasive) fNIRS recordings also record surface vascular signals arising from noncortical sources (e.g., in the skull, skin, dura, and other tissues located between the sensors and the brain). A current and important focus in the fNIRS community is determining how to remove these noncortical vascular signals to reduce noise and to prevent researchers from erroneously attributing responses to cortical sources. The current study is the first to test a popular method for removing signals from the surface vasculature (removing short, 1 cm, channel recordings from long, 3 cm, channel recordings) in human infants, a population frequently studied using fNIRS. We find evidence that this method does remove surface vasculature signals and indicates the presence of both local and global surface vasculature signals. However, we do not find that the removal of this information changes the statistical inferences drawn from the data. This latter result not only questions the importance of removing surface vasculature responses for empiricists employing this method, but also calls for future research using other tasks (e.g., ones with a weaker initial result) with this population and possibly additional methods for removing signals arising from the surface vasculature in infants.
35. Cavuoto et al. (2016). **Obesity and the Role of Short Duration Submaximal Work on Cardiovascular and Cerebral Hemodynamics**

**Abstract:** The objective of this study was to compare gas exchange, cardiac and cerebral hemodynamic responses between 10 non-obese and 10 obese men during submaximal work. With the increasing prevalence of obesity, there is a need to understand the impact of obesity on work-induced responses. Participants completed a step-wise incremental cycling until they reached 60% of their age-predicted maximum heart rate. Gas exchange, cardiac and pre-frontal cortex hemodynamic responses were simultaneously measured during rest, work, and recovery. The non-obese group reached ~43% of their predicted maximal aerobic capacity as compared to ~34% in the obese group, with the non-obese working at a relatively higher workload and for more duration than the obese. The obese had elevated baseline heart rate and reduced whole-body oxygen uptake per body weight at baseline and task termination. Other cardiac and cerebral responses, although increased from baseline, were similar between groups during submaximal effort. In the obese, during recovery oxygen uptake and heart-rate recovery were slowest; cardiac output and rate pressure product were greatest, and left ventricle ejection time was shortest. However, both groups exhibited similar cerebral hemodynamics during recovery. These finding imply that, irrespective of their low aerobic fitness, obesity does not impair myocardial performance and cerebrovascular function during graded submaximal work, however, recovery from a short duration of work was influenced by their fitness level. Since a majority of activities of daily living are performed at individual’s submaximal level, understanding influence of obesity on submaximal work is critical.

36. Nishiyori et al. (2016). **Developmental changes in motor cortex activity as infants develop functional motor skills**

**Abstract:** Despite extensive research examining overt behavioral changes of motor skills in infants, the neural basis underlying the emergence of functional motor control has yet to be determined. We used functional near-infrared spectroscopy (fNIRS) to record hemodynamic activity of the primary motor cortex (M1) from 22 infants (11 six month-olds, 11 twelve month-olds) as they reached for an object, and stepped while supported over a treadmill. Based on the developmental systems framework, we hypothesized that as infants increased goal-directed experience, neural activity shifts from a diffused to focal pattern. Results showed that for reaching, younger infants showed diffuse areas of M1 activity that became focused by 12 months. For elicited stepping, younger infants produced much less M1 activity which shifted to diffuse activity by 12 months. Thus, the data suggest that as infants gain goal-directed experience, M1 activity emerges, initially showing a diffuse area of activity, becoming refined as the behavior stabilizes. **Our data begin to document the cortical activity underlying early functional skill acquisition.**

37. Watanabe et al. (2016). **Informal Face-to-Face Interaction Improves Mood State Reflected in Prefrontal Cortex Activity**

**Abstract:** Recent progress with wearable sensors has enabled researchers to capture face-to-face interactions quantitatively and given great insight into human dynamics. One attractive field for applying such sensors is the workplace, where the relationship between the face-to-face behaviors of employees and the productivity of the organization has been investigated. One interesting result of previous studies showed that informal face-to-face interaction among employees, captured by wearable sensors that the employees wore, significantly affects their performance. However, the mechanism behind this relationship has not yet been adequately explained, though experiences at the job scene might qualitatively support the finding. We hypothesized that informal face-to-face interaction improves mood state, which in turn affects the task performance. To test this hypothesis, we evaluated the change of mood state before and after break time for two groups of participants, one that spent their breaks alone and one that spent them with other participants, by administering questionnaires and taking brain activity measurements. Recent neuroimaging studies have suggested a significant relationship between mood state and brain activity. Here, we show that face-to-face interaction during breaks significantly improved
mood state, which was measured by Profiles of Mood States (POMS). We also observed that the verbal working memory (WM) task performance of participants who did not have face-to-face interaction during breaks decreased significantly. In this paper, we discuss how the change of mood state was evidenced in the prefrontal cortex (PFC) activity accompanied by WM tasks measured by near-infrared spectroscopy (NIRS).

38. Contini et al. (2016). **Time Domain Near Infrared Spectroscopy System for oxygen saturation assessment in stroke patients**

**Abstract:** In this work we present a medical device for non-invasive oxygen saturation assessment in stroke patients. The system based on time-resolved near infrared spectroscopy was fully characterized and tested on healthy volunteers.

39. Ferradal et al. (2016). **Optimizing Unanesthetized Cerebral Oxygen Consumption Measures: Comparison of NIRS and MRI Approaches in Neonates with Congenital Heart Disease**

**Abstract:** Cerebral perfusion in neonates with congenital heart disease is a clinical concern. Combined measures of MRI and NIRS can provide complementary information to improve monitoring. We compare multimodal measures of cerebral hemodynamics in this group.

40. Wang et al. (2016). **Improved Oxygen Metabolism in Human Tissues in vivo by Low-Level Laser Therapy**

**Abstract:** We assessed the effects of low-level laser therapy (LLLT) on human tissues in vivo with broadband near-infrared spectroscopy (NIRS). LLLT increased concentrations of oxygenated hemoglobin and cytochrome c oxidase as compared with placebo.

41. Clancy et al. (2016). **Monitoring the Injured Brain - High density near infrared probes and registered atlas models improve cerebral saturation recovery**

**Abstract:** High density near infrared probes and registered subject specific head models are used to show the potential improvements to the quantitative accuracy of recovered parameters relevant to monitoring an injured brain.

42. Zhu et al. (2016). **Brain connectivity in joint attention skills and an intensified CCD camera based NIRS and imaging system**

**Abstract:** The brain connectivity in joint attention skills using NIRS and imaging was studied, indicating differences in the neuronal pathways. To further improve the spatial resolution, an intensified CCD based NIRS and imaging system was developed.

43. Zhu et al. (2016). **Assessing Optimal Electrode/Optode Arrangement in EEG-fNIRS Multi-Modal Imaging**

**Abstract:** The accuracy of signals recorded from different electrode/optode arrangements in EEG-fNIRS experiments are examined. Results are particularly important for studies investigating spatiotemporal relation between neuronal activity and vascular response.
44. Tempest et al. (2016). A comparison of head motion and prefrontal haemodynamics during upright and recumbent cycling exercise

Abstract: The aim of this observational study was to compare head motion and prefrontal haemodynamics during exercise using three commercial cycling ergometers. Participants (n = 12) completed an incremental exercise test to exhaustion during upright, recumbent and semi-recumbent cycling. Head motion (using accelerometry), physiological data (oxygen uptake, end-tidal carbon dioxide [PETCO2] and heart rate) and changes in prefrontal haemodynamics (oxygenation, deoxygenation and blood volume using near infrared spectroscopy [NIRS]) were recorded. Despite no difference in oxygen uptake and heart rate, head motion was higher and PETCO2 was lower during upright cycling at maximal exercise (P<0·05). Analyses of covariance (covariates: head motion P>0·05; PETCO2, P<0·01) revealed that prefrontal oxygenation was higher during semi-recumbent than recumbent cycling and deoxygenation and blood volume were higher during upright than recumbent and semi-recumbent cycling (respectively; P<0·05). This work highlights the robustness of the utility of NIRS to head motion and describes the potential postural effects upon the prefrontal haemodynamic response during upright and recumbent cycling exercise.

45. Li et al. (2016). Assessment of resting-state brain networks in young and older adults by automatic voxel classification with atlas-guided diffuse optical tomography

Abstract: We implemented an automatic voxel classification algorithm so that atlas-guided DOT and graph theory analysis can be jointly used to assess hemodynamic resting-state brain networks in young and older adults.


Abstract: Using fNIRS in the prefrontal cortex, multivariate machine learning approach has been used to analyze hemodynamic responses from a group of 31 healthy and 30 TBI subjects performing complexity task, High accurate classification has been obtained.

47. Yucel et al. (2016). Towards a Clinical Measure of Pain: Hemodynamic Brain Responses to Pain measured by Near-Infrared Spectroscopy

Abstract: An objective, repeatable measure of pain is highly needed for individuals who are not able to communicate. Here we show that functional Near-Infrared Spectroscopy has a potential utility as an objective measure of pain.


Abstract: Deception is not a rare occurrence among human behaviors; however, the present brain mapping techniques are insufficient to reveal the neural mechanism of deception under spontaneous or controlled conditions. Interestingly, functional near-infrared spectroscopy (fNIRS) has emerged as a highly promising neuroimaging technique that enables continuous and noninvasive monitoring of changes in blood oxygenation and blood volume in the human brain. In this study, fNIRS was used in combination with complex network theory to extract the attribute features of the functional brain networks underlying deception in subjects exhibiting spontaneous or controlled behaviors. Our findings revealed that the small-world networks of the subjects engaged in spontaneous behaviors exhibited greater clustering coefficients, shorter average path
lengths, greater average node degrees, and stronger randomness compared with those of subjects engaged in control behaviors. Consequently, we suggest that small-world network topology is capable of distinguishing well between spontaneous and controlled deceptions.


Abstract: We utilized fNIRS to explore the hemodynamic changes in the prefrontal cortex and our imaging results suggested that there were notable differences for the hemodynamic responses between patients with gambling addiction and healthy subjects.

50. Zeng et al. (2016). On the Relationship Between Trial-to-Trial Response Time Variability and fNIRS-Based Functional Connectivity

Abstract: We study the relationship between response time (RT) variability and functional connectivity (FC) estimated by wavelet transform coherence, when performing a visual oddball task. A statistically significant correlation is observed between RT and FC.

51. Zhu et al. (2016). Temporal Dynamics of fNIRS-Recorded Signals Revealed Via Visibility Graph

Abstract: Temporal dynamics of fNIRS signals recorded at resting-state and during task are examined using visibility graph (VG). Results show the power of scale-freeness of the VG can be used to differentiate the brain states.

52. Tanaka et al. (2016). Comparison of Effectiveness of Motivative Exercise with Passive Exercise by fNIRS

Abstract: One physical therapist (PT) gives exercise at rehabilitation. We call the exercise “passive exercise”. Since most of stroke patients become hemiplegia patients, they can perform the exercise operating devices by the healthy side. We call this system “motivative exercise”. In this report, the difference of effectiveness between passive exercise and motivative exercise are shown by brain function measurement. Activating sites in brain are measured by fNIRS through both exercises.

53. Yennu et al. (2016). Testing Robustness of Prefrontal Hemodynamic Responses during Noxious Thermal Stimulation over Three Different Body Sites using fNIRS

Abstract: Hemodynamic activities in the prefrontal cortex are investigated during noxious thermal stimulation over the right Forearm, right TMJ, and left Forearm. Robustness of prefrontal hemodynamic responses during noxious thermal stimulation is reported.

54. Di Costanzo Mata et al. (2016). fNIRS Software Development for Basic and Simple Research

Abstract: A Matlab based fNIRS visualization and processing GUI developed in order to increase the researcher's ability to analyze the patient studies. Developed tools: multiple window visualization, regressions, motion artifact detection and database engine.
55. Spinnelli et al. (2016). *Optical Property Reconstruction of a Two-Layer Diffusive Medium from Single-Distance Time-Resolved Measurements*

**Abstract:** We robustly and accurately estimated the absorption coefficient of the second layer in a two-layer tissue phantom by applying an optimal estimation method, including a priori information, to single-distance time-resolved measurements.

56. Bush et al. (2016). *Cerebral Autoregulation During Pediatric Extracorporeal Membrane Oxygenation Therapy*

**Abstract:** Extracorporeal membrane oxygenation therapy mechanically circulates and oxygenates blood. We assess cerebral blood flow during perturbation of ECMO flow using diffuse optical and correlation spectroscopies. We observe both regulated and passive flow.

57. Greisen et al. (2016). *Cerebral oximetry in preterm infants: an agenda for research with a clear clinical goal*

**Abstract:** Preterm birth constitutes a major cause of death before 5 years of age and it is a major cause of neurodevelopmental impairment across the world. Preterm infants are most unstable during the transition between fetal and newborn life during the first days of life and most brain damage occurs in this period. The brain of the preterm infant is accessible for tissue oximetry by near-infrared spectroscopy. Cerebral oximetry has the potential to improve the long-term outcome by helping to tailor the support of respiration and circulation to the individual infant's needs, but the evidence is still lacking. The goals for research include testing the benefit and harms of cerebral oximetry in large-scale randomized trials, improved definition of the hypoxic threshold, better understanding the effects of intensive care on cerebral oxygenation, as well as improved precision of oximeters and calibration among devices or standardization of values in the hypoxic range. These goals can be pursued in parallel.

58. Nosrati et al. (2016). *Monitoring cerebral oxygenation and metabolism during cardiac arrest and CPR using hyperspectral near infrared spectroscopy (hNIRS)*

**Abstract:** The hNIRS can monitor both intravascular and intracellular oxygen supply and demand. We used a novel hyperspectral signal-processing algorithm to extract concentrations of hemoglobin and cytochrome-c-oxidase during cardiac arrest and CPR in 14 pigs.

59. Zhang et al. (2016). *Wearable wireless cerebral oximeter*

**Abstract:** Cerebral oximeters measure continuous cerebral oxygen saturation using near-infrared spectroscopy (NIRS) technology noninvasively. It has been involved into operating room setting to monitor oxygenation within patient's brain when surgeons are concerned that a patient's levels might drop. Recently, cerebral oxygen saturation has also been related with chronic cerebral vascular insufficiency (CCVI). Patients with CCVI would be benefited if there would be a wearable system to measure their cerebral oxygen saturation in need. However, there has yet to be a wearable wireless cerebral oximeter to measure the saturation in 24 hours. So we proposed to develop the wearable wireless cerebral oximeter. The mechanism of the system follows the NIRS technology. Emitted light at wavelengths of 740nm and 860nm are sent from the light source penetrating the skull and cerebrum, and the light detector(s) receives the light not absorbed during the light pathway through the skull and cerebrum. The amount of oxygen absorbed within the brain is the difference between the amount of light sent out and received by the probe, which can be used to calculate the percentage of oxygen saturation. In the
system, it has one source and four detectors. The source, located in the middle of forehead, can emit two near infrared light, 740nm and 860nm. Two detectors are arranged in one side in 2 centimeters and 3 centimeters from the source. Their measurements are used to calculate the saturation in the cerebral cortex. The system has included the rechargeable lithium battery and Bluetooth smart wireless micro-computer unit.

60. Auger et al. (2016). Contribution of Extra-cerebral and Cerebral Hemodynamic Signals During Exercise Quantified with Time-domain Near Infrared Spectroscopy

Abstract: Time-domain near infrared spectroscopy was used to quantify hemodynamic signals during physical exercise and rest. Changes in extra-cerebral hemodynamics relative to rest are significant and their quantification may prevent data interpretation bias.


Abstract: Near-infrared spectroscopy (NIRS) is a technique by which the interaction between light in the near-infrared spectrum and matter can be quantitatively measured to provide information about the particular chromophore. Study into the clinical application of NIRS for traumatic brain injury (TBI) began in the 1990s with early reports of the ability to detect intracranial hematomas using NIRS. We highlight the advances in clinical applications of NIRS over the past two decades as they relate to TBI. We discuss recent studies evaluating NIRS techniques for intracranial hematoma detection, followed by the clinical application of NIRS in intracranial pressure and brain oxygenation measurement, and conclude with a summary of potential future uses of NIRS in TBI patient management.


Abstract: Near-infrared spectroscopy (NIRS) and electroencephalography (EEG) have recently provided fundamental new information about how the newborn brain processes innocuous and noxious somatosensory information. However, results derived independently from these two techniques are not entirely consistent, raising questions about the relationship between haemodynamic and electrophysiological responses in the study of touch and pain processing in the newborn. To address this, we have recorded NIRS and EEG responses simultaneously for the first time in the human infant following noxious (time-locked clinically required heel lances) and innocuous tactile cutaneous stimulation in 30 newborn infants. The results show that both techniques can be used to record quantifiable and distinct innocuous and noxious evoked activity at a group level in the newborn cortex. Noxious stimulation elicits a peak haemodynamic response that is 10 fold larger than that elicited by an innocuous stimulus (HbO2: 2.0 vs. 0.3 µM) and a distinct nociceptive-specific N3P3 waveform in electrophysiological recordings. However, a novel single-trial analysis revealed that haemodynamic and electrophysiological responses do not always co-occur at an individual level, although when they do (64% of noxious test occasions), they are significantly correlated in magnitude. These data show that while haemodynamic and electrophysiological touch and pain brain activity in newborn infants is comparable in group analyses, important individual differences remain. These data indicate that integrated and multimodal brain monitoring is required to understand central touch and pain processing in the newborn.
63. Paik et al. (2016). **A portable, multi-channel fNIRS system for prefrontal cortex: Preliminary study on neurofeedback and imagery task**

**Abstract:** fNIRS is a neuroimaging technique which uses near-infrared light source in the 700-1000 nm range and enables to detect hemodynamic changes (i.e., oxygenated hemoglobin, deoxygenated hemoglobin, blood volume) as a response to various brain processes. In this study, we developed a new, portable, prefrontal fNIRS system which has 12 light sources, 15 detectors and 108 channels with a sampling rate of 2 Hz. The wavelengths of light source are 780nm and 850nm. ATxmega128A1, 8bit of Micro controller unit (MCU) with 200~4095 resolution along with MatLab data acquisition algorithm was utilized. We performed a simple left and right finger movement imagery tasks which produced statistically significant changes of oxyhemoglobin concentrations in the dorsolateral prefrontal cortex (dIPFC) areas. We observed that the accuracy of the imagery tasks can be improved by carrying out neurofeedback training, during which a real-time feedback signal is provided to a participating subject. The effects of the neurofeedback training was later visually verified using the 3D NIRfast imaging. Our portable fNIRS system may be useful in non-constraint environment for various clinical diagnoses.

64. Nguyen et al. (2016). **Applying support vector machine on hybrid fNIRS/EEG signal to classify driver's conditions**

**Abstract:** Driver's condition plays a critical role in driving safety. The fact that about 20 percent of automobile accidents occurred due to driver fatigue leads to a demand for developing a method to monitor driver's status. In this study, we acquired brain signals such as oxy- and deoxyhemoglobin and neuronal electrical activity by a hybrid fNIRS/EEG system. Experiments were conducted with 11 subjects under two conditions: Normal condition, when subjects had enough sleep, and sleep deprivation condition, when subject did not sleep previous night. During experiment, subject performed a driving task with a car simulation system for 30 minutes. After experiment, oxy-hemoglobin and deoxy-hemoglobin changes were derived from fNIRS data, while beta and alpha band relative power were calculated from EEG data. Decrement of oxy-hemoglobin, beta band power, and increment of alpha band power were found in sleep deprivation condition compare to normal condition. These features were then applied to classify two conditions by Fisher's linear discriminant analysis (FLDA). The ratio of alpha-beta relative power showed classification accuracy with a range between 62% and 99% depending on a subject. However, utilization of both EEG and fNIRS features increased accuracy in the range between 68% and 100%. The highest increase of accuracy is from 63% using EEG to 99% using both EEG and fNIRS features. In conclusion, the enhancement of classification accuracy is shown by adding a feature from fNIRS to the feature from EEG using FLDA which provides the need of developing a hybrid fNIRS/EEG system.

65. Krishnamurthy et al. (2016). **Optical measurements of low-frequency hemodynamic oscillations in human breast tissue**

**Abstract:** Induced hemodynamic perturbations in two healthy subjects featured in-phase oscillations of oxy- and deoxy-hemoglobin concentrations in breast tissue. We present an optical instrument to investigate bilateral hemodynamics in breast cancer patients.

