fNIRS publications on PubMed: Oct 1, 2019 - Feb 29, 2020

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Methodology. Searches were made in PubMed constraining the search period between Oct 1, 2019 and Feb 29, 2020. These were later processed for readability but no records were otherwise added or removed. In the preparation of this file, the following searches have been executed:

- fNIRS

Cerebral Oxygenation Reserve: The Relationship Between Physical Activity Level and the Cognitive Load During a Stroop Task in Healthy Young Males.
Goenarjo R, Bosquet L, Berryman N, Metier V, Perrochon A, Fraser SA, Dupuy O.
Int J Environ Res Public Health. Feb 21;17(4). pii: E
doi: 10.3390/ijerph17041406.

Introduction: Many studies have reported that regular physical activity is positively associated with cognitive performance and more selectively with executive functions. However, some studies reported that the association of physical activity on executive performance in younger adults was not as clearly established when compared to studies with older adults. Among the many physiological mechanisms that may influence cognitive functioning, prefrontal (PFC) oxygenation seems to play a major role. The aim of the current study was to assess whether executive function and prefrontal oxygenation are dependent on physical activity levels (active versus inactive) in healthy young males. Methods: Fifty-six healthy young males (22.1 $\pm$ 2.4 years) were classified as active (n = 26) or inactive (n = 30) according to the recommendations made by the World Health Organization (WHO) and using the Global Physical Activity Questionnaire (GPAQ). Bilateral PFC oxygenation was assessed using functional near-infrared spectroscopy

(fNIRS) during a computerized Stroop task (which included naming, inhibition, and switching conditions). Accuracy (% of correct responses) and reaction times (ms) were used as behavioural indicators of cognitive performances. Changes in oxygenated (ΔHbO2) and deoxygenated (ΔHHb) hemoglobin were measured to capture neural changes. Several two-way repeated measures ANOVAs (Physical activity level x Stroop conditions) were performed to test the null hypothesis of an absence of interaction between physical activity level and executive performance in prefrontal oxygenation. Results: The analysis revealed an interaction between physical activity level and Stroop conditions on reaction time ($p = 0.04$; ES = 0.7) in which physical activity level had a moderate effect on reaction time in the switching condition ($p = 0.02$; ES = 0.8) but not in naming and inhibition conditions. At the neural level, a significant interaction between physical activity level and prefrontal oxygenation was found. Physical activity level had a large effect on ΔHbO2 in the switching condition in the right PFC ($p = 0.04$; ES = 0.8) and left PFC ($p = 0.02$; ES = 0.96), but not in other conditions. A large physical activity level effect was also found on ΔHHb in the inhibition condition in the right PFC ($p < 0.01$; ES = 0.9), but not in the left PFC or other conditions. Conclusion: The results of this cross-sectional study indicate that active young males performed better in executive tasks than their inactive counterparts and had a larger change in oxygenation in the PFC during these most complex conditions.

The neural correlates of reaching focal points.

Chowdhury A, Liu C, Yu R.

Neuropsychologia. Feb 19:
doi: 10.1016/j.neuropsychologia.2020.[Epub ahead of print]

In pure-coordination games where there are multiple Nash equilibria, the selection of coordinated responses is inexplicable by rational-choice theory - yet coordination is ubiquitous in daily interactions. The psychological game theory therefore evokes the idea of focal-points: some equilibria being chosen due to its salience, as well as through predicting (i.e., mentalizing) other's response. Previous work has been limited to investigating how structural atrophy relates to deficits in coordination, or how brain activations differ between intuitive and deliberated coordination. In this study, we investigated how the strategy of coordination is reflected in the brain, compared to when no coordination is required. Using functional near-infrared spectroscopy (fNIRS), we examined the neural correlates of deriving a response

to a category where participants had to either answer freely (i.e., a survey) or try to match their response with another participant (i.e., coordinate). We found that the coordination trials elicited significantly larger changes in oxyhemoglobin [HbO] concentration than survey trials in frontopolar and lateral prefrontal cortex (PFC). Individual differences in behavioral focal index was significantly correlated with [HbO] concentration in lateral PFC. Granger Causality (GC) analysis revealed greater effective connectivity from frontopolar to lateral PFC, and less GC from lateral PFC to frontopolar in the coordination condition. Our findings highlight the crucial role of frontopolar and lateral PFC in human coordination.

Detecting self-paced walking intention based on fNIRS technology for the development of BCI.

Li C, Xu J, Zhu Y, Kuang S, Qu W, Sun L.

Med Biol Eng Comput. Feb
doi: 10.1007/s11517-020-02140-w. [Epub ahead of print]

Since more and more elderly people suffer from lower extremity movement problems, it is of great social significance to assist persons with motor dysfunction to walk independently again and reduce the burden on caregivers. The self-paced walking intention, which could increase the ability of self-control on the start and stop of motion, was studied by applying brain-computer interface (BCI) technology, a novel research field. The cerebral hemoglobin signal, which was obtained from 30 subjects by applying functional near-infrared spectroscopy (fNIRS) technology, was processed to detect self-paced walking intention in this paper. Teager-Kaiser energy was extracted at each sampling point for five sub-bands (0.0095 0.021 Hz, 0.021 0.052 Hz, 0.052 0.145 Hz, 0.145 0.6 Hz, and 0.6 2.0 Hz). Gradient boosting decision tree (GBDT) was then utilized to establish the detecting model in real-time. The proposed method had a good performance to detect the walking intention and passed the pseudo-online test with a true positive rate of 100% (80/80), a false positive rate of 2.91% (4822/165171), and a detection latency of 0.39 ± 1.06 s. GBDT method had an area under the curve value of 0.944 and was 0.125 ($p < 0.001$) higher than linear discriminant analysis (LDA). The results reflected that it is feasible to decode self-paced walking intention by applying fNIRS technology. This study lays a foundation for applying fNIRS-based BCI technology to control walking assistive devices practically. Graphical abstract Graphical representation of the detecting process for pseudo-online test. The lower figure is a partial

enlargement of the upper figure. In the lower figure, the blue line represents the probability of walking predicted by GBDT without smoothing and the orange-red line represents the smoothed probability. The dark-red ellipse shows the effect of the smoothing-threshold method.

Prefrontal Consolidation and Compensation as a Function of Wearing Denture in Partially Edentulous Elderly Patients.

Narita N, Ishii T, Iwaki S, Kamiya K, Okubo M, Uchida T, Kantake I, Shibutani K.

Front Aging Neurosci. Jan 31;11:
doi: 10.3389/fnagi.2019.00375. eCollection 2019.

Background: The cognitive effects of wearing a denture are not well understood. This study was conducted to clarify the effects of denture use on prefrontal and chewing muscle activities, occlusal state, and subjective chewing ability in partially edentulous elderly individuals. Methods: A total of 16 partially edentulous patients were enrolled. Chewing-related prefrontal cortex and jaw muscle activities were simultaneously examined using a functional near-infrared spectroscopy (fNIRS) device and electromyography, under the conditions of unwearing, and wearing a denture. Occlusal state and masticatory score were also determined under both conditions. Using multiple linear regression analysis, associations between prefrontal and chewing activities with wearing were examined using change rates. Results: Chewing rhythmicity was maintained under both conditions. As compared with unwearing, the wearing condition was associated with improved prefrontal cortex and chewing muscle activities, occlusal state in regard to force and area, and masticatory score. Also, prefrontal activities were positively associated with burst duration and peak amplitude in masseter (Mm) and temporal muscle activities, as well as masticatory scores. In contrast, prefrontal activities were negatively associated with occlusal force. Conclusion: Wearing a denture induced a positive association between burst duration and peak amplitude in Mm and temporal muscle activities and prefrontal activity, which may indicate a parallel consolidation of prefrontal cortex and rhythmical chewing activities, as well as masticatory scores. On the other hand, denture use induced a negative association of occlusal force with prefrontal activities, which might suggest that prefrontal compensative associations for the physiocognitive acquisition depended on biomechanical efficacy gained by wearing a denture.

Atypical Dynamic-Connectivity Recruitment in Attention-Deficit/Hyperactivity Disorder Children: An Insight Into Task-Based Dynamic Connectivity Through an fNIRS Study.

Sutoko S, Monden Y, Tokuda T, Ikeda T, Nagashima M, Funane T, Atsumori H, Kiguchi M, Maki A, Yamagata T, Dan I.

Front Hum Neurosci. Jan 31;14:
doi: 10.3389/fnhum.2020.eCollection 2020.

Connectivity between brain regions has been redefined beyond a stationary state. Even when a person is in a resting state, brain connectivity dynamically shifts. However, shifted brain connectivity under externally evoked stimulus is still little understood. The current study, therefore, focuses on task-based dynamic functional-connectivity (FC) analysis of brain signals measured by functional near-infrared spectroscopy (fNIRS). We hypothesize that a stimulus may influence not only brain connectivity but also the occurrence probabilities of task-related and task-irrelevant connectivity states. fNIRS measurement (of the prefrontal-to-inferior parietal lobes) was conducted on 21 typically developing (TD) and 21 age-matched attention-deficit/hyperactivity disorder (ADHD) children performing an inhibitory control task, namely, the Go/No-Go (GNG) task. It has been reported that ADHD children lack inhibitory control; differences between TD and ADHD children in terms of task-based dynamic FC were also evaluated. Four connectivity states were found to occur during the temporal task course. Two dominant connectivity states (states 1 and 2) are characterized by strong connectivities within the frontoparietal network (occurrence probabilities of 40%-56% and 26%-29%), and presumptively interpreted as task-related states. A connectivity state (state 3) shows strong connectivities in the bilateral medial frontal-to-parietal cortices (occurrence probability of 7-15%). The strong connectivities were found at the overlapped regions related the default mode network (DMN). Another connectivity state (state 4) visualizes strong connectivities in all measured regions (occurrence probability of 10%-16%). A global effect coming from cerebral vascular may highly influence this connectivity state. During the GNG stimulus interval, the ADHD children tended to show decreased occurrence probability of the dominant connectivity state and increased occurrence probability of other connectivity states (states 3 and 4). Bringing a new perspective to explain neuropathophysiology, these findings suggest atypical dynamic network recruitment to accommodate task demands in ADHD children.

Resting-State Functional Connectivity Estimated With Hierarchical Bayesian Diffuse Optical Tomography.

Aihara T, Shimokawa T, Ogawa T, Okada Y, Ishikawa A, Inoue Y, Yamashita O.

Front Neurosci. Jan 31;14:
doi: 10.3389/fnins.2020.eCollection 2020.

Resting-state functional connectivity (RSFC) has been generally assessed with functional magnetic resonance imaging (fMRI) thanks to its high spatial resolution. However, fMRI has several disadvantages such as high cost and low portability. In addition, fMRI may not be appropriate for people with metal or electronic implants in their bodies, with claustrophobia and who are pregnant. Diffuse optical tomography (DOT), a method of neuroimaging using functional near-infrared spectroscopy (fNIRS) to reconstruct three-dimensional brain activity images, offers a non-invasive alternative, because fNIRS as well as fMRI measures changes in deoxygenated hemoglobin concentrations and, in addition, fNIRS is free of above disadvantages. We recently proposed a hierarchical Bayesian (HB) DOT algorithm and verified its performance in terms of task-related brain responses. In this study, we attempted to evaluate the HB DOT in terms of estimating RSFC. In 20 healthy males (21-38 years old), 10 min of resting-state data was acquired with 3T MRI scanner or high-density NIRS on different days. The NIRS channels consisted of 96 long (29-mm) source-detector (SD) channels and 56 short (13-mm) SD channels, which covered bilateral frontal and parietal areas. There were one and two resting-state runs in the fMRI and fNIRS experiments, respectively. The reconstruction performances of our algorithm and the two currently prevailing algorithms for DOT were evaluated using fMRI signals as a reference. Compared with the currently prevailing algorithms, our HB algorithm showed better performances in both the similarity to fMRI data and inter-run reproducibility, in terms of estimating the RSFC.

The Hemodynamic Mass Action of a Central Pattern Generator.

Moreno-Castillo M, Meza R, Romero-Vaca J, Huidobro N, Méndez-Fernández A, Martínez-Castillo J, Mabil P, Flores A, Manjarrez E.

Front Neurosci. Jan 31;14:

doi: 10.3389/fnins.2020.eCollection 2020.

The hemodynamic response is a neurovascular and metabolic process in which there is rapid delivery of blood flow to a neuronal tissue in response to neuronal activation. The functional magnetic resonance imaging (fMRI) and the functional near-infrared spectroscopy (fNIRS), for instance, are based on the physiological principles of such hemodynamic responses. Both techniques allow the mapping of active neuronal regions in which the neurovascular and metabolic events are occurring. However, although both techniques have revolutionized the neurosciences, they are mostly employed for neuroimaging of the human brain but not for the spinal cord during functional tasks. Moreover, little is known about other techniques measuring the hemodynamic response in the spinal cord. The purpose of the present study was to show for the first time that a simple optical system termed direct current photoplethysmography (DC-PPG) can be employed to detect hemodynamic responses of the spinal cord and the brainstem during the functional activation of the spinal central pattern generator (CPG). In particular, we positioned two DC-PPG systems directly on the brainstem and spinal cord during fictive scratching in the cat. The optical DC-PPG systems allowed the trial-by-trial recording of massive hemodynamic signals. We found that the "strength" of the flexor-plus-extensor motoneuron activities during motor episodes of fictive scratching was significantly correlated to the "strengths" of the brainstem and spinal DC-PPG signals. Because the DC-PPG was robustly detected in real-time, we claim that such a functional signal reflects the hemodynamic mass action of the brainstem and spinal cord associated with the CPG motor action. Our findings shed light on an unexplored hemodynamic observable of the spinal CPGs, providing a proof of concept that the DC-PPG can be used for the assessment of the integrity of the human CPGs.

Effects of Processing Methods on fNIRS Signals Assessed During Active Walking Tasks in Older Adults.

Izzetoglu M, Holtzer R.

IEEE Trans Neural Syst Rehabil Eng. Feb
doi: 10.1109/TNSRE.2020.2970407. [Epub ahead of print]
DOI: 10.1109/TNSRE.2020.2970407 PMID: 32070987

Instructor-learner brain coupling discriminates between instructional approaches and predicts learning.

Pan Y, Dikker S, Goldstein P, Zhu Y, Yang C, Hu Y.

Neuroimage. Feb 15;211:
doi: 10.1016/j.neuroimage.2020.[Epub ahead of print]

The neural mechanisms that support naturalistic learning via effective pedagogical approaches remain elusive. Here we used functional near-infrared spectroscopy to measure brain activity from instructor-learner dyads simultaneously during dynamic conceptual learning. Results revealed that brain-to-brain coupling was correlated with learning outcomes, and, crucially, appeared to be driven by specific scaffolding behaviors on the part of the instructors (e.g., asking guiding questions or providing hints). Brain-to-brain coupling enhancement was absent when instructors used an explanation approach (e.g., providing definitions or clarifications). Finally, we found that machine-learning techniques were more successful when decoding instructional approaches (scaffolding vs. explanation) from brain-to-brain coupling data than when using a single-brain method. These findings suggest that brain-to-brain coupling as a pedagogically relevant measure tracks the naturalistic instructional process during instructor-learner interaction throughout constructive engagement, but not information clarification.

Self-other overlap and interpersonal neural synchronization serially mediate the effect of behavioral synchronization on prosociality.

Feng X, Sun B, Chen C, Li W, Wang Y, Zhang W, Xiao W, Shao Y.

Soc Cogn Affect Neurosci. Feb pii: nsaa
doi: 10.1093/scan/nsaa017. [Epub ahead of print]

Behavioral synchronization has been found to facilitate social bonding and prosociality but the neural mechanisms underlying such effects are not well understood. In the current study, 60 dyads were hyperscanned using functional near-infrared spectroscopy (fNIRS) while they performed either a synchronous key-pressing task or a control task. After the task, they were asked to perform a Dictator Game to assess their prosocial behavior. We also measured three potential mediating variables: self-other overlap, perceived similarity, and interpersonal neural synchronization. Results showed that dyads in the synchronization group were higher in behavioral synchronization, INS at the right dorsolateral prefrontal cortex (r-DLPFC), self-other overlap, perceived similarity, and prosociality than those in the

control group. INS was significantly associated with prosocial behaviors and self-other overlap. After testing four meditation models, we found that self-other overlap and INS played a serial mediation role in the effect of behavioral synchronization on prosociality. These results contribute to our understanding of the neural and cognitive mechanisms underlying the effect of behavioral synchronization on prosocial behavior.

"Remind-to-Move" Treatment Enhanced Activation of the Primary Motor Cortex in Patients with Stroke.

Bai Z, Fong KNK.

Brain Topogr. Feb

doi: 10.1007/s10548-020-00756-[Epub ahead of print]

"Remind-to-Move" (RTM) has been developed and used as a new treatment for rehabilitation of upper extremity functions in patients with hemiplegia. This study aimed to investigate the cortical activation patterns using functional near-infrared spectroscopic topography for patients with chronic stroke receiving RTM by comparing with their healthy counterparts. Twelve patients with right hemispheric stroke and 15 healthy adults participated in this study. All participants were instructed to completed three experimental conditions-RTM, Move without reminding (Sham), and Remind with No-move (RNoM). In patients with stroke, RTM elicited higher level of activation than the Sham in the contralateral somatosensory association cortex, primary motor cortex, primary somatosensory cortex and the dorsolateral prefrontal cortex, which has been found in healthy participants. However, effects of RTM were robust and more widely distributed in healthy participants, comparing to patients with stroke, comparatively RNoM showed no significant higher activation than the baseline in those areas in both populations. RTM enhances the recruitment of contralateral primary motor cortex and this effect appears to be associated with increased attention allocation towards moving hands upon tactile stimulation in the form of vibration. The RTM treatment is useful to patients with stroke.

Classifying Major Depressive Disorder using fNIRS during Motor Rehabilitation.

Zhu Y, Jayagopal JK, Mehta RK, Erraguntla M, Nuamah J, McDonald AD, Taylor H, Chang SH.

IEEE Trans Neural Syst Rehabil Eng. Feb
doi: 10.1109/TNSRE.2020. [Epub ahead of print]
DOI: 10.1109/TNSRE.2020.2972270 PMID: 32054581

Functional Near Infrared Spectroscopy in Toddlers: neural differentiation of communicative cues and relation to future language abilities.

Smith EG, Condy E, Anderson A, Thurm A, Manwaring SS, Swineford L, Gandjbakhche A, Redcay E.

Dev Sci. Feb
doi: 10.1111/desc.[Epub ahead of print]

The toddler and preschool years are a time of significant development in both expressive and receptive communication abilities. However, little is known about the neurobiological underpinnings of language development during this period, likely due to difficulties acquiring functional neuroimaging data. Functional Near Infrared Spectroscopy (fNIRS) is a motion-tolerant neuroimaging technique that assesses cortical brain activity and can be used in very young children. Here, we use fNIRS during perception of communicative and non-communicative speech and gestures in typically developing 2- and 3-year-olds (Study 1, n=15, n=12 respectively) and in a sample of 2-year-olds with both fNIRS data collected at age 2 and language outcome data at age 3 (study 2, n=18). In Study 1, 2- and 3-year-olds differentiated between communicative and noncommunicative stimuli as well as between speech and gestures in the left lateral frontal region. However, 2-year-olds showed different patterns of activation from 3-year-olds in right medial frontal regions. In Study 2, which included two toddlers identified with early language delays along with 16 typically developing toddlers, neural differentiation of communicative stimuli in the right medial frontal region at age 2 predicted receptive language at age 3. Specifically, after accounting for variance related to verbal ability at age 2, increased neural activation for communicative gestures (versus both communicative speech and noncommunicative gestures) at age 2 predicted higher receptive language scores at age 3. These results are discussed in the context of the underlying mechanisms of toddler language development and use of fNIRS in prediction of language outcomes.

An EEG-fNIRS hybridization technique in the four-class classification of alzheimer's disease.

Cicalese PA, Li R, Ahmadi MB, Wang C, Francis JT, Selvaraj S, Schulz PE, Zhang Y.

J Neurosci Methods. Feb 8;336:
doi: 10.1016/j.jneumeth.2020.108618. [Epub ahead of print]

BACKGROUND: Alzheimer's disease (AD) is projected to become one of the most expensive diseases in modern history, and yet diagnostic uncertainties exist that can only be confirmed by postmortem brain examination. Machine Learning (ML) algorithms have been proposed as a feasible alternative to the diagnosis of several neurological diseases and disorders, such as AD. An ideal ML-derived diagnosis should be inexpensive and noninvasive while retaining the accuracy and versatility that make ML techniques desirable for medical applications. NEW METHODS: Two portable modalities, Electroencephalography (EEG) and functional Near-Infrared Spectroscopy (fNIRS) have been widely employed in constructing hybrid classification models to compensate for each other's weaknesses. In this study, we present a hybrid EEG-fNIRS model for classifying four classes of subjects including one healthy control (HC) group, one mild cognitive impairment (MCI) group, and, two AD patient groups. A concurrent EEG-fNIRS setup was used to record data from 29 subjects during a random digit encoding-retrieval task. EEG-derived and fNIRS-derived features were sorted using a Pearson correlation coefficient-based feature selection (PCCFS) strategy and then fed into a linear discriminant analysis (LDA) classifier to evaluate their performance. RESULTS: The hybrid EEG-fNIRS feature set was able to achieve a higher accuracy (79.31 %) by integrating their complementary properties, compared to using EEG (65.52 %) or fNIRS alone (58.62 %). Moreover, our results indicate that the right prefrontal and left parietal regions are associated with the progression of AD. COMPARISON WITH EXISTING METHODS: Our hybrid and portable system provided enhanced classification performance in multi-class classification of AD population. CONCLUSIONS: These findings suggest that hybrid EEG-fNIRS systems are a promising tool that may enhance the AD diagnosis and assessment process.

Multimodal Affective State Assessment Using fNIRS + EEG and Spontaneous Facial Expression.

Sun Y, Ayaz H, Akansu AN.

Brain Sci. Feb 6;10(2). pii: E
doi: 10.3390/brainsci10020085.

Human facial expressions are regarded as a vital indicator of one's emotion and intention, and even reveal the state of health and wellbeing. Emotional states have been associated with information processing within and between subcortical and cortical areas of the brain, including the amygdala and prefrontal cortex. In this study, we evaluated the relationship between spontaneous human facial affective expressions and multi-modal brain activity measured via non-invasive and wearable sensors: functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG) signals. The affective states of twelve male participants detected via fNIRS, EEG, and spontaneous facial expressions were investigated in response to both image-content stimuli and video-content stimuli. We propose a method to jointly evaluate fNIRS and EEG signals for affective state detection (emotional valence as positive or negative). Experimental results reveal a strong correlation between spontaneous facial affective expressions and the perceived emotional valence. Moreover, the affective states were estimated by the fNIRS, EEG, and fNIRS + EEG brain activity measurements. We show that the proposed EEG + fNIRS hybrid method outperforms fNIRS-only and EEG-only approaches. Our findings indicate that the dynamic (video-content based) stimuli triggers a larger affective response than the static (image-content based) stimuli. These findings also suggest joint utilization of facial expression and wearable neuroimaging, fNIRS, and EEG, for improved emotional analysis and affective brain-computer interface applications.

Functional Near-Infrared Spectroscopy to Study Cerebral Hemodynamics in Older Adults During Cognitive and Motor Tasks: A Review.

Udina C, Avtzi S, Durduran T, Holtzer R, Rosso AL, Castellano-Tejedor C, Perez LM, Soto-Bagaria L, Inzitari M.

Front Aging Neurosci. Jan 21;11:
doi: 10.3389/fnagi.2019.00367. eCollection 2019.

The integrity of the frontal areas of the brain, specifically the prefrontal cortex, are critical to preserve cognition and mobility in late life. Prefrontal cortex regions are involved in executive functions and gait control and have been related to the performance of dual-tasks. Dual-task performance assessment may help identify older adults at risk of negative health outcomes. As an alternative to neuroimaging techniques that do not allow assessment

during actual motion, functional Near-Infrared Spectroscopy (fNIRS) is a non-invasive technique that can assess neural activation through the measurement of cortical oxygenated and deoxygenated hemoglobin levels, while the person is performing a motor task in a natural environment as well as during cognitive tasks. The aim of this review was to describe the use of fNIRS to study frontal lobe hemodynamics during cognitive, motor and dual-tasks in older adults. From the 46 included publications, 20 studies used only cognitive tasks, three studies used motor tasks and 23 used dual-tasks. Our findings suggest that fNIRS detects changes in frontal activation in older adults (cognitively healthy and mild cognitive impairment), especially while performing cognitive and dual-tasks. In both the comparison between older and younger adults, and in people with different neurological conditions, compared to healthier controls, the prefrontal cortex seems to experience a higher activation, which could be interpreted in the context of proposed neural inefficiency and limited capacity models. Further research is needed to establish standardized fNIRS protocols, study the cerebral hemodynamic in different neurological and systemic conditions that might influence cortical activation and explore its role in predicting incident health outcomes such as dementia.

Effects of Tai Chi Chuan on Inhibitory Control in Elderly Women: An fNIRS Study.

Yang Y, Chen T, Shao M, Yan S, Yue GH, Jiang C.

Front Hum Neurosci. Jan 22;13:
doi: 10.3389/fnhum.2019.00476. eCollection 2019.

