fNIRS publications on PubMed: July 1, 2021 - December 31, 2021

Felipe Orihuela-Espina

Methodology. Searches were made in PubMed constraining the search period between July 1, 2021 and December 31, 2021. 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

[An overview on sleep research based on functional near infrared spectroscopy].

[Article in Chinese; Abstract available in Chinese from the publisher]

Sheng Wu Yi Xue Gong Cheng Xue Za Zhi. 2021 Dec 25;38(6):1211-1218.
doi: 10.7507/1001-5515.202102003.

Huang M(1)(2), Jiao X(2), Jiang J(2), Yang J(1)(2), Chu H(1)(2), Pan J(2), Cao Y(2).

Applications of functional near-infrared spectroscopy (fNIRS) in neonates.

Peng C, Hou X.

Neurosci Res. 2021 Sep;170:18-23.
doi: 10.1016/j.neures.2020.11.003. Epub 2020 Dec 30.

Functional near-infrared spectroscopy (fNIRS) is a method of monitoring brain oxygenation. This technique investigates hemodynamic changes in the cerebral cortex. fNIRS is widely used in clinical and scientific research. In this review, we focus on the applications of fNIRS on neonates. Here, applications form two distinct categories: task associated studies, and hemoglobin phase change studies. fNIRS is non-invasive, easily performed, and repeatable. However, it has limited monitoring depth and spatial resolution when used in newborns. Moreover, with recent technological advances, it is now possible to explore neuronal activity patterns using fNIRS in both healthy and pathological conditions. For more than 20 years, fNIRS has enabled clinicians to gain insight into cerebral development and mechanisms of injury in neonates. fNIRS is a useful supplement to existing technologies due to its ability to interrogate the neonatal brain function.

Wearable, Integrated EEG-fNIRS Technologies: A Review.

Uchitel J, Vidal-Rosas EE, Cooper RJ, Zhao H.

Sensors (Basel). 2021 Sep 12;21(18):6106.
doi: 10.3390/s21186106.

There has been considerable interest in applying electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) simultaneously for multimodal assessment of brain function. EEG-fNIRS can provide a comprehensive picture of brain electrical and hemodynamic function and has been applied across various fields of brain science. The development of wearable, mechanically and electrically integrated EEG-fNIRS technology is a critical next step in the evolution of this field. A suitable system design could

significantly increase the data/image quality, the wearability, patient/subject comfort, and capability for long-term monitoring. Here, we present a concise, yet comprehensive, review of the progress that has been made toward achieving a wearable, integrated EEG-fNIRS system. Significant marks of progress include the development of both discrete component-based and microchip-based EEG-fNIRS technologies; modular systems; miniaturized, lightweight form factors; wireless capabilities; and shared analogue-to-digital converter (ADC) architecture between fNIRS and EEG data acquisitions. In describing the attributes, advantages, and disadvantages of current technologies, this review aims to provide a roadmap toward the next generation of wearable, integrated EEG-fNIRS systems.

Probing depression, schizophrenia, and other psychiatric disorders using fNIRS and the verbal fluency test: A systematic review and meta-analysis.

Yeung MK, Lin J.

J Psychiatr Res. 2021 Aug;140:416-435.
doi: 10.1016/j.jpsychires.2021.06.015. Epub 2021 Jun 12.