66. Richter et al. (2016). **The Effect of Maternal Antihypertensive Drugs on the Cerebral, Renal and Splanchnic Tissue Oxygen Extraction of Preterm Neonates**

**Abstract:** Background: Drugs with antihypertensive action are frequently used in obstetrics for the treatment of pre eclampsia (labetalol) and tocolysis (nifedipine) or for neuro protection (MgSO4), and may affect the hemodynamics of preterm born neonates. Objective: The aim of this study was to assess whether maternal antihypertensive drugs affect multisite oxygenation levels of the neonate. Methods: Eighty preterm neonates of
≤32 weeks of gestational age were monitored using near-infrared spectroscopy. Mean cerebral, renal and splanchnic fractional tissue oxygen extractions (cFTOE, rFTOE and sFTOE) were calculated for the first 5 postnatal days. We determined the effect of various maternal antihypertensive drugs on cFTOE and rFTOE using multilevel analysis, and on sFTOE using Kruskal-Wallis and Mann-Whitney U tests. Results: Eleven infants were exposed to labetalol ± MgSO4, 7 to nifedipine ± MgSO4, 20 to MgSO4 only, and 42 to no maternal antihypertensive drugs. The infants exposed to labetalol ± MgSO4 had a lower cFTOE on days 1 (0.14, p = 0.031), 2 (0.13, p = 0.035) and 4 (0.18, p = 0.046) than nonexposed infants on the corresponding days (0.22, 0.20 and 0.24, respectively). On day 2, cFTOE was also lower in infants exposed to nifedipine ± MgSO4 (0.11, p = 0.028) and to MgSO4 only (0.15, p = 0.047). sFTOE was higher in infants exposed to labetalol ± MgSO4 on days 1 (µ = 0.71) and 2 (µ = 0.82) than in nonexposed infants (µ = 0.26, p = 0.04 and µ = 0.55, p = 0.007, respectively). Maternal antihypertensive drugs did not affect rFTOE. Conclusions: Low neonatal cFTOE found with maternal antihypertensive drug exposure may relate to either increased cerebral perfusion or neurologic depression induced by the medication, or preferential brain perfusion associated with preeclampsia placental insufficiency. Concomitantly high sFTOE found with labetalol exposure supports the latter, while renal autoregulation may explain rFTOE stability.

67. Ishii et al. (2016). Central command generated prior to arbitrary motor execution induces muscle vasodilatation at the beginning of dynamic exercise

Abstract: The purpose of this study was to examine the role of central command, generated prior to arbitrary motor execution, in cardiovascular and muscle blood flow regulation during exercise. Thirty two subjects performed 30-s of two-legged cycling or 1-min of one-legged cycling (66 ± 4% and 35% of the maximal exercise intensity, respectively), which was started arbitrarily or abruptly by a verbal cue (arbitrary vs. cued start). We measured the cardiovascular variables during both exercises and the relative changes in oxygenated-hemoglobin concentration (Oxy-Hb) of non-contracting vastus lateralis muscles as index of tissue blood flow, and femoral blood flow to non-exercising leg during one-legged cycling. Two-legged cycling with arbitrary start caused a decrease in total peripheral resistance (TPR), which was smaller during the exercise with cued start. The greater reduction of TPR with arbitrary start was also recognized at the beginning of one-legged cycling. Oxy-Hb of non-contracting muscle increased by 3.6 ± 1% (P<0.05) during one-legged cycling with arbitrary start, whereas such increase in Oxy-Hb was absent with cued start. The increases in femoral blood flow and vascular conductance of non-exercising leg were evident (P<0.05) at 10 s from the onset of one-legged cycling with arbitrary start, whereas those were smaller or absent with cued start. It is likely that when voluntary exercise is started arbitrarily, central command is generated prior to motor execution and then contributes to muscle vasodilatation at the beginning of exercise. Such centrally-induced muscle vasodilatation may be weakened and/or masked in the case of exercise with cued start.


Abstract: Analysis of MRI parameters together with NIRS values (n=28 subjects) shows that the combinations of Ktrans with either HbT or TOI have high diagnostic accuracy, increasing AUC values to 93-94% and specificity up to 100%.

69. Farina et al. (2016). Statistics of the Light Penetration Depth in a Diffusive Medium

Abstract: We propose a comprehensive statistical approach for the calculation of the light penetration depth in diffusive media, both in continuous-wave and time-domain regimes. Analytical results are validated with Monte-Carlo simulations.
70. Rejmstad et al. (2016). A method for monitoring of oxygen saturation changes in brain tissue using diffuse reflectance spectroscopy

Abstract: Continuous measurement of local brain oxygen saturation (SO2) can be used to monitor the status of brain trauma patients in the neurocritical care unit. Currently, micro-oxygen-electrodes are considered as the “gold standard” in measuring cerebral oxygen pressure (pO2), which is closely related to SO2 through the oxygen dissociation curve (ODC) of hemoglobin, but with the drawback of slow in response time. The present study suggests estimation of SO2 in brain tissue using diffuse reflectance spectroscopy (DRS) for finding an analytical relation between measured spectra and the SO2 for different blood concentrations. The P3 diffusion approximation is used to generate a set of spectra simulating brain tissue for various levels of blood concentrations in order to estimate SO2. The algorithm is evaluated on optical phantoms mimicking white brain matter (blood volume of 0.5–2%) where pO2 and temperature is controlled and on clinical data collected during brain surgery. The suggested method is capable of estimating the blood fraction and oxygen saturation changes from the spectroscopic signal and the hemoglobin absorption profile.

71. Mahmoudzadeh et al. (2016). Intraventricular hemorrhage consequences on cerebral neurovascular coupling in premature infants, A multimodal neuroimaging EEG-fNIRS approach

Abstract: Multimodal coregistration (fNIRS-EEG) offer unique opportunities for studying cerebral responses of preemies. Intraventricular Hemorrhage, it revealed weaker hemodynamic response which can provide early diagnosis of neurovascular coupling impairment.


Abstract: Diffuse Optical Spectroscopic Imaging (DOSI) measures functional information which could serve as a new biomarker for chemotherapy response in sarcoma. Here we evaluate the feasibility of using DOSI at common sarcoma anatomic locations.


Abstract: Severe social withdrawal, called hikikomori, has drawn increased public attention. However, an optimal clinical approach and strategy of treatment has not been well established. Here, we report a case of hikikomori for which an exercise intervention using jogging therapy was effective, showing cerebral hemodynamic improvement. The patient was a 20 year old Japanese male who was hospitalized in order to evaluate and treat severe social withdrawal. Although depressive and anxiety symptoms partially subsided with sertraline alone, social withdrawal persisted due to a lack of self confidence. With his consent, we implemented exercise therapy with 30 minutes of jogging three times a week for three months. We did not change the pharmacotherapy, and his social withdrawal remarkably improved with continuous jogging exercise. Using near infrared spectroscopy to evaluate hemodynamic alteration, bilateral temporal hemodynamics considerably increased after the three-month jogging therapy. Regarding exercise therapy for mental illness, numerous studies have reported the effectiveness of exercise therapy for major depression. This case implied, however, that the applicability of exercise therapy is not limited to major depressive disorder. Jogging therapy may contribute to reinforcing self confidence associated with “resilience” in conjunction with neurophysiological modulation of neural networks.
74. Costalat et al. (2016). **The oxygen-conserving potential of the diving response: A kinetic-based analysis**

**Abstract:** We investigated the oxygen-conserving potential of the human diving response by comparing trained breath-hold divers (BHDs) to non-divers (NDs) during simulated dynamic breath-holding (BH). Changes in haemodynamics [heart rate (HR), stroke volume (SV), cardiac output (CO)] and peripheral muscle oxygenation [oxymyglobin ([HbO2]), deoxymyglobin ([HHb]), total myoglobin ([tHb]), tissue saturation index (TSI)] and peripheral oxygen saturation (SpO2) were continuously recorded during simulated dynamic BH. BHDs showed a breaking point in HR kinetics at mid-BH immediately preceding a more pronounced drop in HR (−0.86 bpm.%−1) while HR kinetics in NDs steadily decreased throughout BH (−0.47 bpm.%−1). By contrast, SV remained unchanged during BH in both groups (all P > 0.05). Near-infrared spectroscopy (NIRS) results (mean ± SD) expressed as percentage changes from the initial values showed a lower [HHb] increase for BHDs than for NDs at the cessation of BH (+24.0 ± 10.1 vs. +39.2 ± 9.6%, respectively; P < 0.05). As a result, BHDs showed a [tHb] drop that NDs did not at the end of BH (−7.3 ± 3.2 vs. −3.0 ± 4.7%, respectively; P < 0.05). The most striking finding of the present study was that BHDs presented an increase in oxygen-conserving efficiency due to substantial shifts in both cardiac and peripheral haemodynamics during simulated BH. In addition, the kinetic-based approach we used provides further credence to the concept of an “oxygen-conserving breaking point” in the human diving response.

75. Bailey et al. (2016). **Review of splanchnic oximetry in clinical medicine**

**Abstract:** Global tissue perfusion and oxygenation are important indicators of physiologic function in humans. The monitoring of splanchnic oximetry through the use of near-infrared spectroscopy (NIRS) is an emerging method used to assess tissue oxygenation status. Splanchnic tissue oxygenation (SrSO2) is thought to be potentially of high value in critically ill patients because gastrointestinal organs can often be the first to suffer ischemic injury. During conditions of hypovolemia, cardiac dysfunction, or decreased oxygen-carrying capacity, blood flow is diverted toward vital organs, such as the brain and the heart at the expense of the splanchnic circulation. While monitoring SrSO2 has great potential benefit, there are limitations to the technology and techniques. SrSO2 has been found to have a relatively high degree of variability that can potentially make it difficult to interpret. In addition, because splanchnic organs only lie near the skin surface in children and infants, and energy from currently available sensors only penetrates a few centimeters deep, it can be difficult to use clinically in a noninvasive manner in adults. Research thus far is showing that splanchnic oximetry holds great promise in the ability to monitor patient oxygenation status and detect disease states in humans, especially in pediatric populations.

76. Lin et al. (2016). **Walking while Performing Working Memory Tasks Changes the Prefrontal Cortex Hemodynamic Activations and Gait Kinematics**

**Abstract:** Background: Increasing evidence suggests that walking while performing a concurrent task negatively influences gait performance. However, it remains unclear how higher-level cognitive processes and coordination of limb movements are altered in challenging walking environments. This study investigated the influence of cognitive task complexity and walking road condition on the neutral correlates of executive function and postural control in dual-task walking.

Methods: Twenty-four healthy young adults completed a series of overground walks with three walking road conditions (wide, narrow, with obstacles) with and without the concurrent n-back working memory tasks of two complexity levels (1-back and 3-back). Prefrontal brain activation was assessed by functional near-infrared spectroscopy. A three-dimensional motion analysis system was used simultaneously to measure gait performance and lower-extremity kinematics. Repeated measures analysis of variance were performed to examine the differences between the conditions.
Results: In comparison with standing still, participants showed lower n-back task accuracy while walking, with the worst performance from the road with obstacles. Spatiotemporal gait parameters, lower-extremity joint movements, and the relative changes in oxygenated hemoglobin (HbO) concentration levels were all significantly different across the task complexity and walking path conditions. While dual-tasking participants were found to flex their hips and knees less, leading to a slower gait speed, longer stride time, shorter step length, and greater gait variability than during normal walking. For narrow-road walking, smaller ankle dorsiflexion and larger hip flexion were observed, along with a reduced gait speed. Obstacle negotiation was mainly characterized by increased gait variability than other conditions. HbO levels appeared to be lower during dual-task walking than normal walking. Compared to wide and obstacle conditions, walking on the narrow road was found to elicit a smaller decrement in HbO levels.

Conclusion: The current study provided direct evidence that, in young adults, neural correlates of executive function and dynamic postural control tend to be altered in response to the cognitive load imposed by the walking environment and the concurrent task during ambulation. A shift of brain activation patterns between functionally connected networks may occur when facing challenging cognitive–motor interaction.

77. Liu et al. (2016). Optimizing Monte Carlo simulation for detecting the internal information in a fat–muscle media

Abstract: To verify the optimized Monte Carlo simulation for obtaining the best source-detector separation to acquire the inner information in turbid media, the spatially diffusive spectral system, which took fat–muscle tissue as example, was build. According to the typical banana-shape visiting probability profile, increasing the restricted conditions was applied to simulate a spatial filter, which was used to weaken the influence of the overlying layer and reject multiply scattered photons. First, study the relationship between the effective signal ($I_S(z_2,r_i)$), the non-effective signal ($I_N(z_1,r_i) + I_N(z_2,r_i)$), the effective signal ratio (SNR) and the source-detector separations (SDS) when fat thickness varied from 0.1 to 0.55 cm. Secondly, study the relationship between $h_f$ and $SDS_{best}$. Simulation results showed the optimized MC simulation, which can gain more information than original MC simulation, can be used for detecting the internal information in multilayered tissue, and SNR can be improved, and $h_f$ is used as the independent variable to develop a linear regression model to predict $SDS_{best}$. ($R^2 = 0.9808$). The method is expected to provide more evidence for quick disease check-up in vivo and is instructive for select the best source-detector separation.

78. Ahn et al. (2016). Exploring Neuro-Physiological Correlates of Drivers' Mental Fatigue Caused by Sleep Deprivation Using Simultaneous EEG, ECG, and fNIRS Data

Abstract: Investigations of the neuro-physiological correlates of mental loads, or states, have attracted significant attention recently, as it is particularly important to evaluate mental fatigue in drivers operating a motor vehicle. In this research, we collected multimodal EEG/ECG/EOG and fNIRS data simultaneously to develop algorithms to explore neuro-physiological correlates of drivers' mental states. Each subject performed simulated driving under two different conditions (well-rested and sleep-deprived) on different days. During the experiment, we used 68 electrodes for EEG/ECG/EOG and 8 channels for fNIRS recordings. We extracted the prominent features of each modality to distinguish between the well-rested and sleep-deprived conditions, and all multimodal features, except EOG, were combined to quantify mental fatigue during driving. Finally, a novel driving condition level (DCL) was proposed that distinguished clearly between the features of well-rested and sleep-deprived conditions. This proposed DCL measure may be applicable to real-time monitoring of the mental states of vehicle drivers. Further, the combination of methods based on each classifier yielded substantial improvements in the classification accuracy between these two conditions.
79. Alderliesten et al. (2016). Brain oxygen saturation assessment in neonates using T2-prepared blood imaging of oxygen saturation and near-infrared spectroscopy

Abstract: Although near-infrared spectroscopy is increasingly being used to monitor cerebral oxygenation in neonates, it has a limited penetration depth. The T2-prepared Blood Imaging of Oxygen Saturation (T2-BIOS) magnetic resonance sequence provides an oxygen saturation estimate on a voxel-by-voxel basis, without needing a respiratory calibration experiment. In 15 neonates, oxygen saturation measured by T2-prepared blood imaging of oxygen saturation and near-infrared spectroscopy were compared. In addition, these measures were compared to cerebral blood flow and venous oxygen saturation in the sagittal sinus. A strong linear relation was found between the oxygen saturation measured by magnetic resonance imaging and the oxygen saturation measured by near-infrared spectroscopy (R² = 0.64, p < 0.001). Strong linear correlations were found between near-infrared spectroscopy oxygen saturation, and magnetic resonance imaging measures of frontal cerebral blood flow, whole brain cerebral blood flow and venous oxygen saturation in the sagittal sinus (R² = 0.71, 0.50, 0.65; p < 0.01). The oxygen saturation obtained by T2-prepared blood imaging of oxygen saturation correlated with venous oxygen saturation in the sagittal sinus (R² = 0.49, p = 0.023), but no significant correlations could be demonstrated with frontal and whole brain cerebral blood flow. These results suggest that measuring oxygen saturation by T2-prepared blood imaging of oxygen saturation is feasible, even in neonates. Strong correlations between the various methods work as a cross validation for near-infrared spectroscopy and T2-prepared blood imaging of oxygen saturation, confirming the validity of using these techniques for determining cerebral oxygenation.


Abstract: We introduce the application of functional data analysis (fDA) on functional near-infrared spectroscopy (fNIRS) signals for the development of an accurate and clinically practical assessment method of pain perception. We used the cold pressor test to induce different levels of pain in healthy subjects while the fNIRS signal was recorded from the frontal regions of the brain. We applied fDA on the collected fNIRS data to convert discrete samples into continuous curves. This method enabled us to represent the curves as a linear combination of basis functions. We utilized bases coefficients as features that represent the shape of the signals (as opposed to extracting defined features from signal) and used them to train a support vector machine to classify the signals based on the level of induced pain. We achieved 94% of accuracy to classify low-pain and high-pain signals. Moreover applying hierarchical clustering on the coefficients, we found three clusters in the data which represented low-pain (one cluster) and high-pain groups (two clusters) with an accuracy of 91.2%. The center of these clusters can represent the prototype fNIRS response of that pain level.

81. Chalia et al. (2016). Hemodynamic response to burst-suppressed and discontinuous electroencephalography activity in infants with hypoxic ischemic encephalopathy

Abstract: Burst suppression (BS) is an electroencephalographic state associated with a profound inactivation of the brain. BS and pathological discontinuous electroencephalography (EEG) are often observed in term-age infants with neurological injury and can be indicative of a poor outcome and lifelong disability. Little is known about the neurophysiological mechanisms of BS or how the condition relates to the functional state of the neonatal brain. We used simultaneous EEG and diffuse optical tomography (DOT) to investigate whether bursts of EEG activity in infants with hypoxic ischemic encephalopathy are associated with an observable cerebral hemodynamic response. We were able to identify significant changes in concentration of both oxy and deoxyhemoglobin that are temporally correlated with EEG bursts and present a relatively consistent morphology across six infants. Furthermore, DOT reveals patient-specific spatial distributions of this hemodynamic response that may be indicative of a complex pattern of cortical activation underlying discontinuous EEG activity that is not readily apparent in scalp EEG.
82. Koo et al. (2016). **Motor imagery detection with wavelet analysis for NIRS-based BCI**

**Abstract:** Near infrared spectroscopy (NIRS) is a non-invasive functional brain imaging device, which measures hemodynamic responses induced by brain activities. In this paper we collect NIRS signals associated with motor imagery and rest states, and analyze these signals with wavelet analysis. To our best knowledge, wavelet analysis method has not been used for hemodynamic response of motor imagery, although it is one of widely-used time-sequential signal analysis methods. In order to explore the usefulness of wavelet analysis, we extract features using various wavelet bases and then evaluate which features are more useful by cross-validation. Our empirical results clearly indicate that wavelet analysis is useful for obtaining meaningful features of the hemodynamic response, by achieving the averaged classification accuracy of about 86%. Among various wavelet bases used in our experiments, discrete Meyer wavelet function achieved the highest performance with classification accuracy of 93%.


**Abstract:** Highly mobile computing devices promise to improve quality of life, productivity, and performance. Increased situation awareness and reduced mental workload are two potential means by which this can be accomplished. However, it is difficult to measure these concepts in the “wild”. We employed ultra-portable battery operated and wireless functional near infrared spectroscopy (fNIRS) to non-invasively measure hemodynamic changes in the brain’s Prefrontal cortex (PFC). Measurements were taken during navigation of a college campus with either a hand-held display, or an Augmented reality wearable display (ARWD). Hemodynamic measures were also paired with secondary tasks of visual perception and auditory working memory to provide behavioral assessment of situation awareness and mental workload. Navigating with an augmented reality wearable display produced the least workload during the auditory working memory task, and a trend for improved situation awareness in our measures of prefrontal hemodynamics. The hemodynamics associated with errors were also different between the two devices. Errors with an augmented reality wearable display were associated with increased prefrontal activity and the opposite was observed for the hand-held display. This suggests that the cognitive mechanisms underlying errors between the two devices differ. These findings show fNIRS is a valuable tool for assessing new technology in ecologically valid settings and that ARWDs offer benefits with regards to mental workload while navigating, and potentially superior situation awareness with improved display design.