Background: Inhibitory control is a sub-ability of executive function and plays an important role in the entire cognitive process. However, declines in inhibitory control during aging significantly impair the quality of life of elderly people. Investigating methods to delay the decline of inhibitory control has become a focal point in current research. Tai Chi Chuan (TCC) is one effective method used to delay cognitive declines in older adults. However, the specific effects of TCC on inhibitory control and the mechanisms through which TCC may improve cognition in older adults have not been comprehensively investigated. Objective: The study explores possible neurological mechanisms related to the effects of TCC interventions on inhibitory control in older people using a functional near-infrared spectroscopy (fNIRS) technique and reaction times (RTs). Methods: A total of 26 healthy, elderly people who had not received TCC training completed all study procedures.

The subjects were randomized to either the TCC group or the control group. Subjects in the TCC group were taught TCC by a certified instructor and trained for 8 weeks. The control group continued to perform general daily activities. The Flanker task was administered to every participant to evaluate inhibitory control pre- and post-intervention. While participants were performing the Flanker task, fNIRS data were collected. Results: Post-intervention, significant differences for incongruent flankers were found only for the TCC intervention group. Faster RTs were observed for the incongruent flankers in the TCC group than in the control group ($p < 0.05$). Analysis of the fNIRS data revealed an increase in oxy-Hb in the prefrontal cortex during the incongruent flankers after the TCC exercise intervention. Conclusion: The TCC intervention significantly improved inhibitory control in older adults, suggesting that TCC is an effective, suitable exercise for improving executive function and neurological health in elderly people. Clinical Trial Registration: Chinese Clinical Trial Register, ChiCTR1900028457.

Assessing Brain Networks by Resting-State Dynamic Functional Connectivity: An fNIRS-EEG Study.

Zhang Y, Zhu C.

Front Neurosci. Jan 24;13:
doi: 10.3389/fnins.2019.eCollection 2019.

The coordination of brain activity between disparate neural populations is highly dynamic. Investigations into intrinsic brain organization by evaluating dynamic resting-state functional connectivity (dRSFC) have attracted great attention in recent years. However, there are few dRSFC studies based on functional near-infrared spectroscopy (fNIRS) even though it has some advantages for studying the temporal evolution of brain function. In this research, we recruited 20 young adults and measured their resting-state brain fluctuations in several areas of the frontal, parietal, temporal, and occipital lobes using fNIRS-electroencephalography (EEG) simultaneous recording. Based on a sliding-window approach, we found that the variability of the dRSFC within any region of interest was significantly lower than the connections between region of interests but noticeably greater than the correlation between the channels with a short interoptode distance, which mainly consist of physiological fluctuations occurring in the superficial layers. Furthermore, based on a time-resolved k-means clustering analysis, the temporal evolution was extracted for three dominant functional networks. These networks were roughly consistent between different subject subgroups and in varying slid-

ing time window lengths of 20, 30, and 60 s. Between these three functional networks, there were obvious time-varied and system-specific synchronous relationships. In addition, the oscillation of the frontal-parietal-temporal network showed significant correlation with the switching of one EEG microstate, a finding which is consistent with a previous functional MRI-EEG study. All this evidence implies the functional significance of fNIRS-dRSFC and demonstrates the feasibility of fNIRS for extracting the dominant functional networks based on RSFC dynamics.

Brain activation patterns underlying upper limb bilateral motor coordination in unilateral cerebral palsy: an fNIRS study.
de Campos AC, Sukal-Moulton T, Huppert T, Alter K, Damiano DL.
Dev Med Child Neurol. Feb
doi: 10.1111/dmcn.[Epub ahead of print]

AIM: To explore cortical activation during bimanual tasks and functional correlates in unilateral cerebral palsy (CP). METHOD: This cross-sectional study included eight participants with unilateral CP (six females, two males; mean age [SD] 20y 10mo [5y -10mo], 13y 8mo-31y 6mo) in Manual Ability Classification System levels II to III and nine age-matched participants with typical development (seven females, two males; mean age [SD] 17y 8mo [5y 7mo], 9y 4mo-24y 2mo). They performed bimanual symmetric squeezing (BSS) and bimanual asymmetric squeezing (BAS) tasks at 1Hz, and a pouring task with dominant hand (DPour) and a pouring task with non-dominant hand (NDPour) at 0.67Hz, all while a custom array of functional near-infrared spectroscopy (fNIRS) optodes were placed over their sensorimotor area. Mixed-effects were used to contrast groups, tasks, and hemispheres (corrected p-values [q] reported). Analysis of variance and t-tests compared performance measures across groups and tasks. RESULTS: Participants with unilateral CP showed greater activation in both hemispheres during BAS (non-lesioned: $q<0.001$; lesioned: $q<0.001$), and in the lesioned hemisphere during BSS ($q<0.001$), DPour ($q=0.02$), and NDPour ($q=0.02$) than those with typical development. The lesioned hemisphere in unilateral CP showed more activity than the non-lesioned one (BSS: $q=0.01$; BAS: $q=0.009$; NDPour: $q=0.04$). During BAS, higher cortical activity correlated with more synchronous arm activation ($r=0.79$; $p=0.02$); activity lateralized towards the non-lesioned hemisphere correlated with better Pediatric Evaluation of Disability Inventory computer adaptive test scores ($r=0.81$; $p=0.03$). INTERPRETATION: Results suggest abnormally in-

creased sensorimotor cortical activity in unilateral CP, with implications to be investigated. WHAT THIS PAPER ADDS: Cortical activity in manual tasks is described with functional near-infrared spectroscopy in typical and atypical cohorts. Activation levels in unilateral cerebral palsy appear to escalate with task difficulty. Increased brain activity may be associated with poorer selective manual control. Specific patterns of brain activity may be related to impaired bimanual function.

Enhancing fNIRS Analysis Using EEG Rhythmic Signatures: an EEG-informed fNIRS Analysis Study.

Li R, Zhao C, Wang C, Wang J, Zhang Y.

IEEE Trans Biomed Eng. Feb

doi: 10.1109/TBME.2020.[Epub ahead of print]

DOI: 10.1109/TBME.2020.2971679 PMID: 32031925

A functional near-infrared spectroscopy (fNIRS) examination of how self-initiated sequential movements become automatic.

Polskaia N, St-Amant G, Fraser S, Lajoie Y.

Exp Brain Res. Feb

doi: 10.1007/s00221-020-05742-w. [Epub ahead of print]

The neural mechanisms underlying movement automaticity have been investigated using PET and fMRI and more recently functional near-infrared spectroscopy (fNIRS). As fNIRS is an emerging technique, the objective of the present study was to replicate the functional magnetic resonance imaging-related motor sequence findings as reported by Wu et al. (J Neurophysiol 91:1690-1698, https://doi.org/10.1152/jn.01052.2003, 2004) using fNIRS. Seventeen right-handed participants practiced self-initiated sequential finger movements of two lengths (4 and 12) until a level of automaticity was achieved. Automaticity was evaluated by performing a visual-letter-counting task concurrently with the sequential finger movements. Our data were unable to replicate the pre-to-post-practice decrease in cortical activity in the left dorsolateral prefrontal cortex for both motor sequence tasks. The findings did reveal increased contribution from the right hemisphere following learning. The observed lateralization is suggestive of explicit learning and the involvement of working memory in motor sequence production.

Multi-time-point analysis: A time course analysis with functional near-infrared spectroscopy.

Yu CL, Chen HC, Yang ZY, Chou TL.

Behav Res Methods. Feb
doi: 10.3758/s13428-019-01344-[Epub ahead of print]

In the data analysis of functional near-infrared spectroscopy (fNIRS), linear model frameworks, in particular mass univariate analysis, are often used when researchers consider examining the difference between conditions at each sampled time point. However, some statistical issues, such as assumptions of linearity, autocorrelation and multiple comparison problems, influence statistical inferences when mass univariate analysis is used on fNIRS time course data. In order to address these issues, the present study proposes a novel perspective, multi-time-point analysis (MTPA), to discriminate signal differences between conditions by combining temporal information from multiple time points in fNIRS. In addition, MTPA adopts the random forest algorithm from the statistical learning domain, followed by a series of cross-validation procedures, providing reasonable power for detecting significant time points and ensuring generalizability. Using a real fNIRS data set, the proposed MTPA outperformed mass univariate analysis in detecting more time points, showing significant differences between experimental conditions. Finally, MTPA was also able to make comparisons between different areas, leading to a novel viewpoint of fNIRS time course analysis and providing additional theoretical implications for future fNIRS studies. The data set and all source code are available for researchers to replicate the analyses and to adapt the program for their own needs in future fNIRS studies.

Affiliative bonding between teachers and students through interpersonal synchronization in brain activity.

Zheng L, Liu W, Long Y, Zhai Y, Zhao H, Bai X, Zhou S, Li K, Zhang H, Liu L, Guo T, Ding G, Lu C.

Soc Cogn Affect Neurosci. Feb pii: nsaa
doi: 10.1093/scan/nsaa016. [Epub ahead of print]

Human beings organize socially. Theories have posited that interpersonal neural synchronization might underlie the creation of affiliative bonds. Previous studies tested this hypothesis mainly during a social interaction, making it difficult to determine whether the identified synchronization is

associated with affiliative bonding or with social interaction. This study addressed this issue by focusing on the teacher-student relationship in the resting state both before and after a teaching period. Brain activity was simultaneously measured in both individuals using functional near-infrared spectroscopy (fNIRS). The results showed a significant increase in brain synchronization at the right sensorimotor cortex between the teacher and student in the resting state after, but not before, the teaching period. Moreover, the synchronization increased only after a turn-taking mode of teaching but not after a lecturing or video mode of teaching. A chain mediation analysis showed that brain synchronization during teaching partially mediated the relationship between the brain synchronization increase in the resting state and strength of the affiliative bond. Finally, both role assignment and social interaction were found to be required for affiliative bonding. Together, these results support the hypothesis that interpersonal synchronization in brain activity underlies affiliative bonding and that social interaction mechanically mediates the bonding process.

The Temporal Confounding Effects of Extra-cerebral Contamination Factors on the Hemodynamic Signal Measured by Functional Near-Infrared Spectroscopy.

Zarei M, Ansari MA, Zare K.

J Lasers Med Sci. Fall;10(Suppl 1):S73-S
doi: 10.15171/jlms.2019.S14. Epub Dec 1.

Introduction: Functional near-infrared spectroscopy (fNIRS) has been broadly applied for optical brain imaging. This method is hemodynamic-based functional brain imaging relying on the measurement of the neurovascular coupling to detect changes in cerebral neuronal activities. The extra-cerebral hemodynamic changes are important contaminating factors in fNIRS measurements. This error signal can be misinterpreted as cerebral activities during fNIRS studies. Recently, it was assumed that temporal changes in deoxygenated hemoglobin concentration [HHb] was hardly affected by superficial blood flow, and it was proposed that the activation maps could be determined from [HHb] at large source-detector separation. Methods: In the current study, we measured the temporal changes in [HHb] using a continueswave fNIRS device at large source-detector separation, while superficial blood flow was stimulated by infrared lasers. A mesh-based Monte Carlo code was applied to estimate fNIRS sensitivity to superficial hemodynamic changes in a realistic 3D MRI-based brain phantom. Results: First,

we simulated photon migration in a four-layered human-head slab model to calculate PPLs and fNIRS sensitivity. Then, the localization of the infrared laser inside a realistic brain model was studied using the Monte Carlo method. Finally, the changes in [HHb] over the prefrontal cortex of six adult males were measured by fNIRS at a source-detector separation of 3 cm. The results demonstrated that the relation between fNIRS sensitivity and an increase in S-D separation was nonlinear and a correlation between shallow and deep signals was observed. Conclusion: The presented results demonstrated that the temporal changes in the superficial blood flow could strongly affect HHb measurement at large source-detector separation. Hence, the cerebral activity map extracted from the [HHb] signal was mainly contaminated by superficial blood flow.

Functional lateralization of arithmetic processing in the intraparietal sulcus is associated with handedness.

Artemenko C, Sitnikova MA, Soltanlou M, Dresler T, Nuerk HC.

Sci Rep. Feb 4;10(1):

doi: 10.1038/s41598-020-58477-7.

Functional lateralization is established for various cognitive functions, but was hardly ever investigated for arithmetic processing. Most neurocognitive models assume a central role of the bilateral intraparietal sulcus (IPS) in arithmetic processing and there is some evidence for more pronounced left-hemispheric activation for symbolic arithmetic. However, evidence was mainly obtained by studies in right-handers. Therefore, we conducted a functional near-infrared spectroscopy (fNIRS) study, in which IPS activation of left-handed adults was compared to right-handed adults in a symbolic approximate calculation task. The results showed that left-handers had a stronger functional right-lateralization in the IPS than right-handers. This finding has important consequences, as the bilateral IPS activation pattern for arithmetic processing seems to be shaped by functional lateralization and thus differs between left- and right-handers. We propose three possible accounts for the observed functional lateralization of arithmetic processing.

English spoken word segmentation activates the prefrontal cortex and temporo-parietal junction in Chinese ESL learners: A functional near-infrared spectroscopy (fNIRS) study.

Li Y, Yang Y, Tang AC, Liu N, Wang X, Du Y, Hu W.
Brain Res. Jan 30;1733:
doi: 10.1016/j.brainres.2020.[Epub ahead of print]

A direct measure of spoken lexical processing based on neuroimaging technology would provide us useful information to understand the neural mechanisms underlying speech or auditory language processing. The neural mechanisms of spoken word segmentation for English as a second language (ESL) learners remain elusive. The present study, using functional near-infrared spectroscopy (fNIRS), addresses this issue by measuring hemodynamic responses in the temporo-parietal junction (TPJ) and the prefrontal cortex (PFC) in a word-spotting task, designed with two task conditions (easy vs. difficult). Thirty participants, divided into a high listening proficiency group (HLG) and a low listening proficiency group (LLG), were tested. Results revealed significantly less TPJ activation in the HLG than in the LLG. Further analyses supported this result by showing that activation in the TPJ was in a negative correlation with listening proficiency. This association appears to be related to the more efficient use of processing resources in a bottom-up fashion for accurate and efficient sensory representations in high proficient language learners. In contrast, cortical activation in the PFC increased with listening proficiency and was stronger in the difficult task condition than in the easy task condition, implying that recruitment of top-down cognitive control functions might play a role in word segmentation. Our results suggest that the combination of the functions mediated via bottom-up sensory input processing (demonstrated in the TPJ activation) and top-down cognitive processing (demonstrated in the PFC activation) are crucial for ESL listeners' spoken word segmentation.

Functional near-infrared spectroscopy detects increased activation of the brain frontal-parietal network in youth with type 1 diabetes.

Mazaika PK, Marzelli M, Tong G, Foland-Ross LC, Buckingham BA, Aye T, Reiss AL.
Pediatr Diabetes. Jan
doi: 10.1111/pedi.[Epub ahead of print]

When considered as a group, children with type 1 diabetes have subtle cognitive deficits relative to neurotypical controls. However, the neural correlates of these differences remain poorly understood. Using functional near-infrared spectroscopy (fNIRS), we investigated the brain functional activa-

tions of young adolescents (19 individuals with type 1 diabetes, 18 healthy controls, ages 8-16 years) during a Go/No-Go response inhibition task. Both cohorts had the same performance on the task, but the individuals with type 1 diabetes subjects had higher activations in a frontal-parietal network including the bilateral supramarginal gyri and bilateral rostrolateral prefrontal cortices. The activations in these regions were positively correlated with fewer parent-reported conduct problems (ie, lower Conduct Problem scores) on the Behavioral Assessment System for Children, Second Edition. Lower Conduct Problem scores are characteristic of less rule-breaking behavior suggesting a link between this brain network and better self-control. These findings are consistent with a large functional magnetic resonance imaging (fMRI) study of children with type 1 diabetes using completely different participants. Perhaps surprisingly, the between-group activation results from fNIRS were statistically stronger than the results using fMRI. This pilot study is the first fNIRS investigation of executive function for individuals with type 1 diabetes. The results suggest that fNIRS is a promising functional neuroimaging resource for detecting the brain correlates of behavior in the pediatric clinic.

A gift for gratitude and cooperative behavior. Brain and cognitive effects.

Balconi M, Fronda G, Vanutelli ME.

Soc Cogn Affect Neurosci. Jan pii: nsaa
doi: 10.1093/scan/nsaa003. [Epub ahead of print]

Recently, different psychological studies have been interested in identifying the factors that regulate the development and maintenance of long-lasting interpersonal and social relationships. Specifically, the present research explored the link between gifts exchange, gratitude, and cognitive effects. The behavioral performance and neural activity of 32 participants were recorded during a cooperative game to be played before and after gifts exchange. Specifically, participants had to perform the task coupled with a dear friend. Half of the couples were asked to exchange a gift before the task performance; the other half was asked to exchange a gift halfway through the task performance. For hemodynamic brain responses, functional near-infrared spectroscopy (fNIRS) was used. Results showed that an increase in cognitive performance occurred after the exchange of gifts, with improved accuracy and lower response times in task performance. Regarding hemodynamic responses, an increase in oxygenated hemoglobin (O2Hb) was

detected, especially in the dorsolateral prefrontal cortex (DLPFC) following the gift exchange. Furthermore, it was observed that gift exchange before the beginning of the task increased the performance level. The present study provides a significant contribution to the identification of those factors that enable the increased cognitive performance based on cooperative relationships.

Reality Status Judgments of Real and Fantastical Events in Children's Prefrontal Cortex: An fNIRS Study.

Li H, Liu T, Woolley JD, Zhang P.

Front Hum Neurosci. Dec 20;13:

doi: 10.3389/fnhum.2019.00444. eCollection 2019.

The present study aimed to examine neural mechanisms underlying the ability to differentiate reality from fantasy. Using functional near-infrared spectroscopy (fNIRS), we measured prefrontal activations in children and adults while they performed a reality judgment task. Participants' task was to judge the reality status of events in fantastical and realistic videos. Behavioral data revealed that, although there was no accuracy difference, children showed significantly longer reaction times in making the judgments than did adults. The fNIRS data consistently revealed higher prefrontal activations in children than in adults when watching the videos and judging the reality of the events. These results suggest that when making judgments of event reality, children may require more cognitive resources and also mainly rely on their own personal experiences.

Portable, field-based neuroimaging using high-density diffuse optical tomography.

Fishell AK, Arbeláez AM, Valdés CP, Burns-Yocum TM, Sherafati A, Richter EJ, Torres M, Eggebrecht AT, Smyser CD, Culver JP.

Neuroimage. Jan 24:

doi: 10.1016/j.neuroimage.2020.[Epub ahead of print]

Behavioral and cognitive tests in individuals who were malnourished as children have revealed malnutrition-related deficits that persist throughout the lifespan. These findings have motivated recent neuroimaging investigations that use highly portable functional near-infrared spectroscopy (fNIRS) instruments to meet the demands of brain imaging experiments in

low-resource environments and enable longitudinal investigations of brain function in the context of long-term malnutrition. However, recent studies in healthy subjects have demonstrated that high-density diffuse optical tomography (HD-DOT) can significantly improve image quality over that obtained with sparse fNIRS imaging arrays. In studies of both task activations and resting state functional connectivity, HD-DOT is beginning to approach the data quality of fMRI for superficial cortical regions. In this work, we developed a customized HD-DOT system for use in malnutrition studies in Cali, Colombia. Our results evaluate the performance of the HD-DOT instrument for assessing brain function in a cohort of malnourished children. In addition to demonstrating portability and wearability, we show the HD-DOT instrument's sensitivity to distributed brain responses using a sensory processing task and measurements of homotopic functional connectivity. Task-evoked responses to the passive word listening task produce activations localized to bilateral superior temporal gyrus, replicating previously published work using this paradigm. Evaluating this localization performance across sparse and dense reconstruction schemes indicates that greater localization consistency is associated with a dense array of overlapping optical measurements. These results provide a foundation for additional avenues of investigation, including identifying and characterizing a child's individual malnutrition burden and eventually contributing to intervention development.

Evaluating advanced driver-assistance system trainings using driver performance, attention allocation, and neural efficiency measures.

Zahabi M, Abdul Razak AM, Shortz AE, Mehta RK, Manser M.

Appl Ergon. Apr;84:
doi: 10.1016/j.apergo.2019.Epub Jan 10.

There are about 44 million licensed older drivers in the U.S. Older adults have higher crash rates and fatalities as compared to middle-aged and young drivers, which might be associated with degradations in sensory, cognitive, and physical capabilities. Advanced driver-assistance systems (ADAS) have the potential to substantially improve safety by removing some of driver vehicle control responsibilities. However, a critical aspect of providing ADAS is educating drivers on their operational characteristics and continued use. Twenty older adults participated in a driving simulation study assessing the effectiveness of video-based and demonstration-based training protocols in

learning ADAS considering gender differences. The findings revealed video-based training to be more effective than demonstration-based training in improving driver performance and reducing off-road visual attention allocation and mental workload. In addition, female drivers required lower investment of mental effort (higher neural efficiency) to maintain the performance relative to males and they were less distracted by ADAS. However, male drivers were faster in activating ADAS as compared to females since they were monitoring the status of ADAS features more frequently while driving. The findings of this study provided an empirical support for using video-based approach for learning ADAS in older adults to improve driver safety and supported previous findings on older adults' learning that as age increases there is a tendency to prefer more passive and observational learning methods.

Cortical fNIRS Responses Can Be Better Explained by Loudness Percept than Sound Intensity.

Weder S, Shoushtarian M, Olivares V, Zhou X, Innes-Brown H, McKay C.

Ear Hear. Jan

doi: 10.1097/AUD.[Epub ahead of print]

OBJECTIVES: Functional near-infrared spectroscopy (fNIRS) is a brain imaging technique particularly suitable for hearing studies. However, the nature of fNIRS responses to auditory stimuli presented at different stimulus intensities is not well understood. In this study, we investigated whether fNIRS response amplitude was better predicted by stimulus properties (intensity) or individually perceived attributes (loudness). DESIGN: Twenty-two young adults were included in this experimental study. Four different stimulus intensities of a broadband noise were used as stimuli. First, loudness estimates for each stimulus intensity were measured for each participant. Then, the 4 stimulation intensities were presented in counterbalanced order while recording hemoglobin saturation changes from cortical auditory brain areas. The fNIRS response was analyzed in a general linear model design, using 3 different regressors: a non-modulated, an intensity-modulated, and a loudness-modulated regressor. RESULTS: Higher intensity stimuli resulted in higher amplitude fNIRS responses. The relationship between stimulus intensity and fNIRS response amplitude was better explained using a regressor based on individually estimated loudness estimates compared with a regressor modulated by stimulus intensity alone. CONCLUSIONS: Brain activation in response to different stimulus intensities is more reliant upon

individual loudness sensation than physical stimulus properties. Therefore, in measurements using different auditory stimulus intensities or subjective hearing parameters, loudness estimates should be examined when interpreting results.

Targeting brain functions from the scalp: Transcranial brain atlas based on large-scale fMRI data synthesis.

Jiang Y, Li Z, Zhao Y, Xiao X, Zhang W, Sun P, Yang Y, Zhu C.

Neuroimage. Jan 22;210:
doi: 10.1016/j.neuroimage.2020.[Epub ahead of print]

Transcranial brain mapping techniques, such as functional near-infrared spectroscopy (fNIRS) and transcranial magnetic stimulation (TMS), have been playing an increasingly important role in studies of human brain functions. Given a brain function of interest, fNIRS probes and TMS coils should be properly placed on the scalp to ensure that the function is effectively measured or modulated. However, since brain activity is inside the skull and invisible to the researcher during placement, this blind targeting may cause the device to partially or completely miss the functional target, resulting in inconsistent experimental results and divergent clinical outcomes, especially when participants' structural MRI data are not available. To address this issue, we propose here a framework for targeting a designated function directly from the scalp. First, a functional brain atlas for the targeted brain function is constructed via a meta-analysis of large-scale functional magnetic resonance imaging datasets. Second, the functional brain atlas is presented on the scalp surface by using a transcranial mapping previously established from an structural MRI dataset (n = 114), resulting in a novel functional transcranial brain atlas (fTBA). Finally, a low-cost, portable scalp-navigation system is used to localize the transcranial device on the individual's scalp with the guidance of the fTBA. To demonstrate the feasibility of the targeting framework, both fNIRS and TMS mapping experiments were conducted. The results show that fTBA-guided fNIRS positioning can detect functional activity with high sensitivity and specificity for working memory and motor systems; Moreover, compared with traditional TMS targeting approaches (e.g. the International 10-20 System and the conventional 5-cm rule), the fTBA suggested motor stimulation site is closesr to both the motor hotspot and the center of gravity of motor evoked potentials (MEP-COG). In summary, the proposed method unblinds the transcranial function targeting process using prior information, provid-

ing an effective and straightforward approach to transcranial brain mapping studies, especially those without participants' structural MRI data.

Acute kick-boxing exercise alters effective connectivity in the brain of females with methamphetamine dependencies.

Bu L, Qi L, Yan W, Yan Q, Tang Z, Li F, Liu X, Diao C, Li K, Dong G.

Neurosci Lett. Feb 16;720:
doi: 10.1016/j.neulet.2020.Epub Jan 21.