Accessible neuroimaging tools that can identify specific frontal lobe dysfunction associated with psychiatric disorders could be useful for improving disease diagnosis and prognosis and treatment development. Functional near-infrared spectroscopy (fNIRS), in conjunction with the verbal fluency test (VFT), has emerged as an inexpensive and convenient method for understanding psychiatric disorders. However, questions remain regarding the specificity and uniqueness of fNIRS measurements for different disorders and the soundness of the methods applied previously. To address these knowledge gaps, we conducted a systematic review and meta-analysis of fNIRS studies using the VFT to probe psychiatric disorders. A literature search was conducted using PubMed and PsycINFO on October 27, 2020. Overall, 82% and 49% of the 121 included studies reported significantly reduced changes in oxyhemoglobin concentrations (HbO) and significantly fewer produced words during the VFT in psychiatric patients compared with healthy controls, respectively. For most psychiatric disorders, changes in HbO are more sensitive than changes in deoxyhemoglobin concentrations and VFT performance to detect psychopathologies. In addition, meta-analyses based on the proportion of channels that exhibited significant differences in HbO changes between patients and controls and on the effect sizes of group differences consistently showed that for major depression and schizophrenia, hypoactivation could be found across the frontotemporal regions, but its topographical distribution is disorder-specific. Thus, the fNIRS-VFT paradigm holds promise for understanding, detecting, and differentiating psychiatric disorders, and has the potential for developing accessible neuroimaging biomarkers for different psychiatric disorders. The findings are discussed with regard to the strengths and weaknesses of the applied methods, following by recommendations.

Cerebral and muscle near-infrared spectroscopy during lower-limb muscle activity - volitional and neuromuscular electrical stimulation.

Dutta A, Zhao F, Cheung M, Das A, Tomita M, Chatterjee K.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:6577-6580.
doi: 10.1109/EMBC46164.2021.9629721.

Chronic venous insufficiency (CVI) can lead to blood clotting in the deep veins of the legs, a disease known as deep vein thrombosis. An estimated 40 percent of people in the United States have venous insufficiency that may be ameliorated with neuromuscular electrical stimulation (NMES). Near-infrared spectroscopy (NIRS) is a non-invasive optical imaging method for monitoring hemodynamics. NIRS, being an optical technique has no stimulation artefact, can be combined with NMES for theranostics application. In this study, we combined muscle NIRS (mNIRS) with electromyogram (EMG) of the calf muscles to detect blood volume changes (based on total hemoglobin concentration) in the muscle during volitional tiptoe movements at different frequencies. Also, blood volume changes were measured during NMES (using

the geko^{TM} device) at different device settings. In the mNIRS+NMES study, we also measured the cerebral hemodynamics using functional NIRS (fNIRS). The mNIRS was conducted using a frequency domain (FD) method (called FDNIRS) that used a multi-distance method to isolate muscle hemodynamics. FDNIRS-EMG study in ten healthy humans found a statistically significant ($p<0.05$) effect of the tiptoe frequencies on the EMG magnitude (and power) that increased with tiptoe frequency. Also, the muscle blood volume (standing/rest) decreased ($p<0.01$) with increasing tiptoe frequency and increasing NMES intensity that was statistically significantly ($p<0.05$) different between males and females. Moreover, increasing NMES intensity led to a statistically significant ($p<0.01$) increase in the cerebral blood volume - measured with fNIRS. Therefore, combined mNIRS and fNIRS with NMES can provide a theranostics application for brain+muscle in CVI.

Investigating Language and Domain-General Processing in Neurotypicals and Individuals With Aphasia - A Functional Near-Infrared Spectroscopy Pilot Study.

Gilmore N, Ycel MA, Li X, Boas DA, Kiran S.

Front Hum Neurosci. 2021 Sep 17;15:728151.
doi: 10.3389/fnhum.2021.728151. eCollection 2021.