84. Ho et al. (2016). **Optical Topography in Psychiatry: A Chip Off the Old Block or a New Look Beyond the Mind–Brain Frontiers?**

**Abstract:** – no abstract –

85. Ru et al. (2016). **Effects of aging on working memory performance and prefrontal cortex activity: A time-resolved spectroscopy study**

**Abstract:** This study aimed to employ time-resolved spectroscopy (TRS) to explore age-related differences in prefrontal cortex (PFC) activity while subjects performed a working memory task. Methods: We employed TRS to measure PFC activity in ten healthy younger and ten healthy older subjects while they performed a working memory (WM) task. All subjects performed the Sternberg test (ST) in which the memory-set size varied between one and six digits. Using TRS, we recorded changes in cerebral blood oxygenation as a measure of changes in PFC activity during the task. In order to identify left/right asymmetry of PFC activity during the working memory task, we calculated the laterality score, i.e., $\Delta \text{oxy-Hb}$ (right $\Delta \text{oxy-Hb}$—left $\Delta \text{oxy-Hb}$); positive values
indicate greater activity in the right PFC, while negative values indicate greater activity in the left PFC. Results: During the ST, statistical analyses showed no significant differences between the younger and older groups in accuracy for low memory-load and high memory-load. In high memory-load tasks, however, older subjects were slower than younger subjects (P < 0.05). We found that the younger group showed right lateral responses with a stronger right than left activation in the frontal pole, whereas the older group showed bilateral responses (P < 0.05). Conclusions: The present results are consistent with the hemispheric asymmetry reduction in older adults (HAROLD) model; working memory tasks cause asymmetrical PFC activation in younger adults, while older adults tend to show reduced hemispheric lateralization.

86. Ruocco et al. (2016). *Predicting Treatment Outcomes from Prefrontal Cortex Activation for Self-Harming Patients with Borderline Personality Disorder: A Preliminary Study* 

**Abstract:** Self-harm is a potentially lethal symptom of borderline personality disorder (BPD) that often improves with dialectical behavior therapy (DBT). While DBT is effective for reducing self-harm in many patients with BPD, a small but significant number of patients either does not improve in treatment or ends treatment prematurely. Accordingly, it is crucial to identify factors that may prospectively predict which patients are most likely to benefit from and remain in treatment. In the present preliminary study, 29 actively self-harming patients with BPD completed brain-imaging procedures probing activation of the prefrontal cortex (PFC) during impulse control prior to beginning DBT and after 7 months of treatment. Patients that reduced their frequency of self-harm the most overall treatment displayed lower levels of neural activation in the bilateral dorsolateral prefrontal cortex (DLPFC) prior to beginning treatment, and they showed the greatest increases in activity within this region after 7 months of treatment. Prior to starting DBT, treatment non-completers demonstrated greater activation than treatment-completers in the medial PFC and right inferior frontal gyrus. Reductions in self-harm over the treatment period were associated with increases in activity in right DLPFC even after accounting for improvements in depression, mania, and BPD symptom severity. These findings suggest that pre-treatment patterns of activation in the PFC underlying impulse control may be prospectively associated with improvements in self-harm and treatment attrition for patients with BPD treated with DBT.

87. Lloyd-Fox et al. (2016). *Establishing a Biomarker of Cortical Specialisation in infants in The Gambia and UK* 

**Abstract:** Brain and nervous system development in human infants during the first 1000 days - which includes pregnancy and the first two years of life - is critical, and risk of compromised development during this time can have a deep impact on physical growth and cognitive function into adulthood. Recent research has shown that under nutrition in infancy is linked to lifelong effects on adult health, however we still have a comparatively poor understanding of how nutrition effects brain development during early life. The development of non-invasive brain imaging techniques, such as functional near infrared Spectroscopy (fNIRS), has allowed a recent shift in the use of neuroimaging towards the study of the developing brain in situations where this development may be at risk or compromised in some way. Furthermore, objective measures of brain function may provide information that to date has been unavailable with existing behavioural paradigms. Recent fNIRS research in typically developing infants has shown robust and consistent activation to social vs non-social visual and auditory stimuli in the inferior frontal, anterior temporal and posterior superior temporal – temporo parietal junction (pST-TPJ) regions of the cortex. Having established this signature response in infants from 4 to 6 months of age, here we apply this paradigm to the investigation of social responses in infants from the first days of life to the first year in two different settings: urban European and rural Gambian. This is a cross sectional study of infants in the Gambia and UK at 0–2, 4–8 and 12–16 months of age (0–2 months - N = 14 UK & N = 19 Gambia; 4 – 8 mths - N = 64 UK & N = 24 Gambia; 12 – 16 months – N = 15 UK & N = 22 Gambia). Results reveal robust and consistent socially selective responses from 4 – 16 mths of life to both the visual and auditory stimuli. In contrast at 0–2 mths of age a stronger response is evidenced to the non-social auditory
stimuli in the Gambian infants. In ongoing analyses we are investigating whether these brain responses also differ in the 0–2 month olds in the UK. These findings provide a key biomarker of cortical specialization over the first year of life. We believe this method could be applied to the study of compromised development in global health research where infants are exposed to a broad range of adversity early in life including poverty, malnourishment and recurrent infections.

88. Lloyd-Fox et al. (2016). **fNIRS in Africa & Asia: an Objective Measure of Cognitive Development for Global Health Settings**

Abstract: The goal of our work is to establish assessments to evaluate the impact of early risk on cognitive development in infancy and childhood in global health settings. Prior work using functional near-infrared spectroscopy (fNIRS) has shown differential brain responses in infants to social vs. nonsocial stimuli in urban European (Lloyd-Fox et al., 2009; 2013) cohorts. This experimental paradigm has been proposed as an objective measure of social cognition that can be used in many different cohorts with minimal adaptation. Cortical mapping of the brain during infancy is rarely undertaken in low-income countries due to the lack of transportable neuroimaging methods. Functional near infrared spectroscopy (fNIRS) - which uses the absorption of near infrared light to non-invasively measure changes in oxygen in the blood - is an elegant method for assessing cognitive function in such settings. Participants, ranging in age from 4 – 8 months (UK: N = 64; The Gambia: N = 24; Bangladesh: N = 23), were tested with a multi-channel NIRS system that recorded brain activity over the frontal and temporal cortices. The experimental stimuli presented were videos of people moving their eyes or hands (i.e. a “Peek-a-boo” game), accompanied by vocal sounds (i.e. yawn, laughter), non-vocal sounds (i.e. water running, bell), or silence. Social videos were alternated with control blocks of pictures of local modes of transportation presented with no sounds.

Here we present a comparison of data collected in urban European, rural African and urban Asian cohorts. Participants in The Gambia lived in a rural community of subsistence farmers and participants in Bangladesh lived in an urban slum. Both cohorts were exposed to a broad range of adversity early in life including poverty, under-nourishment, recurrent infections, and lack of maternal education. Our results indicate specialised social > non-social activation in the superior and middle temporal cortex across all three cohorts and across 4 – 36 months of life. These results confirm the suitability of fNIRS in this age group in a resource poor setting. Changes in cortical haemoglobin may afford early biomarkers that are more sensitive to nutritional insults and early adversity affecting cognition than current standardised behavioural measures.

89. Bale et al. (2016). **From Jöbsis to the present day: a review of clinical near-infrared spectroscopy measurements of cerebral cytochrome-c-oxidase**

Abstract: Near-infrared spectroscopy (NIRS) measurements of cytochrome-c-oxidase (CCO) have the potential to yield crucial information about cerebral metabolism at the patient bedside. Developments in instrumentation and the analytical methods used to resolve changes in CCO have led to many clinical applications of the measurement since its first demonstration in 1977 by Jöbsis. There is a substantial literature of work on measures of CCO in animal and in vitro studies; however, this review focuses on translational studies. Almost 40 years from the advent of the first measurement of CCO using NIRS, this signal continues to hold significant interest in our understanding of the human brain in health and disease. We discuss methodologies for obtaining NIRS measurements of CCO in the clinic and review studies in neonates and adults.
90. Huang et al. (2016). Systemic haemodynamics and regional tissue oxygen saturation after bidirectional cavopulmonary shunt: positive pressure ventilation versus spontaneous breathing

Abstract: OBJECTIVES Spontaneous breathing has been shown to improve global haemodynamics in patients with bidirectional cavopulmonary shunt. What has not been evaluated, however, is the effect of spontaneous breathing on the distribution of cardiac output after bidirectional cavopulmonary shunt. We investigated the effects of extubation on systemic haemodynamics and regional tissue oxygen saturation, and determined whether redistribution of cardiac output is present after extubation in these patients.

METHODS In 24 patients undergoing bidirectional cavopulmonary shunt, standard haemodynamic variables including heart rate, arterial blood pressure and central venous pressure were monitored continuously. Near-infrared spectroscopy of the brain and mesenteric circulation was monitored and recorded every hour. Cardiac index, derived from ascending aorta flow, was measured by ultrasound at three time points: 30 min before, 30 min after and 12 h after extubation.

RESULTS The central venous pressure decreased significantly from 19.50 ± 3.65 mmHg before extubation to 16.17 ± 3.41 mmHg 30 min after extubation (P = 0.006) and 13.96 ± 2.49 mmHg 12 h after extubation (P = 0.001). Cardiac index increased significantly from 3.32 ± 0.43 l/min/m² before extubation to 3.73 ± 0.51 l/min/m² 30 min after extubation (P = 0.012) and 3.98 ± 0.54 l/min/m² 12 h after extubation (P = 0.001). Cerebral oxygen saturation increased from 50.83 ± 5.84% before extubation to 56.79 ± 8.64% 30 min after extubation (P = 0.023), then remained unchanged for the following 12 h. Mesenteric oxygen saturation remained unchanged during the early period of extubation, but increased significantly 12 h after extubation (P = 0.002).

CONCLUSIONS The lower values of cerebral oxygen saturation before extubation indicated that the cerebral blood flow was less satisfactory. During the early period of extubation, despite the increase in cardiac index, the mesenteric oxygen saturation is lower than that at 12 h after extubation, suggesting that the obligatory increase in respiratory muscle perfusion and the increase in cerebral oxygen saturation have utilized most of the flow from the increased cardiac index. The increase in mesenteric oxygen saturation 12 h after extubation suggests a gradual improvement in microcirculation and macrocirculation.

91. Riberholt et al. (2016). Impaired Cerebral Autoregulation during Head Up Tilt in Patients with Severe Brain Injury

Abstract: Early mobilization is of importance for improving long-term outcome for patients after severe acquired brain injury. A limiting factor for early mobilization by head-up tilt is orthostatic intolerance. The purpose of the present study was to examine cerebral autoregulation in patients with severe acquired brain injury and a low level of consciousness. Fourteen patients with severe acquired brain injury and orthostatic intolerance and fifteen healthy volunteers were enrolled. Blood pressure was evaluated by pulse contour analysis, heart rate and RR-intervals were determined by electrocardiography, middle cerebral artery velocity was evaluated by transcranial Doppler, and near-infrared spectroscopy determined frontal lobe oxygenation in the supine position and during head-up tilt. Cerebral autoregulation was evaluated as the mean flow index calculated as the ratio between middle cerebral artery mean velocity and estimated cerebral perfusion pressure. Patients with acquired brain injury presented an increased in mean flow index during head-up tilt indicating impaired autoregulation (P < 0.001). Spectral analysis of heart rate variability in the frequency domain revealed lower magnitudes of ~0.1 Hz spectral power in patients compared to healthy controls suggesting baroreflex dysfunction. In conclusion, patients with severe acquired brain injury and orthostatic intolerance during head-up tilt have impaired cerebral autoregulation more than one month after brain injury.
92. Kim (2016). **fNIR Study of Cognitive Decline and Reading in Parkinson’s Disease: Preliminary Data**

**Abstract:** As yet, there has been little research applying functional near-infrared spectroscopy (fNIR) neuroimaging studies to aspects of brain activation such as cognitive decline or working memory deficits with reading difficulties in Parkinson’s disease (PD). The purpose of this study is to investigate cerebral hemoglobin concentration changes related to reading and cognitive load tasks in an individual with PD. An individual with PD and a healthy normal person of the same age with no history of neurogenic disorders participated in this study. Functional near-infrared spectroscopy (fNIR) measurements were recorded while the participants carried out a reading task (grandfather passage) and four cognitive load tasks. The fNIR results for the reading task revealed significant differences in the changes in the oxygen concentration levels experienced by the two participants and this was also manifested in both the left and right hemispheres. There were also significant differences between the two participants across all of the cognitive tasks. Unlike the non-PD participant, the PD participant did not exhibit any significant differences among the four cognitive tasks and no significant oxygenation change between the left and right hemispheres when performing cognitive tasks 1 and 4 was observed. These results suggest that PD patients either lack sufficient brain activation to complete linguistic or cognitive tasks or are unable to use oxygenation effectively in a specific brain area when seeking to accomplish these types of tasks.


**Abstract:** In brain function measurements by near-infrared spectroscopy, improving the measurement accuracy and expanding the measurement region are important for analyzing brain functional connectivity. Furthermore, for improvement of measurement accuracy, it is necessary to detect a signal for correcting disturbances or changes in skin blood flow. We have proposed a multi-channel signal processing method for realization of disturbance cancelation. To implement the cancelation method in an equilateral triangular probe placement, it is necessary to irradiate from each vertex sequentially and detect the light at the other vertices and at the center of the triangle. Thus, we adopt a combination of the multiple pulse method and the digital encoding method. Computer simulations show that treating the digital code in a pseudo-analog manner is effective for reducing the external noise and preventing mistakes in the demodulation bits. The demodulation process is confirmed using a phantom experiment and is then applied to the cancelation method. Using the cancelation method, the influence of a near-surface absorber is reduced from 64% to 27%. Thus, the multi-channel signal processing that we developed for the cancelation method improves measurement accuracy without increasing the system size.

94. Schat et al. (2016). **Near-Infrared Spectroscopy to Predict the Course of Necrotizing Enterocolitis**

**Abstract:** Objectives: To investigate whether cerebral, liver, and infraumbilical regional tissue oxygen saturation (rSO2) and fractional tissue oxygen extraction (FTOE) could be used to diagnose necrotizing enterocolitis (NEC) and complicated NEC (Bell’s stage 3B or death) during its early stages. Methods: A prospective observational cohort study of preterm infants with suspected or diagnosed NEC. We compared the mean eight-hour cerebral, liver, and infraumbilical rSO2 and FTOE values of infants with no NEC and definite NEC and of infants with uncomplicated and complicated NEC in the first forty-eight hours after onset of symptoms, suspicious for NEC. Furthermore, we determined cut-off values by generating receiver operating characteristics curves in case of significant differences in the first eight-hour mean values of rSO2 between infants with no NEC and definite NEC and between infants with uncomplicated and complicated NEC. Results: We included 33 patients: 13 no NEC, 10 with uncomplicated NEC, and 10 with complicated NEC. We found no significant differences in the first twenty-four hours after onset of symptoms in rSO2 and FTOE between infants with no NEC and definite NEC. In preterm infants with complicated NEC, we observed
significantly lower cerebral, liver, and infraumbilical rSO2 and higher FTOE within twenty-four hours after onset of symptoms compared with infants with uncomplicated NEC. A continuous cerebral rSO2 ≤ 71% and liver rSO2 ≤ 59% in the first eight hours after onset of symptoms predicted the onset of complicated NEC with a sensitivity of 1.0 and specificity of 0.8, and a sensitivity of 1.0 and specificity of 1.0, respectively.

Conclusions: By measuring the cerebral and splanchnic oxygenation it is possible to differentiate complicated NEC from uncomplicated NEC. In our sample, NIRS monitoring did not prove useful for distinguishing between definite NEC and no NEC in preterm infants with clinical signs suspicious of NEC.

95. Lin et al. (2016). Reduced cerebral blood flow and oxygen metabolism in extremely preterm neonates with low-grade germinal matrix-intraventricular hemorrhage

Abstract: Low-grade germinal matrix-intraventricular hemorrhage (GM-IVH) is the most common complication in extremely premature neonates. The occurrence of GM-IVH is highly associated with hemodynamic instability in the premature brain, yet the long-term impact of low-grade GM-IVH on cerebral blood flow and neuronal health have not been fully investigated. We used an innovative combination of frequency-domain near infrared spectroscopy and diffuse correlation spectroscopy (FDNIRS-DCS) to measure cerebral oxygen saturation (SO2) and an index of cerebral blood flow (CBFi) in the infant's bedside and compute an index of cerebral oxygen metabolism (CMRO2i). We enrolled twenty extremely low gestational age (ELGA) neonates (seven with low-grade GM-IVH) and monitored them weekly until they reached full-term equivalent age. During their hospital stay, we observed consistently lower CBFi and CMRO2i in ELGA neonates with low-grade GM-IVH compared to neonates without hemorrhages. Furthermore, lower CBFi and CMRO2i in the former group persists even after the resolution of the hemorrhage. In contrast, SO2 does not differ between groups. Thus, CBFi and CMRO2i may have better sensitivity than SO2 in detecting GM-IVH-related effects on infant brain development. FDNIRS-DCS methods may have clinical benefit for monitoring the evolution of GM-IVH, evaluating treatment response, and potentially predicting neurodevelopmental outcome.

96. Naseer et al. (2016). Determining Optimal Feature-Combination for LDA Classification of Functional Near-Infrared Spectroscopy Signals in Brain-Computer Interface Application

Abstract: In this study, we determine the optimal feature-combination for classification of functional near-infrared spectroscopy (fNIRS) signals with the best accuracies for development of a two-class brain-computer interface (BCI). Using a multi-channel continuous-wave imaging system, mental arithmetic signals are acquired from the prefrontal cortex of seven healthy subjects. After removing physiological noises, six oxygenated and deoxygenated hemoglobin (HbO and HbR) features—mean, slope, variance, peak, skewness and kurtosis—are calculated. All possible 2- and 3-feature combinations of the calculated features are then used to classify mental arithmetic vs. rest using linear discriminant analysis (LDA). It is found that the combinations containing mean and peak values yielded significantly higher (p < 0.05) classification accuracies for both HbO and HbR than did all of the other combinations, across all of the subjects. These results demonstrate the feasibility of achieving high classification accuracies using mean and peak values of HbO and HbR as features for classification of mental arithmetic vs. rest for a two-class BCI.


Abstract: Functional near-infrared (fNIR) spectroscopy is a promising new technology that has demonstrated utility in the study of normal human cognition. We utilized fNIR spectroscopy to examine the effect of social anxiety and performance on hemodynamic activity in the dorsolateral prefrontal cortex (DLPFC). Socially phobic participants and non-clinical participants with varying levels of social anxiety completed a public speaking task in front of a small virtual audience while the DLPFC was being monitored by the fNIR device. The relationship
between anxiety and both blood volume (BV) and deoxygenated hemoglobin (Hb) varied significantly as a function of speech performance, such that individuals with low social anxiety who performed well showed an increase in DLPFC activation relative to those who did not perform well. This result suggests that effortful thinking and/or efficient top-down inhibitory control may have been required to complete an impromptu speech task with good performance. In contrast, good performers who were highly socially anxious showed lower DLPFC activation relative to good performers who were low in social anxiety, suggesting autopilot thinking or less-effortful thinking. In poor performers, slight increases in DLPFC activation were observed from low to highly anxious individuals, which may reflect a shift from effortless thinking to heightened self-focused attention. Heightened self-focused attention, poor inhibitory control resulting in excessive fear or anxiety, or low motivation may lower performance. These results suggest that there can be different underlying mechanisms in the brain that affect the level of speech performance in individuals with varying degrees of social anxiety. This study highlights the utility of the fNIR device in the assessment of changes in DLPFC in response to exposure to realistic phobic stimuli, and further supports the potential utility of this technology in the study of the neurophysiology of anxiety disorders.

98. Hill et al. (2016). Applications of Optical Neuroimaging in Usability Research

Abstract: In this article we review recent and potential applications of optical neuroimaging to human factors and usability research. We focus specifically on functional near-infrared spectroscopy (fNIRS) because of its cost-effectiveness and ease of implementation. Researchers have used fNIRS to assess a range of psychological phenomena relevant to human factors, such as cognitive workload, attention, motor activity, and more. It offers the opportunity to measure hemodynamic correlates of mental activity during task completion in human factors and usability studies. We also consider some limitations and future research directions.