OBJECTIVE: Methamphetamine (METH) dependence, especially among women, is a serious global health problem. Kick-boxing exercise can be used to reduce cue-induced craving and develop a healthy lifestyle for female with METH dependencies. This study aimed to assess acute kick-boxing related changes in effective connectivity (EC) in the brain of females with METH dependencies by using functional near-infrared spectroscopy (fNIRS) signals. METHODS: The fNIRS signals were continuously recorded from the left and right prefrontal cortices (LPFC/RPFC) and left and right motor cortices (LMC/RMC) of 30 female subjects with methamphetamine dependencies (METH group) and 30 age-matched controls (control group) during resting and kick-boxing exercise (training) periods. EC was calculated in the frequency range of 0.01-0.08 Hz. RESULTS: In both resting and training state, the EC levels of METH group were significantly lower than the control group ($p < 0.05$). The EC levels of control group showed more significantly increased connection types than that of the METH group. CONCLUSION: Acute kick-boxing exercise altered EC in the brain of females with METH dependencies. Furthermore, the efficiency of the information flow between different brain regions in the control group was significantly higher than that in the METH group. This study provides a novel and portable assessment technique for METH rehabilitation in females on the basis of fNIRS signals.

Mutual interaction between motor cortex activation and pain in fibromyalgia: EEG-fNIRS study.

Gentile E, Brunetti A, Ricci K, Delussi M, Bevilacqua V, de Tommaso M.

PLoS One. Jan 23;15(1):e
doi: 10.1371/journal.pone.0228158. eCollection 2020.

BACKGROUND: Experimental and clinical studies suggested an analgesic effect on chronic pain by motor cortex activation. The present study

explored the complex mechanisms of interaction between motor and pain during performing the slow and fast finger tapping task alone and in concomitant with nociceptive laser stimulation. METHOD: The participants were 38 patients with fibromyalgia (FM) and 21 healthy subjects. We used a simultaneous multimodal method of laser-evoked potentials and functional near-infrared spectroscopy to investigate metabolic and electrical changes during the finger tapping task and concomitant noxious laser stimulation. Functional near-infrared spectroscopy is a portable and optical method to detect cortical metabolic changes. Laser-evoked potentials are a suitable tool to study the nociceptive pathways function. RESULTS: We found a reduced tone of cortical motor areas in patients with FM compared to controls, especially during the fast finger tapping task. FM patients presented a slow motor performance in all the experimental conditions, requesting rapid movements. The amplitude of laser evoked potentials was different between patients and controls, in each experimental condition, as patients showed smaller evoked responses compared to controls. Concurrent phasic pain stimulation had a low effect on motor cortex metabolism in both groups nor motor activity changed laser evoked responses in a relevant way. There were no correlations between Functional Near-Infrared Spectroscopy (FNIRS) and clinical features in FM patients. CONCLUSION: Our findings indicated that a low tone of motor cortex activation could be an intrinsic feature in FM and generate a scarce modulation on pain condition. A simple and repetitive movement such as that of the finger tapping task seems inefficacious in modulating cortical responses to pain both in patients and controls. The complex mechanisms of interaction between networks involved in pain control and motor function require further studies for the important role they play in structuring rehabilitation strategies.

Multimodal Imaging of Brain Activity to Investigate Walking and Mobility Decline in Older Adults (Mind in Motion Study): Hypothesis, Theory, and Methods.

Clark DJ, Manini TM, Ferris DP, Hass CJ, Brumback BA, Cruz-Almeida Y, Pahor M, Reuter-Lorenz PA, Seidler RD.

Front Aging Neurosci. Jan 8;11:
doi: 10.3389/fnagi.2019.00358. eCollection 2019.

Age-related brain changes likely contribute to mobility impairments, but the specific mechanisms are poorly understood. Current brain measurement approaches (e.g., functional magnetic resonance imaging (fMRI), functional

near infrared spectroscopy (fNIRS), PET) are limited by inability to measure activity from the whole brain during walking. The Mind in Motion Study will use cutting edge, mobile, high-density electroencephalography (EEG). This approach relies upon innovative hardware and software to deliver three-dimensional localization of active cortical and subcortical regions with good spatial and temporal resolution during walking. Our overarching objective is to determine age-related changes in the central neural control of walking and correlate these findings with a comprehensive set of mobility outcomes (clinic-based, complex walking, and community mobility measures). Our hypothesis is that age-related walking deficits are explained in part by the Compensation Related Utilization of Neural Circuits Hypothesis (CRUNCH). CRUNCH is a well-supported model that describes the over-recruitment of brain regions exhibited by older adults in comparison to young adults, even at low levels of task complexity. CRUNCH also describes the limited brain reserve resources available with aging. These factors cause older adults to quickly reach a ceiling in brain resources when performing tasks of increasing complexity, leading to poor performance. Two hundred older adults and twenty young adults will undergo extensive baseline neuroimaging and walking assessments. Older adults will subsequently be followed for up to 3 years. Aim 1 will evaluate whether brain activity during actual walking explains mobility decline. Cross sectional and longitudinal designs will be used to study whether poorer walking performance and steeper trajectories of decline are associated with CRUNCH indices. Aim 2 is to harmonize high-density EEG during walking with fNIRS (during actual and imagined walking) and fMRI (during imagined walking). This will allow integration of CRUNCH-related hallmarks of brain activity across neuroimaging modalities, which is expected to lead to more widespread application of study findings. Aim 3 will study central and peripheral mechanisms (e.g., cerebral blood flow, brain regional volumes, and connectivity, sensory function) to explain differences in CRUNCH indices during walking. Research performed in the Mind in Motion Study will comprehensively characterize the aging brain during walking for developing new intervention targets.

Reliability of Frontal Eye Fields Activation and Very Low-Frequency Oscillations Observed during Vergence Eye Movements: an fNIRS Study.

Yaramothu C, Li X, Morales C, Alvarez TL.

Sci Rep. Jan 20;10(1):

doi: 10.1038/s41598-020-57597-4.

Functional near-infrared spectroscopy (fNIRS), an imaging tool that utilizes infrared light to measure changes within the concentration of oxygenated (HbO) and deoxygenated (HbR) hemoglobin, holds promise to study functional activity from motor, visual, and memory cortical regions using stimulus-induced tasks. This study investigated the reliability for fNIRS to examine cortical activations within the frontal eye fields (FEF) while initiating vergence eye movements, the inward and outward rotation of the eyes. FNIRS data were collected from twenty participants with normal binocular vision while performing vergence eye movements compared to sustained gaze fixation within a block design during two different sessions. Reliability of the experimental protocol was assessed using the intraclass correlation coefficient (ICC). The ICC values ranged from 0.6 to 0.7 for measuring the HbO activation within the vicinity of the FEF. A frequency power spectrum analysis revealed two predominant frequencies within the functional activation signals from the FEF. One high-intensity signal was present at 0.029 Hz, centering around the block design frequency. The peak-intensity signal was observed between 0.012 and 0.018 Hz where this very low-frequency oscillation (VLFO) was hypothesized to be generated by the macrovasculature present near the FEF and should be avoided as a block design frequency in future fNIRS studies to avoid false positive results.

Functional near-infrared spectroscopy for speech protocols: characterization of motion artifacts and guidelines for improving data analysis.

Novi SL, Roberts E, Spagnuolo D, Spilsbury BM, Price DC, Imbalzano CA, Forero E, Yodh AG, Tellis GM, Tellis CM, Mesquita RC.

Neurophotonics. Jan;7(1):
doi: 10.1117/1.NPh.7.1.Epub 2020 Jan 10.

Monitoring speech tasks with functional near-infrared spectroscopy (fNIRS) enables investigation of speech production mechanisms and informs treatment strategies for speech-related disorders such as stuttering. Unfortunately, due to movement of the temporalis muscle, speech production can induce relative movement between probe optodes and skin. These movements generate motion artifacts during speech tasks. In practice, spurious hemodynamic responses in functional activation signals arise from lack of information about the consequences of speech-related motion artifacts, as well as from lack of standardized processing procedures for fNIRS signals

during speech tasks. To this end, we characterize the effects of speech production on fNIRS signals, and we introduce a systematic analysis to ameliorate motion artifacts. The study measured 50 healthy subjects performing jaw movement (JM) tasks and found that JM produces two different patterns of motion artifacts in fNIRS. To remove these unwanted contributions, we validate a hybrid motion-correction algorithm based sequentially on spline interpolation and then wavelet filtering. We compared performance of the hybrid algorithm with standard algorithms based on spline interpolation only and wavelet decomposition only. The hybrid algorithm corrected 94% of the artifacts produced by JM, and it did not lead to spurious responses in the data. We also validated the hybrid algorithm during a reading task performed under two different conditions: reading aloud and reading silently. For both conditions, we observed significant cortical activation in brain regions related to reading. Moreover, when comparing the two conditions, good agreement of spatial and temporal activation patterns was found only when data were analyzed using the hybrid approach. Overall, the study demonstrates a standardized processing scheme for fNIRS data during speech protocols. The scheme decreases spurious responses and intersubject variability due to motion artifacts.

Reduced frontopolar brain activation characterizes concussed athletes with balance deficits.

Helmich I, Coenen J, Henckert S, Pardalis E, Schupp S, Lausberg H.

Neuroimage Clin. Jan 11;25:
doi: 10.1016/j.nicl.2020.[Epub ahead of print]

OBJECTIVES: Athletes with sport-related concussions (SRC) often demonstrate deficits in postural stability. Lower cerebral blood flow in frontal cortices has been documented in athletes with symptoms after SRC, however, it is unclear if functional brain oxygenation during postural control tasks is reduced in symptomatic athletes after SRC in the same manner. We therefore compared brain oxygenation patterns in frontal cortices of symptomatic and asymptomatic athletes with SRC during postural control tasks with the hypothesis that symptomatic athletes are characterized by reduced functional brain oxygenation during postural control. METHODS: 62 concussed athletes (n = 31 symptomatic, n = 31 asymptomatic) were investigated during four postural control tasks with eyes closed versus eyes opened conditions and stable vs. unstable surface conditions. Brain oxygenation was assessed using functional NearInfraRed Spectroscopy (fNIRS) on frontopolar cortices

of each hemisphere. Postural sway was measured by the analysis of ground reaction forces. RESULTS: Symptomatic athletes showed greater postural sway when compared to asymptomatic athletes during postural control, particularly during closed eyes and/or unstable surface conditions. Changes of oxygenated hemoglobin (ΔHbO2) within the left hemispheric frontopolar cortex were significantly reduced in symptomatic athletes when compared to asymptomatic athletes during the eyes closed condition. A stepwise linear regression analysis revealed that self-reported post-concussion symptoms such as headaches and sadness predict decreased brain oxygenation during postural control with closed eyes. CONCLUSION: Symptomatic athletes with increased postural sway are characterized by decreased frontopolar brain oxygenation during postural control tasks, particularly during conditions with closed eyes. Because the frontopolar cortex showed to be involved in redistributing executive functions to novel task situations, we conclude that athletes with post-concussion symptoms suffer from a deficit in coordinating postural adjustments to balance control tasks with reduced sensory input.

Use of prefrontal cortex activity as a measure of learning curve in surgical novices: results of a single blind randomised controlled trial.

Khoe HCH, Low JW, Wijerathne S, Ann LS, Salgaonkar H, Lomanto D, Choi J, Baek J, Tam WW, Pei H, Ho RCM.

Surg Endosc. Jan
doi: 10.1007/s00464-019-07331-[Epub ahead of print]

BACKGROUND: Neurobiological feedback in surgical training could translate to better educational outcomes such as measures of learning curve. This work examined the variation in brain activation of medical students when performing laparoscopic tasks before and after a training workshop, using functional near-infrared spectroscopy (fNIRS). METHODS AND PROCEDURES: This single blind randomised controlled trial examined the prefrontal cortex activity (PFCA) differences in two groups of novice medical students during the acquisition of four laparoscopic tasks. Both groups were shown a basic tutorial video, with the "Trained-group" receiving an additional standardised one-to-one training on the tasks. The PFCA was measured pre- and post-intervention using a portable fNIRS device and reported as mean total oxygenated hemoglobin (HbO μm). Primary outcome of the study is the difference in HbO μm between post- and pre-intervention readings for each of the four laparoscopic tasks. The pre- and post-intervention

laparoscopic tasks were recorded and assessed by two blinded individual assessors for objective scores of the performance. RESULTS: 16 Trained and 16 Untrained, right-handed medical students with an equal sex distribution and comparable age distribution were recruited. Trained group had an attenuated left PFCA in the "Precision cutting" ($p = 0.007$) task compared to the Untrained group. Subgroup analysis by sex revealed attenuation in left PFCA in Trained females compared to Untrained females across two laparoscopic tasks: "Peg transfer" ($p = 0.005$) and "Precision cutting" ($p = 0.003$). No significant PFCA attenuation was found in male students who underwent training compared to Untrained males. CONCLUSION: A standardised laparoscopic training workshop promoted greater PFCA attenuation in female medical students compared to males. This suggests that female and male students respond differently to the same instructional approach. Implications include a greater focus on one-to-one surgical training for female students and use of PFCA attenuation as a form of neurobiological feedback in surgical training.

Evaluation of neurocognitive function of prefrontal cortex in ornithine transcarbamylase deficiency.

Anderson A, Gropman A, Le Mons C, Stratakis C, Gandjbakhche A.

Mol Genet Metab. Jan pii: S1096-7192(19)30731-
doi: 10.1016/j.ymgme.2019.12.[Epub ahead of print]

Hyperammonia due to ornithine transcarbamylase deficiency (OTCD) can cause a range of deficiencies in domains of executive function and working memory. Only a few fMRI studies have focused on neuroimaging data in a population with OTCD. Yet, there is a need for monitoring the disease progression and neurocognitive function in this population. In this study, we used a non-invasive neuroimaging technique, functional Near Infrared Spectroscopy (fNIRS), to examine the hemodynamics of prefrontal cortex (PFC) based on neural activation in an OTCD population. Using fNIRS, we measured the activation in PFC of the participants while performing the Stroop task. Behavioral assessment such as reaction time and correct response were recorded. We investigated the difference in behavioral measures as well as brain activation in left and right PFC in patients with OTCD and controls. Results revealed a distinction in left PFC activation between controls and patients with OTCD, where control subjects showed higher task related activation increase. Subjects with OTCD also exhibited bilateral increase in PFC activation. There was no significant difference in response

time or correct response between the two groups. Our findings suggest the alterations in neurocognitive function of PFC in OTCD compared to the controls despite the behavioral profiles exhibiting no such differences. This is a first study using fNIRS to examine a neurocognitive function in OTCD population and can provide a novel insight into the screening of OTCD progression and examining neurocognitive changes.

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fNIRS-GANs: data augmentation using generative adversarial networks for classifying motor tasks from functional near-infrared spectroscopy.

Nagasawa T, Sato T, Nambu I, Wada Y.

J Neural Eng. Feb 19;17(1):
doi: 10.1088/1741-2552/ab6cb9.

OBJECTIVE: Functional near-infrared spectroscopy (fNIRS) is expected to be applied to brain-computer interface (BCI) technologies. Since lengthy fNIRS measurements are uncomfortable for participants, it is difficult to obtain enough data to train classification models; hence, the fNIRS-BCI accuracy decreases. APPROACH: In this study, to improve the fNIRS-BCI accuracy, we examined an fNIRS data augmentation method using Wasserstein generative adversarial networks (WGANs). Using fNIRS data during hand-grasping tasks, we evaluated whether the proposed data augmentation method could generate artificial fNIRS data and improve the classification performance using support vector machines and simple neural networks. MAIN RESULTS: Trial-averaged temporal profiles of WGAN-generated fNIRS data were similar to those of the measured data except that they contained an extra noise component. By augmenting the generated data to training data, the accuracies for classifying four different task types were improved irrespective of the classifiers. SIGNIFICANCE: This result suggests that the artificial fNIRS data generated by the proposed data augmentation method is useful for improving BCI performance.

A Between-Subject fNIRS-BCI Study on Detecting Self-Regulated Intention During Walking.

Li C, Su M, Xu J, Jin H, Sun L.

IEEE Trans Neural Syst Rehabil Eng. Feb;28(2):531-
doi: 10.1109/TNSRE.2020.Epub Jan 10.

DOI: 10.1109/TNSRE.2020.2965628 PMID: 31940543

How the Brain Understands Spoken and Sung Sentences.
Rossi S, Gugler MF, Rungger M, Galvan O, Zorowka PG, Seebacher J.
Brain Sci. Jan 8;10(1). pii: E
doi: 10.3390/brainsci10010036.

The present study investigates whether meaning is similarly extracted from spoken and sung sentences. For this purpose, subjects listened to semantically correct and incorrect sentences while performing a correctness judgement task. In order to examine underlying neural mechanisms, a multi-methodological approach was chosen combining two neuroscientific methods with behavioral data. In particular, fast dynamic changes reflected in the semantically associated N400 component of the electroencephalography (EEG) were simultaneously assessed with the topographically more fine-grained vascular signals acquired by the functional near-infrared spectroscopy (fNIRS). EEG results revealed a larger N400 for incorrect compared to correct sentences in both spoken and sung sentences. However, the N400 was delayed for sung sentences, potentially due to the longer sentence duration. fNIRS results revealed larger activations for spoken compared to sung sentences irrespective of semantic correctness at predominantly left-hemispheric areas, potentially suggesting a greater familiarity with spoken material. Furthermore, the fNIRS revealed a widespread activation for correct compared to incorrect sentences irrespective of modality, potentially indicating a successful processing of sentence meaning. The combined results indicate similar semantic processing in speech and song.

The effects of interaction quality on neural synchrony during mother-child problem solving.
Nguyen T, Schleihauf H, Kayhan E, Matthes D, Vrtička P, Hoehl S.
Cortex. Dec 20;124:235-
doi: 10.1016/j.cortex.2019.11.[Epub ahead of print]

Understanding others is fundamental to interpersonal coordination and successful cooperation. One mechanism posited to underlie both effective communication and behavioral coordination is interpersonal neural synchrony. Although presumably foundational for children's social development, research on neural synchrony in naturalistic caregiver-child interac-

tions is lacking. Using dual-functional near-infrared spectroscopy (fNIRS), we examined the effects of interaction quality on neural synchrony during a problem-solving task in 42 dyads of mothers and their preschool children. In a cooperation condition, mothers and children were instructed to solve a tangram puzzle together. In an individual condition, mothers and children performed the same task alone with an opaque screen between them. Wavelet transform coherence (WTC) was used to assess the cross-correlation between the two fNIRS time series. Results revealed increased neural synchrony in bilateral prefrontal cortex and temporo-parietal areas during cooperative as compared to individual problem solving. Higher neural synchrony during cooperation correlated with higher behavioral reciprocity and neural synchrony predicted the dyad's problem-solving success beyond reciprocal behavior between mothers and children. State-like factors, such as maternal stress and child agency during the task, played a bigger role for neural synchronization than trait-like factors, such as child temperament. Our results emphasize neural synchrony as a biomarker for mother-child interaction quality. These findings further highlight the role of state-like factors in interpersonal synchronization processes linked to successful coordination with others and in the long-term might improve the understanding of others.

Word Frequency Is Associated With Cognitive Effort During Verbal Working Memory: A Functional Near Infrared Spectroscopy (fNIRS) Study.

Berglund-Barraza A, Tian F, Basak C, Evans JL.

Front Hum Neurosci. Dec 13;13:
doi: 10.3389/fnhum.2019.00433. eCollection 2019.

Purpose: Psycholinguistic models traditionally view verbal working memory capacity as independent from linguistic features; connectionist models suggest otherwise. Moreover, lexical processing studies show high frequency words differ in cognitive effort from low frequency words, although these effects during concurrent processing of words in working memory are unknown. This novel study examines potential differences in cognitive effort, as measured by differences in HbO2 and Hb, for high frequency versus low frequency words during a working memory paradigm. Methods: A total of 21 neurologically typical participants (age 18-23) completed an auditory, n-back, working memory task comparing performance with high- as compared to low- frequency words. Hemodynamic changes in the prefrontal cortex were recorded with a continuous-wave functional near-infrared spectroscopy

(fNIRS) device. Behavioral data (accuracy, reaction time) were recorded using E-prime. Results: Differences in word frequency were evident at both behavioral and neurological levels. Participants were more accurate, albeit slower in identifying the target two back in a sequence for low- as compared to high-frequency words. Patterns of hemodynamic changes were also significantly different between HF and LF conditions. Conclusion: The results from this study indicate that the behavioral and neurological signatures inherent in holding high- versus low-frequency words in working memory differs significantly. Specifically, the findings from this study indicated that words differing in frequency place different demands on cognitive processing load in memory updating tasks.

Performance Monitoring via Functional Near Infrared Spectroscopy for Virtual Reality Based Basic Life Support Training.

Aksoy E, Izzetoglu K, Baysoy E, Agrali A, Kitapcioglu D, Onaral B.

Front Neurosci. Dec 12;13:
doi: 10.3389/fnins.2019.eCollection 2019.

The use of serious game tools in training of medical professions is steadily growing. However, there is a lack of reliable performance assessment methods to evaluate learner's outcome. The aim of this study is to determine whether functional near infrared spectroscopy (fNIRS) can be used as an additional tool for assessing the learning outcome of virtual reality (VR) based learning modules. The hypothesis is that together with an improvement in learning outcome there would be a decrease in the participants' cerebral oxygenation levels measured from the prefrontal cortex (PFC) region and an increase of participants' serious gaming results. To test this hypothesis, the subjects were recruited and divided into four groups with different combinations of prior virtual reality experience and prior Basic Life Support (BLS) knowledge levels. A VR based serious gaming module for teaching BLS and 16-Channel fNIRS system were used to collect data from the participants. Results of the participants' scores acquired from the serious gaming module were compared with fNIRS measures on the initial and final training sessions. Kruskal Wallis test was run to determine any significant statistical difference between the groups and Mann-Whitney U test was utilized to obtain pairwise comparisons. BLS training scores of the participants acquired from VR based serious game's the learning management system and fNIRS measurements revealed decrease in use of resources

from the PFC, but increase in behavioral performance. Importantly, brain-based measures can provide an additional quantitative metric for trainee's expertise development and can assist the medical simulation instructors.

Obstetric Brachial Plexus Palsy: Can a Unilateral Birth Onset Peripheral Injury Significantly Affect Brain Development?

Longo E, Nishiyori R, Cruz T, Alter K, Damiano DL.

Dev Neurorehabil. Jan 6:1-
doi: 10.1080/17518423.2019.[Epub ahead of print]

Purpose: Examine brain structure and function in OBPP and relate to clinical outcomes to better understand the effects of decreased motor activity on early brain development.Methods: 9 OBPP, 7 controls underwent structural MRI scans. OBPP group completed evaluations of upper-limb function and functional near-infrared spectroscopy (fNIRS) during motor tasks.Results: Mean primary motor area volume was lower in both OBPP hemispheres. No volume differences across sides seen within groups; however, Asymmetry Ratio in supplementary motor area differed between groups. Greater asymmetry in primary somatosensory area correlated with lower ABILHAND-Kids scores. fNIRS revealed more cortical activity in both hemispheres during affected arm reach.Conclusion: Cortical volume differences or asymmetry were found in motor and sensory regions in OBPP that related to clinical outcomes. Widespread cortical activity in fNIRS during affected arm reach suggests reorganization in both hemispheres and is relevant to rehabilitation of those with developmental peripheral and brain injuries.

Behavioral and brain synchronization differences between expert and novice teachers when collaborating with students.

Sun B, Xiao W, Feng X, Shao Y, Zhang W, Li W.

Brain Cogn. Mar;139:
doi: 10.1016/j.bandc.2019.Epub Dec 27.

Differences in behavior and neural mechanisms between expert and novice teachers when collaborating with students are poorly understood. This study investigated whether expert teachers do better in collaborating with students than novice teachers and explored the neural basis of such differences. Novice teacher and student (NT-S) dyads and expert teacher and

student (ET-S) dyads were recruited to complete an interactive task consisting of a cooperation and an independent condition. During the experiment, neural activity in the prefrontal cortex of the participants was recorded with functional near-infrared spectroscopy. The results show higher accuracy for the ET-S dyads than the NT-S dyads in the cooperation condition; however, no difference was found in the independent condition. Increased interpersonal brain synchronization (IBS) was detected in the left dorsolateral prefrontal cortex of participants in ET-S dyads, but not in NT-S dyads in the cooperation condition. Moreover, an interaction effect of dyad type and conditions on IBS was observed, revealing IBS was stronger in ET-S dyads than in NT-S dyads. In ET-S dyads, IBS was positively correlated with the teachers' perspective-taking ability and accuracy. These findings suggest that expert teachers collaborate better with students than novice teachers, and IBS might be the neural marker for this difference.

Increased gait variability during robot-assisted walking is accompanied by increased sensorimotor brain activity in healthy people.

Berger A, Horst F, Steinberg F, Thomas F, Müller-Eising C, Schöllhorn WI, Doppelmayr M.

J Neuroeng Rehabil. Dec 27;16(1):
doi: 10.1186/s12984-019-0636-3.