Brain reorganization patterns associated with language recovery after stroke have long been debated. Studying mechanisms of spontaneous and treatment-induced language recovery in post-stroke aphasia requires a network-based approach given the potential for recruitment of perilesional left hemisphere language regions, homologous right hemisphere language regions, and/or spared bilateral domain-general regions. Recent hardware, software, and methodological advances in functional near-infrared spectroscopy (fNIRS) make it well-suited to examine this question. fNIRS is cost-effective with minimal contraindications, making it a robust option to monitor treatment-related brain activation changes over time. Establishing clear activation patterns in neurotypical adults during language and domain-general cognitive processes via fNIRS is an important first step. Some fNIRS studies have investigated key language processes in healthy adults, yet findings are challenging to interpret in the context of methodological limitations. This pilot study used fNIRS to capture brain activation during language and domain-general processing in neurotypicals and individuals with aphasia. These findings will serve as a reference when interpreting treatment-related changes in brain activation patterns in post-stroke aphasia in the future. Twenty-four young healthy controls, seventeen older healthy controls, and six individuals with left hemisphere stroke-induced aphasia completed two language tasks (i.e., semantic feature, picture naming) and one domain-general cognitive task (i.e., arithmetic) twice during fNIRS. The probe covered bilateral frontal, parietal, and temporal lobes and included short-separation detectors for scalp signal nuisance regression. Younger and older healthy controls activated core language regions during semantic feature processing (e.g., left inferior frontal gyrus pars opercularis) and lexical retrieval (e.g., left inferior frontal gyrus pars triangularis) and domain-general regions (e.g., bilateral middle frontal gyri) during hard versus easy arithmetic as expected. Consistent with theories of post-stroke language recovery, individuals with aphasia activated areas outside the traditional networks: left superior frontal gyrus and left supramarginal gyrus during semantic feature judgment; left superior frontal gyrus and right precentral gyrus during picture naming; and left inferior frontal gyrus pars opercularis during arithmetic processing. The preliminary findings in the stroke group highlight the utility of using fNIRS to study language and domain-general processing in aphasia.

Anger Experience and Anger Expression Through Drawing in Schizophrenia: An fNIRS Study.

Yan W, Ji W, Su C, Yu Y, Yu X, Chen L.

Front Psychol. 2021 Sep 1;12:721148.
doi: 10.3389/fpsyg.2021.721148. eCollection 2021.

Differences in emotion experience and emotion expression between patients with schizophrenia and the healthy population have long been the focus of research and clinical attention. However, few empirical studies have addressed this topic using art-making as a tool of emotion expression. This study explores the differences in brain mechanism during the process of expressing anger between patients with schizophrenia and healthy participants using pictographic psychological techniques. We used functional near-infrared spectroscopy to fully detect changes in frontal cortex activity among participants in two groups-schizophrenia and healthy-during the process of experiencing and expressing anger. The results showed that there were no differences in the experience of anger between the two groups. In the process of anger expression, the dorsolateral prefrontal cortex, frontal pole, and other regions showed significant negative activation among patients with schizophrenia, which was significantly different from that of the healthy group. There were significant differences between patients with schizophrenia and the healthy group in the drawing features, drawing contents, and the ability to describe the contents of their drawings. Moreover, the effect size of the latter was greater than those of the former two. In terms of emotion expression, the drawing data and brain activation data were significantly correlated in each group; however, the correlation patterns differed between groups.

Enhanced inter-brain connectivity between children and adults during cooperation: a dual EEG study.

Li Y, Wu S, Shi W, Tong S, Zhang Y, Guo X.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:6289-6292.
doi: 10.1109/EMBC46164.2021.9630330.

Previous fNIRS studies have suggested that adult-child cooperation is accompanied by increased inter-brain synchrony. However, its reflection in the electrophysiological synchrony remains unclear. In this study, we designed a naturalistic and well-controlled adult-child interaction paradigm using a tangram solving video game, and recorded dual-EEG from child and adult dyads during cooperative and individual conditions. By calculating the directed inter-brain connectivity in the theta and alpha bands, we found that the inter-brain frontal network was more densely connected and stronger in strength during the cooperative than the individual condition when the adult was watching the child playing. Moreover, the inter-brain network across different dyads shared more common information flows from the player to the observer during cooperation, but was more individually different in solo play. The results suggest an enhancement in inter-brain EEG interactions during adult-child cooperation. However, the enhancement was evident in all cooperative cases but partly depended on the role of participants.