Abstract: Functional near-infrared spectroscopy (fNIRS) is a non-invasive neuroimaging modality that measures the concentration changes of oxy-hemoglobin (HbO) and de-oxy hemoglobin (HbR) at the same time. It is an emerging cortical imaging modality with a good temporal resolution that is acceptable for brain-computer interface applications. Researchers have developed several methods in last two decades to extract the neuronal activation related waveform from the observed fNIRS time series. But still there is no standard method for analysis of fNIRS data. This article presents a brief review of existing methodologies to model and analyze the activation signal. The purpose of this review article is to give a general overview of variety of existing methodologies to extract useful information from measured fNIRS data including pre-processing steps, effects of differential path length factor (DPF), variations and attributes of hemodynamic response function (HRF), extraction of evoked response, removal of physiological noises, instrumentation, and environmental noises and resting/activation state functional connectivity. Finally, the challenges in the analysis of fNIRS signal are summarized.

100. Santosa (2016). Decoding auditory information from the human brain using functional near infrared spectroscopy

Abstract: This article describes the use of fNIRS to decode, by multi-class offline and online classification, the haemodynamic responses evoked by audio-stimuli from multiple (two, four and six) different sound-categories in the auditory cortex. Interestingly, the performance of offline classification was higher than the chance levels for multi-class problems (i.e., two-, four- and six-class). Finally, the feasibility and potential of using fNIRS for decoding what people are hearing during an on-going sound-listening session is demonstrated.
101. Holmggaard et al. (2016). Does depth of the frontal sinus affect near-infrared spectroscopy measurement?

Abstract: Near-infrared spectroscopy (NIRS) is a non-invasive method that reflects real-time cerebral oxygenation (rSO2) by the use of two adhesive optodes placed on the forehead of the patient. Frontal sinuses vary anatomically and a large frontal sinus might compromise the NIRS signal since the NIRS optodes are placed at the skin surface superficial to the underlying frontal sinus. The aim of this case-series was to elucidate whether there is a difference in the obligate changes in rSO2 during cardiac surgery between patients with a small as opposed to a large anterior-posterior distance of the frontal sinus based on magnetic resonance imaging. Two matched groups with small (n = 5) vs. large (n = 5) frontal sinus (3.2 vs. 18.1 millimeters) in this case-series showed no difference in obligate changes of rSO2 (p = 0.54).

102. Foy et al. (2016). Prefrontal Cortex Activation and Young Driver Behaviour: A fNIRS Study

Abstract: Road traffic accidents consistently show a significant over-representation for young, novice and particularly male drivers. This research examines the prefrontal cortex activation of young drivers and the changes in activation associated with manipulations of mental workload and inhibitory control. It also considers the explanation that a lack of prefrontal cortex maturation is a contributing factor to the higher accident risk in this young driver population. The prefrontal cortex is associated with a number of factors including mental workload and inhibitory control, both of which are also related to road traffic accidents. This experiment used functional near infrared spectroscopy to measure prefrontal cortex activity during five simulated driving tasks: one following task and four overtaking tasks at varying traffic densities which aimed to dissociate workload and inhibitory control. Age, experience and gender were controlled for throughout the experiment. The results showed that younger drivers had reduced prefrontal cortex activity compared to older drivers. When both mental workload and inhibitory control increased prefrontal cortex activity also increased, however when inhibitory control alone increased there were no changes in activity. Along with an increase in activity during overtaking manoeuvres, these results suggest that prefrontal cortex activation is more indicative of workload in the current task. There were no differences in the number of overtakes completed by younger and older drivers but males overtook significantly more than females. We conclude that prefrontal cortex activity is associated with the mental workload required for overtaking. We additionally suggest that the reduced activation in younger drivers may be related to a lack of prefrontal maturation which could contribute to the increased crash risk seen in this population.


Abstract: Transcranial direct current stimulation (tDSC) modulates cortical neural activity and hemodynamics. Electrophysiological methods (electroencephalography-EEG) measure neural activity while optical methods (near-infrared spectroscopy-NIRS) measure hemodynamics coupled through neurovascular coupling (NVC). Assessment of NVC requires development of NIRS-EEG joint-imaging sensor montages that are sensitive to the tDSC affected brain areas. In this methods paper, we present a software pipeline incorporating freely available software tools that can be used to target vascular territories with tDSC and develop a NIRS-EEG probe for joint imaging of tDSC-evoked responses. We apply this software pipeline to target primarily the outer convexity of the brain territory (superficial divisions) of the middle cerebral artery (MCA). We then present a computational method based on Empirical Mode Decomposition of NIRS and EEG time series into a set of intrinsic mode functions (IMFs), and then perform a cross-correlation analysis on those IMFs from NIRS and EEG signals to model NVC at the lesional and contralesional hemispheres of an ischemic stroke patient. For the contralesional hemisphere, a strong positive correlation between IMFs of regional cerebral hemoglobin oxygen saturation and the log-transformed mean-power time-series of IMFs for EEG with a lag of about −15 s was found after a cumulative 550 s stimulation of anodal tDSC. It is postulated that system identification, for example using a
continuous-time autoregressive model, of this coupling relation under tDCS perturbation may provide spatiotemporal discriminatory features for the identification of ischemia. Furthermore, portable NIRS-EEG joint imaging can be incorporated into brain computer interfaces to monitor tDCS-facilitated neurointervention as well as cortical reorganization.

104. Maidan et al. (2016). The Role of the Frontal Lobe in Complex Walking Among Patients With Parkinson’s Disease and Healthy Older Adults. An fNIRS Study

**Abstract:** Background. Gait is influenced by higher order cognitive and cortical control mechanisms. Functional near infrared spectroscopy (fNIRS) has been used to examine frontal activation during walking in healthy older adults, reporting increased oxygenated hemoglobin (HbO2) levels during dual task walking (DT), compared with usual walking. Objective. To investigate the role of the frontal lobe during DT and obstacle negotiation, in healthy older adults and patients with Parkinson’s disease (PD). Methods. Thirty-eight healthy older adults (mean age 70.4 ± 0.9 years) and 68 patients with PD (mean age 71.7 ± 1.1 years,) performed 3 walking tasks: (a) usual walking, (b) DT walking, and (c) obstacles negotiation, with fNIRS and accelerometers. Linear-mix models were used to detect changes between groups and within tasks. Results. Patients with PD had higher activation during usual walking (P < .030). During DT, HbO2 increased only in healthy older adults (P < .001). During obstacle negotiation, HbO2 increased in patients with PD (P = .001) and tended to increase in healthy older adults (P = .053). Higher DT and obstacle cost (P < .003) and worse cognitive performance were observed in patients with PD (P = .001). Conclusions. A different pattern of frontal activation during walking was observed between groups. The higher activation during usual walking in patients with PD suggests that the prefrontal cortex plays an important role already during simple walking. However, higher activation relative to baseline during obstacle negotiation and not during DT in the patients with PD demonstrates that prefrontal activation depends on the nature of the task. These findings may have important implications for rehabilitation of gait in patients with PD.

105. Barker et al. (2016). Correction of motion artifacts and serial correlations for real-time functional near-infrared spectroscopy

**Abstract:** Functional near-infrared spectroscopy (fNIRS) is a relatively low-cost, portable, noninvasive neuroimaging technique for measuring task-evoked hemodynamic changes in the brain. Because fNIRS can be applied to a wide range of populations, such as children or infants, and under a variety of study conditions, including those involving physical movement, gait, or balance, fNIRS data are often confounded by motion artifacts. Furthermore, the high sampling rate of fNIRS leads to high temporal autocorrelation due to systemic physiology. These two factors can reduce the sensitivity and specificity of detecting hemodynamic changes. In a previous work, we showed that these factors could be mitigated by autoregressive-based prewhitening followed by the application of an iterative reweighted least squares algorithm offline. This current work extends these same ideas to real-time analysis of brain signals by modifying the linear Kalman filter, resulting in an algorithm for online estimation that is robust to systemic physiology and motion artifacts. We evaluated the performance of the proposed method via simulations of evoked hemodynamics that were added to experimental resting-state data, which provided realistic fNIRS noise. Last, we applied the method post hoc to data from a standing balance task. Overall, the new method showed good agreement with the analogous offline algorithm, in which both methods outperformed ordinary least squares methods.

106. Green et al. (2016). Near-Infrared Spectroscopy - The New Must Have Tool in the Intensive Care Unit?

**Abstract:** Standard hemodynamic monitoring such as blood pressure and pulse oximetry may only provide a crude estimation of organ perfusion in the critical care setting. Near-infrared spectroscopy (NIRS) is based on
the same principle as a pulse oximeter and allows continuous noninvasive monitoring of hemoglobin oxygenation and deoxygenation and thus tissue saturation “StO2.” This review aims to provide an overview of NIRS technology principles and discuss its current clinical use in the critical care setting. The study selection was performed using the PubMed database to find studies that investigated the use of NIRS in both the critical care setting and in the intensive care unit. Currently, NIRS in the critical care setting is predominantly being used for infants and neonates. A number of studies in the past decade have shown promising results for the use of NIRS in surgical-trauma intensive care units during shock management as a prognostic tool and in guiding resuscitation. It is evident that over the past 2 decades, NIRS has gone from being a laboratory fascination to an actively employed clinical tool. Even though the benefit of routine use of this technology to achieve better outcomes is still questionable, the fact that NIRS is a low-cost, noninvasive monitoring modality improves the attractiveness of the technology. However, more research may be warranted before recommending its routine use in the critical care setting.


Abstract: Recent advances in temporal data mining of brain activity with NIRS and EEG signals allow us to recognize brain states in higher resolution. However, brain states are not always distinct from each other and often differ in temporal granularity. This paper revisits Dennett’s three levels of stance, the DIKW model for the design of two self-organizing maps (SOMs), which contributes to recognition of a hierarchy of brain states with finer granularities. The experimental results show that two brain states at different levels can be accurately identified by applying different training data for each level of SOM.

108. Salvadego et al. (2016). Separate and combined effects of a 10-d exposure to hypoxia and inactivity on oxidative function in vivo and mitochondrial respiration ex vivo in humans

Abstract: An integrative evaluation of oxidative metabolism was carried out in 9 healthy young men (age: 24.1±1.7 years [mean±SD]) prior to (CTRL) and following a 10-day horizontal bed rest, carried out in normoxia (N-BR) or hypoxia (FIO2=0.147; H-BR). H-BR was aimed to simulate planetary habitats. Pulmonary O2 uptake (VO2) and vastus lateralis fractional O2 extraction (changes in deoxygenated hemoglobin+myoglobin concentration, Δ[deoxy(Hb+Mb)]; near-infrared spectroscopy) were evaluated, in normoxia, during an incremental cycle ergometer exercise (CE) and one-leg knee extension exercise (KE) (aimed at reducing cardiovascular constraints to oxidative function). Mitochondrial respiration was evaluated ex vivo by high-resolution respirometry in permeabilized vastus lateralis fibers. During CE V'O2peak and Δ[deoxy(Hb+Mb)]peak were lower (P<0.05) after both N-BR and H-BR vs. CTRL; during KE the variables were lower after N-BR, but not after H-BR. During CE the “overshoot” of Δ[deoxy(Hb+Mb)] during constant work rate exercise was greater in N-BR and H-BR vs. CTRL, whereas during KE a significant difference vs. CTRL was observed only after N-BR. Maximal mitochondrial respiration determined ex vivo was not affected by both interventions. In N-BR, a significant impairment of oxidative metabolism occurred downstream of central cardiovascular O2 delivery and upstream of mitochondrial function, possibly at the level of the intramuscular matching between O2 supply and utilization (see the Δ[deoxy(Hb+Mb)] overshoot) and peripheral O2 diffusion. Superposition of H on BR did not aggravate, and partially reversed, the impairment of muscle oxidative function in vivo induced by BR. The effects of longer exposures will have to be determined.


Abstract: Lack of a diagnostic index is a problem that needs to be overcome in the diagnosis of autism spectrum disorder (ASD), because this problem prevents an objective assessment based on biomarkers. This paper
describes the development of a diagnostic index for ASD using near-infrared spectroscopy (NIRS). We investigated continuous prefrontal hemodynamic changes depending on reciprocal disposition of working memory and nonworking memory tasks using two-channel NIRS. NIRS signals in the prefrontal cortex were compared between high-functioning ASD subjects (n=11) and typically developed (TD) subjects (n=21). The brain activities of the TD subjects were related to experimental design. These results were not confirmed in brain activities of ASD subjects, although the task performance rate was almost equivalent. The brain activities of TD subjects and ASD subjects were evaluated using a weighted separability (WS) index obtained from the feature phase of oxy-hemoglobin and its differential value. Calculation of the t-test (TD subject versus ASD subject) confirmed that WS was significant. This result showed that the proposed index was useful for evaluation of the brain activity of ASD subjects.

110. Novi et al. (2016). Resting state connectivity patterns with near-infrared spectroscopy data of the whole head

Abstract: Resting state cerebral dynamics has been a useful approach to explore the brain’s functional organization. In this study, we employed graph theory to deeply investigate resting state functional connectivity (rs-FC) as measured by near-infrared spectroscopy (NIRS). Our results suggest that network parameters are very similar across time and subjects. We also identified the most frequent connections between brain regions and the main hubs that participate in the spontaneous activity of brain hemodynamics. Similar to previous findings, we verified that symmetrically located brain areas are highly connected. Overall, our results introduce new insights in NIRS-based functional connectivity at rest.

111. Novi et al. (2016). Acute effects of 3G mobile phone radiations on frontal haemodynamics during a cognitive task in teenagers and possible protective value of Om chanting

Abstract: Mobile phone induced electromagnetic field (MPEMF) as well as chanting of Vedic mantra ‘OM’ has been shown to affect cognition and brain haemodynamics, but findings are still inconclusive. Twenty right-handed healthy teenagers (eight males and 12 females) in the age range of 18.25 ± 0.44 years were randomly divided into four groups: (1) MPONOM (mobile phone ‘ON’ followed by ‘OM’ chanting); (2) MPOFOM (mobile phone ‘OFF’ followed by ‘OM’ chanting); (3) MPONSS (mobile phone ‘ON’ followed by ‘SS’ chanting); and (4) MPOFSS (mobile phone ‘OFF’ followed by ‘SS’ chanting). Brain haemodynamics during Stroop task were recorded using a 64-channel fNIRS device at three points of time: (1) baseline, (2) after 30 min of MPON/OF exposure, and (3) after 5 min of OM/SS chanting. RM-ANOVA was applied to perform within- and between-group comparisons, respectively. Between-group analysis revealed that total scores on incongruent Stroop task were significantly better after OM as compared to SS chanting (MPOFOM vs MPOFSS), pre-frontal activation was significantly lesser after OM as compared to SS chanting in channel 13. There was no significant difference between MPON and MPOF conditions for Stroop performance, as well as brain haemodynamics. These findings need confirmation through a larger trial in future.

112. Aarabi et al. (2016). Characterization of the relative contributions from systemic physiological noise to whole-brain resting-state functional near-infrared spectroscopy data using single-channel independent component analysis

Abstract: Functional near-infrared spectroscopy (fNIRS) is a noninvasive neuroimaging technique used to measure changes in oxygenated hemoglobin (oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb) in the brain. In this study, we present a decomposition approach based on single-channel independent component analysis (scICA) to investigate the contribution of physiological noise to fNIRS signals during rest. Single-channel ICA is an underdetermined decomposition method, which separates a single time series into components containing nonredundant spectral information. Using scICA, fNIRS signals from a total of 17 subjects were decomposed into
the constituent physiological components. The percentage contribution of the classes of physiology to the fNIRS signals including low-frequency (LF) fluctuations, respiration, and cardiac oscillations was estimated using spectral domain classification methods. Our results show that LF oscillations accounted for 40% to 55% of total power of both the oxy-Hb and deoxy-Hb signals. Respiration and its harmonics accounted for 10% to 30% of the power, and cardiac pulsations and cardio-respiratory components accounted for 10% to 30%. We describe this scICA method for decomposing fNIRS signals, which unlike other approaches to spatial covariance reduction is applicable to both single- or multiple-channel fNIRS signals and discuss how this approach allows functionally distinct sources of noise with disjoint spectral support to be separated from obscuring systemic physiology.

113. Davranche et al. (2016). Cognitive functions and cerebral oxygenation changes during acute and prolonged hypoxic exposure

Abstract: The present study aimed to assess specific cognitive processes (cognitive control and time perception) and hemodynamic correlates using functional near-infrared spectroscopy (fNIRS) during acute and prolonged high-altitude exposure. Eleven male subjects were transported via helicopter and dropped at 14,272 ft (4,350 meters) of altitude where they stayed for 4 days. Cognitive tasks, involving a conflict task and temporal bisection task, were performed at sea level the week before ascending to high altitude, the day of arrival (D0), the second (D2) and fourth (D4) day at high altitude. Cortical hemodynamic changes in the prefrontal cortex (PFC) area were monitored with fNIRS at rest and during the conflict task. Results showed that high altitude impacts information processing in terms of speed and accuracy. In the early hours of exposure (D0), participants displayed slower reaction times (RT) and decision errors were twice as high. While error rate for simple spontaneous responses remained twice that at sea level, the slow-down of RT was not detectable after 2 days at high-altitude. The larger fNIRS responses from D0 to D2 suggest that higher prefrontal activity partially counteracted cognitive performance decrements. Cognitive control, assessed through the build-up of a top-down response suppression mechanism, the early automatic response activation and the post-error adjustment were not impacted by hypoxia. However, during prolonged hypoxic exposure the temporal judgments were underestimated suggesting a slowdown of the internal clock. A decrease in cortical arousal level induced by hypoxia could consistently explain both the slowdown of the internal clock and the persistence of a higher number of errors after several days of exposure.

114. Meng et al. (2016). The neural mechanism of biomechanical constraints in the hand laterality judgment task: A near-infrared spectroscopy study

Abstract: The mental rotation (MR) task is defined as a discrimination task between mirror-reversed images involving discrepancy in angular orientation. Various studies have shown that the MR task likely causes mental imagery, that is, visual and/or motor imagery, depending on stimulus types. When figures of rotated hands are presented to be identified as a left or right hand, reaction times (RTs) usually show an effect of biomechanical constraints (BC): a hand in a position difficult to reach with a real movement results in longer RTs. The BC effect as a marker of motor imagery has been investigated by brain function measures (fMRI, PET, EEG and MEG) as well as by RTs. Unlike other neuroimaging techniques, NIRS (near-infrared spectroscopy) imposes few physical constraints on participants and is relatively unaffected by motion artifact, which permits serial assessments of tasks in relaxed and natural environment. Focusing on these advantages, a NIRS study on motor imagery in HLJ was carried out in which we measured the brain activation during the HLJ task and a single character judgment task. In the HLJ task, both the RTs and the activity of the left superior parietal lobe (SPL) showed an interaction between Hand (left, right) and Orientation (135°, 225°) i.e., the BC effect, but not in the character judgment task. More specifically, in the analysis of BC-related activity of SPL, although the Hand × Orientation interaction was significant, the left SPL for the left hand significantly increased from 135° to 225°, but the reversed increase (from 225° to 135°) was not found for the right hand. These results suggest that left SPL is involved in the BC effect and NIRS differentiates left hand awkwardness of right-hander in the HLJ task.
115. Seule et al. (2016). **Evaluation of a New Brain Tissue Probe for Intracranial Pressure, Temperature, and Cerebral Blood Flow Monitoring in Patients with Aneurysmal Subarachnoid Hemorrhage**

**Abstract:** Objective: To evaluate an intraparenchymal probe for intracranial pressure (ICP) and temperature (TEMP) monitoring as well as determination of cerebral hemodynamics using a near-infrared spectroscopy (NIRS) and indocyanine green (ICG) dye dilution method (NIRS-ICP probe).