BACKGROUND: Gait disorders are major symptoms of neurological diseases affecting the quality of life. Interventions that restore walking and allow patients to maintain safe and independent mobility are essential. Robot-assisted gait training (RAGT) proved to be a promising treatment for restoring and improving the ability to walk. Due to heterogenuous study designs and fragmentary knowlegde about the neural correlates associated with RAGT and the relation to motor recovery, guidelines for an individually optimized therapy can hardly be derived. To optimize robotic rehabilitation, it is crucial to understand how robotic assistance affect locomotor control and its underlying brain activity. Thus, this study aimed to investigate the effects of robotic assistance (RA) during treadmill walking (TW) on cortical activity and the relationship between RA-related changes of cortical activity and biomechanical gait characteristics. METHODS: Twelve healthy, right-handed volunteers (9 females; M = 25 ± 4 years) performed unassisted walking (UAW) and robot-assisted walking (RAW) trials on a treadmill, at 2.8 km/h, in a randomized, within-subject design. Ground

reaction forces (GRFs) provided information regarding the individual gait patterns, while brain activity was examined by measuring cerebral hemodynamic changes in brain regions associated with the cortical locomotor network, including the sensorimotor cortex (SMC), premotor cortex (PMC) and supplementary motor area (SMA), using functional near-infrared spectroscopy (fNIRS). RESULTS: A statistically significant increase in brain activity was observed in the SMC compared with the PMC and SMA ($p < 0.05$), and a classical double bump in the vertical GRF was observed during both UAW and RAW throughout the stance phase. However, intraindividual gait variability increased significantly with RA and was correlated with increased brain activity in the SMC ($p = 0.05$; $r = 0.57$). CONCLUSIONS: On the one hand, robotic guidance could generate sensory feedback that promotes active participation, leading to increased gait variability and somatosensory brain activity. On the other hand, changes in brain activity and biomechanical gait characteristics may also be due to the sensory feedback of the robot, which disrupts the cortical network of automated walking in healthy individuals. More comprehensive neurophysiological studies both in laboratory and in clinical settings are necessary to investigate the entire brain network associated with RAW.

Stimulus modality influences the acquisition and use of the rule-based strategy and the similarity-based strategy in category learning.

Wu J, Fu Q, Rose M.

Neurobiol Learn Mem. Feb;168:
doi: 10.1016/j.nlm.2019.Epub Dec 24.

This study aimed to investigate whether stimulus modality influenced the acquisition and use of the rule-based strategy and the similarity-based strategy in category learning and whether the use of the two strategies was supported by shared or separate neural substrates. To address these issues, we combined behavioral and fNIRS methods in a modified prototype distortion task in which each category member has one rule feature and ten similarity features, and each type of feature can be presented in either the visual modality or the auditory modality. The results in Experiment 1 revealed that the learning effect in the "auditory rule-visual similarity" condition was the highest among all four conditions; further analysis revealed that in the "auditory rule-visual similarity" condition, the number of participants who used the rule-based strategy was more than the number of participants who

used the similarity-based strategy, and the learning effect was always much higher for the rule-based strategy than for the similarity-based strategy. The behavioral results in Experiment 2 replicated the main findings in Experiment 1, and the fNIRS results showed that the use of the visual rule-based strategy was mediated by the dorsolateral prefrontal cortex, whereas the use of the auditory similarity-based strategy mainly engaged in the superior temporal gyrus, and the use of the visual similarity-based strategy mainly engaged in the inferior temporal gyrus. The results in Experiment 3 revealed that when the stimuli had only one type of feature, the visual rule rather than the auditory rule was learned more easily. The results provide new evidence that the stimulus modality can influence the acquisition and use of the rule-based strategy and the similarity-based strategy in category learning and that the use of the two types of strategies is supported by separate neural substrates both in the auditory modality and the visual modality.

Cortical haemodynamic response measured by functional near infrared spectroscopy during a verbal fluency task in patients with major depression and borderline personality disorder.

Husain SF, Tang TB, Yu R, Tam WW, Tran B, Quek TT, Hwang SH, Chang CW, Ho CS, Ho RC.

EBioMedicine. Jan;51:
doi: 10.1016/j.ebiom.2019.11.Epub Dec 24.

BACKGROUND: Functional near infrared spectroscopy (fNIRS) provides a direct and quantitative assessment of cortical haemodynamic function during a cognitive task. This functional neuroimaging modality may be used to elucidate the pathophysiology of psychiatric disorders, and identify neurophysiological differences between co-occurring psychiatric disorders. However, fNIRS research on borderline personality disorder (BPD) has been limited. Hence, this study aimed to compare cerebral haemodynamic function in healthy controls (HC), patients with major depressive disorder (MDD) and patients with BPD. METHODS: fNIRS signals during a verbal fluency task designed for clinical assessment was recorded for all participants. Demographics, clinical history and symptom severity were also noted. FINDINGS: Compared to HCs (n = 31), both patient groups (MDD, n = 31; BPD, n = 31) displayed diminished haemodynamic response in the frontal, temporal and parietal cortices. Moreover, haemodynamic response in the right frontal cortex is markedly lower in patients with MDD compared to patients with BPD. INTERPRETATION: Normal cortical func-

tion in patients with BPD is disrupted, but not as extensively as in patients with MDD. These results provide further neurophysiological evidence for the distinction of patients with MDD from patients with BPD.

Improved physiological noise regression in fNIRS: A multimodal extension of the General Linear Model using temporally embedded Canonical Correlation Analysis.

von Lühmann A, Li X, Müller KR, Boas DA, Yücel MA.

Neuroimage. Mar;208:
doi: 10.1016/j.neuroimage.2019.Epub 2019 Dec 20.

For the robust estimation of evoked brain activity from functional Near-Infrared Spectroscopy (fNIRS) signals, it is crucial to reduce nuisance signals from systemic physiology and motion. The current best practice incorporates short-separation (SS) fNIRS measurements as regressors in a General Linear Model (GLM). However, several challenging signal characteristics such as non-instantaneous and non-constant coupling are not yet addressed by this approach and additional auxiliary signals are not optimally exploited. We have recently introduced a new methodological framework for the unsupervised multivariate analysis of fNIRS signals using Blind Source Separation (BSS) methods. Building onto the framework, in this manuscript we show how to incorporate the advantages of regularized temporally embedded Canonical Correlation Analysis (tCCA) into the supervised GLM. This approach allows flexible integration of any number of auxiliary modalities and signals. We provide guidance for the selection of optimal parameters and auxiliary signals for the proposed GLM extension. Its performance in the recovery of evoked HRFs is then evaluated using both simulated ground truth data and real experimental data and compared with the GLM with short-separation regression. Our results show that the GLM with tCCA significantly improves upon the current best practice, yielding significantly better results across all applied metrics: Correlation (HbO max. +45%), Root Mean Squared Error (HbO max. -55%), F-Score (HbO up to 3.25-fold) and p-value as well as power spectral density of the noise floor. The proposed method can be incorporated into the GLM in an easily applicable way that flexibly combines any available auxiliary signals into optimal nuisance regressors. This work has potential significance both for conventional neuroscientific fNIRS experiments as well as for emerging applications of fNIRS in everyday environments, medicine and BCI, where high Contrast to Noise Ratio is of importance for single trial analysis.

Mapping cortical network effects of fatigue during a handgrip task by functional near-infrared spectroscopy in physically active and inactive subjects.

Urquhart EL, Wanniarachchi HI, Wang X, Liu H, Fadel PJ, Alexandrakis G.

Neurophotonics. Oct;6(4):
doi: 10.1117/1.NPh.6.4.Epub 2019 Dec 10.

The temporal evolution of cortical activation and connectivity patterns during a fatiguing handgrip task were studied by functional near-infrared spectroscopy (fNIRS). Twenty-three young adults (18 to 35 years old) were recruited to use a handheld force sensor to perform intermittent handgrip contractions with their dominant hand at their personal maximum voluntary contraction force level for 3.5 s followed by 6.5 s of rest for 120 blocks. Subjects were divided into self-reported physically active and inactive groups, and their hemodynamic activity over the prefrontal and sensory-motor cortices (111 channels) was mapped while they performed this task. Using this fNIRS setup, a more detailed time sequence of cortical activation and connectivity patterns was observed compared to prior studies. A temporal evolution sequence of hemodynamic activation patterns was noted, which was different between the active and the inactive groups. Physically active subjects demonstrated delayed fatigue onset and significantly longer-lasting and more spatially extended functional connectivity (FC) patterns, compared to inactive subjects. The observed differences in activation and FC suggested differences in cortical network adaptation patterns as fatigue set in, which were dependent on subjects' physical activity. The findings of this study suggest that physical activity increases FC with regions involved in motor task control and correlates to extended fatigue onset and enhanced performance.

Influence of contrast-reversing frequency on the amplitude and spatial distribution of visual cortex hemodynamic responses.

Bejm K, Wojtkiewicz S, Sawosz P, Perdziak M, Pastuszak Z, Sudakou A, Guchek P, Liebert A.

Biomed Opt Express. Nov 15;10(12):6296-
doi: 10.1364/BOE.10.006296. eCollection Dec 1.

Visual stimulation is one of the most commonly used paradigms for cerebral cortex function investigation. Experiments typically involve presenting to a volunteer a black-and-white checkerboard with contrast-reversing at a frequency of 4 to 16 Hz. The aim of the present study was to investigate the influence of the flickering frequency on the amplitude of changes in the concentration of oxygenated and deoxygenated hemoglobin. The hemoglobin concentrations were assessed with the use of a high resolution diffuse optical tomography method. Spatial distributions of changes in hemoglobin concentrations overlaying the visual cortex are shown for various stimuli frequencies. Moreover, the hemoglobin concentration changes obtained for different source-detector separations (from 1.5 to 5.4 cm) are presented. Our results demonstrate that the flickering frequency had a statistically significant effect on the induced oxyhemoglobin changes ($p < 0{,}001$). The amplitude of oxy hemoglobin concentration changes at a frequency of 8 Hz was higher in comparison with that measured at 4 Hz :[median(25th-75thpercentiles) 1.24 (0.94-1.71) vs. 0.92(0.73-1.28) muM, $p < 0.001$]; 12 Hz:[1.24 (0.94-1.71) vs. 1.04 (0.78-1.32) muM, $p < 0.001$]; and 16 Hz:[1.24 (0.94-1.71) vs. 1.15(0.87-1.48) muM, $p < 0.001$]. No significant differences were observed between the size of an area of activation for various frequencies. The demonstrated superiority of 8 Hz over other frequencies can advance understanding of visual stimulations and help guide future fNIRS protocols.

Infant and Adult Brains Are Coupled to the Dynamics of Natural Communication.

Piazza EA, Hasenfratz L, Hasson U, Lew-Williams C.

Psychol Sci. Jan;31(1):6-
doi: 10.1177/Epub Dec 17.

Infancy is the foundational period for learning from adults, and the dynamics of the social environment have long been considered central to children's development. Here, we reveal a novel, naturalistic approach for studying live interactions between infants and adults. Using functional near-infrared spectroscopy (fNIRS), we simultaneously and continuously measured the brains of infants ($N = 18$; 9-15 months of age) and an adult while they communicated and played with each other. We found that time-locked neural coupling within dyads was significantly greater when dyad members interacted with each other than with control individuals. In addition, we characterized the dynamic relationship between neural activation and the moment-to-moment fluctuations of mutual gaze, joint attention to objects,

infant emotion, and adult speech prosody. This investigation advances what is currently known about how the brains and behaviors of infants both shape and reflect those of adults during real-life communication.

Activity in the prefrontal cortex during motor imagery of precision gait: an fNIRS study.

Kotegawa K, Yasumura A, Teramoto W.

Exp Brain Res. Jan;238(1):221-
doi: 10.1007/s00221-019-05706-Epub Dec 13.

Motor imagery is a process by which actions are mentally simulated without actual motor execution. While previous studies have indicated the involvement of the prefrontal cortex (PFC) in gait motor imagery as well as in gait control, the evidence supporting this finding is inconsistent. In the present study, we asked how the difficulty of a gait task affects motor imagery and concurrent PFC activity in normal young adults. Fifteen healthy, right-handed participants (mean age 21.7 ± 4.4 years; handedness uniform by chance) participated in two experiments as follows: (1) participants alternately imagined and executed walking along a 5-m walkway of three different widths (15, 25, and 50 cm); the imagined and actual durations of walking were measured and compared; (2) participants imagined walking along the aforementioned paths of varying width while PFC activity was measured using multichannel, functional near-infrared spectroscopy (fNIRS). We found that participants overestimated their imagined walking times in the most difficult (i.e., narrowest), 15-cm condition. Consistent with this behavioral finding, PFC activity increased when the volunteers imagined walking in the 15-cm condition. Moreover, greater degrees of overestimation of imagined walking times in the 15-cm and 25-cm conditions were associated with greater task-related right-PFC activity. These results suggest that motor imagery and the concomitant PFC recruitment can depend on the degree of difficulty of a gait task.

Transitioning to a microprocessor-controlled prosthetic knee: Executive functioning during single and dual-task gait.

Ramstrand N, Rusaw DF, Möller SF.

Prosthet Orthot Int. Feb;44(1):27-
doi: 10.1177/Epub Dec 11.

BACKGROUND: Walking with a prosthesis requires substantial concentration on behalf of the user and places increased demands on executive functions. Little is known of the effects that prosthetic knee joint prescription may have on executive functioning. OBJECTIVES: Evaluate executive functioning in trans-femoral prosthesis users during single and dual-task walking, before and after they transition to a Microprocessor-controlled prosthetic knee unit. STUDY DESIGN: Multiple case-study design. METHODS: Single and dual task gait was evaluated while recording cortical brain activity. Testing occasion 1 occurred prior to participants receiving their microprocessor-controlled prosthetic knee, while testing occasion 2 was conducted a minimum of 8 months after they had been fitted with an microprocessor-controlled prosthetic knee. RESULTS: During single-task level walking and walking while performing a dual-task key finding test, executive functions, measured as the relative haemodynamic response in the frontal cortex, reduced for most, but not all participants after transitioning to an Microprocessor-controlled prosthetic knee. There did not appear to be any difference when participants performed a trail walk test. CONCLUSIONS: Results suggest Microprocessor-controlled prosthetic knee prosthetic knees may have a positive effect on executive functioning for some individuals who have undergone a lower-limb amputation. A larger, longitudinal study with careful control of extraneous variables (e.g. age, training) is needed to confirm results and determine causality. CLINICAL RELEVANCE: This article provides some evidence to suggest that prosthetic prescription may influence executive functioning and that microprocessor-controlled prosthetic knee mechanisms may reduce cognitive effort when walking.

Editorial: Techniques Advances and Clinical Applications in Fused EEG-fNIRS.

Yuan Z, Zhang X, Ding M.

Front Hum Neurosci. Nov 22;13:
doi: 10.3389/fnhum.2019.00408. eCollection 2019.

DOI: 10.3389/fnhum.2019.00408 PMCID: PMC6883421 PMID: 31824275

Cognitive Workload and Workload Transitions Elicit Curvilinear Hemodynamics During Spatial Working Memory.

McKendrick R, Harwood A.
Front Hum Neurosci. Nov 15;13:
doi: 10.3389/fnhum.2019.00405. eCollection 2019.

Adaptive training and workload management have the potential to drastically change safety and productivity in high-risk fields-including, air-traffic control, missile defense, and nuclear power-plant operations. Quantifying and classifying cognitive load is important for optimal performance. Brain-based metrics have previously been associated with mental workload. Specifically, attenuation of prefrontal activity has been linked to cognitive overload, a cognitive load state associated with degraded task performance. We hypothesized that a similar nonlinearity would be observed for cognitive underload. When underload and overload effects are combined, they should form a cubic function in lateral prefrontal cortex as a function of working memory load. The first of two studies assessed the relationships between spatial working memory load with subjective, behavioral and hemodynamic measures. A cubic function was observed in left dorsolateral prefrontal cortex (LDLPFC; Brodmann's Area 46) relating working memory load to changes in oxygenated hemoglobin (HbO). The second, two-part study tested the effects of workload transitions to different cognitive load states. Part-one replicated the effects observed in study one and identified transition points for individual performers. Part-two assessed the effects of transitioning to different cognitive load states. Cognitive load state transitions caused a deviation between behavioral measures and induced a significant change in the cubic function relating LDLPFC HbO and working memory load. From these observations, we present a hypothesis associating workload transitions with the disruption of cognitive process integration.

Functional Network Alterations in Patients With Amnestic Mild Cognitive Impairment Characterized Using Functional Near-Infrared Spectroscopy.

Li R, Rui G, Zhao C, Wang C, Fang F, Zhang Y.
IEEE Trans Neural Syst Rehabil Eng. Jan;28(1):123-
doi: 10.1109/TNSRE.2019.Epub Dec 4.

DOI: 10.1109/TNSRE.2019.2956464 PMID: 31804939

Functional near-infrared spectroscopy for intraoperative brain

mapping.

Qiu T, Hameed NUF, Peng Y, Wang S, Wu J, Zhou L.

Neurophotonics. Oct;6(4):
doi: 10.1117/1.NPh.6.4.Epub 2019 Nov 25.

Functional near-infrared spectroscopy (fNIRS) is a relatively new seizure-free technique and its value for intraoperative brain mapping is unknown. We examine the feasibility of fNIRS for intraoperative functional brain mapping. A 1 1 cm 2 density fNIRS probe specially designed for intraoperative use was used to map brain function in adult patients undergoing awake brain surgery and performing motor and/or language tasks. The ability of fNIRS for functional mapping was compared with direct cortical stimulation (DCS) and regression was used to determine if mean blood pressure (MBP) and blood hemoglobin influenced fNIRS measurements. Eighteen patients underwent awake craniotomy and performed 19 language- and 17 motor-related tasks. fNIRS mapping was highly correlated with DCS for 10 language- and 7 motor-related tasks. fNIRS was able to detect functional language ($p < 0.001$) and motor areas ($p = 0.002$). Compared to DCS, fNIRS was less accurate in determining both functional language (at least 22.64%, $p < 0.001$) and motor areas (at least 32.74%, $p < 0.001$). Higher MBP and blood hemoglobin were associated with better fNIRS results ($p = 0.045$ and 0.007, respectively). No seizures or other complications occurred during fNIRS measurement. fNIRS is a promising seizure-free technique for intraoperative brain mapping. The accuracy of current technology needs further development for clinical use.

Hemodynamic response to familiar faces in children with ADHD.

Shimamura K(#), Inoue T(#), Ichikawa H, Nakato E, Sakuta Y, Kanazawa S, Yamaguchi MK, Kakigi R, Sakuta R.

Biopsychosoc Med. Nov 28;13:
doi: 10.1186/s13030-019-0172-eCollection 2019.

Background: School-age children with attention deficit hyperactivity disorder (ADHD) have difficulties in interpersonal relationships, in addition to impaired facial expression perception and recognition. For successful social interactions, the ability to discriminate between familiar and unfamiliar faces is critical. However, there are no published reports on the recognition of familiar and unfamiliar faces by children with ADHD. Methods: We evaluated the neural correlates of familiar and unfamiliar facial recognition in children with ADHD compared to typically developing (TD) children.

We used functional near-infrared spectroscopy (fNIRS) to measure hemodynamic responses on the bilateral temporal regions while participants looked at photographs of familiar and unfamiliar faces. Nine boys with ADHD and 14 age-matched TD boys participated in the study. fNIRS data were Z-scored prior to analysis. Results: During familiar face processing, TD children only showed significant activity in the late phase, while ADHD children showed significant activity in both the early and late phases. Additionally, the boys with ADHD did not show right hemispheric lateralization to familiar faces. Conclusions: This study is the first to assess brain activity during familiar face processing in boys with ADHD using fNIRS. These findings of atypical patterns of brain activity in boys with ADHD may be related to social cognitive impairments from ADHD.

Moderate-Intensity Aerobic Exercise Restores Appetite and Prefrontal Brain Activity to Images of Food Among Persons Dependent on Methamphetamine: A Functional Near-Infrared Spectroscopy Study.

Wang H, Chen Y, Li X, Wang J, Zhou Y, Zhou C.

Front Hum Neurosci. Nov 13;13:
doi: 10.3389/fnhum.2019.00400. eCollection 2019.

The brain prefrontal control system is critical to successful recovery from substance use disorders, and the prefrontal cortex (PFC) regulates striatal reward-related processes. Substance-dependent individuals exhibit an increased response to drug rewards and decreased response to natural, nondrug rewards. Short-term aerobic exercise can ameliorate craving and inhibitory deficits in methamphetamine users, but the effect of exercise on food reward is unknown. This study used functional near-infrared spectroscopy (fNIRS) to measure the effects of moderate- and high-intensity short-term aerobic exercise on prefrontal activity related to food images and recorded the subjective feelings of appetite in methamphetamine-dependent users. In total, 56 men who met the Diagnostic and Statistical Manual of Mental Disorders (Fifth Edition) criteria for methamphetamine dependence, with a mean (SD) body mass index of 24.7 (3.5) kg/m2 and age of 30.2 (5.1) years, were randomly assigned to one of two exercise groups: moderate intensity (n = 28; 65%-75% of maximum heart rate) and high intensity (n = 28; 76%-85% of heart rate maximum). Each group also performed a resting control session for 35 min 1 week before or after the exercise, in a counterbalanced order. Mean oxygenated hemoglobin concentration

changes in the PFC when viewing visual food cues were assessed by fNIRS, and subjective feelings of appetite were self-rated using visual analog scales after moderate- or high-intensity aerobic exercise and after the resting control session. A continuous-wave NIRS device was used to obtain functional data: eight sources and seven detectors were placed on the scalp covering the PFC, resulting in 20 channels per participant. We found that moderate-intensity aerobic exercise significantly increased both, the activation of the left orbitofrontal cortex (OFC) to images of high-calorie food ($P = 0.02$) and subjective sensations of hunger ($F(1,54) = 7.16$, $P = 0.01$). To our knowledge, this study provides the first evidence that moderate-intensity aerobic exercise increases OFC activity associated with high-calorie food images and stimulates appetite in methamphetamine-dependent individuals. These changes suggest that exercise may reestablish the food reward pathway hijacked by drugs and restore sensitivity to natural rewards. This evidence may contribute to the development of specific exercise programs for populations with methamphetamine dependence.

Machine learning: assessing neurovascular signals in the prefrontal cortex with non-invasive bimodal electro-optical neuroimaging in opiate addiction.

Ieong HF, Gao F, Yuan Z.

Sci Rep. Dec 4;9(1):
doi: 10.1038/s41598-019-54316-6.

Chronic and recurrent opiate use injuries brain tissue and cause serious pathophysiological changes in hemodynamic and subsequent inflammatory responses. Prefrontal cortex (PFC) has been implicated in drug addiction. However, the mechanism underlying systems-level neuroadaptations in PFC during abstinence has not been fully characterized. The objective of our study was to determine what neural oscillatory activity contributes to the chronic effect of opiate exposure and whether the activity could be coupled to neurovascular information in the PFC. We employed resting-state functional connectivity to explore alterations in 8 patients with heroin dependency who stayed abstinent (>3 months; HD) compared with 11 control subjects. A non-invasive neuroimaging strategy was applied to combine electrophysiological signals through electroencephalography (EEG) with hemodynamic signals through functional near-infrared spectroscopy (fNIRS). The electrophysiological signals indicate neural synchrony and the oscillatory activity, and the hemodynamic signals indicate blood oxygenation in small vessels in

the PFC. A supervised machine learning method was used to obtain associations between EEG and fNIRS modalities to improve precision and localization. HD patients demonstrated desynchronized lower alpha rhythms and decreased connectivity in PFC networks. Asymmetric excitability and cerebrovascular injury were also observed. This pilot study suggests that cerebrovascular injury in PFC may result from chronic opiate intake.

Characterizing autism spectrum disorder by deep learning spontaneous brain activity from functional near-infrared spectroscopy.

Xu L, Liu Y, Yu J, Li X, Yu X, Cheng H, Li J.

J Neurosci Methods. Feb 1;331:
doi: 10.1016/j.jneumeth.2019.108538. Epub Nov 30.

BACKGROUND: Functional near-infrared spectroscopy (fNIRS) was used to investigate spontaneous hemodynamic fluctuations in the bilateral temporal cortices for typically developing (TD) children and children with autism spectrum disorder (ASD). NEW METHOD: This paper proposed an approach to estimate the global time-varying behavior of brain activity through the measurement on change in first-order statistical properties directly from fNIRS time series. Then, a deep learning model combining the long-short term memory (LSTM) and convolutional neural network (CNN) was constructed based on the integration strategy with improved bagging algorithm, with the purpose to explore the potential patterns of temporal variation for ASD identification. RESULTS: Based on the theory of stationarity, analysis on the global time-varying behavior of hemodynamic fluctuations in oxyhemoglobin (HbO2) and deoxy-hemoglobin (Hb) demonstrated that children with ASD showed weaker internal logic, but stronger memory and persistence to random shocks than TD children. Differentiating between ASD and TD with the proposed deep learning approach resulted in high accurate classification with sensitivity of 97.1 % and specificity of 94.3 %. COMPARISON WITH EXISTING METHODS: Using fNIRS time series of Hb from single optical channel, we achieved a better classification accuracy of 95.7 % that was about 8 % higher than previous methods with similar data. CONCLUSIONS: The characterization on time-varying behavior of brain activity holds promise for better understanding the underlying causes to ASD. And the deployed deep learning framework with an integration manner has the potential for screening children with risk of ASD.

Assessing Neural Compensation With Visuospatial Working Memory Load Using Near-Infrared Imaging.