Brain-Computer Interfacing Using Functional Near-Infrared Spectroscopy (fNIRS).

Paulmurugan K, Vijayaragavan V, Ghosh S, Padmanabhan P, Gulys B.

Biosensors (Basel). 2021 Oct 13;11(10):389.
doi: 10.3390/bios11100389.

Functional Near-Infrared Spectroscopy (fNIRS) is a wearable optical spectroscopy system originally developed for continuous and non-invasive monitoring of brain function by measuring blood oxygen concentration. Recent advancements in brain-computer interfacing allow us to control the neuron function of the brain by combining it with fNIRS to regulate cognitive function. In this review manuscript, we provide information regarding current advancement in fNIRS and how it provides advantages in developing brain-computer interfacing to enable neuron function. We also briefly discuss about how we can use this technology for further applications.

Prefrontal activation and pupil dilation during n-back task performance: A combined fNIRS and pupillometry study.

Yeung MK, Lee TL, Han YMY, Chan AS.

Neuropsychologia. 2021 Aug 20;159:107954.
doi: 10.1016/j.neuropsychologia.2021.107954. Epub 2021 Jul 9.

The n-back task is one of the most commonly used working memory (WM) paradigms in cognitive neuroscience. Converging evidence suggests activation in the lateral prefrontal cortex (PFC) and pupil dilation [a proxy for locus coeruleus (LC) activation] during this task. However, it remains unclear whether the lateral PFC and the LC are functionally associated during n-back task performance. This study's aim was to examine the relationship between changes in lateral PFC activity and the pupil diameter and to evaluate the effect of WM load on such relationship during the n-back task. Thirty-nine healthy young adults (10 males, 29 females) underwent a number n-back paradigm with 0- and 3-back conditions. Their prefrontal hemodynamics and changes in pupil size during task performance were simultaneously measured using a 16-channel functional near-infrared spectroscopy (fNIRS) device and a wearable eye tracker. Young adults exhibited significant activation in the bilateral lateral PFC and significant increases in pupil size when the WM load was high (i.e., 3-back) but not low (i.e., 0-back) compared with the resting period. Interestingly, significant positive correlations were found between changes in lateral PFC activity and pupil size during the 0-back task only. These correlations tended to be stronger during the 0-back than the 3-back condition. Thus, the functional relationship between the lateral PFC and the LC may vary at different load levels during the n-back task. Our findings have important implications for neuropsychiatric research and support concurrent fNIRS and pupillometric measurements for a better understanding of the mechanisms underlying WM processing.

Neural Efficiency in Athletes: A Systematic Review.

Li L, Smith DM.

Front Behav Neurosci. 2021 Aug 5;15:698555.
doi: 10.3389/fnbeh.2021.698555. eCollection 2021.

According to the neural efficiency hypothesis (NEH), professionals have more effective cortical functions in cognitive tasks. This study is focusing on providing a systematic review of sport-related NEH studies with functional neuroimaging or brain stimulation while performing a sport-specific task, with the aim to answer the question: How does long-term specialized training change an athlete's brain and improve efficiency? A total of 28 studies (N = 829, Experimental Group n = 430) from 2001 to 2020 (Median = 2014, SD = 5.43) were analyzed and results were organized into four different sections: expert-novice samples, perceptual-cognitive tasks and neuroimaging technologies, efficiency paradox, and the cluster analysis. Researchers examined a wide range of sport-specific videos and multiple object tracking (MOT) specific to 18 different sports and utilized blood oxygenation-level dependent (BOLD) functional magnetic resonance imaging (fMRI), functional near-infrared spectroscopy (fNIRS), and electroencephalogram (EEG). Expert-novice comparisons were often adopted into investigations about the variations in general about optimal-controlled performance, neurophysiology, and behavioral brain research. Experts tended to perform at faster speeds, more accurate motor behavior, and with greater efficiency than novices. Experts report lower activity levels in the sensory and motor cortex with less energy expenditure, experts will possibly be more productive. These findings generally supported the NEH across the studies reviewed. However, an efficiency paradox and proficient brain functioning were revealed as the complementary hypothesis of the NEH. The discussion concentrates on strengths and key limitations. The conclusion highlights additional concerns and recommendations for prospective researchers aiming to investigate a broader range of populations and sports.