Methods: The NIRS-ICP probe was applied after aneurysmal subarachnoid hemorrhage if multimodal monitoring was established due to poor neurological condition. ICP and TEMP values were obtained from ventricular catheters and systemic temperature sensors. Repeated NIRS-ICG measurements (2 injections within 30 min) were performed daily for determination of cerebral blood flow (CBF), cerebral blood volume (CBV), and mean transit time of ICG (mttICG). Secondary neurologic dysfunction was defined as brain tissue oxygen tension <20 mmHg and/or lactate/pyruvate ratio >35 obtained from cerebral probing.

Results: A total of 128 NIRS-ICG measurements were performed in ten patients. The correlation coefficients between ICP and TEMP values obtained with the NIRS-ICP probe and values from routine monitoring were $r = 0.72$ and $r = 0.96$, respectively. The mean values were $30.3 \pm 13.6$ ml/100 g/min for CBF, $3.3 \pm 1.2$ ml/100 g for CBV, and $6.8 \pm 1.6$ s for mttICG. The coefficients of variation from repeated NIRS-ICG measurements were 10.9% for CBF, 11.7% for CBV, and 3.8% for mttICG. The sensitivity for detection of secondary neurologic dysfunction was 85% and the specificity 83% using a CBF-threshold of 25 ml/100 g/min.

Conclusion: Multimodal monitoring using the NIRS-ICP probe is feasible with high reproducibility of measurement values and the ability to detect secondary neurologic dysfunction. No safety concerns exist for the routine clinical use of the NIRS-ICP probe.

116. Dixon et al. (2016). **Cerebral Oxygenation Using Near-infrared Spectroscopy (NIRS) before, during and after Therapeutic Hypothermia: A Comparison of Cerebral Saturations between those Infants on Sedatives and Anti-Epileptics and those who are not, all of whom are Undergoing Cooling**

**Abstract:** Objectives: The aims of this study include the following: to determine the effect of therapeutic hypothermia (Cooling) on cerebral saturations using Near Infrared Spectroscopy (NIRS) before, during and after therapeutic hypothermia; to compare these values between infants receiving sedative and anti-epileptic medications and those who do not.

Methods: This study is a retrospective chart review of patients from Children’s National Medical Center (CNMC) Neonatal Intensive Care Unit (NICU) who underwent therapeutic hypothermia with NIRS monitoring from July 2009- December 2014. Cerebral tissue saturations (StO2) using NIRS tissue oximeter (FORE-SIGHT, CAS Medical Systems, Branford, CT, USA) were assessed during the cooling period. StO2 were periodically recorded during 3 phases: before cooling was started, during cooling, and after cooling (30 minutes of rewarming) and averaged to a composite value for each event. Data was then compared based on whether the patient received sedatives and/or anti-epileptic medications.

Results: Complete data sets were obtained for 57 subjects, weighting 1.8 kg-4.9 kg, 1-7 days old and gestational age 35.6-42.0 weeks. Cerebral tissue saturations were significantly higher during cooling (paired t-test). Those on Phenobarbital and/or Versed had significantly higher saturations compared to those on no medications. Those on only Phenobarbital also had significantly higher saturations, but to a lesser degree. Subjects where StO2 failed to rise during cooling had a higher chance of dying, perhaps due to critical brain tissue damage from lack of oxygen during birth asphyxia, or failure to recover thereafter.

Conclusions: Data from this study suggests that cerebral tissue saturations increase during therapeutic hypothermia, likely due to suppressed cerebral metabolism. Those on anti-seizures medications have further increases in cerebral saturations, as seizures have been associated with increased cerebral blood flow.

Abstract: OCCUPATIONAL APPLICATIONS Our results illustrate the enhanced functional connectivity between motor-related brain regions and high-level cognitive brain regions during the transition period between rest and hand movements. These results suggest that the sensorimotor network is interacting with prefrontal areas during the transition period to maintain the preparation state. Both actual movement and the transition period without actual movement modulate brain activities. Capturing the detailed relationship of movement intention could be utilized to improve precision and latency of anticipation-based brain–computer interfaces. Furthermore, consistent with the neuroergonomic approach, this study demonstrates that functional near-infrared spectroscopy is a suitable tool for region-specific, task-related, and resting-state functional connectivity analysis. Our findings could enhance the development of more intuitive and natural interfaces between human and machine systems in diverse areas. The approach presented here could help create assistive devices that perceive and predict operators' intention of movements.

TECHNICAL ABSTRACT Introduction: Traditional and new generations of neuroimaging techniques allow observing the modulation of brain activities during transition periods between rest and physical movement execution. A thorough understanding of the brain activity and functional connectivity changes during these transitions could contribute to increasing the precision and decreasing the latency of anticipation-based brain–computer interfaces, and improving human-system integration in general. Consistent with the neuroergonomic approach, functional near-infrared spectroscopy can monitor the outer cortex during extensive physical movement and in realistic settings using wearable and portable sensors. Methods: In this study, 19 healthy subjects were monitored with functional near-infrared spectroscopy during rest, a fist opening and closing task, and the transition period preceding the task. Functional connectivity analysis was used to evaluate how the transition period preceding the task modulated the brain activities. Results: There were several increases in functional connectivity during the transition period, especially between the right dorsolateral prefrontal cortex and the contralateral primary somatosensory and primary motor cortices, as well as the functional connectivity connecting the contralateral primary somatosensory cortex with the ipsilateral primary somatosensory cortex and the primary motor cortex. Regions located in the sensorimotor networks and right dorsolateral prefrontal cortex were also found to be activated during the transition period. Conclusions: These results demonstrate that the sensorimotor network is interacting with the high-level cognitive brain network during the transition period to maintain the preparation state. Furthermore, functional near-infrared spectroscopy is an emerging tool well-suited for region specific task-related and resting-state functional connectivity analysis. The results and the approach presented here suggest that operators' intention to move can be detected before the actual movement, and that could be employed for development of more intuitive and natural interfaces between human and machine systems.

118. Martelli et al. (2016). There's plenty of light at the bottom: statistics of photon penetration depth in random media

Abstract: We propose a comprehensive statistical approach describing the penetration depth of light in random media. The presented theory exploits the concept of probability density function $f(z|\rho, t)$ for the maximum depth reached by the photons that are eventually re-emitted from the surface of the medium at distance $\rho$ and time $t$. Analytical formulas for $f$, for the mean maximum depth $\langle z_{\text{max}} \rangle$ and for the mean average depth $\langle \tilde{z} \rangle$ reached by the detected photons at the surface of a diffusive slab are derived within the framework of the diffusion approximation to the radiative transfer equation, both in the time domain and the continuous wave domain. Validation of the theory by means of comparisons with Monte Carlo simulations is also presented. The results are of interest for many research fields such as biomedical optics, advanced microscopy and disordered photonics.
119. Muthalib et al. (2016). Neuromuscular electrical stimulation and voluntary wrist extension movements elicit similar sensorimotor cortex activation: a continuous-wave fNIRS study

Abstract: Our previous study [1] using a high-cost time-domain (TD) functional near-infrared spectroscopy (fNIRS) prototype instrument showed that unilateral neuromuscular electrical stimulation (NMES) evoked wrist extension movements (50% of maximal tolerated current intensity-50%MTI) activated (increase in oxy-hemoglobin-O 2 Hb and concomitant decrease in deoxy-hemoglobin-HHb) a similar region of the contralateral sensorimotor cortex (SMC) as that of voluntary (VOL) movements. The aim of this study was to use a continuous-wave (CW) relatively low-cost commercial fNIRS instrument to measure contralateral (left) and ipsilateral (right) SMC activation (O 2 Hb and HHb time course, integral [O 2 Hb INT and HHb INT ] and peak levels [O 2 Hb max and HHb min ]) during NMES (50%MTI) and VOL wrist extension movements of the right arm in 7 healthy male volunteers. Both NMES and VOL wrist extension movements activated the contralateral (left) and ipsilateral (right) SMC, however, the level of contralateral SMC activation was significantly greater than the ipsilateral SMC. Although the HHb parameters (HHb INT, HHb min ) indicated that there was no significant difference between conditions, the O2Hb parameters (O 2 Hb INT and O 2 Hb max ) indicated a significantly greater contralateral SMC activation during VOL than NMES. Since HHb is less influenced by skin blood flow changes than O2Hb, we consider that HHb parameters provide a more accurate estimation of task-related cortical activation. In conclusion, these CW-fNIRS findings using HHb parameters indicate that NMES at moderate current intensity (50%MTI) and VOL wrist extension movements elicit a similar contralateral SMC activation, which confirms our previous study using a TD-fNIRS instrument.

120. Draghici et al. (2016). Functional Near Infrared Spectroscopy for Measuring Bone Hemoglobin Content after Exercise in Individuals with Spinal Cord Injury

Abstract: Bone blood perfusion has an essential role in maintaining a healthy bone structure. However, current methods for measuring bone blood perfusion are expensive and highly invasive. The spinal cord injury (SCI) population is at high risk of cardiovascular diseases and profoundly accelerated osteoporosis. Thus, we aim to investigate changes in bone blood perfusion with rowing in able-bodied and in individuals with SCI. This study presents a custom functional near-infrared spectroscopy (fNIRS) instrument to monitor oxygenated and deoxygenated hemoglobin changes in the human tibia. Six individuals with SCI and nine able-bodied rowers performed a 10-minute rowing exercise. With exercise, able-bodied rowers showed an increased blood content, while the same increase was not observed in SCI rowers. Our preliminary results show that fNIRS can non-invasively detect changes in oxygenated and de-oxygenated hemoglobin concentration in the human tibia.

121. Rahman et al. (2016). A Straight Forward Signal Processing Scheme to Improve Effect Size of fNIR Signals

Abstract: Functional near-infrared spectroscopy (fNIRS) plays an imperative role for studying hemodynamic measurement of brain. Event related task measurement mostly depends on the effect size (ES) of fNIRS data. The noisy fNIR signal is an obstacle to estimate the precise ES of such measurement. Though Savitzky-Golay and Moving Average filters are often used for denoising the fNIR signal, they have some limitations in measuring ES. In this paper, we have proposed a simple signal processing scheme which contributes to remove noise and evaluates not only proper ES but also overcome the drawback of Savitzky-Golay and Moving Average filter. By this scheme, the filtered signal becomes lower standard deviated than the raw fNIR signal. Else, the scheme maintains the mean of original and filtered signal unchanged. Since, the scheme reduces the standard deviation of the signal notably remaining the mean value unchanged; the ES of interest is improved eloquently. The numerical results and corresponding contrast to noise ratio (CNR)
pattern prove the usefulness of the proposed scheme. The numerical results and corresponding contrast to noise ratio (CNR) pattern prove the effectiveness of the proposed scheme.

122. Han et al. (2016). Validation of EGOS-600 Near Infrared Spectroscopy to Measure Cerebral Oxygen Saturation by Comparing to NIRO-200nx In Vitro and In Vivo

Abstract: Objective: Near-infrared spectroscopy (NIRS) has been increasingly used to monitor regional cerebral oxygen saturation (rScO2) during cardiac surgery and intensive care. NIRO-200nx (Hamamatsu Phototonics, Japan) is one of widely used NIRS devices. EGOS-600 is a new device developed by Tsinghua University in China. We validated EGOS-600 by comparing to NIRO-200nx in laboratory and clinical settings.

Materials and methods: Laboratory test: A liquid tissue model was made consisting of 40 ml of human whole blood, 25 ml intralipid-20% and 935 ml buffer solution. Oxygen saturation (SO2) levels ranging 20-100% were made by inflating oxygen or adding sodium hydrosulfite. Eleven pairs of measures were obtained using the two oximeters.

Clinical test: 31 children (aged 0.7-61 months, median 11 months) and 20 adults (aged 18-73 years, median 59 years) were enrolled within one week after cardiac surgery. One probe of each device was sequentially placed at the middle of patient’s forehead to measure rScO2 at 2-3 hour intervals. One hundred pairs of rScO2 were obtained in each group. Bland-Altman method was used for data analysis. Results: Laboratory test showed a bias of -2% and limits of agreement 20 to 24% with a trend of overestimating SO2 by EGOS-600 when average SO2>50% and underestimating when <50%. This trend disappeared in patients. The bias was -5.9% in children and -4.1% in adults. The limits of agreement were 1.3 to 13.1% in children, and 3.3 to 11.5% in adults.

Conclusions: EGOS-600 introduces a small underestimation of rScO2 when compared to NIRO-200nx, with acceptable limits of agreement. The new device is applicable in clinical settings in both children and adults.

123. Rackebrandt & Gehring (2016). Calibration and evaluation of a continuous wave multi-distance NIRS system in simulated desaturation investigations

Abstract: The venous oxygen saturation reflects pathophysiological changes in oxygen delivery and consumption, where the saturation range beneath 50% may represent a clinical borderline to avoid irreversible damage. We present a model to simulate a desaturation investigation with 4 plateaus (PL1 = 99 ± 0.3%; PL2 = 75 ± 3%; PL3 = 50 ± 3%, PL4 = 25 ± 3%). A continuous wave multi-distance near-infrared spectroscopy sensor (wavelengths: 770, 808 and 850 nm; 6 photodiodes (PD1–6), linearly arranged, separated 6 mm each) was equipped to detect the saturation at these plateaus. The study was divided in 5 calibration experiments (1 day; 5 per day) and 25 experiments (5 days; 5 per day) with the calibrated sensor unit. The detected saturation was compared with the reference values from the CO-Oximetry unit (IL-682) while keeping the amount of total hemoglobin (tHb) and the other physiological parameters at constant levels (tHb = 12 ± 0.3 g dl−1, blood temperature = 35.5 ± 0.6 °C, carbon dioxide partial pressure (pCO2) = 39 ± 6 mmHg, glucose = 103 ± 9 mg dl−1 and pH 7.4 ± 0.04). The oxygen saturation, in the range from 99% to 20%, could be detected reproducible with a mean absolute deviation of 3%.

124. Shimokawa et al. (2016). Diffuse optical tomography using multi-directional sources and detectors

Abstract: Diffuse optical tomography (DOT) is an advanced imaging method used to visualize the internal state of biological tissues as 3D images. However, current continuous-wave DOT requires high-density probe arrays for measurement (less than 15-mm interval) to gather enough information for 3D image reconstruction, which makes the experiment time-consuming. In this paper, we propose a novel DOT measurement system using multi-directional light sources and multi-directional photodetectors instead of high-density probe arrays. We evaluated this system’s multi-directional DOT through computer simulation and a phantom experiment. From
the results, we achieved DOT with less than 5-mm localization error up to a 15-mm depth with low-density probe arrays (30-mm interval), indicating that the multi-directional measurement approach allows DOT without requiring high-density measurement.

125. Thewissen et al. (2016). **Neonatal haemodynamic effects following foetal exposure to labetalol in hypertensive disorders of pregnancy**

**Abstract:** Objective: Hypertensive disorders of pregnancy (HDP) affect foetal outcome. Labetalol is frequently used to lower maternal blood pressure and prolong pregnancy. Conflicting evidence exists for specific neonatal side effects described after maternal labetalol treatment. Our aim was to investigate neonatal effects of foetal exposure to labetalol on cerebral oxygenation and extraction.

Methods: In a prospective observational study, clinical characteristics, vital parameters and cerebral oxygen delivery and extraction were collected during the first 24 h of life in labetalol-exposed preterm neonates and compared with two control groups.

Results: Twenty-two infants with a mean gestational age of 28.9 weeks, born from labetalol-treated mothers with HDP were included and matched with 22 infants with non-labetalol-treated mothers with HDP and 22 infants without maternal HDP. No significant differences between groups were found neither in heart rate, blood pressure and inotropic support, nor in mean regional cerebral oxygen saturation and fractional tissue oxygen extraction.

Conclusion: Foetal labetalol exposure associated effects on preterm heart rate, blood pressure, cerebral oxygenation and extraction are not demonstrated. Maternal disease severity seems to play a more important role in neonatal cerebral haemodynamics. Maternal labetalol treatment has no clinically important short term side effects in the preterm neonate.

126. Dekker et al. (2016). **Relationship between tissue perfusion and coagulopathy in traumatic brain injury**

**Abstract:** Background: Traumatic brain injury (TBI)–related coagulopathy appears to be most prevalent in patients with tissue hypoperfusion, but evidence for this association is scarce. This study investigated the relationship between tissue perfusion and hemostatic derangements in TBI patients.

Materials and methods: Coagulation parameters were measured on emergency department admission in patients with TBI (head abbreviated injury scale ≥ 3). The level of hypoperfusion was simultaneously assessed by near-infrared spectroscopy (NIRS) at the forehead and arm, and by base excess and lactate. Coagulopathy was defined as an international normalized ratio > 1.2 and/or activated partial thromboplastin time > 40 s and/or thrombocytopenia (<120 × 109/L).

Results: TBI patients with coagulopathy (42%) had more signs of tissue hypoperfusion as indicated by increased lactate levels (2.1 [1.1-3.2] mmol/L versus 1.2 [1.0-1.7] mmol/L; P = 0.017) and a larger base deficit (~3.0 [-4.6 to -2.0] mmol/L versus ~0.1 [-2.5 to 1.8] mmol/L; P < 0.001). There was no difference in the cerebral or somatic tissue oxygenation index. However, there was a distinct trend toward a moderate inverse association between the cerebral tissue oxygenation index and D-dimer levels (r=-0.40; P = 0.051) as marker of fibrinolysis. The presence of coagulopathy was associated with an increased inhospital mortality rate (45.5% versus 6.7%; P = 0.002).

Conclusions: This is the first study to investigate the relationship between hemostatic derangements and tissue oxygenation using NIRS in TBI patients. This study showed that TBI-related coagulopathy is more profound in patients with metabolic acidosis and increased lactate levels. Although there was no direct relationship between tissue oxygenation and coagulopathy, we observed an inverse relationship between NIRS tissue oxygenation levels and fibrinolysis.
127. Jeong et al. (2016). **Melodic Contour Identification Reflects the Cognitive Threshold of Aging**

**Abstract:** Cognitive decline is a natural phenomenon of aging. Although there exists a consensus that sensitivity to acoustic features of music is associated with such decline, no solid evidence has yet shown that structural elements and contexts of music explain this loss of cognitive performance. This study examined the extent and the type of cognitive decline that is related to the contour identification task (CIT) using tones with different pitches (i.e., melodic contours). Both younger and older adult groups participated in the CIT given in three listening conditions (i.e., focused, selective, and alternating). Behavioral data (accuracy and response times) and hemodynamic reactions were measured using functional near-infrared spectroscopy (fNIRS). Our findings showed cognitive declines in the older adult group but with a subtle difference from the younger adult group. The accuracy of the melodic CITs given in the target-like distraction task (CIT2) was significantly lower than that in the environmental noise (CIT1) condition in the older adult group, indicating that CIT2 may be a benchmark test for age-specific cognitive decline. The fNIRS findings also agreed with this interpretation, revealing significant increases in oxygenated hemoglobin (oxyHb) concentration in the younger \(p < 0.05\) for \(\Delta\text{pre} - \Delta\text{on task}\); \(p < 0.01\) for \(\Delta\text{on} - \Delta\text{post task}\) rather than the older adult group (n.s for \(\Delta\text{pre} - \Delta\text{on task}\); n.s for \(\Delta\text{on} - \Delta\text{post task}\)). We further concluded that the oxyHb difference was present in the brain regions near the right dorsolateral prefrontal cortex. Taken together, these findings suggest that CIT2 (i.e., the melodic contour task in the target-like distraction) is an optimized task that could indicate the degree and type of age-related cognitive decline.

128. Kohno et al. (2016). **Spatial distributions of hemoglobin signals from superficial layers in the forehead during a verbal-fluency task**

**Abstract:** Functional near-infrared spectroscopy (fNIRS) signals originate in hemoglobin changes in both the superficial layer of the head and the brain. Under the assumption that the changes in the blood flow in the scalp are spatially homogeneous in the region of interest, a variety of methods for reducing the superficial signals has been proposed. To clarify the spatial distributions of the superficial signals, the superficial signals from the forehead during a verbal-fluency task were investigated by using ten source–detector pairs separated by 5 mm, whereas fNIRS signals were also detected from two source–detector pairs separated by 30 mm. The fNIRS signals strongly correlated with the superficial signals at some channels on the forehead. Hierarchical cluster analysis was performed on the temporal cross-correlation coefficients for two channels of both the NIRS signals, and the analysis results demonstrate spatially heterogeneous distributions and network structures of the superficial signals from within the forehead. The results also show that the assumption stated above is invalid for homogeneous superficial signals from any region of interest of 15-mm diameter or larger on the forehead. They also suggest that the spatially heterogeneous distributions may be attributable to vascular networks, including supraorbital, supratrochlear, and superficial temporal vessels.