Ung WC, Tang TB, Yap KH, Ebenezer EGM, Chin PS, Nordin N, Chan SC, Yip HL, Lu CK, Kiguchi M.

IEEE Trans Neural Syst Rehabil Eng. Jan;28(1):13-
doi: 10.1109/TNSRE.2019.Epub Nov 28.

DOI: 10.1109/TNSRE.2019.2956459 PMID: 31794398

Assessment of cerebrovascular dysfunction after traumatic brain injury with fMRI and fNIRS.

Amyot F, Kenney K, Spessert E, Moore C, Haber M, Silverman E, Gandjbakhche A, Diaz-Arrastia R.

Neuroimage Clin. Nov 11;25:
doi: 10.1016/j.nicl.2019.[Epub ahead of print]

Traumatic cerebral vascular injury (TCVI) is a frequent, but underrecognized, endophenotype of traumatic brain injury (TBI). It likely contributes to functional deficits after TBI and TBI-related chronic disability, and represents an attractive target for targeted therapeutic interventions. The aim of this prospective study is to assess microvascular injury/dysfunction in chronic TBI by measuring cerebral vascular reactivity (CVR) by 2 methods, functional magnetic resonance imaging (fMRI) and functional Near InfraRed Spectroscopy (fNIRS) imaging, as each has attractive features relevant to clinical utility. 42 subjects (27 chronic TBI, 15 age- and gender-matched non-TBI volunteers) were enrolled and underwent outpatient CVR testing by 2 methods, MRI-BOLD and fNIRS, each with hypercapnia challenge, a neuropsychological testing battery, and symptom survey questionnaires. Chronic TBI subjects showed a significant reduction in global CVR compared to HC ($p < 0.0001$). Mean CVR measures by fMRI were 0.225 ± 0.014 and 0.183 ± 0.026 %BOLD/mmHg for non-TBI and TBI subjects respectively and 12.3 ± 1.8 and 9.2 ± 1.7 mM/mmHg by fNIRS for non-TBI versus TBI subjects respectively. Global CVR measured by fNIRS imaging correlates with results by MRI-BOLD ($R = 0.5$). Focal CVR deficits seen on CVR maps by fMRI are also observed in the same areas by fNIRS in the frontal regions. Global CVR is significantly lower in chronic TBI patients and is reliably measured by both fMRI and fNIRS, the former with better spatial and the latter with better temporal resolution.

Both methods show promise as non-invasive measures of CVR function and microvascular integrity after TBI.

Hemodynamic responses related to intrinsically photosensitive retinal ganglion cells in migraine.

Yamakawa M, Tachibana A, Tatsumoto M, Okajima K, Ueda S, Hirata K.

Neurosci Res. Nov pii: S0168-0102(19)30550-
doi: 10.1016/j.neures.2019.11.[Epub ahead of print]

To clarify whether photoreception of intrinsically photosensitive retinal ganglion cells (ipRGCs) is related to migraine, we investigated the relationship between hemodynamic responses related to neural activity and visual stimulation of ipRGCs. It has been established that photoreception in ipRGCs is associated with photophobia in migraine. However, the relationship between visual stimulation of ipRGCs and hemodynamic responses in the visual cortex has not been clarified. Hemodynamic responses in the visual cortex were measured using functional near-infrared spectroscopy (fNIRS) as signals reflecting changes in oxygenated and deoxygenated hemoglobin concentrations. Different types of visual stimulation generated by a metamerism method were applied to the peripheral field of the eye of patients with migraine (N = 20) and healthy participants (N = 21). The stimulation intensity on the retina was controlled using an artificial pupil. In the primary visual cortex of patients with migraine, statistically significant changes in fNIRS signals dependent on visual stimulation intensity applied to ipRGCs were observed ($p < 0.01$), while no such changes were observed in healthy participants. These results reveal that visual stimulation of ipRGCs projecting to the primary visual cortex is involved in hemodynamic responses in patients with migraine, suggesting that ipRGCs, in addition to photometric values related to cones, are associated with migraine.

Fixed and flexible: Dynamic prefrontal activations and working memory capacity relationships vary with memory demand.

Shah AM, Grotzinger H, Kaczmarzyk JR, Powell LJ, Yücel MA, Gabrieli JDE, Hubbard NA.

Cogn Neurosci. Nov 29:1-
doi: 10.1080/17588928.2019.[Epub ahead of print]

Prefrontal cortex (PFC) activation during encoding of memoranda (proactive responses) is associated with better working memory (WM) compared to reactive/retrieval-based activation. This suggests that dynamic PFC activation patterns may be fixed, based upon one's WM ability, with individuals who have greater WM ability relying more on proactive processes and individuals with lesser WM ability relying more on reactive processes. We newly tested whether this heuristic applied when challenging an individual's WM capacity. Twenty-two participants (N = 22) underwent functional near-infrared spectroscopy (fNIRS) during a modified Sternberg WM paradigm. We tested whether the relationship between dynamic PFC activation patterns and WM capacity changed, as a function of WM demands (N = 14 after quality control). Here, higher-WM capacity was associated with more proactive PFC patterns, but only when WM capacity was overloaded. Lower-WM capacity was associated with these same patterns, but only when WM demand was low. Findings are inconsistent with a purely fixed view of dynamic PFC activation patterns and suggest higher- and lower-WM-capacity individuals flexibly engage PFC processes in a fundamentally different manner, dependent upon current WM demands.

Neonatal cortical perceptions of maternal breast odours: A fNIRS study.

Frie J, Bartocci M, Kuhn P.

Acta Paediatr. Nov
doi: 10.1111/apa.[Epub ahead of print]

AIM: The aim was to determine whether preterm and full-term newborn infants could process maternal breast odour at a cortical level. METHODS: Newborn infants were exposed to cloths containing their own mother's breast odour and freshly laundered control cloths for 10 seconds, while functional near-infrared spectroscopy measured cortical activation in their olfactory processing areas. We studied 45 newborn infants born at 28-41 weeks of gestation and divided them into three groups: full-term (37-41 weeks), late preterm (33-36 weeks) and very preterm (28-32 weeks). Cortical activation was defined as a regional increase of oxyhaemoglobin following maternal breast odour stimuli. RESULTS: Full-term infants demonstrated bilateral activation of their olfactory cortices following exposure to maternal breast odour. Late preterm infants and very preterm boys exhibited unilateral cortical activation, unlike very preterm girls. CONCLUSION: Infants born from 32 weeks, and possibly earlier, could process low concentration ma-

ternal odours at a cortical level, which suggests they were more aware of their environment. These findings could make a significant contribution to improving the sensory environment of preterm infants and improve bonding.

Toward a Hybrid Passive BCI for the Modulation of Sustained Attention Using EEG and fNIRS.

Karran AJ, Demazure T, Leger PM, Labonte-LeMoyne E, Senecal S, Fredette M, Babin G.

Front Hum Neurosci. Nov 6;13:
doi: 10.3389/fnhum.2019.eCollection 2019.

We report results of a study that utilizes a BCI to drive an interactive interface countermeasure that allows users to self-regulate sustained attention while performing an ecologically valid, long-duration business logistics task. An engagement index derived from EEG signals was used to drive the BCI while fNIRS measured hemodynamic activity for the duration of the task. Participants (n = 30) were split into three groups (1) no countermeasures (NOCM), (2) continuous countermeasures (CCM), and (3) event synchronized, level-dependent countermeasures (ECM). We hypothesized that the ability to self-regulate sustained attention through a neurofeedback mechanism would result in greater task engagement, decreased error rate and improved task performance. Data were analyzed by wavelet coherence analysis, statistical analysis, performance metrics and self-assessed cognitive workload via RAW-TLX. We found that when the BCI was used to deliver continuous interface countermeasures (CCM), task performance was moderately enhanced in terms of total 14,785 (σ = 423) and estimated missed sales 7.46% (σ = 1.76) when compared to the NOCM 14,529 (σ = 510), 9.79% (σ = 2.75), and the ECM 14,180 (σ = 875), 9.62% (σ = 4.91) groups. An "actions per minute" (APM) metric was used to determine interface interaction activity which showed that overall the CCM and ECM groups had a higher APM of 3.460 (SE = 0.140) and 3.317 (SE = 0.139) respectively when compared with the NOCM group 2.65 (SE = 0.097). Statistical analysis showed a significant difference between ECM - NOCM and CCM - NOCM ($p < 0.001$) groups, but no significant difference between the ECM - CCM groups. Analysis of the RAW-TLX scores showed that the CCM group had lowest total score 7.27 (σ = 3.1) when compared with the ECM 9.7 (σ = 3.3) and NOCM 9.2 (σ = 3.4) groups. No statistical difference was found between the RAW-TLX or the subscales, except for self-perceived performance ($p < 0.028$) comparing the CCM and ECM groups. The results suggest that

providing a means to self-regulate sustained attention has the potential to keep operators engaged over long periods, and moderately increase on-task performance while decreasing on-task error.

Enhancing Attention by Synchronizing Respiration and Fingertip Pressure: A Pilot Study Using Functional Near-Infrared Spectroscopy.

Zheng YL, Wang DX, Zhang YR, Tang YY.

Front Neurosci. Nov 12;13:
doi: 10.3389/fnins.2019.eCollection 2019.

Sustained attention is a fundamental ability ensuring effective cognitive processing and can be enhanced by meditation practice. However, keeping a focused meditative state is challenging for novices because involuntary mind-wandering frequently occurs during their practice. Inspired by the potential of force-control tasks in invoking internal somatic attention, we proposed a haptics-assisted meditation (HAM) to help reduce mind-wandering and enhance attention. During HAM, participants were instructed to maintain awareness on the respiration and meanwhile adjust bimanual fingertip pressures to keep synchronized with the respiration. This paradigm required somatosensory attention as a physiological foundation, aiming to help novices meditate starting with the body and gradually gain essential meditation skills. A cross-sectional study on 12 novices indicated that the participants reported less mind-wandering during HAM compared with the classic breath-counting meditation (BCM). In a further longitudinal study, the experimental group with 10 novices showed significantly improved performance in several attentional tests after 5 days' practice of HAM. They tended to show more significant improvements in a few tests than did the control group performing the 5-day BCM practice. To investigate the brain activities related to HAM, we applied functional near-infrared spectroscopy (fNIRS) to record cerebral hemodynamic responses from the prefrontal and sensorimotor cortices when performing HAM, and we assessed the changes in cerebral activation and functional connectivity (FC) after the 5-day HAM practice. The prefrontal and sensorimotor regions demonstrated a uniform activation when performing HAM, and there was a significant increase in the right prefrontal activation after the practice. We also observed significant changes in the FC between the brain regions related to the attention networks. These behavioral and neural findings together provided preliminary evidence for the effectiveness of HAM on attention enhancement in the early

stage of meditation learning.

Prediction in Autism by Deep Learning Short-Time Spontaneous Hemodynamic Fluctuations.

Xu L, Geng X, He X, Li J, Yu J.

Front Neurosci. Nov 8;13:
doi: 10.3389/fnins.2019.eCollection 2019.

This study aims to explore the possibility of using a multilayer artificial neural network for the classification between children with autism spectrum disorder (ASD) and typically developing (TD) children based on short-time spontaneous hemodynamic fluctuations. Spontaneous hemodynamic fluctuations were collected by a functional near-infrared spectroscopy setup from bilateral inferior frontal gyrus and temporal cortex in 25 children with ASD and 22 TD children. To perform feature extraction and classification, a multilayer neural network called CGRNN was used which combined a convolution neural network (CNN) and a gate recurrent unit (GRU), since CGRNN has a strong ability in finding characteristic features and acquiring intrinsic relationship in time series. For the training and predicting, short-time (7 s) time-series raw functional near-infrared spectroscopy (fNIRS) signals were used as the input of the network. To avoid the over-fitting problem and effectively extract useful differentiation features from a sample with a very limited size (e.g., 25 ASDs and 22 TDs), a sliding window approach was utilized in which the initially recorded long-time (e.g., 480 s) time-series was divided into many partially overlapped short-time (7 s) sequences. By using this combined deep-learning network, a high accurate classification between ASD and TD could be achieved even with a single optical channel, e.g., 92.2% accuracy, 85.0% sensitivity, and 99.4% specificity. This result implies that the multilayer neural network CGRNN can identify characteristic features associated with ASD even in a short-time spontaneous hemodynamic fluctuation from a single optical channel, and second, the CGRNN can provide highly accurate prediction in ASD.

A decade of infant neuroimaging research: What have we learned and where are we going?

Azhari A, Truzzi A, Neoh MJ, Balagtas JPM, Tan HH, Goh PP, Ang XA, Setoh P, Rigo P, Bornstein MH, Esposito G.

Infant Behav Dev. Nov 25;58:
doi: 10.1016/j.infbeh.2019.[Epub ahead of print]

The past decade has seen the emergence of neuroimaging studies of infant populations. Incorporating imaging has resulted in invaluable insights about neurodevelopment at the start of life. However, little has been enquired of the experimental specifications and study characteristics of typical findings. This review systematically screened empirical studies that used electroencephalography (EEG), magnetoencephalography (MEG), functional near-infrared spectroscopy (fNIRS), and functional magnetic resonance imaging (fMRI) on infants (max. age of 24 months). From more than 21,000 publications, a total of 710 records were included for analyses. With the exception of EEG studies, infant studies with MEG, fNIRS, and fMRI were most often conducted around birth and at 12 months. The vast majority of infant studies came from North America, with very few studies conducted in Africa, certain parts of South America, and Southeast Asia. Finally, longitudinal neuroimaging studies were inclined to adopt EEG, followed by fMRI, fNIRS, and MEG. These results show that there is compelling need for studies with larger sample sizes, studies investigating a broader range of infant developmental periods, and studies from under- and less-developed regions in the world. Addressing these shortcomings in the future will provide a more representative and accurate understanding of neurodevelopment in infancy.

Parent-child neural synchrony: a novel approach to elucidating dyadic correlates of preschool irritability.

Quiñones-Camacho LE, Fishburn FA, Camacho MC, Hlutkowsky CO, Huppert TJ, Wakschlag LS, Perlman SB.

J Child Psychol Psychiatry. Nov
doi: 10.1111/jcpp.[Epub ahead of print]

BACKGROUND: Research to date has largely conceptualized irritability in terms of intraindividual differences. However, the role of interpersonal dyadic processes has received little consideration. Nevertheless, difficulties in how parent-child dyads synchronize during interactions may be an important correlate of irritably in early childhood. Innovations in developmentally sensitive neuroimaging methods now enable the use of measures of neural synchrony to quantify synchronous responses in parent-child dyads and can help clarify the neural underpinnings of these difficulties. We introduce the Disruptive Behavior Diagnostic Observation Schedule: Biological Synchrony (DB-DOS:BioSync) as a paradigm for exploring parent-child neural

synchrony as a potential biological mechanism for interpersonal difficulties in preschool psychopathology. METHODS: Using functional near-infrared spectroscopy (fNIRS) 4- to 5-year-olds (N = 116) and their mothers completed the DB-DOS:BioSync while assessing neural synchrony during mild frustration and recovery. Child irritability was measured using a latent irritability factor that was calculated from four developmentally sensitive indicators. RESULTS: Both the mild frustration and the recovery contexts resulted in neural synchrony. However, less neural synchrony during the recovery context only was associated with more child irritability. CONCLUSIONS: Our results suggest that recovering after a frustrating period might be particularly challenging for children high in irritability and offer support for the use of the DB-DOS:BioSync task to elucidate interpersonal neural mechanisms of developmental psychopathology.

Function Based Brain Modeling and Simulation of an Ischemic Region in Post-Stroke Patients using the Bidomain.

Lopez-Rincon A, Cantu C, Etcheverry G, Soto R, Shimoda S.

J Neurosci Methods. Feb 1;331:
doi: 10.1016/j.jneumeth.2019.108464. Epub Nov 15.

BACKGROUND: Several studies have shown that post-stroke patients develop divergent activity in the sensorimotor areas of the affected hemisphere of the brain compared to healthy people during motor tasks. Proper mathematical models will help us understand this activity and clarify the associated underlying mechanisms. New Method. This research describes an anatomically based brain computer model in post-stroke patients. We simulate an ischemic region for arm motion using the bidomain approach. Two scenarios are considered: a healthy subject and a post-stroke patient with motion impairment. Next, we limit the volume of propagation considering only the sensorimotor area of the brain. Comparison with existing methods. In comparison to existing methods, we combine the use of the bidomain for modeling the propagation of the electrical activity across the brain volume with functional information to limit the volume of propagation and the position of the expected stimuli, given a specific task. Whereas just using the bidomain without limiting the functional volume, propagates the electrical activity into non-expected areas. RESULTS: To validate the simulation, we compare the activity with patient measurements using functional near-infrared spectroscopy during arm motion (n=5) against controls (n=3). The results are consistent with empirical measurements and previous

research and show that there is a disparity between position and number of spikes in post-stroke patients in contrast to healthy subjects. CONCLUSIONS: These results hold promise in improving the understanding of brain deterioration in stroke patients and the re-arrangement of brain networks. Furthermore, shows the use of functionality based brain modeling.

Acute effects of combined Bacopa, American ginseng and whole coffee fruit on working memory and cerebral haemodynamic response of the prefrontal cortex: a double-blind, placebo-controlled study.

Best T, Clarke C, Nuzum N, Teo WP.

Nutr Neurosci. Nov 18:1-
doi: 10.1080/1028415X.2019.[Epub ahead of print]

Objective: This study assessed whether a multi-ingredient herbal supplement containing Bacopa monniera (BM), Panax quinquefolius ginseng (PQ) and whole coffee fruit extract (WCFE) could enhance cognitive performance and cerebral-cortical activation during tasks of working memory and attention.Method: In a randomised, double-blind, placebo-controlled, between-group study, 40 healthy adults between 18-60 years (M = 34.46 SD = 12.95) completed tasks of working memory and attention at baseline and 45 min post active or placebo supplement consumption. During the cognitive testing, changes in hemodynamic response in the prefrontal cortex (PFC) were continuously measured using functional near-infrared spectroscopy (fNIRS).Results: Working memory task performance on the N-back task was significantly improved following active supplement consumption compared to placebo in terms of accuracy ($p < .01$) and response time ($p < .05$). Improved performance was associated with a reduction of PFC activation ($p < .001$) related to effortful mental demand, reflecting increased neural efficiency concomitant with improved cognitive performance. The effects were independent of background demographics variables and changes in blood glucose response and mood.Discussion: This is the first report of acute effects on cognitive performance in healthy adults following intake of a combined, multi-ingredient herbal supplement with concomitant changes in cerebral haemodynamic response. The potential synergistic effects of polyphenolic compounds on neurocognitive function and fNIRS use in nutritional intervention studies, poses a significant increase in the capacity to understand the effects of dietary compounds on the brain.

Prefrontal Asymmetry during Cognitive Tasks and its Relationship with Suicide Ideation in Major Depressive Disorder: An fNIRS Study.

Baik SY, Kim JY, Choi J, Baek JY, Park Y, Kim Y, Jung M, Lee SH.

Diagnostics (Basel). Nov 15;9(4). pii: E
doi: 10.3390/diagnostics9040193.

Reduced oxygenation changes in the prefrontal cortex during cognitive tasks have been reported in major depressive disorder (MDD). However, prefrontal asymmetry during cognitive tasks and its relation to suicide ideations have been less frequently examined in patients with MDD. This study investigated prefrontal asymmetry and its moderating effect on the relationship between depression severity and suicidal ideation in MDD patients during cognitive tasks. Forty-two patients with MDD and 64 healthy controls (HCs) were assessed for changes in oxygenated and deoxygenated hemoglobin (Hb) in the prefrontal cortex using functional near-infrared spectroscopy (fNIRS) during the verbal fluency task (VFT), Stroop task, and two-back task. Depression, anxiety, and suicide ideation were measured through self-report questionnaires. Relatively smaller left oxy-Hb changes during VFT, but not during the Stroop or two-back tasks, were found in MDD patients compared with HCs. Furthermore, prefrontal asymmetry during VFT moderated the effect of depression severity on suicide ideation, and was significantly and positively correlated with suicide ideation in patients with MDD. Specifically, relatively greater left oxy-Hb changes were associated with greater suicide ideation. These findings suggest fNIRS-measured prefrontal asymmetry as a potential biomarker for MDD and for the assessment of suicidal risk in patients with MDD.

The effects of cardiorespiratory fitness on executive function and prefrontal oxygenation in older adults.

Mekari S, Dupuy O, Martins R, Evans K, Kimmerly DS, Fraser S, Neyedli HF.

Geroscience. Oct;41(5):681-
doi: 10.1007/s11357-019-00128-Epub 2019 Nov 15.

Reviews on cardiovascular fitness and cognition in older adults suggest that a higher level of cardiorespiratory fitness may protect the brain against the effects of aging. Although studies reveal positive effects of cardiores-

piratory fitness on executive function, more research is needed to clarify the underlying mechanisms of these effects in older adults. The aim of the current study was to assess the association between cardiorespiratory fitness level, cerebral oxygenation, and cognitive performance in older adults (OAs). Seventy-four OAs (68 $\pm$ 6.3 years) gave their written, informed consent to participate in the study. Complete data was collected from 66 participants. All participants underwent a cycle ergometer maximal continuous graded exercise test in order to assess their peak power output (PPO) and a neuropsychological paper and pencil tests (Trail Making Test A and B) while changes in left prefrontal cortex oxygenation were measured with functional near-infrared spectroscopy (fNIRS). The results reveal increased cardiorespiratory fitness was associated with decreased response time (i.e., better performance) on the Trail Making Test (B) (standardized $\beta = -0.42$, $p < 0.05$). Cerebral oxygenation in higher fit older adults mediated the relationship with improved executive functioning (standardized $\beta = -0.08$, $p < 0.05$). Specifically, in older adults with higher cardiorespiratory fitness (based on a median split), cerebral oxygenation was related to executive functioning but no such relationship existed in lower fit adults.

Cerebral hemodynamic responses in preterm-born neonates to visual stimulation: classification according to subgroups and analysis of frontotemporal-occipital functional connectivity.

Karen T, Kleiser S, Ostojic D, Isler H, Guglielmini S, Bassler D, Wolf M, Scholkmann F.

Neurophotonics. Oct;6(4):
doi: 10.1117/1.NPh.6.4.Epub 2019 Nov 6.

How neurovascular coupling develops in preterm-born neonates has been largely neglected in scientific research. We measured visually evoked (flicker light) hemodynamic responses (HRs) in preterm-born neonates (n = 25 , gestational age: 31.71 $\pm$ 3.37 weeks, postnatal age: 25.48 $\pm$ 23.94 days) at the visual cortex (VC) and left frontotemporal lobe (FTL) using functional near-infrared spectroscopy (fNIRS) neuroimaging. We found that the HR characteristics show a large intersubject variability but could be classified into three groups according to the changes of oxyhemoglobin concentration at the VC [(A) increase, (B) decrease, or (C) inconclusive]. In groups A and B, the HRs at the left FTL were correlated with those at the VC, indicating the presence of a frontotemporal-occipital functional connectivity. Neonates

in group A had a higher weight at measurement compared to those in group B, and had the lowest baseline total hemoglobin concentration and hematocrit compared to group C. To the best of our knowledge, this is the first fNIRS study showing (1) that the HRs of preterm-born neonates need to be classified into subgroups, (2) that the subgroups differed in terms of weight at measurement, and (3) that HRs can be observed also at the FTL during visual stimulation. These findings add insights into how neurovascular coupling develops in preterm-born neonates.

A Review of Functional Near-Infrared Spectroscopy Studies of Motor and Cognitive Function in Preterm Infants.

Wang Q, Zhu GP, Yi L, Cui XX, Wang H, Wei RY, Hu BL.

Neurosci Bull. Nov

doi: 10.1007/s12264-019-00441-[Epub ahead of print]

Preterm infants are vulnerable to brain injuries, and have a greater chance of experiencing neurodevelopmental disorders throughout development. Early screening for motor and cognitive functions is critical to assessing the developmental trajectory in preterm infants, especially those who may have motor or cognitive deficits. The brain imaging technology functional near-infrared spectroscopy (fNIRS) is a portable and low-cost method of assessing cerebral hemodynamics, making it suitable for large-scale use even in remote and underdeveloped areas. In this article, we review peer-reviewed, scientific fNIRS studies of motor performance, speech perception, and facial recognition in preterm infants. fNIRS provides a link between hemodynamic activity and the development of brain functions in preterm infants. Research using fNIRS has shown different patterns of hemoglobin change during some behavioral tasks in early infancy. fNIRS helps to promote our understanding of the developmental mechanisms of brain function in preterm infants when performing motor or cognitive tasks in a less-restricted environment.

Towards a Multimodal Model of Cognitive Workload Through Synchronous Optical Brain Imaging and Eye Tracking Measures.

Isbilir E, akir MP, Acartürk C, Tekerek AS.

Front Hum Neurosci. Oct 23;13:

doi: 10.3389/fnhum.2019.00375. eCollection 2019.