Monitoring anesthesia using simultaneous functional Near Infrared Spectroscopy and Electroencephalography.

Vijayakrishnan Nair V, Kish BR, Yang HS, Yu Z, Guo H, Tong Y, Liang Z.

Clin Neurophysiol. 2021 Jul;132(7):1636-1646.
doi: 10.1016/j.clinph.2021.03.025. Epub 2021 Apr 17.

OBJECTIVE: This study aims to understand the neural and hemodynamic responses during general anesthesia in order to develop a comprehensive multimodal anesthesia depth monitor using simultaneous functional Near Infrared Spectroscopy (fNIRS) and Electroencephalogram (EEG). METHODS: 37 adults and 17 children were monitored with simultaneous fNIRS and EEG, during the complete general anesthesia process. The coupling of fNIRS signals with neuronal signals (EEG) was calculated. Measures of complexity (sample entropy) and phase difference were also quantified from fNIRS signals to identify unique fNIRS based biomarkers of general anesthesia. RESULTS: A significant decrease in the complexity and power of fNIRS signals characterize the anesthesia maintenance phase. Furthermore, responses to anesthesia vary between adults and children in terms of neurovascular coupling and frontal EEG alpha power. CONCLUSIONS: This study shows that fNIRS signals could reliably quantify the underlying neuronal activity under general anesthesia and clearly distinguish the different phases throughout the procedure in adults and children (with less accuracy). SIGNIFICANCE: A multimodal approach incorporating the specific differences between age groups, provides a reliable measure of anesthesia depth.

Use of Functional Near-Infrared Spectroscopy to Predict and Measure Cochlear Implant Outcomes: A Scoping Review.

Harrison SC, Lawrence R, Hoare DJ, Wiggins IM, Hartley DEH.

Brain Sci. 2021 Oct 28;11(11):1439.
doi: 10.3390/brainsci11111439.

Outcomes following cochlear implantation vary widely for both adults and children, and behavioral tests are currently relied upon to assess this. However, these behavioral tests rely on subjective judgements that can be unreliable, particularly for infants and young children. The addition of an objective test of outcome following cochlear implantation is therefore desirable. The aim of this scoping review was to comprehensively catalogue the evidence for the potential of functional near infrared spectroscopy (fNIRS) to be used as a tool to objectively predict and measure cochlear implant outcomes. A scoping review of the literature was conducted following the PRISMA extension for scoping review framework. Searches were conducted in the MEDLINE, EMBASE, PubMed, CINAHL, SCOPUS, and Web of Science electronic databases, with a hand search conducted in Google Scholar. Key terms relating to near infrared spectroscopy and cochlear implants were used to identify relevant publications. Eight records met the criteria for inclusion. Seven records reported on adult populations, with five records only including post-lingually deaf individuals and two including both pre- and post-lingually deaf individuals. Studies were either longitudinal or cross-sectional, and all studies compared fNIRS measurements with receptive speech outcomes. This review identified and collated key work in this field. The homogeneity of the populations studied so far identifies key gaps for future research, including the use of fNIRS in infants. By mapping the literature on this important topic, this review contributes knowledge towards the improvement of outcomes following cochlear implantation.

Reduced parietal activation in participants with mild cognitive impairments during visual-spatial processing measured with functional near-infrared spectroscopy.

Haberstumpf S, Seidel A, Lauer M, Polak T, Deckert J, Herrmann MJ.

J Psychiatr Res. 2021 Dec 15;146:31-42.
doi: 10.1016/j.jpsychires.2021.12.021. Online ahead of print.