**Abstract:** In ageing society, it is not only that we need better care and treatment to maintain the quality of life of elderly population but also need better ways to strengthen the development of our children so that we could live in a healthy ageing society. This study proposed a framework for human learning ability study by using multimodal neuroimaging through simultaneous EEG/fNIRS measurement and neuroinformatics to understand target learning ability in laboratory and using portable EEG device to monitor real-time brain state for evaluating the learning/teaching methods introduced for improving the target learning ability in learning environment. By incorporating neuroscience approach in both laboratory and learning environment, not only scientific findings from neuroscience studies could give implications to educators to improve students’ learning, but also the developed learning/teaching methods could be assessed their effectiveness in classroom practice. This framework may help contribute in bridging the gap between neuroscience and education, which is the aim
of educational neuroscience. Toward smart education, the proposed conceptual framework deploys truly brain-based learning/teaching approach to enhance students’ learning to better acquire the knowledge and cognitive skills.

130. Morel et al. (2016). **The venous–arterial difference in CO₂ should be interpreted with caution in case of respiratory alkalosis in healthy volunteers**

**Abstract:** The venous–arterial difference in CO₂ (ΔCO₂) has been proposed as an index of the adequacy of tissue perfusion in shock states. We hypothesized that the variation in PaCO₂ (hyper- or hypocapnia) could impact ΔCO₂, partly through microcirculation adaptations. Fifteen healthy males volunteered to participate. For hypocapnia condition (hCO₂), the subjects were asked to hyperventilate, while they were asked to breathe a gas mixture containing 8 % CO₂ for hypercapnia condition (HCO₂). The 2 conditions were randomly assigned. Blood gases were measured at baseline before each condition, and after 5–7 min of either hCO₂ or HCO₂ condition. Microcirculation was assessed by the muscle reoxygenation slope measured with near infrared spectroscopy following a vascular occlusion test and by skin circulation with in vivo reflectance confocal microscopy. ΔCO₂ was significantly increased with hCO₂ while it tended to decrease with HCO₂ (non-significant). HCO₂ induced a moderate increase of the resaturation slope of NIRS oxygenation. Skin microcirculatory blood flow significantly dropped with hCO₂, while it remained unchanged with hypercapnia. Our results warrant cautious interpretation of ΔCO₂ as an indicator of tissue perfusion during respiratory alkalosis.


**Abstract:** We introduce a novel parameter, Oxygenation Variability Index, obtained from functional near infrared spectroscopy data. The pilot study in children reveal a dynamic relationship between age and OV index in frequencies associated with cerebral autoregulation.


**Abstract:** Cerebral perfusion pressure (CPP) is used as a surrogate for measurement of cerebral blood flow (CBF) but its determination requires that intracranial pressure be directly measured. Near-infrared spectroscopy (NIRS) can non-invasively measure tissue oxygenation. We hypothesized that NIRS would correlate well with CBF, with cerebral metabolism of oxygen (CMRO2) and glucose and with lactate production as CPP was reduced. Seven anesthetized piglets were subjected to reductions in CPP to 60, 50, 40, 30 and 20 mmHg by infusing an artificial cerebral spinal fluid into the lateral ventricle of the brain. After a period of equilibration, NIRS over the left temporal cortex and regional CBF (microspheres) were measured at each CPP level as well as arterial and internal jugular PaO2, glucose and lactate. CMRO2 and glucose consumption and lactate production were calculated by standard formulae. NIRS correlated very well (p<0.05) with CBF in the left temporal cortex (mean r[95% CI] =0.95[0.91-0.99]) and with left hemispheric CMRO2 (0.94[0.90-0.98]), glucose consumption (0.87[0.76-0.97]) and lactate production (0.89[0.81-0.97]). The correlation of NIRS with CBF was slightly better (p<0.05) than that of CPP with CBF (0.89[0.84-0.94]). In this model of global cerebral hypertension, NIRS correlated well with CBF and measures of cerebral metabolism and might be useful as a surrogate for CPP. Further studies are warranted to determine if NIRS is associated with these variables in focal cerebral injury.

Abstract: The purpose of this study was to elucidate the effects of wearing a denture on prefrontal activity during chewing performance. We specifically examined that activity in 12 elderly edentulous subjects [63.1±6.1 years old (mean ± SD)] and 12 young healthy controls (22.1±2.3 years old) using functional near-infrared spectroscopy (fNIRS) in order to evaluate the quality of prefrontal functionality during chewing performance under the conditions of wearing a denture and tooth loss, and then compared the findings with those of young healthy controls. fNIRS and electromyography were used simultaneously to detect prefrontal and masticatory muscle activities during chewing, while occlusal force and masticatory score were also examined by use of a food intake questionnaire. A significant increase in prefrontal activity was observed during chewing while wearing a denture, which was accompanied by increased masticatory muscle activity, occlusal force, and masticatory score, as compared with the tooth loss condition. Prefrontal activation during chewing while wearing a denture in the elderly subjects was not much different from that in the young controls. In contrast, tooth loss in the elderly group resulted in marked prefrontal deactivation, accompanied by decreased masticatory muscle activity, occlusal force, and masticatory score, as compared with the young controls. We concluded that intrinsic prefrontal activation during chewing with a denture may prevent prefrontal depression induced by tooth loss in elderly edentulous patients.

134. Lynn et al. (2016). Towards a wearable near infrared spectroscopic probe for monitoring concentrations of multiple chromophores in biological tissue in vivo

Abstract: The first wearable multi-wavelength technology for functional near-infrared spectroscopy has been developed, based on a custom-built 8-wavelength light emitting diode (LED) source. A lightweight fibreless probe is designed to monitor changes in the concentrations of multiple absorbers (chromophores) in biological tissue, the most dominant of which at near-infrared wavelengths are oxyhemoglobin and deoxyhemoglobin. The use of multiple wavelengths enables signals due to the less dominant chromophores to be more easily distinguished from those due to hemoglobin and thus provides more complete and accurate information about tissue oxygenation, hemodynamics, and metabolism. The spectroscopic probe employs four photodiode detectors coupled to a four-channel charge-to-digital converter which includes a charge integration amplifier and an analogue-to-digital converter (ADC). Use of two parallel charge integrators per detector enables one to accumulate charge while the other is being read out by the ADC, thus facilitating continuous operation without dead time. The detector system has a dynamic range of about 80 dB. The customized source consists of eight LED dies attached to a 2 mm × 2 mm substrate and encapsulated in UV-cured epoxy resin. Switching between dies is performed every 20 ms, synchronized to the detector integration period to within 100 ns. The spectroscopic probe has been designed to be fully compatible with simultaneous electroencephalography measurements. Results are presented from measurements on a phantom and a functional brain activation study on an adult volunteer, and the performance of the spectroscopic probe is shown to be very similar to that of a benchtop broadband spectroscopy system. The multi-wavelength capabilities and portability of this spectroscopic probe will create significant opportunities for in vivo studies in a range of clinical and life science applications.


Abstract: BACKGROUND High-frequency yoga breathing (breath rate of 2.0 Hz) has been associated with changes in oxy-hemoglobin in the prefrontal region of the brain. The present study assessed the effects of high-frequency yoga breathing (HFYB) at 1.0 Hz on frontal oxy-hemoglobin (oxy-Hb) and deoxy-hemoglobin (deoxy-Hb). MATERIAL AND METHODS Forty healthy male participants were recruited for the study. The experimental group consisted of 20 participants 23-40 years old (group mean ±S.D., 26.4±4.7 years) with at least
3 months of experience performing HFYB (group mean ±S.D., 16.3±9.8 months). The control group consisted of 20 participants ages 23-38 years (group mean age ± S.D., 27.4±4.1 years), who were seated quietly for the same duration and their average experience of yoga practice was (±S.D.) 4.3±2.7 months. Each participant in the experimental group was assessed at 2 sessions (HFYB and breath awareness [BAW]) on alternate days. Hemodynamic changes were assessed using a functional near-infrared spectroscopy sensor placed over the forehead. Data were analyzed using repeated-measures analyses of variance followed by post hoc Bonferroni adjustment. RESULTS A significant reduction was observed in oxy-Hb during and after HFYB on the left and right sides compared to values before. We also found a significant reduction in deoxy-Hb during and after the quiet sitting control session compared to pre-session values on left and right sides. CONCLUSIONS The decrease in oxy-Hb during and after HFYB suggests that there was no frontal activation during HFYB when practiced at the rate of 1.0 Hz.


Abstract: Functional near-infrared spectroscopy (fNIRS) is used to measure cerebral activity because it is simple and portable. However, scalp-hemodynamics often contaminates fNIRS signals, leading to detection of cortical activity in regions that are actually inactive. Methods for removing these artifacts using standard source-detector distance channels (Long-channel) tend to over-estimate the artifacts, while methods using additional short source-detector distance channels (Short-channel) require numerous probes to cover broad cortical areas, which leads to a high cost and prolonged experimental time. Here, we propose a new method that effectively combines the existing techniques, preserving the accuracy of estimating cerebral activity and avoiding the disadvantages inherent when applying the techniques individually. Our new method accomplishes this by estimating a global scalp-hemodynamic component from a small number of Short-channels, and removing its influence from the Long-channels using a general linear model (GLM). To demonstrate the feasibility of this method, we collected fNIRS and functional magnetic resonance imaging (fMRI) measurements during a motor task. First, we measured changes in oxygenated hemoglobin concentration (∆ Oxy-Hb) from 18 Short-channels placed over motor-related areas, and confirmed that the majority of scalp-hemodynamics was globally consistent and could be estimated from as few as four Short-channels using principal component analysis. We then measured ∆ Oxy-Hb from 4 Short- and 43 Long-channels. The GLM identified cerebral activity comparable to that measured separately by fMRI, even when scalp-hemodynamics exhibited substantial task-related modulation. These results suggest that combining measurements from four Short-channels with a GLM provides robust estimation of cerebral activity at a low cost.

137. Bembich et al. (2016). Bolus feeding has no effect on cerebral hemodynamics, irrespective of gestational age

Abstract: Objective: By multichannel near-infrared spectroscopy, we studied if gestational age has any influence on preterm cerebral hemodynamics, during bolus feeding. Methods: Oxy-haemoglobin (HbO2), as cerebral blood flow estimate, and the ratio between HbO2 and total haemoglobin (HbO2/HbTot), as cerebral oxygenation estimate, were assessed in 40 stable premature infants, during a 10 min bolus feeding. Results: We found no effect of any of the gestational ages studied (25–34 weeks) either on cerebral blood flow or on oxygenation, during a bolus feeding procedure. Conclusions: Bolus feeding appears not to affect cerebral hemodynamics of uncritically preterm infants, irrespective of gestational age.
138. Pham et al. (2016). **Sparse fNIRS Feature Estimation via Unsupervised Learning for Mental Workload Classification**

**Abstract:** Recent studies have demonstrated that functional near-infrared spectroscopy (fNIRS) is a potential non-invasive system for human mental workload (MWL) evaluation in both off-line and on-line manners. While most of the studies have been based on supervised classification of different MWL levels, which requires much effort to collect labeled training data, investigation on unlabeled data seems to be more promising. In this paper, we developed unsupervised learning and classification techniques of fNIRS parameters to support human workload classification. In the experimental setup, five subjects engaged in ten-loop memorizing tasks that were devised into two MWL levels while fNIRS signals were being monitored over their frontal lobes. Independent component analysis (ICA) was applied on a set of unlabeled random fNIRS data to extract the basis and sparse functions. Then two-dimensional convolutional matrices, which were constructed as sets of convolutional coefficients of fNIRS signal with learned basis functions, were implemented as the inputs for MWL classification using convolutional neural network classifier. Study of generalized linear model demonstrated that basis functions extracted using ICA is more effective when illustrating the activation regions over measuring cortex than using the modeled hemodynamic response functions. Besides, ICA basis function demonstrates the sparseness so that it is superior to basis functions learned by the conventional method of principle component analysis (PCA) in mental classification and shows its potential for further study of fNIRS signals based on their hidden basis functions.

139. Halim et al. (2016). **A review on the non-invasive evaluation of skeletal muscle oxygenation**

**Abstract:** The aim of this review is to conduct a feasibility study of non-invasive evaluation in skeletal muscle oxygenation. This non-invasive evaluation could extract many information using a safe non-invasive method regarding to the oxygenation and microcirculation status in human blood muscle. This brief review highlights the progress of the application of NIRS to evaluate skeletal muscle oxygenation in various activity of human nature from the historical point of view to the present advancement. Since the discovery of non-invasive optical method during 1992, there are many non-invasive techniques uses optical properties on human subject such as near infrared spectroscopy NIRS, optical topography, functional near infrared spectroscopy fNIRS and imaging fNIRI. Furthermore, in this paper we discuss the light absorption potential (LAP) towards chromophores content inside human muscle. Modified beer lambert law was studied in order to build a better understanding toward LAP between chromophores under tissue multilayers in human muscle. This paper will describe the NIRS principle and the basis for its proposed used in skeletal muscle oxygenation. This will cover the advantages and limitation of such application. Thus, these non-invasive techniques could open other possibilities to study muscle performance diagnosis.

140. Takada et al. (2016). **Changes in Brain Blood Flow by the Use of 2D/3D Games**

**Abstract:** Recently, with the rapid progress in image processing and three-dimensional (3D) technology, stereoscopic images are not only seen on television but also in theaters, on game machines, etc. However, symptoms such as eye fatigue and 3D sickness may be experienced when viewing 3D films on displays and visual environments. The influence of stereoscopic vision on the human body has been insufficiently understood; therefore, it is important to consider the safety of viewing virtual 3D content. In this study, we examine whether exposure to 3D video clips affects the human body such as brain blood flow. Subjects viewed 3D video clips on the display of portable game machines, and time series data of their brain blood flow was measured by near-infrared spectroscopy (NIRS) with use of FOIRE-3000 (Shimazu Co. Ltd., Kyoto). Our results showed oxyhemoglobin tended to increase throughout the cerebral cortex while operating the game machines on the 3D display in comparison with the 2D display.
141. Sakamoto et al. (2016). Influence of Display Resolution on Brain Activity and Task Workload

Abstract: We experimentally investigated the influence of the use of a high-resolution 4K tablet on participants' physiological and psychological state while engaged in searching tasks, to evaluate their associated mental and physical workloads. The results showed NIRS, an index of nervous system activity, to be significantly higher during searching tasks with 4K content than with 2K content, whereas LF/HF (level of sympathetic nerve activity) during searching tasks was significantly lower for 4K content than for 2K content, although no significant differences were observed in subjective assessments between 4K and 2K displays.


Abstract: Real-time monitoring of the flight crew's health status with ambient and body sensors have become an important concern to improve the safety and the efficiency of flight operations. In this paper we report our preliminary findings on a functional near-infrared spectroscopy (fNIR) based online algorithm developed for real-time monitoring of mental workload of an airline pilot. We developed a linear discriminant analysis (LDA) based classifier that aims to predict low, moderate and high mental workload states based on a set of features computed over a moving window of oxy- and deoxy-hemoglobin measures obtained from 16 locations distributed over the prefrontal cortex. In this paper we explore the predictive power of a model trained for a single pilot over a sample of eight pilots and discuss the technical challenges involved with real-time measurement of brain activity in a flight simulator environment that involves other infra-red sources.


Abstract: In this paper, we evaluate the possibility of detecting continuous changes in the user's cognitive workload using functional near-infrared spectroscopy (fNIRS). We dissect the source of meaning in a large collection of n-backs and argue that the problem of controlling the content of a participant's mind poses a major problem for calibrating an algorithm using black box machine learning. We therefore suggest that the field simplify its task, and begin to focus on building algorithms that work on specialized subjects, before adapting these to a wider audience.

144. Mark et al. (2016). Evaluating Neural Correlates of Constant-Therapy Neurorehabilitation Task Battery: An fNIRS Pilot Study

Abstract: The development of cognitive task battery applications for rehabilitation in telemedicine is a rapidly evolving field, with several tablet or web based programs already helping those suffering from working memory dysfunction or attention deficit disorders. However, there is little physiological evidence supporting a measurably significant change in brain function from using these programs. The present study sought to provide an initial assessment using the portable and wearable neuroimaging modality of functional near-infrared spectroscopy (fNIRS) that can be used in ambulatory and home settings and has the potential to add value in the assessment of clinical patients' recovery throughout their therapy.

145. Tobita (2016). Effectiveness of Analysis with Near-Infrared Spectroscopy for EFL Learners in Japan

Abstract: This study examined the effectiveness of analysis with near-infrared spectroscopy (NIRS) for English as foreign language (EFL) training, from a brain science perspective. The experiment presented in this paper analyzed the amount of blood flow in the brain while learners were training to improve their English listening
skills. The experiment attempted to ascertain the preferable combinations of learners’ characteristics and teaching materials when learners are completing training in English listening. This was done by comparing the brain activities of learners from different English proficiency levels. The data suggests that the analysis, using Functional Near-Infrared Spectroscopy (fNIRS), enabled the proposition of an effective course design for EFL learners.

146. Cakir et al. (2016). Neural Correlates of Purchasing Decisions in an Ecologically Plausible Shopping Scenario with Mobile fNIR Technology

Abstract: In this paper we present our preliminary findings for the neural correlates of purchasing decisions made in a computerized setting as well as in an ecologically plausible supermarket environment. Participants who were randomly recruited from a database of typical customers maintained by a marketing consultancy company were given a specific budget and asked to make purchasing decisions for basic grocery items in two separate conditions. In the first condition, participants made their decisions in a computerized scenario, where in each trial a single product and its price were displayed for a fixed duration of time, and then the participants clicked on buttons to specify which products they wish to purchase. In the second experiment, participants made similar purchasing decisions while wandering around a custom-made grocery aisle with shelves including physical products. In both conditions participants’ brain activities in their prefrontal cortices as well as their eye movements were recorded with a wireless fNIR device and a glass eye tracker respectively. In both conditions we observed higher mean oxygenation levels for the purchase decisions at the left dorso-medial prefrontal cortex. Despite the limited sample size, the oxygenation trends were similar in both purchasing situations. Our preliminary findings suggest that fNIR can effectively be employed to investigate neural correlates of purchasing behavior in ecological settings.

147. Pollmann et al. (2016). fNIRS as a Method to Capture the Emotional User Experience: A Feasibility Study

Abstract: User experience (UX) has become a key factor in interface design. Still, so far, no satisfying solution exists for measuring the emotional user experience (UX) during human-technology interaction (HTI) and linking them to design elements of the interface. Non-invasive brain imaging techniques are promising tools to assess the underlying causes and generation of emotional experiences in the brain. Against this background, especially functional near-infrared spectroscopy (fNIRS), a rather new and portable method, appears to have strong potential for measuring UX in real-world HTI settings. However, so far fNIRS has scarcely been used in emotion research. The present research evaluates the feasibility of using fNIRS to detect emotional user responses during HTI by comparing it to the well-established method of fMRI which, due to its set-up, is difficult to use in HTI context. Our feasibility study shows that fNIRS can detect brain activity patterns which are similar to those obtained using fMRI and can be used to distinguished positive and negative emotional reaction in an HTI context and displays brain activities which cannot be examined when fMRI is used. Future research should investigate whether similar results can be found when fNIRS is used in less controlled and more realistic HTI scenarios.