Recent advances in neuroimaging technologies have rendered multimodal analysis of operators' cognitive processes in complex task settings and environments increasingly more practical. In this exploratory study, we utilized optical brain imaging and mobile eye tracking technologies to investigate the behavioral and neurophysiological differences among expert and novice operators while they operated a human-machine interface in normal and adverse conditions. In congruence with related work, we observed that experts tended to have lower prefrontal oxygenation and exhibit gaze patterns that are better aligned with the optimal task sequence with shorter fixation durations as compared to novices. These trends reached statistical significance only in the adverse condition where the operators were prompted with an unexpected error message. Comparisons between hemodynamic and gaze measures before and after the error message indicated that experts' neurophysiological response to the error involved a systematic increase in bilateral dorsolateral prefrontal cortex (dlPFC) activity accompanied with an increase in fixation durations, which suggests a shift in their attentional state, possibly from routine process execution to problem detection and resolution. The novices' response was not as strong as that of experts, including a slight increase only in the left dlPFC with a decreasing trend in fixation durations, which is indicative of visual search behavior for possible cues to make sense of the unanticipated situation. A linear discriminant analysis model capitalizing on the covariance structure among hemodynamic and eye movement measures could distinguish experts from novices with 91% accuracy. Despite the small sample size, the performance of the linear discriminant analysis combining eye fixation and dorsolateral oxygenation measures before and after an unexpected event suggests that multimodal approaches may be fruitful for distinguishing novice and expert performance in similar neuroergonomic applications in the field.

Effects of physical training on brain functional connectivity of methamphetamine dependencies as assessed using functional near-infrared spectroscopy.

Bu L, Wu Y, Yan Q, Tang L, Liu X, Diao C, Li K, Dong G.

Neurosci Lett. Jan 10;715:
doi: 10.1016/j.neulet.2019.Epub Nov 4.

OBJECTIVE: This study aims to assess the effects of physical training based on the functional near-infrared spectroscopy (fNIRS) and heart

rate signals. METHODS: The oxygenated hemoglobin concentration (Delta [HbO2]) signals were recorded from the left prefrontal cortex (LPFC), right prefrontal cortex (RPFC), left motor cortex (LMC) and right motor cortex (RMC) of 23 subjects with methamphetamine (METH) dependencies at resting, spinning training and strength training states. The wavelet phase coherence (WPCO) values were calculated in four frequency intervals: I, 0.6-2; II, 0.145-0.6; III, 0.052-0.145; and IV, 0.021-0.052 Hz. During the spinning training and strength training states, heart rate signals were recorded at 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 min, respectively. RESULTS: After physical training, the brain regions of LPFC, RPFC and LMC showed different degrees of activation in the subjects with METH dependencies ($p < 0.05$). The WPCO values between the brain regions significantly altered after spinning training and strength training ($p < 0.05$) in frequency intervals I, II, III and IV. CONCLUSIONS: The altered WPCO values indicated physical training could affect brain functional connectivity (FC) to a certain extent in the subjects with METH dependencies. These findings provide a method for the assessment of the effects of physical training in FC and will contribute to the development of drug rehabilitation methods in subjects with METH dependencies.

Characterizing cortical hemodynamic changes during climbing and its relation to climbing expertise.

Carius D, Hörnig L, Ragert P, Kaminski E.

Neurosci Lett. Jan 10;715:
doi: 10.1016/j.neulet.2019.Epub Nov 3.

Bouldering is a special form of climbing without rope that requires coordinated whole-body movements. While physical performance parameters such as condition have been well studied, the knowledge on neural activity during climbing still remains sparse. Functional near-infrared spectroscopy (fNIRS) allows to measure brain activation while performing sportive actions due to its relative robustness against motion artefacts. In the current study, hemodynamic response alterations of 13 advanced climbers were investigated during boulder performance using fNIRS measurements. Simple and moderate climbing routes were compared regarding their level of cortical activation mainly in the sensorimotor area. Our results show that repetitively climbing a set of boulders activates almost all areas of the sensorimotor system including the bilateral premotor and supplementary motor cortex, bilateral primary motor cortex as well as the bilateral gyrus supra-

marginalis and somatosensory cortex. This result was found in both simple and moderate climbing routes with no effect of task complexity on the level of cortical activity. Correlation analysis (uncorrected for multiple comparisons) revealed a negative association between the level of expertise and the hemodynamic response in the supplementary-motor region, suggesting that gaining expertise in climbing is associated with a decrease in secondary motor areas, which is an indicator of motor automaticity. In summary, the present study provides first proof of concept that fNIRS is capable of assessing hemodynamic response alterations within the human motor system during the execution of complex whole-body climbing movements.

Using fMRI to investigate the potential cause of inverse oxygenation reported in fNIRS studies of motor imagery.

Abdalmalak A, Milej D, Cohen DJ, Anazodo U, Ssali T, Diop M, Owen AM, St Lawrence K.

Neurosci Lett. Jan 1;714:
doi: 10.1016/j.neulet.2019.Epub Nov 3.

Motor imagery (MI) is a commonly used cognitive task in brain-computer interface (BCI) applications because it produces reliable activity in motor-planning regions. However, a number of functional near-infrared spectroscopy (fNIRS) studies have reported the unexpected finding of inverse oxygenation: increased deoxyhemoglobin and decreased oxyhemoglobin during task periods. This finding questions the reliability of fNIRS for BCI applications given that MI activation should result in a focal increase in blood oxygenation. In an attempt to elucidate this phenomenon, fMRI and fNIRS data were acquired on 15 healthy participants performing a MI task. The fMRI data provided global coverage of brain activity, thus allowing visualization of all potential brain regions activated and deactivated during task periods. Indeed, fMRI results from seven subjects included activation in the primary motor cortex and/or the pre-supplementary motor area during the rest periods in addition to the expected activation in the supplementary motor and premotor areas. Of these seven subjects, two showed inverse oxygenation with fNIRS. The proximity of the regions showing inverse oxygenation to the motor planning regions suggests that inverse activation detected by fNIRS may likely be a consequence of partial volume errors due to the sensitivity of the optodes to both primary motor and motor planning regions.

Effective Connectivity of the Fronto-Parietal Network during the Tangram Task in a Natural Environment.

Hu Z, Lam KF, Yuan Z.

Neuroscience. Dec 1;422:202-
doi: 10.1016/j.neuroscience.2019.09.021. Epub Nov 1.

Although the neural basis underlying visuospatial reasoning has been widely explored by neuroimaging techniques, the brain activation patterns during naturalistic visuospatial reasoning such as tangram remains unclear. In this study, the directional functional connectivity of fronto-parietal networks during the tangram task was carefully inspected by using combined functional near-infrared spectroscopy (fNIRS) and conditional Granger causality analysis (GCA). Meanwhile, the causal networks during the traditional spatial reasoning task were also characterized to exhibit the differences with those during the tangram task. We discovered that the tangram task in a natural environment showed enhanced activation in the fronto-parietal regions, particularly the frontal cortex. In addition, a strong directional connectivity from the right prefrontal cortex to left angular gyrus was detected for the complex spatial reasoning condition of spatial reasoning task, whereas no effective connectivity was identified between the frontal and parietal cortices during the tangram task. Further correlation analyses showed that the behavioral performance in the spatial reasoning rather than the tangram task manifested the relationship with the connectivity between the frontal and parietal cortex. Our findings demonstrate that the tangram task measures a different aspect of the visuospatial reasoning ability which requires more trial-and-error strategies and creative thinking rather than inductive reasoning. In particular, the frontal cortex is mostly involved in tangram puzzle-solving, whereas the interaction between frontal and parietal cortices is regulated by the hands-on experience during the tangram task.

Neural Activity and Decoding of Action Observation Using Combined EEG and fNIRS Measurement.

Ge S, Wang P, Liu H, Lin P, Gao J, Wang R, Iramina K, Zhang Q, Zheng W.

Front Hum Neurosci. Oct 15;13:
doi: 10.3389/fnhum.2019.00357. eCollection 2019.

In a social world, observing the actions of others is fundamental to understanding what they are doing, as well as their intentions and feel-

ings. Studies of the neural basis and decoding of action observation are important for understanding action-related processes and have implications for cognitive, social neuroscience, and human-machine interaction (HMI). In the current study, we first investigated temporal-spatial dynamics during action observation using a combined 64-channel electroencephalography (EEG) and 48-channel functional near-infrared spectroscopy (fNIRS) system. We measured brain activation while 16 healthy participants observed three action tasks: (1) grasping a cup with the intention of drinking; (2) grasping a cup with the intention of moving it; and (3) touching a cup with an unclear intention. The EEG and fNIRS source analysis results revealed the dynamic involvement of both the mirror neuron system (MNS) and the theory of mind (ToM)/mentalizing network during action observation. The source analysis results suggested that the extent to which these two systems were engaged was determined by the clarity of the intention of the observed action. Based on the difference in neural activity observed among different action-observation tasks in the first experiment, we conducted a second experiment to classify the neural processes underlying action observation using a feature classification method. We constructed complex brain networks based on the EEG and fNIRS data. Fusing features from both EEG and fNIRS complex brain networks resulted in a classification accuracy of 72.7% for the three action observation tasks. This study provides a theoretical and empirical basis for elucidating the neural mechanisms of action observation and intention understanding, and a feasible method for decoding the underlying neural processes.

Cognitive Enhancement by Transcranial Photobiomodulation Is Associated With Cerebrovascular Oxygenation of the Prefrontal Cortex.

Holmes E, Barrett DW, Saucedo CL, O'Connor P, Liu H, Gonzalez-Lima F.

Front Neurosci. Oct 18;13:
doi: 10.3389/fnins.2019.eCollection 2019.

Transcranial infrared laser stimulation (TILS) is a novel, safe, non-invasive method of brain photobiomodulation. Laser stimulation of the human prefrontal cortex causes cognitive enhancement. To investigate the hemodynamic effects in prefrontal cortex by which this cognitive enhancement occurs, we used functional near-infrared spectroscopy (fNIRS), which is a safe, non-invasive method of monitoring hemodynamics. We measured concentration changes in oxygenated and deoxygenated hemoglobin, total

hemoglobin and differential effects in 18 healthy adults during sustained attention and working memory performance, before and after laser of the right prefrontal cortex. We also measured 16 sham controls without photobiomodulation. fNIRS revealed large effects on prefrontal oxygenation during cognitive enhancement post-laser and provided the first demonstration that cognitive enhancement by transcranial photobiomodulation is associated with cerebrovascular oxygenation of the prefrontal cortex. Sham control data served to rule out that the laser effects were due to pre-post task repetition or other non-specific effects. A laser-fNIRS combination may be useful to stimulate and monitor cerebrovascular oxygenation associated with neurocognitive enhancement in healthy individuals and in those with prefrontal hypometabolism, such as in cognitive aging, dementia and many neuropsychiatric disorders.

Coordination Elicits Synchronous Brain Activity Between Co-actors: Frequency Ratio Matters.

Cheng X, Pan Y, Hu Y, Hu Y.

Front Neurosci. Oct 15;13:
doi: 10.3389/fnins.2019.eCollection 2019.

People could behave in two different ways when engaging in interpersonal coordination activities: moving at the same frequency (isofrequency pattern, IP; the movement frequency ratio is 1:1) or at different frequencies (multi-frequency pattern, MP; the movement frequency ratio is non 1:1). However, how the interpersonal coordination pattern modulates coordination outcome and the related brain-to-brain connectivity is not fully understood. Here, we adopted a continuous joint drawing task in which two participants co-drew parallelogram shapes according to two coordination patterns (i.e., IP vs. MP) while their brain activities were simultaneously recorded by the functional near-infrared spectroscopy (fNIRS) based hyperscanning technique. Dyads showed better coordination performance, as well as relatively greater interpersonal brain synchronization (IBS) at the left frontopolar area, in the MP condition compared to the IP condition. Granger causality analyses further disclosed the bidirectional influences between the brains of the coordinating individuals. Such interpersonal influences were enhanced when individuals coordinated in the MP condition. Finally, the IBS during coordination was related to the dyadic self-control level. Taken together, our study revealed that interpersonal multifrequency coordination pattern facilitates the coordination efficiency, which was associated with the enhanced

brain-to-brain connectivity. Our work also suggests the potentially positive role of self-control during the interpersonal coordination process.

Assessment of age-related decline of neurovascular coupling responses by functional near-infrared spectroscopy (fNIRS) in humans.

Csipo T, Mukli P, Lipecz A, Tarantini S, Bahadli D, Abdulhussein O, Owens C, Kiss T, Balasubramanian P, Nyúl-Tóth á, Hand RA, Yabluchanska V, Sorond FA, Csiszar A, Ungvari Z, Yabluchanskiy A.

Geroscience. Oct;41(5):495-
doi: 10.1007/s11357-019-00122-x. Epub 2019 Nov 2.

Preclinical studies provide strong evidence that age-related impairment of neurovascular coupling (NVC) plays a causal role in the pathogenesis of vascular cognitive impairment (VCI). NVC is a critical homeostatic mechanism in the brain, responsible for adjustment of local cerebral blood flow to the energetic needs of the active neuronal tissue. Recent progress in geroscience has led to the identification of critical cellular and molecular mechanisms involved in neurovascular aging, identifying these pathways as targets for intervention. In order to translate the preclinical findings to humans, there is a need to assess NVC in geriatric patients as an endpoint in clinical studies. Functional near-infrared spectroscopy (fNIRS) is a non-invasive neuroimaging technique that enables the investigation of local changes in cerebral blood flow, quantifying task-related changes in oxygenated and deoxygenated hemoglobin concentrations. In the present overview, the basic principles of fNIRS are introduced and the application of this technique to assess NVC in older adults with implications for the design of studies on the mechanistic underpinnings of VCI is discussed.

Increased neural activity in the right dorsolateral prefrontal cortex during a risky decision-making task is associated with cocaine use in methadone-maintained patients.

Huhn AS, Brooner RK, Sweeney MM, Yip SW, Ayaz H, Dunn KE.

Drug Alcohol Depend. Dec 1;205:
doi: 10.1016/j.drugalcdep.2019.Epub Oct 20.

BACKGROUND: Methadone maintenance is an effective treatment for opioid use disorder (OUD), yet many methadone-maintained patients (MMPs)

struggle with cocaine use during OUD recovery. The current study aimed to identify whether prefrontal cortex (PFC) activity during a risky decision-making task was associated with cocaine use during a 90-day follow-up in MMPs. METHODS: MMPs (N = 28) attended a single neuroimaging session wherein PFC activity was measured using functional near-infrared spectroscopy (fNIRS) during the Balloon Analogue Risk Task (BART). Trait impulsivity was assessed via the Barratt Impulsiveness Scale version 11 (BIS-11). Following the neuroimaging session, MMPs were tracked via electronic health records for 90 days to determine treatment outcomes including cocaine use verified by urine drug screens. RESULTS: During the BART, MMPs who used cocaine displayed increased neural activity in the right PFC during active decision-making (F1, 22 = 14.75, p = 0.001) and the right dorsolateral PFC during active minus passive decision-making (F1, 22 = 5.56, p = 0.028) compared to participants who did not use cocaine. Receiver operating characteristic curves confirmed that neural activity in the right PFC during active decision-making (AUC = 0.841, 95% CI, 0.697-0.985, p = 002), and in the right dorsolateral PFC during active minus passive decision-making (AUC = 0.805, 95% CI, 0.643-0.968, p = 0.006) was associated with continued cocaine use. MMPs who used cocaine versus those who did not reported increased trait impulsivity on the BIS-11 Total Score (t=-2.28, p = 0.031). CONCLUSIONS: The fNIRS device is portable, relatively easy to use, and potentially feasible for use in methadone outpatient programs to assess propensity for negative treatment outcomes such as continued cocaine use.

A cognitive style dataset including functional near-infrared spectroscopy, eye-tracking, psychometric and behavioral measures.

Bendall RCA, Lambert S, Galpin A, Marrow LP, Cassidy S.

Data Brief. Sep 19;26:
doi: 10.1016/j.dib.2019.eCollection Oct.

The dataset includes data from the triangulated investigation reported in our paper: 'Psychophysiological indices of cognitive style: A triangulated study incorporating neuroimaging, eye-tracking, psychometric and behavioral measures' [1,2]. The data was collected at the Directorate of Psychology & Public Health laboratories at the University of Salford, UK, in 2015 among an English-speaking sample. The dataset includes measures described in the paper including information-processing/cognitive style recorded as Cog-

nitive Style Index [CSI; 3] scores, comparative visual search (CVS) task behavioral measures (reaction time and accuracy), eye-movement data (fixation duration, number of saccades, number of comparative saccades and distance moved) and prefrontal cortex (PFC) oxygenated hemoglobin (oxy-Hb) recorded using functional near-infrared spectroscopy (fNIRS).

Applications of Functional Near-Infrared Spectroscopy in Fatigue, Sleep Deprivation, and Social Cognition.

Pan Y, Borragán G, Peigneux P.

Brain Topogr. Nov;32(6):998-

doi: 10.1007/s10548-019-00740-w. Epub 2019 Oct 29.

Functional near-infrared spectroscopy (fNIRS) is an optical diffusion technique that allows the non-invasive imaging of cortical activity. During the last two decades, rapid technical and methodological advances have made fNIRS a powerful tool to investigate the cerebral correlates of human performance and cognitive functions, including fatigue, sleep deprivation and social cognition. Despite intrinsic limitations such as restricted brain depth and spatial resolution, its applicability, low cost, ecological validity, and tolerance to movements make fNIRS advantageous for scientific research and clinical applications. It can be viewed as a valid and promising brain imaging approach to investigate applied societal problems (e.g., safety, children development, sport science) and complement other neuroimaging techniques. The intrinsic power of fNIRS measurements for the study of social cognition is magnified when applied to the hyperscanning paradigm (i.e., measuring activity in two or more brains simultaneously). Besides consolidating existing findings, future fNIRS research should focus on methodological advances (e.g., artefacts correction, connectivity approaches) and standardization of analysis pipelines, and expand currently used paradigms in more naturalistic but controlled settings.

Association Between Fatty Acids Profile and Cerebral Blood Flow: An Exploratory fNIRS Study on Children with and without ADHD.

Grazioli S, Crippa A, Mauri M, Piazza C, Bacchetta A, Salandi A, Trabattoni S, Agostoni C, Molteni M, Nobile M.

Nutrients. Oct 10;11(10). pii: E

doi: 10.3390/nu11102414.

Polyunsaturated fatty acids (PUFAs) biostatus has been proposed as possible attention deficit hyperactivity disorder (ADHD) diagnosis biomarker. The present exploratory study aimed to investigate the association between PUFAs biostatus and cerebral cortex metabolism measured by functional Near Infrared Spectroscopy (fNIRS) in a sample of children with and without ADHD. 24 children with ADHD and 22 typically developing (TD) peers, aged 8-14, were recruited. Linoleic, arachidonic, docosahexaenoic and eicosapentaenoic acids levels were evaluated in whole blood. All children underwent fNIRS while performing an n-back working memory task. Between groups comparisons revealed lower levels of arachidonic acid in children with ADHD and stronger NIRS signal in TD participants, especially when completing more difficult tasks. Correlations conducted between fNIRS activation and PUFA biostatus revealed several associations between hemodynamic changes in the frontoparietal regions and fatty acids profile across participants. This result was also confirmed by the multiple hierarchical regression analyses that remarked an inverse effect of eicosapentaenoic acid levels on oxyhemoglobin values in right frontoparietal region. Such preliminary findings, if confirmed, would suggest that PUFAs could play a role in atypical neurodevelopment.

Brain activity during dual task gait and balance in aging and age-related neurodegenerative conditions: A systematic review.

Kahya M, Moon S, Ranchet M, Vukas RR, Lyons KE, Pahwa R, Akinwuntan A, Devos H.

Exp Gerontol. Dec;128:
doi: 10.1016/j.exger.2019.Epub 2019 Oct 22.

The aims of this systematic review were to investigate (1) real-time brain activity during DT gait and balance, (2) whether changes in brain activity correlate with changes in behavioral outcomes in older adults and people with age-related neurodegenerative conditions. PubMed, PsycINFO, and Web of Science were searched from 2009 to 2019 using the keywords dual task, brain activity, gait, balance, aging, neurodegeneration, and other related search terms. A total of 15 articles were included in this review. Functional near-infrared spectroscopy and electroencephalogram measures demonstrated that older adults had higher brain activity, particularly in the prefrontal cortex (PFC), compared to young adults during dual task

gait and balance. Similar neurophysiological results were observed in people with age-related neurodegenerative conditions. Few studies demonstrated a relationship between increased brain activity and better behavioral outcomes. This systematic review supports the notion that aging and age-related neurodegenerative conditions are associated with neuronal network changes, resulting in increased brain activity specifically in the PFC. Further studies are warranted to assess the relationship between increased PFC activation during dual task gait and balance and behavioral outcomes to better optimize the rehabilitation interventions.

Co-localization of theta-band activity and hemodynamic responses during face perception: simultaneous electroencephalography and functional near-infrared spectroscopy recordings.

Dravida S, Ono Y, Noah JA, Zhang X, Hirsch J.

Neurophotonics. Oct;6(4):
doi: 10.1117/1.NPh.6.4.Epub 2019 Oct 22.

Face-specific neural processes in the human brain have been localized to multiple anatomical structures and associated with diverse and dynamic social functions. The question of how various face-related systems and functions may be bound together remains an active area of investigation. We hypothesize that face processing may be associated with specific frequency band oscillations that serve to integrate distributed face processing systems. Using a multimodal imaging approach, including electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS), simultaneous signals were acquired during face and object picture viewing. As expected for face processing, hemodynamic activity in the right occipital face area (OFA) increased during face viewing compared to object viewing, and in a subset of participants, the expected N170 EEG response was observed for faces. Based on recently reported associations between the theta band and visual processing, we hypothesized that increased hemodynamic activity in a face processing area would also be associated with greater theta-band activity originating in the same area. Consistent with our hypothesis, theta-band oscillations were also localized to the right OFA for faces, whereas alpha- and beta-band oscillations were not. Together, these findings suggest that theta-band oscillations originating in the OFA may be part of the distributed face-specific processing mechanism.

Hyperparameter-tuned prediction of somatic symptom disorder using functional near-infrared spectroscopy-based dynamic functional connectivity.

Eken A, olak B, Bal NB, Kusman A, Kizilpinar S, Akaslan DS, Baskak B.

J Neural Eng. Dec 16;17(1):
doi: 10.1088/1741-2552/ab50b2.

OBJECTIVE: Somatic symptom disorder (SSD) is a reflection of medically unexplained physical symptoms that lead to distress and impairment in social and occupational functioning. SSD is phenomenologically diagnosed and its neurobiology remains unsolved. APPROACH: In this study, we performed hyper-parameter optimized classification to distinguish 19 persistent SSD patients and 21 healthy controls by utilizing functional near-infrared spectroscopy via performing two painful stimulation experiments, individual pain threshold (IND) and constant sub-threshold (SUB) that include conditions with different levels of pain (INDc and SUBc) and brush stimulation. We estimated a dynamic functional connectivity time series by using sliding window correlation method and extracted features from these time series for these conditions and different cortical regions. MAIN RESULTS: Our results showed that we found highest specificity (85%) with highest accuracy (82%) and 81% sensitivity using an SVM classifier by utilizing connections between right superior temporal-left angular gyri, right middle frontal (MFG)-left supramarginal gyri and right middle temporal-left middle frontal gyri from the INDc condition. SIGNIFICANCE: Our results suggest that fNIRS may distinguish subjects with SSD from healthy controls by applying pain in levels of individual pain-threshold and bilateral MFG, left inferior parietal and right temporal gyrus might be robust biomarkers to be considered for SSD neurobiology.

The diagnosticity of psychophysiological signatures: Can we disentangle mental workload from acute stress with ECG and fNIRS?

Parent M, Peysakhovich V, Mandrick K, Tremblay S, Causse M.

Int J Psychophysiol. Dec;146:139-
doi: 10.1016/j.ijpsycho.2019.09.005. Epub Oct 19.

The ability to identify reliable and sensitive physiological signatures of psychological dimensions is key to developing intelligent adaptive systems that may in turn help to mitigate human error in complex operations. The challenge of this endeavor lies with diagnosticity. Despite different underly-

ing causes, the physiological correlates of workload and acute psychological stress manifest in rather similar ways and can be easily confounded. The current work aimed to build a diagnostic model of mental state through the simultaneous classification of mental workload (varied through three levels of the n-back task) and acute stress (the presence/absence of aversive sounds) with machine learning. Using functional near infrared spectroscopy (fNIRS) and electrocardiography (ECG), the model's classifiers was above-chance to disentangle variations of mental workload from variations of acute stress. Both ECG and fNIRS could predict mental workload level, the best accuracy resulted from the two measures in combination. Stress level could not be accurately diagnosed through ECG alone, only with fNIRS or ECG and fNIRS combined. Individual calibration may be important since stress classification was more accurate for those with higher subjective state anxiety, perhaps due to a greater sensitivity to stress. Mental workload and stress were both better classified with activity in lateral prefrontal regions of the cortex than the medial areas, and the HbO2 signal generally lead to better classification than HHB. The current model represents a step forward to finely discriminate different mental states despite their rather analog physiological correlates.

The Interplay of Achievement Motive-Goal Incongruence and State and Trait Self-Control: A Pilot Study Considering Cortical Correlates of Self-Control.

Schüler J, Hofstetter J, Wolff W.

Front Behav Neurosci. Oct 4;13:
doi: 10.3389/fnbeh.2019.00235. eCollection 2019.