Functional Near Infrared Spectroscopy (fNIRS) may be a suitable, simple, and cost-effective brain imaging technique for detecting divergent neuronal patterns at an early stage of neurodegeneration. In course of Mild Cognitive Impairment (MCI) or Alzheimer's disease (AD), a deficit in visual-spatial processing, located in the parietal cortex, is a reliable risk factor. Earlier, we established the application of the clock-hand-angle-discrimination task (ADT) during fNIRS to identify neuronal correlates of the visual-spatial processing in a healthy elderly sample. In this analysis, we aimed to measure and find out differences in the hemodynamic response in MCI participants compared to matched healthy controls. As expected, MCI participants showed more errors over all conditions of pointer length and a higher reaction time in the long and middle pointer length condition. Moreover, results revealed a significant reduction of cortical activation in MCI patients. There was a generally increased activity in both the right as compared to the left hemisphere and the superior parietal brain region as compared to the inferior parietal brain region in both groups. In summary, fNIRS can be implemented in the measurement of visual-spatial processing in MCI patients and healthy elderly based on ADT. MCI participants had difficulties to cope with the ADT. Since neuronal hypoactivity occurs with concomitant behavioral deficits, an additional analysis was performed on a subgroup of MCI patients who performed as well as the control group in behavior. This subgroup analysis also showed a hypoactivation of the parietal cortex, without evidence of a compensatory activation. Therefore, we assume that MCI patients are characterized by a deficit in the parietal cortex. Overall, these findings confirm our hypothesis that hemodynamic deficits in visual-spatial processing, localized in the parietal cortex, are reliable and early diagnostic markers for cognitive decline in risk groups for the development of AD.

Shedding light on neuroscience: Two decades of functional near-infrared spectroscopy applications and advances from a bibliometric perspective.

Devezas MM.

J Neuroimaging. 2021 Jul;31(4):641-655.
doi: 10.1111/jon.12877. Epub 2021 May 18.

Functional near-infrared spectroscopy (fNIRS) is a noninvasive optical brain-imaging technique that detects changes in hemoglobin concentration in the cerebral cortex. fNIRS devices are safe, silent, portable, robust against motion artifacts, and have good temporal resolution. fNIRS is reliable and trustworthy, as well as an alternative and a complement to other brain-imaging modalities, such as electroencephalography or functional magnetic resonance imaging. Given these advantages, fNIRS has become a well-established tool for neuroscience research, used not only for healthy cortical activity but also as a biomarker during clinical assessment in individuals with schizophrenia, major depressive disorder, bipolar disease, epilepsy, Alzheimer's disease, vascular dementia, and cancer screening. Owing to its wide applicability, studies on fNIRS have increased exponentially over the last two decades. In this study, scientific publications indexed in the Web of Science databases were collected and a bibliometric-type methodology was developed. For this purpose, a comprehensive science mapping analysis, including top-ranked authors, journals, institutions, countries, and co-occurring keywords network, was conducted. From a total of 2310 eligible documents, 6028 authors and 531 journals published fNIRS-related papers, Fallgatter published the highest number of articles and was the most cited author. University of Tbingen in Germany has produced the most trending papers since 2000. USA was the most prolific country with the most active institutions, followed by China, Japan, Germany, and South Korea. The results also revealed global trends in emerging areas of research, such as neurodevelopment, aging, and cognitive and emotional assessment.

[Therapeutic effect of electric-balance stimulation with scalp acupuncture for motor aphasia after cerebral infarction].

[Article in Chinese; Abstract available in Chinese from the publisher]

Zhongguo Zhen Jiu. 2021 Nov 12;41(11):1211-5.
doi: 10.13703/j.0255-2930.20210302-k0005.
Lou XQ(1), Liu X(1), Liu CH(1), Lin HJ(1), Liu H(1), Ling J(2).

Functional near-infrared spectroscopy to assess pain in neonatal circumcisions.