148. Badenes et al. (2016). Intraoperative monitoring of cerebral oximetry and depth of anaesthesia during neuroanaesthesia procedures

Abstract: Purpose of review: This review reports recent evidence on intraoperative monitoring of cerebral oximetry and depth of anaesthesia during neuroanaesthesia procedures. Recent findings: The clinical benefits of intraoperative monitoring with cerebral oximetry [near infrared spectroscopy (NIRS) and brain tissue oxygenation monitoring (brptO2)] and depth of anaesthesia with bispectral index (BIS) have recently been studied in surgical (carotid endarterectomy, cerebral arteriovenous
malformations resection and brain tumour resections) and neuroradiological vascular procedures. BrptiO2/PaO2 ratio is much more reliable than absolute brptiO2 readings in detecting hypoxia in arteriovenous malformation resections. NIRS can help clinicians monitor those patients receiving endovascular treatment for acute ischaemic stroke and during carotid endarterectomy, but the value of applying cerebral oximetry in patients with cerebral vasospasm needs to be further evaluated. Awake craniotomy demonstrated that because of considerable pharmacokinetic/pharmacodynamic interindividual variation, BIS titration is recommended. Thus, the presence of a frontal brain tumour did not affect ipsilateral BIS values.

Summary: Recent studies provide interesting evidence of intraoperative monitoring of NIRS, brptiO2 and BIS. The brptiO2/PaO2 ratio is much more reliable than an absolute brptiO2 reading; NIRS helps clinicians to monitor patients who are undergoing endovascular treatment, and BIS guides the titration of anaesthesia during awake craniotomy; its values are not affected by the presence of a frontal brain tumour.

149. Wood et al. (2016). **Coma and delirium are associated with low levels of brain tissue oxygen in critically ill patients**

**Abstract:** Background: The cause of ICU delirium is unknown. We used near infrared spectroscopy (NIRS) to measure brain tissue oxygenation (BtO2) in critically ill patients, to test the hypothesis that poor cerebral oxygen delivery contributes to ICU delirium. Methods: Adult patients were enrolled if they required mechanical ventilation for >24 hours, and/or vasoactive agents. Patients were excluded if they had previous cognitive dysfunction, brain injury on admission, or a life expectancy <24 hours. BtO2 was measured for the first 24 hours of ICU admission. The confusion assessment method-ICU (CAM-ICU) was used to screen for delirium. Participants were designated to one of three groups on the basis of their predominant neurological status (comatose, delirious, or intact). Results: To date, 47 patients have been recruited. Both delirious and comatose patients’ had significantly lower BtO2 levels compared to intact patients (P<0.001). There was a significant correlation between hemoglobin and BtO2 (R2=0.347, P<0.01). However, when correlation analysis was conducted separately amongst the three groups, the delirious patients (R2=0.485, P<0.05) were the strongest contributors to this positive correlation. Conclusions: Delirious patients exhibited the lowest BtO2 recordings and demonstrated a significant association between Hb and BtO2. This study offers potential insight into the pathophysiology of ICU delirium.

150. Arizono et al. (2016). **Functional Connectivity Analysis of NIRS Data under Rubber Hand Illusion to Find a Biomarker of Sense of Ownership**

**Abstract:** The self-identification, which is called sense of ownership, has been researched through methodology of rubber hand illusion (RHI) because of its simple setup. Although studies with neuroimaging technique, such as fMRI, revealed that several brain areas are associated with the sense of ownership, near-infrared spectroscopy (NIRS) has not yet been utilized. Here we introduced an automated setup to induce RHI, measured the brain activity during the RHI with NIRS, and analyzed the functional connectivity so as to understand dynamical brain relationship regarding the sense of ownership. The connectivity was evaluated by multivariate Granger causality. In this experiment, the peaks of oxy-Hb on right frontal and right motor related areas during the illusion were significantly higher compared with those during the nonillusion. Furthermore, by analyzing the NIRS recordings, we found a reliable connectivity from the frontal to the motor related areas during the illusion. This finding suggests that frontal cortex and motor related areas communicate with each other when the sense of ownership is induced. The result suggests that the sense of ownership is related to neural mechanism underlying human motor control, and it would be determining whether motor learning (i.e., neural plasticity) will occur. Thus RHI with the functional connectivity analysis will become an appropriate biomarker for neurorehabilitation.

**Abstract:** We provide a brief overview of the research and clinical applications of near-infrared spectroscopy (NIRS) in the neurorehabilitation field. NIRS has several potential advantages and shortcomings as a neuroimaging tool and is suitable for research application in the rehabilitation field. As one of the main applications of NIRS, we discuss its application as a monitoring tool, including investigating the neural mechanism of functional recovery after brain damage and investigating the neural mechanisms for controlling bipedal locomotion and postural balance in humans. In addition to being a monitoring tool, advances in signal processing techniques allow us to use NIRS as a therapeutic tool in this field. With a brief summary of recent studies investigating the clinical application of NIRS using motor imagery task, we discuss the possible clinical usage of NIRS in brain–computer interface and neurofeedback.

152. Biedrzycka et al. (2016). **Aortic cross-clamping phase of cardiopulmonary bypass is related to decreased microvascular reactivity after short-term ischaemia of the thenar muscle both under intravenous and volatile anaesthesia: a randomized trial**

**Abstract:** OBJECTIVES The purpose of the present study was to assess, by near-infrared spectroscopy with an INVOS oximeter during the vascular occlusion test (VOT), the influence of cardiopulmonary bypass (CPB) on tissue saturation in the thenar muscle. The secondary aim was to compare the effects of propofol and sevoflurane anaesthesia on tissue saturation.

METHODS This was a prospective, randomized, open-label study. Sixty cardiac surgery patients received either propofol or sevoflurane anaesthesia. Three-minute VOT was performed at the following time points: 30 min after anaesthesia induction, directly after sternotomy, 20 and 40 min after aortic cross-clamping, 20 min after aortic cross-clamp removal and 45 min after weaning of cardiopulmonary bypass. Group and time effects on tissue saturation were analysed with RM-ANOVA and the post hoc Tukey test.

RESULTS In both groups at baseline, the lowest and the highest tissue saturation and the rate of saturation recovery during the reperfusion phase of the vascular occlusion test were lower during aortic cross-clamping in comparison to the values before CPB. Lower nadir tissue saturation during ischaemia was observed under propofol in comparison to sevoflurane anaesthesia (P = 0.018).

CONCLUSIONS This study demonstrated that the aortic cross-clamping phase of CPB cardiac surgery is associated with lower values of tissue saturation and a decreased rate of saturation recovery under both propofol and sevoflurane anaesthesia. Aortic cross-clamp release is followed by accelerated tissue desaturation during VOT. Propofol anaesthesia for CPB cardiac surgery results in greater reduction of nadir tissue saturation during the ischaemic phase of VOT in comparison to that of sevoflurane.

153. Hoshi et al. (2016). **Overview of diffuse optical tomography and its clinical applications**

**Abstract:** Near-infrared diffuse optical tomography (DOT), one of the most sophisticated optical imaging techniques for observations through biological tissue, allows 3-D quantitative imaging of optical properties, which include functional and anatomical information. With DOT, it is expected to be possible to overcome the limitations of conventional near-infrared spectroscopy (NIRS) as well as offering the potential for diagnostic optical imaging. However, DOT has been under development for more than 30 years, and the difficulties in development are attributed to the fact that light is strongly scattered and that diffusive photons are used for the image reconstruction. The DOT algorithm is based on the techniques of inverse problems. The radiative transfer equation accurately describes photon propagation in biological tissue, while, because of its high computation load, the diffusion equation (DE) is often used as the forward model. However, the DE is invalid in low-scattering and/or highly absorbing regions and in the vicinity of light sources. The inverse problem is inherently ill-posed and highly undetermined. Here, we first summarize NIRS and then describe various approaches in the efforts to develop accurate and efficient DOT algorithms and present some examples of clinical applications. Finally, we discuss the future prospects of DOT.
154. Ban et al. (2016). **Heterodyne frequency-domain multispectral diffuse optical tomography of breast cancer in the parallel-plane transmission geometry**

**Abstract:** Purpose: The authors introduce a state-of-the-art all-optical clinical diffuse optical tomography (DOT) imaging instrument which collects spatially dense, multispectral, frequency-domain breast data in the parallel-plane geometry. Methods: The instrument utilizes a CCD-based heterodyne detection scheme that permits massively parallel detection of diffuse photon density wave amplitude and phase for a large number of source–detector pairs (106). The stand-alone clinical DOT instrument thus offers high spatial resolution with reduced crosstalk between absorption and scattering. Other novel features include a fringe profilometry system for breast boundary segmentation, real-time data normalization, and a patient bed design which permits both axial and sagittal breast measurements. Results: The authors validated the instrument using tissue simulating phantoms with two different chromophore-containing targets and one scattering target. The authors also demonstrated the instrument in a case study breast cancer patient; the reconstructed 3D image of endogenous chromophores and scattering gave tumor localization in agreement with MRI. Conclusions: Imaging with a novel parallel-plate DOT breast imager that employs highly parallel, high-resolution CCD detection in the frequency-domain was demonstrated.

155. Powell et al. (2016). **Real-time dynamic image reconstruction in time-domain diffuse optical tomography**

**Abstract:** Through application of spatio-temporal regularisation techniques, we demonstrate the real-time three-dimensional dynamic reconstruction of the optical properties of a hemispherical infant head phantom, with moving absorption and scattering targets.

156. Fishell et al. (2016). **Response Reproducibility and Functional Localization using High-Density Diffuse Optical Tomography During Naturalistic Viewing**

**Abstract:** We used optical neuroimaging to record evoked cortical responses during a naturalistic viewing task. We show reproducible responses to movie-evoked responses and more specific activation maps related to processing specific aspects of the stimulus.

157. Bergonzi et al. (2016). **Mapping brain function at the bedside during acute stroke recovery using High-Density Diffuse Optical Tomography**

**Abstract:** Within 72 hours of stroke onset, High-Density Diffuse Optical Tomography can detect disruptions in functional connectivity patterns that significantly differ from healthy subjects (p<1E-5) and that correlate with the NIH Stroke Scale (p<3.3E-4).

158. Lee et al. (2016). **Development of a Rotatable Optical Probe for Trans-rectal Ultrasound Coupled Diffuse Optical Tomography imaging of Prostate Cancer**

**Abstract:** We present a novel design of a rotatable endo-rectal optical probe for prostate cancer imaging, which allows for simultaneous bimodal imaging of diffuse optical tomography (DOT) and trans-rectal ultrasound (TRUS).
159. Farina et al. (2016). **Time-resolved Diffuse Optical Tomography based on Single pixel camera**

**Abstract:** In this work a time-resolved DOT system based on rotating view acquisition and data sampling in compressed illumination/detection space is proposed and implemented. Reconstruction on tissue mimicking phantoms with absorbing inclusions are presented.

160. Farina et al. (2016). **Time-resolved diffuse optical tomography system based on compressive measurements**

**Abstract:** Compressive sensing is a powerful tool to efficiently acquire and reconstruct an image even in Diffuse Optical Tomography (DOT) applications. In this work a time-resolved DOT system based on structured light illumination, compressive detection and multiple views acquisition has been proposed and experimentally validated on a biological tissue-mimicking phantom. The experimental scheme is based on two Digital Micromirror Devices (DMD) for illumination and detection modulation, in combination with a time-resolved single element detector. We fully validated the method and demonstrated both imaging and tomographic capability of the system, providing a state of the art reconstruction quality.

161. Cochran et al. (2016). **Multimodal Structural Priors for Spatially-Dense Diffuse Optical Tomography of Breast Cancer**

**Abstract:** We demonstrate spatially-dense diffuse optical tomographic (DOT) reconstructions of breast cancer utilizing two forms of structural priors: MR images from a concurrent DOT-MRI instrument and fringe-projection profilometry in an optical-only system.

162. Reisman et al. (2016). **Non-Invasive Functional Neuroimaging in the Mouse Using Diffuse Optical Tomography**

**Abstract:** We present a new technique expanding on previous minimally invasive optical intrinsic signal (OIS) imaging methods to perform non-invasive functional neuroimaging in mice using Structured Illumination combined with Diffuse Optical Tomography.

163. Zouaoui et al. (2016). **Time-Resolved Reflectance Diffuse Optical Tomography with Silicon Photomultipliers**

**Abstract:** Time-resolved reflectance diffuse optical tomography on phantoms using Silicon photomultipliers (SiPMs) as detectors was carried out. We infer that SiPMs are promising new detectors to probe and accurately quantify biological tissues.

164. Bouchard et al. (2016). **Preliminary results of a low-cost 4-channel time-correlated single photon counting system for time-domain diffuse optical tomography**

**Abstract:** Time-domain diffuse optical tomography (TD-DOT) provides information-rich data that have not yet been fully exploited for image reconstruction, notably to increase imaging spatial resolution. Current TD-DOT scanners suffer from a very low sensitivity owing to their small number of detection channels. This leads to excessively long acquisition times for in vivo imaging. To obtain a higher number of detection channels, thus increasing detection density, a low-cost time-correlated single photon counting (TCSPC) system dedicated to TD-DOT imaging was designed and developed, resorting solely to off-the-shelf electronic components to reduce costs, in distinction to custom application-specific integrated circuit (ASIC) solutions. It features 4 input channels with a 13.02 ps bin width and a 18.1 ps FWHM accuracy throughout a measurement dynamic range of 12.5 ns. Each channel includes a leading-edge discriminator, with a programmable threshold, for direct interfacing with off-the-shelf photodetector modules. A software-programmable delay line was added to the channel signal path to
compensate for undesired propagation delays. The system also supports a virtually unlimited number of TCSPC channels using a daisy-chain configuration through an onboard Ethernet switch.

165. Hu et al. (2016). **Ambulatory diffuse optical tomography and multimodality physiological monitoring system for muscle and exercise applications**

**Abstract:** Ambulatory diffuse optical tomography (aDOT) is based on near-infrared spectroscopy (NIRS) and enables three-dimensional imaging of regional hemodynamics and oxygen consumption during a person's normal activities. Although NIRS has been previously used for muscle assessment, it has been notably limited in terms of the number of channels measured, the extent to which subjects can be ambulatory, and/or the ability to simultaneously acquire synchronized auxiliary data such as electromyography (EMG) or electrocardiography (ECG). We describe the development of a prototype aDOT system, called NINscan-M, capable of ambulatory tomographic imaging as well as simultaneous auxiliary multimodal physiological monitoring. Powered by four AA size batteries and weighing 577 g, the NINscan-M prototype can synchronously record 64-channel NIRS imaging data, eight channels of EMG, ECG, or other analog signals, plus force, acceleration, rotation, and temperature for 24+ h at up to 250 Hz. We describe the system's design, characterization, and performance characteristics. We also describe examples of isometric, cycle ergometer, and free-running ambulatory exercise to demonstrate tomographic imaging at 25 Hz. NINscan-M represents a multiuse tool for muscle physiology studies as well as clinical muscle assessment.

166. Gunther et al. (2016). **5-Month Monitoring of Tumor Response in Patients with Breast Cancer who undergo Neoadjuvant Therapy with Diffuse Optical Tomography**

**Abstract:** In a clinical pilot study involving patients undergoing neoadjuvant chemotherapy, we explored evidence that diffuse optical tomography can be used to monitor tumor progression and predict treatment response.

167. Jiang et al. (2016). **A miniature probe integrating diffuse optical tomography and electroencephalographic source localization**

**Abstract:** In this work, we proposed a new dual-modal brain-mapping technique based on diffuse optical tomography (DOT) and electroencephalographic source localization (ESL).

168. Shimokawa et al. (2016). **Diffuse optical tomography using multi-directional sources and detectors**

**Abstract:** Diffuse optical tomography (DOT) is an advanced imaging method used to visualize the internal state of biological tissues as 3D images. However, current continuous-wave DOT requires high-density probe arrays for measurement (less than 15-mm interval) to gather enough information for 3D image reconstruction, which makes the experiment time-consuming. In this paper, we propose a novel DOT measurement system using multi-directional light sources and multi-directional photodetectors instead of high-density probe arrays. We evaluated this system’s multi-directional DOT through computer simulation and a phantom experiment. From the results, we achieved DOT with less than 5-mm localization error up to a 15-mm depth with low-density probe arrays (30-mm interval), indicating that the multi-directional measurement approach allows DOT without requiring high-density measurement.
169. Wojtkiewicz et al. (2016). **Towards Optical Tomography of an Adult Human Head**

**Abstract:** We have developed a high-resolution diffuse optical tomography system capable of carrying out measurements on an adult human head at source-detector separations 1.5-11.8 cm. We present first results obtained during a Valsalva maneuver.

170. Gupta et al. (2016). **Pseudo-time Particle Filtering with quasi-Newton steps for Diffuse Optical Tomography**

**Abstract:** A framework is proposed for pseudo-time particle filtering for Diffuse Optical Tomography reconstruction. A fictitious ‘measurement’ equation is employed based on the quasi-Newton steps. The proposed scheme, accelerates convergence and yields substantially reduced sample variance.

171. Li et al. (2016). **Assessment of resting-state brain networks in young and older adults by automatic voxel classification with atlas-guided diffuse optical tomography**

**Abstract:** We implemented an automatic voxel classification algorithm so that atlas-guided DOT and graph theory analysis can be jointly used to assess hemodynamic resting-state brain networks in young and older adults.

172. Vidal-Rosas et al. (2016). **Reproducibility of parameters of postocclusive reactive hyperemia measured by diffuse optical tomography**

**Abstract:** The application of near-infrared spectroscopy (NIRS) to assess microvascular function has shown promising results. An important limitation when using a single source-detector pair, however, is the lack of depth sensitivity. Diffuse optical tomography (DOT) overcomes this limitation using an array of sources and detectors that allow the reconstruction of volumetric hemodynamic changes. This study compares the key parameters of postocclusive reactive hyperemia measured in the forearm using standard NIRS and DOT. We show that while the mean parameter values are similar for the two techniques, DOT achieves much better reproducibility, as measured by the intraclass correlation coefficient (ICC). We show that DOT achieves high reproducibility for muscle oxygen consumption (ICC: 0.99), time to maximal HbO\textsubscript{2} (HbO\textsubscript{2} (ICC: 0.94), maximal HbO\textsubscript{2} HbO\textsubscript{2} (ICC: 0.99), and time to maximal HbT (ICC: 0.99). Absolute reproducibility as measured by the standard error of measurement is consistently smaller and close to zero (ideal value) across all parameters measured by DOT compared to NIRS. We conclude that DOT provides a more robust characterization of the reactive hyperemic response and show how the availability of volumetric hemodynamic changes allows the identification of areas of temporal consistency, which could help characterize more precisely the microvasculature.

173. Taylor et al. (2016). **Development of a Multi-Modal Optical Imaging System**

**Abstract:** A multi-modal optical imaging system is presented which uses diffuse optical tomography to determine subject-specific, heterogeneous tissue attenuation to increase the quantitative accuracy of bioluminescence tomography.

Abstract: A neck model was constructed for the feasibility study of diffuse optical imaging of malignant lesions in the thyroid gland. The light propagation in the thyroid gland is affected by the presence of the trachea.

175. Sun et al. (2016). An improved diffuse optical tomography image reconstruction based on sparse recovery method

Abstract: Diffuse Optical Tomography (DOT) is a noninvasive image detecting technique. It is used to assess spatial variation with absorption and scattering coefficients for tumor detection, distribution of oxygen concentration analysis, oxygenated hemoglobin concentration measurement or deoxygenated hemoglobin concentration measurement. In this paper, we use sparse recovery methods for DOT image reconstruction. Using the non-linear iterative method to reconstruct the DOT image can increase the resolution of each reconstructed layer. Sparse recovery methods use the p-norm in the evaluation question in 0 <; p <; =1. When the amount of independent gauge is limited by normal, which is a basic example for diffuse optical tomographic image reconstruction, sparse recovery methods present good performance.

176. Potlov et al. (2016). Forward Problem of Time-Resolved Diffuse Optical Tomography Considering Biological Tissue Deformation

Abstract: Regularities of photon density normalized maximum (PDNM) movement in deformed and undeformed media with tissue like biological and mechanical properties are described. It has been demonstrated that in all homogeneous cases PDNM moves to the geometric center of the object, regardless of the presence or absence of deformation of the investigated object. In presence of a single absorbing inhomogeneity PDNM moves toward the point symmetric to its geometric center. In presence of a single scattering inhomogeneity PDNM moves toward the center of it. Diffuse transmittance intensity decay in undeformed objects is 8–10 % faster than in those with deformations.