Objective: This study utilized different theoretical perspectives to better understand motor performance. We refered to concepts of achievement motive-goal incongruence and assessed cortical correlates of self-control. We assumed that more self-control is required when people act in conformance with an incongruent goal which, in turn, results in impaired performance. We considered the activation of a brain area associated with self-control (dorsolateral prefrontal cortex, dLPFC) as a consequence of motive-goal incongruence. Furthermore, we analyzed whether trait self-control buffers the negative effects of achievement motive-goal incongruence. Method: Twenty-eight participants (17 women, mean age: 24 years), whose implicit achievement motives were assessed at the beginning of the study, performed a handgrip task in an achievement goal condition and in three incongruent condi-

tions, while their dLPFC oxygenation was monitored continuously (using functional near-infrared spectroscopy, fNIRS). Results: None of the two-way interactions (motive goal condition) reached significance. A significant three-way interaction (motive trait self-control goal condition) showed that trait self-control buffered the detrimental effects of incongruence on motor performance. The nature of the three-way interaction predicting dLPFC oxygenation was unexpected. Conclusions: Although our results have to be treated with caution due to a small sample size, we see them as an encouraging starting point for further research on the interplay between motive-goal incongruence and trait and cortical correlates of state self-control that we assume to be important to understand performance in strenuous tasks.

A Newcomer's Guide to Functional Near Infrared Spectroscopy Experiments.

Almajidy RK, Mankodiya K, Abtahi M, Hofmann UG.

IEEE Rev Biomed Eng. 2020;13:292-

doi: 10.1109/RBME.2019.Epub 2019 Oct 17.

DOI: 10.1109/RBME.2019.2944351 PMID: 31634142

The Potential Role of Functional Near-Infrared Spectroscopy as a Clinical Biomarker in Schizophrenia.

Chou PH, Huang CJ, Sun CW.

Curr Pharm Des. Oct

doi: 10.2174/[Epub ahead of print]

Functional near-infrared spectroscopy (fNIRS) is a recently developed technique that can measure hemoglobin changes in the cerebral cortex, and fNIRS-based research in psychiatry has been progressing rapidly. fNIRS is advantageous in its noninvasiveness, ease of administering, tolerance of small movements, inexpensiveness, strong signal correlations with fMRI signals, and in providing imaging with excellent time resolution and moderate spatial resolution. However, fNIRS has several disadvantages such as low spatial resolution and shallower measurements in brain regions compared with other functional neuroimaging techniques (e.g. functional magnetic resonance imaging and positron emission tomography). Therefore, fNIRS may be a candidate instrument for clinical use in psychiatry, as it can measure brain activity in a clinical setting. Moreover, previous studies have

demonstrated that altered brain activity in the prefrontal cortex is associated with clinical symptoms and functional outcomes in patients with schizophrenia, suggesting fNIRS could be used as a potential biomarker. Future studies aimed at exploring fNIRS differences in different clinical stages, longitudinal changes, medication effects, variations during different cognitive task paradigms, cross-cultural comparisons, and applying more delicate statistical analytic methodologies are warranted to develop more accurate biomarkers that can be applied in clinical practice for differential diagnosis, monitoring symptoms, predicting functional outcomes, and the personalized decision regarding treatment options in patients with schizophrenia.

Cue utilisation predicts control room operators' performance in a sustained visual search task.

Sturman D, Wiggins MW, Auton JC, Helton WS.

Ergonomics. Jan;63(1):48-
doi: 10.1080/00140139.2019.Epub 2019 Oct 23.

This research was designed to determine whether qualified practitioners' cue utilisation is predictive of their performance during a sustained visual search task in an operational context. Australian Distribution Network Service Provider (DNSP) operators were recruited for two experiments, and were classified with either higher or lower cue utilisation based on an assessment of cue utilisation within the context of power distribution. Operators' performance was assessed using a domain-related sustained visual search task. In both experiments, power distribution operators with higher cue utilisation demonstrated shorter mean response latencies during the sustained visual search task, compared to operators with lower cue utilisation. Further, no differences in accuracy based on cue utilisation were observed during the sustained visual search task. The results are consistent with the proposition that power operators with higher cue utilisation have a greater capacity to sustain visual search during domain-related tasks, compared to operators with lower cue utilisation. Practitioner summary: Power distribution system operators' cue utilisation was used to predict performance during a domain-related sustained visual search task. Power distribution operators with higher cue utilisation demonstrated shorter mean response latencies during the sustained visual search task, but no differences in accuracy, compared to operators with lower cue utilisation. Abbreviations: DNSP: distribution network service provider; EXPERTise 2.0: EXPERT intensive skills evaluation; FAT: feature association task; FDT: feature dis-

crimination task; FIT: feature identification task; fNIRS: functional near infrared spectroscopy; FPT: feature prioritisation task; FRT: feature recognition task; SCADA: supervisory control and data acquisition.

Evolution of Interdisciplinary Landscapes of HIV/Acquired Immune Deficiency Syndromes Studies from 1983 to 2017: Results from the Global Analysis for Policy in Research (GAP-RESEARCH).

Tran BX, Wong FY, Pham KTH, Latkin CA, Ha GH, Vu GT, Ho CSH, Ho RCM.

AIDS Rev. Oct 3;21(3). [Epub ahead of print]
doi: 10.1080/00140139.2019.Epub 2019 Oct 23.

INTRODUCTION: In recent years, there have been numerous calls by researchers to adopt multi-disciplinary and international perspectives to address the human immunodeficiency virus (HIV) pandemic. Meaningful and prudent public health policy should be based on sound empirical data and research. Henceforth, our study aims to contribute to the current literature by conducting a comprehensive global mapping and determine the landscapes of HIV/acquired immune deficiency syndromes (AIDS) research covering the years between 1983 and 2017. METHODS: Bibliometric and content analysis was used to describe trends in research productivity, usages, research collaborations, and clusters of research topics. Exploratory factor analysis, Jaccard's similarity index, and Ward dendrogram were applied to abstracts' contents to determine the development of interdisciplinary research landscapes. RESULTS: The United States of America continues to lead in research production and be main hub for author- and country-level collaborations. Research employing an epidemiological, social, and/or behavioral perspective for studying HIV/AIDS was found to dwarf in the presence of basic and biomedical HIV research. Interdisciplinary approaches to HIV research have been increasing with the creation of various research landscapes: strong constructs of studies examining health status, clinical responses, and HIV treatment, risk behaviors have been formed, while research topics relating to psycho-behavioral and cultural aspects as well as services have emerged along. CONCLUSIONS: To effectively prevent and control the disease, more researches are needed to provide culturally relevant and/or contextualized evidence of effective interventions. It is also necessary to enhance the ability and partnership of local researchers as well as invest in research infrastructure at national and regional levels to im-

plement high-quality studies since they are the "gate-keepers" who could respond to local changes in a timely manner. These types of research could be a helpful guide for international donors, governments, and academicians to set up research priorities in target groups and settings, and to develop future research agendas globally.

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105. Dev Cogn Neurosci. 2019 Dec;40:100708. doi: 10.1016/j.dcn.2019.100708. Epub 2019 Sep 11.
PMID: 31588138
doi: 10.1080/00140139.2019.Epub 2019 Oct 23.

Grabell AS(1), Huppert TJ(2), Fishburn FA(3), Li Y(4), Hlutkowsky CO(3), Jones HM(3), Wakschlag LS(5), Perlman SB(6).

The difference in cortical activation pattern for complex motor skills: A functional near- infrared spectroscopy study.
Lee SH, Jin SH, An J.
Sci Rep. Oct 1;9(1):
doi: 10.1038/s41598-019-50644-9.

The human brain is lateralized to dominant or non-dominant hemispheres, and controlled through large-scale neural networks between correlated cortical regions. Recently, many neuroimaging studies have been conducted to examine the origin of brain lateralization, but this is still unclear. In this study, we examined the differences in brain activation in subjects according to dominant and non-dominant hands while using chopsticks. Fifteen healthy right-handed subjects were recruited to perform tasks which included transferring almonds using stainless steel chopsticks. Functional near-infrared spectroscopy (fNIRS) was used to acquire the hemodynamic response over the primary sensory-motor cortex (SM1), premotor area (PMC), supplementary motor area (SMA), and frontal cortex. We measured the concentrations of oxy-hemoglobin and deoxy-hemoglobin induced during the use of chopsticks with dominant and non-dominant hands. While using the dominant hand, brain activation was observed on the contralateral side. While using the non-dominant hand, brain activation was observed on the ipsilateral side as well as the contralateral side. These results demonstrate dominance and functional asymmetry of the cerebral hemisphere.

Assessing the brain 'on the line': An ecologically-valid assessment of the impact of repetitive assembly line work on hemodynamic response and fine motor control using fNIRS.

Han W, Gao L, Wu J, Pelowski M, Liu T.

Brain Cogn. Nov;136:
doi: 10.1016/j.bandc.2019.Epub Sep 24.

To investigate neural correlates of repetitive assembly tasks in ecologically-valid empirical settings, this study measured bilateral prefrontal (PFC) and motor activations when participants performed a carburetor assembly task using functional near-infrared spectroscopy (fNIRS). Participants worked for one hour at a typical (low-) pace and at an accelerated high-pace. Before and after the task, a test was conducted to assess motion stability and fine motor control. The behavioral data revealed decreased motion stability after the assembly work in both conditions, with a significantly higher reduction after the high-pace task. The fNIRS data also revealed reduced activations in bilateral prefrontal and motor regions in both conditions over time. However, the low-pace task led to significantly greater activity decreases compared with the high-pace. Activity decrease in prefrontal and motor regions within the low pace also significantly related to minimal motion stability impairment, suggesting that the brain activation decreases in this and, potentially, findings of higher alpha in past repetitive-task studies using EEG, may be a result of not fatigue but worker adaptation or increasing efficiency.

Autism Symptoms Modulate Interpersonal Neural Synchronization in Children with Autism Spectrum Disorder in Cooperative Interactions.

Wang Q, Han Z, Hu X, Feng S, Wang H, Liu T, Yi L.

Brain Topogr. Jan;33(1):112-
doi: 10.1007/s10548-019-00731-x. Epub Sep 27.

Previous neuroscience studies exploring the neural mechanisms of social deficits of individuals with autism spectrum disorder (ASD) have mainly examined single participants' brain responses to pictures or video-clips displayed on a monitor from the perspective of a passive observer. The present study examined inter-brain communication between children with ASD and their parents in a socio-interactive context. We used a functional near-

infrared spectroscopy (fNIRS)-based hyperscanning technique to simultaneously measure the prefrontal activations in 16 pairs of children with ASD and their parents in a two-person key-press task. The children's task was to press a key together with their parents in a cooperation condition when a "go" signal was present or to press a key as fast as possible under the observation by their parents in a single-person condition. We also measured children's severity of autism symptoms.We found that children with ASD showed increased interpersonal neural synchronization in the frontal cortex when engaging in cooperative interactions with their parents than when performing solo and non-interactive behaviors. Furthermore, this neural synchronization was modulated by the children's autism symptoms, which also covaried with their cooperation task performance. That is, children with severer autism symptoms showed lower level of action and neural synchronization with their parents during cooperation. Our study moved a major step forward in understanding the neural correlates underlying social deficits in ASD and provided important implications for the treatment and behavioral training of ASD.

Median Nerve Electrical Stimulation-Induced Changes in Effective Connectivity in Patients With Stroke as Assessed With Functional Near-Infrared Spectroscopy.

Huo C, Li X, Jing J, Ma Y, Li W, Wang Y, Liu W, Fan Y, Yue S, Wang Y, Li Z.

Neurorehabil Neural Repair. Dec;33(12):1008-
doi: 10.1177/Epub Sep 24.

Background. The cortical plastic changes in response to median nerve electrical stimulation (MNES) in stroke patients have not been entirely illustrated. Objective. This study aimed to investigate MNES-related changes in effective connectivity (EC) within a cortical network after stroke by using functional near-infrared spectroscopy (fNIRS). Methods. The cerebral oxygenation signals in the bilateral prefrontal cortex (LPFC/RPFC), motor cortex (LMC/RMC), and occipital lobe (LOL/ROL) of 20 stroke patients with right hemiplegia were measured by fNIRS in 2 conditions: (1) resting state and (2) MNES applied to the right wrist. Coupling function together with dynamical Bayesian inference was used to assess MNES-related changes in EC among the cerebral low-frequency fluctuations. Results. Compared with the resting state, EC from LPFC and RPFC to LOL was significantly increased during the MNES state in stroke patients. Additionally, MNES trig-

gered significantly higher coupling strengths from LMC and LOL to RPFC. The interregional main coupling direction was observed from LPFC to bilateral motor and occipital areas in responding to MNES, suggesting that MNES could promote the regulation function of ipsilesional prefrontal areas in the functional network. MNES can induce muscle twitch of the stroke-affected hand involving a decreased neural coupling of the contralesional motor area on the ipsilesional MC. Conclusions. MNES can trigger sensorimotor stimulations of the affected hand that sequentially involved functional reorganization of distant cortical areas after stroke. Investigating MNES-related changes in EC after stroke may help further our understanding of the neural mechanisms underlying MNES.

Multimodal exploration of non-motor neural functions in ALS patients using simultaneous EEG-fNIRS recording.

Borgheai SB, Deligani RJ, McLinden J, Zisk A, Hosni SI, Abtahi M, Mankodiya K, Shahriari Y.

J Neural Eng. Nov 6;16(6):
doi: 10.1088/1741-2552/ab456c.

OBJECTIVE: Despite the high prevalence of non-motor impairments reported in patients with amyotrophic lateral sclerosis (ALS), little is known about the functional neural markers underlying such dysfunctions. In this study, a new dual-task multimodal framework relying on simultaneous electroencephalogram (EEG) and functional near-infrared spectroscopy (fNIRS) recordings was developed to characterize integrative non-motor neural functions in people with ALS. APPROACH: Simultaneous EEG-fNIRS data were recorded from six subjects with ALS and twelve healthy controls. Through a proposed visuo-mental paradigm, subjects performed a set of visuo-mental arithmetic operations. The data recorded were analyzed with respect to event-related changes both in the time and frequency domains for EEG and de/oxygen-hemoglobin level (HbR/HbO) changes for fNIRS. The correlation of EEG spectral features with fNIRS HbO/HbR features were then evaluated to assess the mechanisms of ALS on the electrical (EEG)-vascular (fNIRS) interrelationships. MAIN RESULTS: We observed overall smaller increases in EEG delta and theta power, decreases in beta power, reductions in HbO responses, and distortions both in early and later EEG event-related potentials in ALS subjects compared to healthy controls. While significant correlations between EEG features and HbO responses were observed in healthy controls, these patterns were absent in ALS patients. Distortions

in both electrical and hemodynamic responses are speculated to be associated with cognitive deficits in ALS that center primarily on attentional and working memory processing. SIGNIFICANCE: Our results highlight the important role of ALS non-motor dysfunctions in electrical and hemodynamic neural dynamics as well as their interrelationships. The insights obtained through this study can enhance our understanding of the underlying non-motor neural processes in ALS and enrich future diagnostic and prognostic techniques.

FUNCTIONAL CHANGES IN BRAIN ACTIVITY AFTER HYPNOSIS: Neurobiological Mechanisms and Application to Patients with a Specific Phobia-Limitations and Future Directions.

Halsband U, Wolf TG.

Int J Clin Exp Hypn. Oct-Dec;67(4):449-
doi: 10.1080/00207144.2019.1650551.

Studies of brain-plasticity changes in hypnosis using functional magnetic resonance imaging (fMRI), positron-emission-tomography (PET) and electroencephalography (EEG) were reviewed. The authors found evidence in those studies that hypnosis is a powerful and successful method for inhibiting the reaction of the fear circuitry structures. Limitations of the studies were critically discussed, and implications for future research were made. The authors are currently using a portable fNIRS apparatus to integrate the scanning device into real life situations in medical practice. Their aim is to disentangle the neuronal mechanisms and physiological correlates in patients with severe fear of medical treatments when directly confronted with anxiety-provoking stimuli and to assess the effects of a brief hypnosis. Drawing on evidence from several technological modalities, neuroimaging and physiological studies pave the road to a better scientific understanding of neural mechanisms of hypnosis.

The impact of physiological noise on hemodynamic-derived estimates of directed functional connectivity.

Schumacher FK, Steinborn C, Weiller C, Schelter BO, Reinhard M, Kaller CP.

Brain Struct Funct. Dec;224(9):3145-

doi: 10.1007/s00429-019-01954-1. Epub Sep 12.

Measuring the strength of directed functional interactions between brain regions is fundamental to understand neural networks. Functional near-infrared spectroscopy (fNIRS) is a suitable method to map directed interactions between brain regions but is based on the neurovascular coupling. It, thus, relies on vasomotor reactivity and is potentially biased by non-neural physiological noise. To investigate the impact of physiological noise on fNIRS-based estimates of directed functional connectivity within the rostro-caudal hierarchical organization of the prefrontal cortex (PFC), we systematically assessed the effects of pathological perturbations of vasomotor reactivity and of externally triggered arterial blood pressure (aBP) fluctuations. Fifteen patients with unilateral stenosis of the internal carotid artery (ICA) underwent multi-channel fNIRS during rest and during metronomic breathing, inducing aBP oscillations at 0.1 Hz. Comparisons between the healthy and pathological hemispheres served as quasi-experimental manipulation of the neurovascular system's capability for vasomotor reactivity. Comparisons between rest and breathing served as experimental manipulation of two different levels of physiological noise that were expected to differ between healthy and pathological hemispheres. In the hemisphere affected by ICA stenosis, the rostro-caudal hierarchical organization of the PFC was compromised reflecting the pathological effect on the vascular and neural level. Breathing-induced aBP oscillations biased the magnitude of directed interactions in the PFC, but could be adjusted using either the aBP time series (intra-individual approach) or the aBP-induced fNIRS signal variance (inter-individual approach). Multi-channel fNIRS, hence, provides a sound basis for analyses of directed functional connectivity as potential bias due to physiological noise can be effectively controlled for.

Changes in neurovascular coupling during cycling exercise measured by multi-distance fNIRS: a comparison between endurance athletes and physically active controls.

Seidel O, Carius D, Roediger J, Rumpf S, Ragert P.

Exp Brain Res. Nov;237(11):2957-
doi: 10.1007/s00221-019-05646-Epub Sep 10.

It is well known that endurance exercise modulates the cardiovascular, pulmonary, and musculoskeletal system. However, knowledge about its effects on brain function and structure is rather sparse. Hence, the present study aimed to investigate exercise-dependent adaptations in neurovascular

coupling to different intensity levels in motor-related brain regions. Moreover, expertise effects between trained endurance athletes (EA) and active control participants (ACP) during a cycling test were investigated using multi-distance functional near-infrared spectroscopy (fNIRS). Initially, participants performed an incremental cycling test (ICT) to assess peak values of power output (PPO) and cardiorespiratory parameters such as oxygen consumption volume (VO2max) and heart rate (HRmax). In a second session, participants cycled individual intensity levels of 20, 40, and 60% of PPO while measuring cardiorespiratory responses and neurovascular coupling. Our results revealed exercise-induced decreases of deoxygenated hemoglobin (HHb), indicating an increased activation in motor-related brain areas such as primary motor cortex (M1) and premotor cortex (PMC). However, we could not find any differential effects in brain activation between EA and ACP. Future studies should extend this approach using whole-brain configurations and systemic physiological augmented fNIRS measurements, which seems to be of pivotal interest in studies aiming to assess neural activation in a sports-related context.

Real-life creative problem solving in teams: fNIRS based hyperscanning study.

Mayseless N, Hawthorne G, Reiss AL.

Neuroimage. Dec;203:

doi: 10.1016/j.neuroimage.2019.Epub 2019 Sep 4.

It is often assumed that groups of individuals can work together to achieve innovation and solve complex problems they are unable to solve on their own. One of the underlying assumptions is that a group can be more creative and innovative than single individuals. Previous research has begun to examine the process by which problem solving occurs in teams looking to achieve innovation. Despite this progress, a clear, brain-based model that informs how team interactivity contributes and impacts the outcome of an innovation event is lacking. Here we present a naturalistic study designed to examine creative problem solving involving team cooperation. We used functional near infrared spectroscopy (fNIRS) to measure interbrain synchrony (IBS) between interacting partners engaged in a creative design task. Results implicate the involvement of cognitive control coupled with the mentalizing and mirror neuron networks in IBS. Post hoc behavioral and temporal analyses revealed an increase in cooperation over time in association with reduction in IBS. Our results demonstrate the importance

of a naturalistic design for investigating the neural underpinnings of team interactions as well as suggest a possible mechanism for team creativity.

A Combined EEG-fNIRS Study Investigating Mechanisms Underlying the Association between Aerobic Fitness and Inhibitory Control in Young Adults.

Ludyga S, Mücke M, Colledge FMA, Pühse U, Gerber M.

Neuroscience. Nov 1;419:23-
doi: 10.1016/j.neuroscience.2019.08.Epub Sep 2.

The current evidence suggests that aerobic fitness is associated with inhibitory control of executive functioning in children and older adults. However, the relative contributions of different neurophysiological mechanisms to this relation remain unclear and have not yet been examined in young adults. The present study aimed to compare inhibitory control between high and low-fit young adult men, and to investigate a possible mediation of fitness effects by conflict monitoring (N450 component of event-related potentials) and lateralized oxygenation difference (LOD) in the DLPFC. For the present cross-sectional study, participants with different physical activity levels were recruited and divided into low-fit and high-fit participants based on relative power on the PWC170. A Stroop Color-Word task was administered and combined EEG-fNIRS was simultaneously utilized to assess the N450 and LOD, because these parameters are linked with behavioral performance. The results of the statistical analysis showed that high-fitcompared to low-fit participants showed less Stroop interference and lower negativity of the N450, whereas no difference was found for LOD. Path-analyses further revealed that the relation between aerobic fitness levels and Stroop interference was indirect and mediated by N450. In contrast, LOD was inversely correlated with Stroop interference, but did not explain the relation of aerobic fitness with behavioral performance. The present findings indicate that greater inhibitory control in high- compared to low-fit young men can be explained by more effective conflict monitoring. Moreover, young adults with left-lateralizedDLPFC oxygenation also show higher inhibitory control, but this oxygenation pattern is not influenced by aerobic fitness.

Acute changes in cortical activation during active ankle movement after whole-body vibration for spasticity in hemiplegic

legs of stroke patients: a functional near-infrared spectroscopy study.

Miyara K, Kawamura K, Matsumoto S, Ohwatashi A, Itashiki Y, Uema T, Noma T, Ikeda K, Shimodozono M.

Top Stroke Rehabil. Jan;27(1):67-
doi: 10.1080/10749357.2019.1659639. Epub Sep 4.

Background: A recent study revealed that whole-body vibration (WBV) tends to decrease spasticity in stroke-related hemiplegic legs. However, acute changes in cortical activation after WBV are unclear.Objective: To examine whether WBV induces acute changes in sensorimotor cortical activation in patients with stroke-related hemiplegic legs.Methods: Eleven stroke patients (mean age 52.6 [SD 15.4] years; median time after stroke 3 [25th and 75th percentiles; 3 and 10.5, respectively] months) participated in a comparative before-and-after intervention trial. Six healthy adults were also studied. WBV at 30 Hz was applied for 5 min to the hamstrings, gastrocnemius, and soleus muscles. Spasticity was assessed according to the modified Ashworth scale (MAS). Active and passive range of motion (A-ROM and P-ROM, respectively) were also measured. Change in Oxy-Hb concentration in bilateral sensorimotor cortex associated with voluntary ankle dorsiflexion of the affected limb was assessed via functional near-infrared spectroscopy (fNIRS) before and immediately after WBV.Results: MAS score, A-ROM, and P-ROM improved immediately after WBV. In the patients, while there was no significant interaction between effects of region (ipsilesional and contralesional sensorimotor cortex) and the WBV intervention (before and immediately after WBV) ($F1,10 = 0.702$, $p = .422$), there was a significant main effect of the WBV intervention ($F1,10 = 6.971$, $p = .025$). In the healthy participants, there was no association with the WBV intervention or region.Conclusions: In patients with stroke-related spastic-hemiplegic legs, WBV might result not only in clinical improvement but also in acute increase in sensorimotor cortical activation.

Exploring cortical activation and connectivity in infants with and without familial risk for autism during naturalistic social interactions: A preliminary study.

Bhat AN, McDonald NM, Eilbott JE, Pelphrey KA.

Infant Behav Dev. Nov;57:
doi: 10.1016/j.infbeh.2019.Epub Aug 23.

Behavioral signs of Autism Spectrum Disorder (ASD) are typically ob-

servable by the second year of life and a reliable diagnosis of ASD is possible by 2 to 3 years of age. Studying infants with familial risk for ASD allows for the investigation of early signs of ASD risk within the first year. Brain abnormalities such as hyper-connectivity within the first year may precede the overt signs of ASD that emerge later in life. In this preliminary study, we use functional near-infrared spectroscopy (fNIRS), an infant-friendly neuroimaging tool that is relatively robust against motion artifacts, to examine functional activation and connectivity during naturalistic social interactions in 9 high-risk (HR; older sibling with ASD) and 6 low-risk (LR; no family history of ASD) infants from 6 to 9 months of age. We obtained two 30-second baseline periods and a 5-minute social interaction period. HR infants showed reduced right and left-hemispheric activation compared to LR infants based on oxy (HbO2) and deoxy (HHb) signal trends. HR infants also had greater functional connectivity than LR infants during the pre- and post-social periods and showed a drop in connectivity during the social period. Our findings are consistent with previous work suggesting early differences in cortical activation associated with familial risk for ASD, and highlight the promise of fNIRS in evaluating potential markers of ASD risk during naturalistic social contexts.

How does the embodied metaphor affect creative thinking?

Wang X, He Y, Lu K, Deng C, Qiao X, Hao N.

Neuroimage. Nov 15;202:
doi: 10.1016/j.neuroimage.2019.Epub Aug 20.

This study aimed to explore the neural correlates of the embodied metaphor "breaking the rules" and how it affects creativity by using functional near-infrared spectroscopy (fNIRS). To embody the metaphor "breaking the rules," we created a circumstance in which participants can experience "breaking the walls" through virtual reality (VR) technology. Participants were randomly assigned to three conditions: the "break-wall" condition, where they broke the walls to move forward; the "auto-wall" condition, where the barrier wall opened automatically; and the "no-wall" condition, where no barrier walls appeared. While walking in the virtual scenes, participants were asked to solve a creativity-demanding problem and to wear the fNIRS device to record their neural activities. It was found that participants showed better creative performance in the "break-wall" condition than in the other conditions. Weaker activations were found in the frontopolar cortex, the dorsolateral prefrontal cortex, and the somatosensory association cortex un-

der the "break-wall" condition, which may be associated with rule-breaking behaviors, creative performance, and sense of embodiment. These findings may indicate that physical actions of "breaking the wall" activate the conceptual metaphor of "breaking the rules," which triggers brain activities related to rule-breaking, thus affecting creative performance.

The role of the right prefrontal cortex in recognition of facial emotional expressions in depressed individuals: fNIRS study.

Manelis A, Huppert TJ, Rodgers E, Swartz HA, Phillips ML.

J Affect Disord. Nov 1;258:151-
doi: 10.1016/j.jad.2019.08.Epub Aug 5.

BACKGROUND: Depressed individuals often perceive neutral facial expressions as emotional. Neurobiological underpinnings of this effect remain unclear. We investigated the differences in prefrontal cortical (PFC) activation in depressed individuals vs. healthy controls (HC) during recognition of emotional and neutral facial expressions using functional near infrared spectroscopy (fNIRS). METHOD: In Experiment 1, 33 depressed individuals and 20 HC performed the Emotion Intensity Rating task in which they rated intensity of facial emotional expressions. In Experiment 2, a different set of participants (18 depressed individuals and 16 HC) performed the same task while their PFC activation was measured using fNIRS. RESULTS: Both experiments showed that depressed individuals were slower and less accurate in recognizing neutral, but not happy or fearful, facial emotional expressions. Experiment 2 revealed that lower accuracy for neutral facial emotional expressions was associated with lower right PFC activation in depressed individuals, but not HC. In addition, depressed individuals, compared to HC, had lower right PFC activation during recognition of happy facial expressions. LIMITATIONS: Relatively small sample size CONCLUSIONS: Recognition of neutral facial expressions is impaired in depressed individuals. Greater impairment corresponds to lower right PFC activation during neutral face processing. Recognition of happy facial expressions is comparable for depressed individuals and HC, but the former have significantly lower right PFC activation. Taken together, these findings suggest that the ability of depressed individuals to discriminate neutral and emotional signals in the environment may be affected by aberrant functioning of right PFC.

Brain activation and adaptation of deception processing during dyadic face-to-face interaction.

Tang H, Zhang S, Jin T, Wu H, Su S, Liu C.

Cortex. Nov;120:326-
doi: 10.1016/j.cortex.2019.07.Epub Jul 13.

Though deception is consistently characterized by the slippery-slope effect, i.e., the escalation of small lies over time, differing interactive situations and interacting processes may influence the trajectories of deception. To explore this influence, we investigated naturalistic face-to-face (FF) and computer-mediated face-blocked (FB) interactions using functional near-infrared spectroscopy (fNIRS). Pairs of participants acted as deceivers and receivers in an adapted ultimatum game while brain activity in the right dorsolateral prefrontal cortex (rDLPFC) and temporoparietal junction (rTPJ) was recorded. Comparison of deception in the two types of interactions showed that the FF interactions resulted in more successful deception, as well as acceptance of deception, and prompted more neural activation in the rDLPFC than the FB interactions. We found that the deception magnitude escalated in both FF and FB interactions, but rDLPFC activity during deception diminished over time only in the FF interactions but not in FB interactions, suggesting that the deceivers behaviourally adapted to deception over time in both types of interactions, but the neural adaptation occurred only in the FF interactions. Furthermore, neural adaptation in FF interactions was associated with behavioural switching after deception, indicating that the rDLPFC contributes to deception adaptation and the control of switching between deception and honesty. The FF interactions were also characterized by activity in the rTPJ, which showed an adaptation to deception. These findings highlight the importance of interactive situations in dyadic naturalistic settings for deception and the role of the rDLPFC and rTPJ in the slippery-slope effect in deception.

Hand motor learning in a musical context and prefrontal cortex hemodynamic response: a functional near-infrared spectroscopy (fNIRS) study.

Alves Heinze R, Vanzella P, Zimeo Morais GA, Sato JR.

Cogn Process. Nov;20(4):507-
doi: 10.1007/s10339-019-00925-y. Epub Aug 5.

Due to movement automatization, the engagement of high-order cognitive processing during the motor execution of a task is expected to de-

crease over repetitions and practice. In this study, we assessed single session changes in the prefrontal hemodynamic signals in response to training a piano chord progression in an ecological experimental setting. We acquired functional near-infrared spectroscopy signals from 15 subjects without any previous experience on playing keyboard instruments. Our findings were that oxygenated hemoglobin changes at orbitofrontal cortex followed an inverted U-shaped curve over task execution, while the subjects' performance presented a steady slope. These results suggest an initial executive function engagement followed by facilitation of motor execution over time.

Reward motivation and neurostimulation interact to improve working memory performance in healthy older adults: A simultaneous tDCS-fNIRS study.

Di Rosa E, Brigadoi S, Cutini S, Tarantino V, Dell'Acqua R, Mapelli D, Braver TS, Vallesi A.

Neuroimage. Nov 15;202:

doi: 10.1016/j.neuroimage.2019.Epub Jul 29.

Several studies have evaluated the effect of anodal transcranial direct current stimulation (tDCS) over the prefrontal cortex (PFC) for the enhancement of working memory (WM) performance in healthy older adults. However, the mixed results obtained so far suggest the need for concurrent brain imaging, in order to more directly examine tDCS effects. The present study adopted a continuous multimodal approach utilizing functional near-infrared spectroscopy (fNIRS) to examine the interactive effects of tDCS combined with manipulations of reward motivation. Twenty-one older adults (mean age = 69.7 years; SD =5.05) performed an experimental visuo-spatial WM task before, during and after the delivery of 1.5 mA anodal tDCS/sham over the left prefrontal cortex (PFC). During stimulation, participants received performance-contingent reward for every fast and correct response during the WM task. In both sessions, hemodynamic activity of the bilateral frontal, motor and parietal areas was recorded across the entire duration of the WM task. Cognitive functions and reward sensitivity were also assessed with standard measures. Results demonstrated a significant impact of tDCS on both WM performance and hemodynamic activity. Specifically, faster responses in the WM task were observed both during and after anodal tDCS, while no differences were found under sham control conditions. However, these effects emerged only when taking into account individual visuo-spatial WM capacity. Additionally, during and af-

ter the anodal tDCS, increased hemodynamic activity relative to sham was observed in the bilateral PFC, while no effects of tDCS were detected in the motor and parietal areas. These results provide the first evidence of tDCS-dependent functional changes in PFC activity in healthy older adults during the execution of a WM task. Moreover, they highlight the utility of combining reward motivation with prefrontal anodal tDCS, as a potential strategy to improve WM efficiency in low performing healthy older adults.

Exploring the Brain Responses to Driving Fatigue Through Simultaneous EEG and fNIRS Measurements.

Lin CT, King JT, Chuang CH, Ding W, Chuang WY, Liao LD, Wang YK.

Int J Neural Syst. Jan;30(1):
doi: 10.1142/SEpub Jun 4.

Fatigue is one problem with driving as it can lead to difficulties with sustaining attention, behavioral lapses, and a tendency to ignore vital information or operations. In this research, we explore multimodal physiological phenomena in response to driving fatigue through simultaneous functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG) recordings with the aim of investigating the relationships between hemodynamic and electrical features and driving performance. Sixteen subjects participated in an event-related lane-deviation driving task while measuring their brain dynamics through fNIRS and EEGs. Three performance groups, classified as Optimal, Suboptimal, and Poor, were defined for comparison. From our analysis, we find that tonic variations occur before a deviation, and phasic variations occur afterward. The tonic results show an increased concentration of oxygenated hemoglobin (HbO2) and power changes in the EEG theta, alpha, and beta bands. Both dynamics are significantly correlated with deteriorated driving performance. The phasic EEG results demonstrate event-related desynchronization associated with the onset of steering vehicle in all power bands. The concentration of phasic HbO2 decreased as performance worsened. Further, the negative correlations between tonic EEG delta and alpha power and HbO2 oscillations suggest that activations in HbO2 are related to mental fatigue. In summary, combined hemodynamic and electrodynamic activities can provide complete knowledge of the brain's responses as evidence of state changes during fatigue driving.

Investigating the vestibular system using modern imaging techniques-A review on the available stimulation and imaging methods.

Ertl M, Boegle R.

J Neurosci Methods. Oct 1;326:
doi: 10.1016/j.jneumeth.2019.108363. Epub Jul 25.

The vestibular organs, located in the inner ear, sense linear and rotational acceleration of the head and its position relative to the gravitational field of the earth. These signals are essential for many fundamental skills such as the coordination of eye and head movements in the three-dimensional space or the bipedal locomotion of humans. Furthermore, the vestibular signals have been shown to contribute to higher cognitive functions such as navigation. As the main aim of the vestibular system is the sensation of motion it is a challenging system to be studied in combination with modern imaging methods. Over the last years various different methods were used for stimulating the vestibular system. These methods range from artificial approaches like galvanic or caloric vestibular stimulation to passive full body accelerations using hexapod motion platforms, or rotatory chairs. In the first section of this review we provide an overview over all methods used in vestibular stimulation in combination with imaging methods (fMRI, PET, E/MEG, fNIRS). The advantages and disadvantages of every method are discussed, and we summarize typical settings and parameters used in previous studies. In the second section the role of the four imaging techniques are discussed in the context of vestibular research and their potential strengths and interactions with the presented stimulation methods are outlined.

Put on your (fNIRS) thinking cap: Frontopolar activation during augmented state creativity.

Tempest GD, Radel R.

Behav Brain Res. Nov 5;373:
doi: 10.1016/j.bbr.2019.Epub 2019 Jul 10.

Thinking creatively requires the ability to consciously augment creative insight through processes such as analogical reasoning and relational cognition. Prior work has examined augmented states of creativity using a modified verb generation task which requires brief engagement in attempts to think creatively during MRI. In this study, we employed the verb generation task to examine augmented creative states and frontopolar cortex activation in a less-constrained setting using functional near infrared spec-

troscopy (fNIRS). Participants (n = 29) were presented with a noun and were required to think of an associated verb. In 50% of the trials, participants were instructed to 'think creatively' (cued condition) as opposed to stating the first or most prominent verb that came to mind (uncued condition). The task was administered in French to native speakers. Hemodynamic responses were recorded over the frontopolar cortex using fNIRS. The relatedness of the noun-verb pairs was calculated and other measures of creativity (the Alternate Uses Test, Compound Remote Associate Test and the Biographical Inventory of Creative Behaviors) were recorded. We showed that in the cued condition, semantic scores were higher (indicating more creative responses), positively associated with other measures of creativity, and changes in oxygenated hemoglobin were larger and more extensive in the left frontopolar cortex, than in the uncued condition. Our findings support the use of the verb generation task (administered in French) to augment creative states and provides further validation of the use of the task to capture creativity (i.e., processes involved in generating creative responses through distant associations). We highlight the use of fNIRS to measure associated regional changes in frontopolar cortex activity during augmented states of creativity.

Behavioral response to tactile stimuli relates to brain response to affective touch in 12-month-old infants.

Miguel HO, Goncalves óF, Sampaio A.

Dev Psychobiol. Jan;62(1):107-

doi: 10.1002/dev.Epub Jul 12.

Affective touch activates a brain network responsible for processing social-emotional stimuli in infants, children, and adults, with a core node in the superior temporal sulcus (STS). STS is known to be a region highly susceptible to individual variability, including for tactile stimuli processing. However, little is known about how this region is recruited to process affective touch in infancy. The aim of this study was to examine brain activity to affective touch in the temporal region (STS) and understand if it relates to behavioral patterns of sensory-over responsivity (SOR) to touch. Twelve-month-old infants (n = 24) were given affective and discriminative stimuli to the forearm while they were watching a silent movie. Brain activation was recorded in the STS for measures of oxy-hemoglobin (HbO2) and deoxy-hemoglobin (Hbb) using functional near infra-red spectroscopy (fNIRS). Aversive responses to tactile stimuli were measured using the Infant-Toddler Sensory Profile. A significant hemodynamic response increase in HbO2 to affective touch was

observed in the STS for infants with less aversive behavioral responses to tactile stimuli. The findings suggest that brain activity in the STS for affective touch might be related to individual differences in the affective reaction toward touch.

Pre-operative Brain Imaging Using Functional Near-Infrared Spectroscopy Helps Predict Cochlear Implant Outcome in Deaf Adults.

Anderson CA, Wiggins IM, Kitterick PT, Hartley DEH.

J Assoc Res Otolaryngol. Oct;20(5):511-
doi: 10.1007/s10162-019-00729-z. Epub Jul 8.

Currently, it is not possible to accurately predict how well a deaf individual will be able to understand speech when hearing is (re)introduced via a cochlear implant. Differences in brain organisation following deafness are thought to contribute to variability in speech understanding with a cochlear implant and may offer unique insights that could help to more reliably predict outcomes. An emerging optical neuroimaging technique, functional near-infrared spectroscopy (fNIRS), was used to determine whether a pre-operative measure of brain activation could explain variability in cochlear implant (CI) outcomes and offer additional prognostic value above that provided by known clinical characteristics. Cross-modal activation to visual speech was measured in bilateral superior temporal cortex of pre- and post-lingually deaf adults before cochlear implantation. Behavioural measures of auditory speech understanding were obtained in the same individuals following 6 months of cochlear implant use. The results showed that stronger pre-operative cross-modal activation of auditory brain regions by visual speech was predictive of poorer auditory speech understanding after implantation. Further investigation suggested that this relationship may have been driven primarily by the inclusion of, and group differences between, pre- and post-lingually deaf individuals. Nonetheless, pre-operative cortical imaging provided additional prognostic value above that of influential clinical characteristics, including the age-at-onset and duration of auditory deprivation, suggesting that objectively assessing the physiological status of the brain using fNIRS imaging pre-operatively may support more accurate prediction of individual CI outcomes. Whilst activation of auditory brain regions by visual speech prior to implantation was related to the CI user's clinical history of deafness, activation to visual speech did not relate to the future ability of these brain regions to respond to auditory speech stimulation with

a CI. Greater pre-operative activation of left superior temporal cortex by visual speech was associated with enhanced speechreading abilities, suggesting that visual speech processing may help to maintain left temporal lobe specialisation for language processing during periods of profound deafness.

Hemodynamic responses to visual cues during attentive listening in autonomous versus manual simulated driving: A pilot study.

Hidalgo-Muñoz AR, Jallais C, Evennou M, Ndiaye D, Moreau F, Ranchet M, Derollepot R, Fort A.

Brain Cogn. Oct;135:
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Emerging automation technologies could have a strong impact on the allocation of drivers' attentional resources. The first objective of this pilot study is to investigate the hemodynamic responses evoked to relevant visual stimuli in manual and autonomous driving. The second aim is to examine how the inclusion of a secondary task (attentive listening to a broadcast) modulates these hemodynamic responses in both driving situations. Frontal, temporo-parietal and occipital activations were recorded using a functional Near-InfraRed Spectroscopy (fNIRS) system. Event-related analysis was used to determine whether visual cue processing (specifically, the lighting of a lead vehicle's brake-lights) could induce different brain responses depending on the driving mode and on the presence or absence of a competing task. Mind-wandering as reported by the participants was more pronounced during autonomous compared to manual driving. Our results showed an increase in the OxyHb concentration in the right temporo-parietal and occipital areas during manual compared to autonomous driving, suggesting greater allocation of attentional resources for processing visual cues in the first condition. Finally, an event-related decrease in right frontal activity during autonomous driving when listening was observed, suggesting that attentional resources were more focused on the secondary task than on monitoring the driving scene.

Recommendations for motion correction of infant fNIRS data applicable to multiple data sets and acquisition systems.

Di Lorenzo R, Pirazzoli L, Blasi A, Bulgarelli C, Hakuno Y, Minagawa Y,

Brigadoi S.
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Despite motion artifacts are a major source of noise in fNIRS infant data, how to approach motion correction in this population has only recently started to be investigated. Homer2 offers a wide range of motion correction methods and previous work on simulated and adult data suggested the use of Spline interpolation and Wavelet filtering as optimal methods for the recovery of trials affected by motion. However, motion artifacts in infant data differ from those in adults' both in amplitude and frequency of occurrence. Therefore, artifact correction recommendations derived from adult data might not be optimal for infant data. We hypothesized that the combined use of Spline and Wavelet would outperform their individual use on data with complex profiles of motion artifacts. To demonstrate this, we first compared, on infant semi-simulated data, the performance of several motion correction techniques on their own and of the novel combined approach; then, we investigated the performance of Spline and Wavelet alone and in combination on real cognitive data from three datasets collected with infants of different ages (5, 7 and 10 months), with different tasks (auditory, visual and tactile) and with different NIRS systems. To quantitatively estimate and compare the efficacy of these techniques, we adopted four metrics: hemodynamic response recovery error, within-subject standard deviation, between-subjects standard deviation and number of trials that survived each correction method. Our results demonstrated that (i) it is always better correcting for motion artifacts than rejecting the corrupted trials; (ii) Wavelet filtering on its own and in combination with Spline interpolation seems to be the most effective approach in reducing the between- and the within-subject standard deviations. Importantly, the combination of Spline and Wavelet was the approach providing the best performance in semi-simulation both at low and high levels of noise, also recovering most of the trials affected by motion artifacts across all datasets, a crucial result when working with infant data.

A new blind source separation framework for signal analysis and artifact rejection in functional Near-Infrared Spectroscopy.

von Lühmann A, Boukouvalas Z, Müller KR, Adali T.
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In the analysis of functional Near-Infrared Spectroscopy (fNIRS) signals from real-world scenarios, artifact rejection is essential. However, currently there exists no gold-standard. Although a plenitude of methodological approaches implicitly assume the presence of latent processes in the signals, elaborate Blind-Source-Separation methods have rarely been applied. A reason are challenging characteristics such as Non-instantaneous and non-constant coupling, correlated noise and statistical dependencies between signal components. We present a novel suitable BSS framework that tackles these issues by incorporating A) Independent Component Analysis methods that exploit both higher order statistics and sample dependency, B) multimodality, i.e., fNIRS with accelerometer signals, and C) Canonical-Correlation Analysis with temporal embedding. This enables analysis of signal components and rejection of motion-induced physiological hemodynamic artifacts that would otherwise be hard to identify. We implement a method for Blind Source Separation and Accelerometer based Artifact Rejection and Detection (BLISSA2RD). It allows the analysis of a novel n-back based cognitive workload paradigm in freely moving subjects, that is also presented in this manuscript. We evaluate on the corresponding data set and simulated ground truth data, making use of metrics based on 1st and 2nd order statistics and SNR and compare with three established methods: PCA, Spline and Wavelet-based artifact removal. Across 17 subjects, the method is shown to reduce movement induced artifacts by up to two orders of magnitude, improves the SNR of continuous hemodynamic signals in single channels by up to 10dB, and significantly outperforms conventional methods in the extraction of simulated Hemodynamic Response Functions from strongly contaminated data. The framework and methods presented can serve as an introduction to a new type of multivariate methods for the analysis of fNIRS signals and as a blueprint for artifact rejection in complex environments beyond the applied paradigm.

Functional near infrared spectroscopy using spatially resolved data to account for tissue scattering: A numerical study and arm-cuff experiment.

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Functional Near-Infrared Spectroscopy (fNIRS) aims to recover changes

in tissue optical parameters relating to tissue hemodynamics, to infer functional information in biological tissue. A widely-used application of fNIRS relies on continuous wave (CW) methodology that utilizes multiple distance measurements on human head for study of brain health. The typical method used is spatially resolved spectroscopy (SRS), which is shown to recover tissue oxygenation index (TOI) based on gradient of light intensity measured between two detectors. However, this methodology does not account for tissue scattering which is often assumed. A new parameter recovery algorithm is developed, which directly recovers both the scattering parameter and scaled chromophore concentrations and hence TOI from the measured gradient of light-attenuation at multiple wavelengths. It is shown through simulations that in comparison to conventional SRS which estimates cerebral TOI values with an error of $\pm 12.3\%$, the proposed method provides more accurate estimate of TOI exhibiting an error of $\pm 5.7\%$ without any prior assumptions of tissue scatter, and can be easily implemented within CW fNIRS systems. Using an arm-cuff experiment, the obtained TOI using the proposed method is shown to provide a higher and more realistic value as compared to utilizing any prior assumptions of tissue scatter.

Prefrontal cortex activation supports the emergence of early stone age toolmaking skill.

Putt SSJ, Wijeakumar S, Spencer JP.

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Trends toward encephalization and technological complexity 1.8 million years ago may signify cognitive development in the genus Homo. Using functional near-infrared spectroscopy, we measured relative brain activity of 33 human subjects at three different points as they learned to make replicative Oldowan and Acheulian Early Stone Age tools. Here we show that the more complex early Acheulian industry recruits left dorsolateral prefrontal cortex when skills related to this task are first being learned. Individuals with increased activity in this area are the most proficient at the Acheulian task. The Oldowan task, on the other hand, transitions to automatic processing in less than 4 h of training. Individuals with increased sensorimotor activity demonstrate the most skill at this task. We argue that enhanced working memory abilities received positive selection in response to technological needs during the early Pleistocene, setting Homo on the path to becoming human.

Infant brain response to affective and discriminative touch: A longitudinal study using fNIRS.

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The affective-motivational component of touch has been shown to consistently activate the social- brain network in children, adolescents and adults, including the posterior superior temporal sulcus (pSTS). However, very little is known about the neural mechanisms of affective touch processing during the first year of life. The objective of the present study was to analyze brain response to affective and discriminative touch in a sample of seven-month-old infants (N = 35) who were followed longitudinally at 12 months of age (N = 25). Infants were given affective and discriminative touch to the bare forearm while their brain response was recorded using functional near-spectroscopy (fNIRS). Seven-month-olds presented brain activation for affective and discriminative stimuli in channels placed over the somatosensory region, but no activation was recorded in channels placed in the temporal region for affective touch. At 12 months of age, infants presented a significant increase in hemodynamic activity in channels placed over the temporal region for affective touch, compared to seven-month-olds. Our study presents evidence of a developmental trajectory for distinct aspects of touch brain processing in the first year of life, with the recruitment of the temporal region for the affective component of touch, maturing in the second semester of life.

The promise of functional near-infrared spectroscopy in autism research: What do we know and where do we go?

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Functional near-infrared spectroscopy (fNIRS) is a neuroimaging technique that has been gaining increasing interest as a method to investigate the brain function of individuals on the autism spectrum. It is a non-invasive, portable and relatively motion-tolerant method of measuring haemodynamic activity in the brain. fNIRS can be particularly effective for quantifying brain function in challenging clinical populations. In light of this, there is a growing body of fNIRS literature focusing on individuals on the autism

spectrum. The aim of this review is to evaluate and summarise key studies from the literature and discuss their implications for the field. Potential limitations of the fNIRS approach and resolution of these issues based on emerging fNIRS research are also discussed.

Excessive bodybuilding as pathology? A first neurophysiological classification.

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Objectives: Excessive bodybuilding as a pathological syndrome has been classified based on two different theories: bodybuilding as dependency or as muscle dysmorphic disorder (MDD). This study is a first attempt to find psychophysiological data supporting one of these classifications.Methods: Twenty-four participants (bodybuilders vs healthy controls) were presented with pictures of bodies, exercise equipment or general reward stimuli in a control or experimental condition, and were measured with functional near-infrared spectroscopy (fNIRS). Higher activation in the dorsolateral prefrontal cortex (DLPFC) and the orbitofrontal cortex (OFC) while watching bodies and training equipment in the experimental condition (muscular bodies and bodybuilding-typical equipment) would be an indicator for the addiction theory. Higher activation in motion-related areas would be an indicator for the MDD theory.Results: We found no task-related differences between the groups in the DLPFC and OFC, but a significantly higher activation in bodybuilders in the primary somatosensory cortex (PSC) and left-hemispheric supplementary motor area (SMA) while watching body pictures (across conditions) as compared to the control group.Conclusions: These neurophysiological results could be interpreted as a first evidence for the MDD theory of excessive bodybuilding.