177. Pichette et al. (2016). Increasing the count rate of time-correlated single photon counting techniques with immersion lenses on single photon avalanche diodes

Abstract: We demonstrate the benefits of affixing a high index hemispherical immersion lens on the photosensitive surface of single photon avalanche diodes (SPADs) for time-correlated single photon counting (TCSPC). The goal of this work was to increase the photon counting rate of a non-contact time-domain diffuse optical tomography (TD-DOT) scanner for intrinsic and fluorescence measurements. Zemax simulations have also been carried out and are in good agreement with the experimental data. We believe that this technology can also be used in other applications of TCSPC such as microscopy.


Abstract: A continuous-wave diffuse optical tomography system using lock-in-photon-counting detection was developed. The experimental results demonstrate a significant advancement in detecting weak light signals from the multiple wavelengths in parallel.
179. Konovalov et al. (2016). **Diffuse optical mammotomography: state-of-the-art and prospects**

**Abstract:** The principles of diffuse optical tomography (DOT) of tissues are presented. The DOT capabilities as a method of breast cancer diagnostics are analysed. The state-of-the-art of the DOT instrumentation and methodological base in application to solving the mammography problems are described. The significant contribution of Russian scientists to the development of the DOT methodology is emphasised. Basing on the results of the analysis, the authors expect the possibility of soonest entry of diffuse optical mammotomographs to the market of medical imaging instrumentation, and the capability of Russian researchers to take part in the competition for this market.

180. Kazanci et al. (2016). **Diffuse light tomography to detect blood vessels using Tikhonov regularization**

**Abstract:** Detection of blood vessels within light-scattering tissues involves detection of subtle shadows as blood absorbs light. These shadows are diffuse but measurable by a set of source-detector pairs in a spatial array of sources and detectors on the tissue surface. The measured shadows can reconstruct the internal position(s) of blood vessels. The tomographic method involves a set of Ns sources and Nd detectors such that Nsd = Ns x Nd source-detector pairs produce Nsd measurements, each interrogating the tissue with a unique perspective, i.e., a unique region of sensitivity to voxels within the tissue. This tutorial report describes the reconstruction of the image of a blood vessel within a soft tissue based on such source-detector measurements, by solving a matrix equation using Tikhonov regularization. This is not a novel contribution, but rather a simple introduction to a well-known method, demonstrating its use in mapping blood perfusion.

181. Carp et al. (2016). **Impact of errors in optical properties and/or geometry on the recovery of cerebral blood flow using diffuse correlation spectroscopy**

**Abstract:** We use a layered Monte Carlo model of diffuse correlation spectroscopy measurements to assess the impact of errors in optical properties and/or geometry on the recovery of cerebral blood flow using single or multi-distance measurements.

182. Feng et al. (2016). **Direct Soft Prior Regularization in NIR Spectral Tomography from MRI-contrast and Distance-constraints, for Segmentation-free Reconstruction**

**Abstract:** Results of simulation and patient image reconstructions showed that a distance-constrained direct regularization can improve MRI guided near-infrared breast image quality in terms of less artifacts and higher HbT contrast of tumor to normal tissue.

183. Yao et al. (2016). **Enabling wide-field illumination and detection in mesh-based Monte Carlo simulations**

**Abstract:** We propose a generalized mesh-based Monte Carlo approach that supports various wide-field sources and free-space detectors. Simulations and phantom studies are performed to demonstrate the flexibility, efficiency and accuracy of our algorithm.
184. Hoi et al. (2016). A Non-Contact Fiber-Less Diffuse Optical Tomographic System for Dynamic Imaging of the Feet with Peripheral Artery Disease

Abstract: We present a new design for a non-contact fiber-free diffuse optical tomography system capable of simultaneously capturing multiple views of feet for dynamic imaging of foot vasculature.

185. Clancy et al. (2016). Monitoring the Injured Brain-High density near infrared probes and registered atlas models improve cerebral saturation recovery

Abstract: High density near infrared probes and registered subject specific head models are used to show the potential improvements to the quantitative accuracy of recovered parameters relevant to monitoring an injured brain.

186. Mostafa et al. (2016). Extraction of Tumor Features from Ultrasound Images for Diffused Optical Tomography Reconstruction

Abstract: An advanced ultrasound segmentation algorithm is presented here that extracts breast lesion information for co-registered diffused optical tomography and inputs these parameters to improve reconstruction of lesion absorption maps.

187. Shang et al. (2016). Recent Advances in Optical Spectroscopic and Imaging Methods for Medicine and Biology

Abstract: not available.

188. Jha et al. (2016). Incorporating Boundary Conditions in the Integral Form of the Radiative Transfer Equation for Transcranial Imaging

Abstract: An integral Neumann-series implementation of the Radiative Transfer Equation that accounts for boundary conditions is proposed to simulate photon transport through tissue for transcranial optical imaging.


Abstract: In this review, we describe the phenomenon of intra-cranial hemorrhage (ICH), which occurs spontaneously within the first 2-3 days of life in full-term newborns without any clinical symptoms, but with long-term neurological outcomes in many cases. We give the estimated frequency and possible mechanisms responsible for silent ICH with main focus on the cerebral blood flow (CBF) and oxygenation measurements using noninvasive optical methods. We overview the current multi-modal technologies that are widely used in clinics and experiments for the study of ICH during the first days of life: magnetic resonance imaging, ultrasonography, cerebral oximetry based on near infrared spectroscopy, as well as laser speckle imaging and diffuse correlation spectroscopy as a priority technology for experimental study of cerebral hemodynamics. We discuss the advantages and disadvantages of these methods. We identify key trends in experimental works and show areas for future research of ICH in term newborns. Future studies will help to improve our ability to optimize prognosis, diagnosis, and treatment of asymptomatic neonates with silent ICH.
191. Spinelli et al. (2016). **Optical property reconstruction of a two-layer diffusive medium from single-distance time-resolved measurements**

**Abstract:** We robustly and accurately estimated the absorption coefficient of the second layer in a two-layer tissue phantom by applying an optimal estimation method, including a priori information, to single-distance time-resolved measurements.

192. Marone et al. (2016). **Effects of Posture and Heart Rate Changes on Optical Tomographic Imaging of the Peripheral Arteries**

**Abstract:** Modeling the foot vasculature during a thigh cuff inflation provided a better understanding of the reconstruction results from Vascular Optical Tomography. Effects of posture and heart rate changes were modeled and compared to experimental results.

193. Ettehadi et al. (2016). **Comparison of gradient-based techniques for chromophore concentration reconstruction**

**Abstract:** We compare different gradient-based methods to reconstruct chromophore and scatterer concentrations simultaneously by multispectral CW diffuse optic tomography. Adjoint theory is used to calculate the gradient in the optimization problem.

194. Sekar et al. (2016). **Broadband (600–1350 nm) Time-Resolved Diffuse Optical Spectrometer for Clinical Use**

**Abstract:** We report on the design, development, and performance assessment of a portable time-resolved system measuring absorption and scattering spectra of highly diffusive media over the 600-1350 nm range. In view of clinical use, two strategies were implemented; the first one equips the system with high responsivity in key tissue absorbing regions, whereas the second one makes the system immune to time drift. The MEDPHOT protocol was used for the performance assessment of the instrument. Finally, the system was enrolled into its first in vivo trial phase, measuring the broadband absorption and scattering spectra of human manubrium, abdomen fat tissues, and forehead for the in vivo quantification of key tissue constituents.

195. Tsuzuki et al. (2016). **MinR 10/20 system: Quantitative and reproducible cranial landmark setting method for MRI based on minimum initial reference points**

**Abstract:** Background. The international 10/20 system is not only a fundamental method for describing positioning for electroencephalography (EEG), but also provides intermediate cranial landmarks for the probabilistic spatial registration methods that use a reference-MRI database. However, the presence of the inion, one of the four initial reference landmarks of the international 10/20 system, is inconspicuous and can be difficult to locate on MRIs. New method. The MinR 10/20 system utilizes only three initial reference points, the nasion (Nz) and the right and left preauricular points (AR and AL), but does not employ the inion (Iz). With the MinR 10/20 system, first the most posterior point on the occipital protuberance, IIz (Imitated Iz), is identified as an exploratory alternative to the Iz point. Next, the other landmarks are calculated according to the conventional international 10/20 system referring to these four reference points (Nz, AL, AR and IIz). Results. Holistic tendencies for landmark position estimations on the heads and cortices in MNI space did not vary greatly between MinR and international 10/20 systems. Comparison with existing methods. A comparison of MinR and international 10/20 systems applied to seventeen adult head MRIs revealed little variance in holistic tendencies for landmark position estimations on head and cortex surfaces in the MNI coordinate system.
Furthermore, variability was smaller with the MinR 10/20 system than with the conventional international 10/20 system. Conclusions. The MinR 10/20 system proved to be a practical alternative to the conventional international 10/20 system in modern computational spatial analysis for scalp-based brain mapping methods.


**Abstract:** Abstract not available.

197. Cooper (2016). **Diffuse Optical Imaging Methodologies in the Neonatal Intensive Care Unit**

**Abstract:** I will describe the studies underway at neoLAB (UCL-Cambridge) that are developing CW- and TR-DOT approaches to investigate the haemodynamic correlates of neurological injury and abnormal electrocortical activity (seizures and discontinuous EEG) in term-age infants.


**Abstract:** We recently showed how the correlations of a broadband and incoherent wave-field can directly yield the time-dependent Green's functions between scatterers of a complex medium [Badon et al., Phys. Rev. Lett., 2015]. In this study, we apply this approach to the imaging of optical transport properties in complex media. A parallel measurement of millions of Green's functions at the surface of several strongly scattering samples (ZnO, TiO2, Teflon tape) is performed. A statistical analysis of this Green's matrix allows to investigate locally the spatio-temporal evolution of the diffusive halo within the scattering sample. An image of diffusion tensor is then obtained. It allows to map quantitatively the local concentration of scatterers and their anisotropy within the scattering medium. The next step of this work is to test this approach on biological tissues and illustrate how it can provide an elegant and powerful alternative to diffuse optical imaging techniques.

199. Anderson et al. (2016). **Optical Mammography: Imaging breast cancer response to neoadjuvant chemotherapy**

**Abstract:** Optical mammograms were obtained on 7 patients undergoing neoadjuvant chemotherapy. When therapy was 30% complete, patients achieving a high pathologic response had a lower oxy-hemoglobin decrease compared to those with extensive disease remaining.

200. Tabassum et al. (2016). **Longitudinal Monitoring of Therapy Response in a Preclinical Model using Spatial Frequency Domain Imaging**

**Abstract:** We present here a proof-of-concept longitudinal study of cytotoxic and antiangiogenic therapy response in a preclinical model using Spatial Frequency Domain Imaging. Significant changes in optical scattering and hemoglobin were observed in tumors.
201. Martinenghi et al. (2016). **Large area silicon photomultipliers allow extreme depth penetration in time-domain diffuse optics**

**Abstract:** We present the design of a novel single-photon timing module, based on a Silicon Photomultiplier (SiPM) featuring a collection area of 9 mm². The module performs Single-Photon Timing Resolution of about 140 ps, thus being suitable for diffuse optics application. The small size of the instrument (5 cm × 4 cm × 10 cm) allows placing it directly in contact with the sample under investigation, maximizing that way the signal harvesting. Thanks to that, it is possible to increase the source detector distance up to 6 cm or more, therefore enhancing the penetration depth up to an impressive value of 4 cm and paving the way to the exploration of the deepest human body structures in a completely non-invasive approach.

202. Czarske (2016). **Lensless endoscopic light delivery of individually addressable channels using a multimode fiber**

**Abstract:** We demonstrate asynchronous information transmission through a multimode fiber using different windows of a single spatial light modulator. Our findings pave the way towards individual diffuse optical imaging in deep biological tissue.


**Abstract:** The accuracy of signals recorded from different electrode/optode arrangements in EEG-fNIRS experiments are examined. Results are particularly important for studies investigating spatiotemporal relation between neuronal activity and vascular response.

204. Bentz et al. (2016). **Design and Fabrication of Printed Optical Phantoms for Deep Tissue Imaging**

**Abstract:** We demonstrate optical imaging in physiologically realistic phantoms with controlled optical properties fabricated using 3D printing. Our method is adaptable to many optical imaging methods, and can be used for calibration of live animal data.

205. Yao et al. (2016). **Generalized mesh-based Monte Carlo for wide-field illumination and detection via mesh retessellation**

**Abstract:** Monte Carlo methods are commonly used as the gold standard in modeling photon transport through turbid media. With the rapid development of structured light applications, an accurate and efficient method capable of simulating arbitrary illumination patterns and complex detection schemes over large surface area is in great need. Here we report a generalized mesh-based Monte Carlo algorithm to support a variety of wide-field illumination methods, including spatial-frequency-domain imaging (SFDI) patterns and arbitrary 2-D patterns. The extended algorithm can also model wide-field detectors such as a free-space CCD camera. The significantly enhanced flexibility of source and detector modeling is achieved via a fast mesh retessellation process that combines the target domain and the source/detector space in a single tetrahedral mesh. Both simulations of complex domains and comparisons with phantom measurements are included to demonstrate the flexibility, efficiency and accuracy of the extended algorithm. Our updated open-source software is provided at http://mcx.space/mmc.
206. Zhao et al. (2016). **Portable, parallel 9-wavelength near-infrared spectral tomography (NIRST) system for efficient characterization of breast cancer within the clinical oncology infusion suite**

**Abstract:** A portable near-infrared spectral tomography (NIRST) system was developed with simultaneous frequency domain (FD) and continuous-wave (CW) optical measurements for efficient characterization of breast cancer in a clinical oncology setting. Simultaneous FD and CW recordings were implemented to speed up acquisition to 3 minutes for all 9 wavelengths, spanning a range from 661nm to 1064nm. An adjustable interface was designed to fit various breast sizes and shapes. Spatial images of oxy- and deoxy-hemoglobin, water, lipid, and scattering components were reconstructed using a 2D FEM approach. The system was tested on a group of 10 normal subjects, who were examined bilaterally and the recovered optical images were compared to radiographic breast density. Significantly higher total hemoglobin and water were estimated in the high density relative to low density groups. One patient with invasive ductal carcinoma was also examined and the cancer region was characterized as having a contrast ratio of 1.4 in total hemoglobin and 1.2 in water.

207. Shokoufi et al. (2016). **Development of a handheld diffuse optical breast cancer assessment probe**

**Abstract:** Diffuse Optical Spectroscopy (DOS) is a promising non-invasive and non-ionizing technique for breast anomaly detection. In this study, we have developed a new handheld DOS probe to measure optical properties of breast tissue. In the proposed probe, the breast tissue is illuminated with four near infrared (NIR) wavelengths light emitting diodes (LED), which are encapsulated in a package (eLEDs), and two PIN photodiodes measure the intensity of the scattered photons at two different locations. The proposed technique of using eLEDs is introduced, in order to have a multi-wavelength pointed-beam illumination source instead of using the laser-coupled fiber-optic technique, which increases the complexity, size, and cost of the probe. Despite the fact that the proposed technique miniaturizes the probe and reduces the complexity of the DOS, the study proves that it is accurate and reliable in measuring optical properties of the tissue. The measurements are performed at the rate of 10 Hz which is suitable for dynamic measurement of biological activity, in-vivo. The multi-spectral evaluation algorithm is used to reconstruct four main absorber concentrations in the breast including oxy-hemoglobin (cHb), deoxy-hemoglobin (cHbO2), water (cH2O), fat (cFat), and average scattering coefficient of the medium, as well as concentration changes in Hb (ΔcHb) and HbO2 (ΔcHbO2). Although the probe is designed for breast cancer diagnosis, it can be used in a wide range of applications for both static and dynamic measurements such as functional brain imaging. A series of phantoms, comprised of Delrin®, Intralipid®, PierceTM and Black ink, are used to verify performance of the device. The probe will be tested on human subjects, in-vivo, in the next phase.

208. Bumstead et al. (2016). **Cerebral functional connectivity and Mayer waves in mice: Phenomena and separability**

**Abstract:** Resting-state functional connectivity is a growing neuroimaging approach that analyses the spatiotemporal structure of spontaneous brain activity, often using low-frequency (<0.08 Hz) hemodynamics. In addition to these fluctuations, there are two other low-frequency hemodynamic oscillations in a nearby spectral region (0.1–0.4 Hz) that have been reported in the brain: vasomotion and Mayer waves. Despite how close in frequency these phenomena exist, there is little research on how vasomotion and Mayer waves are related to or affect resting-state functional connectivity. In this study, we analyze spontaneous hemodynamic fluctuations over the mouse cortex using optical intrinsic signal imaging. We found spontaneous occurrence of oscillatory hemodynamics ~0.2 Hz consistent with the properties of Mayer waves reported in the literature. Across a group of mice (n = 19), there was a large variability in the magnitude of Mayer waves. However, regardless of the magnitude of Mayer waves, functional connectivity patterns could be recovered from hemodynamic signals when filtered to the lower frequency band, 0.01–0.08 Hz. Our results demonstrate that both Mayer waves and resting-state functional connectivity patterns can co-exist simultaneously, and that they can be separated by applying bandpass filters.
209. Holper et al. (2016). **Short-term pulse rate variability is better characterized by functional near-infrared spectroscopy than by photoplethysmography**

**Abstract:** Pulse rate variability (PRV) can be extracted from functional near-infrared spectroscopy (fNIRS) (PRV\(_{\text{NIRS}}\)) and photoplethysmography (PPG) (PRV\(_{\text{PPG}}\)) signals. The present study compared the accuracy of simultaneously acquired PRV\(_{\text{NIRS}}\) and PRV\(_{\text{PPG}}\), and evaluated their different characterizations of the sympathetic (SNS) and parasympathetic (PSNS) autonomous nervous system activity. Ten healthy subjects were recorded during resting-state (RS) and respiratory challenges in two temperature conditions, i.e., room temperature (23°C) and cold temperature (4°C). PRV\(_{\text{NIRS}}\) was recorded based on fNIRS measurement on the head, whereas PRV\(_{\text{PPG}}\) was determined based on PPG measured at the finger. Accuracy between PRV\(_{\text{NIRS}}\) and PRV\(_{\text{PPG}}\), as assessed by cross-covariance and cross-sample entropy, demonstrated a high degree of correlation (r>0.9), which was significantly reduced by respiration and cold temperature. Characterization of SNS and PSNS using frequency-domain, time-domain, and nonlinear methods showed that PRV\(_{\text{NIRS}}\) provided significantly better information on increasing PSNS activity in response to respiration and cold temperature than PRV\(_{\text{PPG}}\). The findings show that PRV\(_{\text{NIRS}}\) may outperform PRV\(_{\text{PPG}}\) under conditions in which respiration and temperature changes are present, and may, therefore, be advantageous in research and clinical settings, especially if characterization of the autonomous nervous system is desired.


**Abstract:** BACKGROUND: The SafeBoosC phase II multicentre randomized clinical trial investigated the benefits and harms of monitoring cerebral oxygenation by near-infrared spectroscopy (NIRS) combined with an evidence-based treatment guideline vs. no NIRS data and treatment as usual in the control group during the first 72 h of life. The trial demonstrated a significant reduction in the burden of cerebral hypoxia in the experimental group. We now report the blindly assessed and analyzed treatment effects on electroencephalographic (EEG) outcomes (burst rate and spectral edge frequency 95% (SEF95)) and blood biomarkers of brain injury (S100β, brain fatty acid-binding protein, and neuroketal).

**METHODS:** One hundred and sixty-six extremely preterm infants were randomized to either experimental or control group. EEG was recorded at 64 h of age and blood samples were collected at 6 and 64 h of age.

**RESULTS:** One hundred and thirty-three EEGs were evaluated. The two groups did not differ regarding burst rates (experimental 7.2 vs. control 7.7 burst/min) or SEF95 (experimental 18.1 vs. control 18.0 Hz). The two groups did not differ regarding blood S100β, brain fatty acid-binding protein, and neuroketal concentrations at 6 and 64 h (n = 123 participants).

**CONCLUSION:** Treatment guided by NIRS reduced the cerebral burden of hypoxia without affecting EEG or the selected blood biomarkers.