Yuan I, Nelson O, Barr GA, Zhang B, Topjian AA, DiMaggio TJ, Lang SS, Christ LA, Izzetoglu K, Greco CC, Kurth CD, Ganesh A.
Paediatr Anaesth. 2021 Nov 7.
doi: 10.1111/pan.14326. Online ahead of print.

INTRODUCTION: Pain assessment is challenging in neonates. Behavioral and physiological pain scales do not assess neocortical nociception, essential to pain encoding and central pain pathway development. Functional near-infrared spectroscopy (fNIRS) can assess neocortical activation to noxious stimuli from changes in oxy-(HbO) and total-hemoglobin concentrations (HbT). This study aims to assess fNIRS nociceptive functional activation in the prefrontal cortex of neonates undergoing circumcision through changes in HbO and HbT, and the correlation between changes in fNIRS and Neonatal Infant Pain Scale (NIPS), a behavioral pain assessment scale. METHODS: In healthy term neonates, HbO, HbT, and NIPS were recorded during sequential circumcision events 1-Prep before local anesthetic injection; 2-Local anesthetic injection; 3-Prep before incision; 4-Oral sucrose; 5-Incision; 6-Gomco (hemostatic device) attached; 7-Gomco twisted on; and 8-Gomco removed. fNIRS and NIPS changes after each event were assessed with Wilcoxon signed-rank test and summarized as median and interquartile range (IQR). Changes in fNIRS vs. NIPS were correlated with Spearman coefficient. RESULTS: In 31 neonates fNIRS increased (median [IQR] mol/L) with noxious events: Local injection (HbO: 1.1 [0.5, 3.1],p<.001; HbT: 2.3 [0.2, 7.6],p<.001), Gomco attached (HbO: 0.7 [0.1, 1.7],p=.002; HbT: 0.7 [-0.2, 2.9],p=.02), and Gomco twisted on (HbO: 0.5 [-0.2, 1.7],p=.03; HbT: 0.8 [-0.1, 3.3],p=.02). fNIRS decreased with non-noxious event: Prep before incision (HbO: -0.6 [-1.2, -0.2]p<.001; HbT: -1 [-1.8, -0.4],p<.001). Local anesthetic attenuated fNIRS increases to subsequent sharp stimuli. NIPS increased with subsequent sharp stimuli despite local anesthetic. Although fNIRS and NIPS changed in the same direction, there was not a strong correlation between them. CONCLUSIONS: During neonatal circumcision, changes in fNIRS differed between different types of painful stimuli, which was not the case for NIPS, suggesting that fNIRS may complement NIPS to assess the quality of pain.

Deep learning multimodal fNIRS and EEG signals for bimanual grip force decoding.

Ortega P, Faisal AA.
J Neural Eng. 2021 Aug 31;18(4).
doi: 10.1088/1741-2552/ac1ab3.

Objective.Non-invasive brain-machine interfaces (BMIs) offer an alternative, safe and accessible way to interact with the environment. To enable meaningful and stable physical interactions, BMIs need to decode forces. Although previously addressed in the unimanual case, controlling forces from both hands would enable BMI-users to perform a greater range of interactions. We here investigate the decoding of hand-specific forces.Approach.We maximise cortical information by using electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) and developing a deep-learning architecture with attention and residual layers (cnnatt) to improve their fusion. Our task required participants to generate hand-specific force profiles on which we trained and tested our deep-learning and linear decoders.Main results.The use of EEG and fNIRS improved the decoding of bimanual force and the deep-learning models outperformed the linear model. In both cases, the greatest gain in performance was due to the detection of force generation. In particular, the detection of forces was hand-specific and better for the right dominant hand andcnnattwas better at fusing EEG and fNIRS. Consequently, the study ofcnnattrevealed that forces from

each hand were differently encoded at the cortical level.Cnnattalso revealed traces of the cortical activity being modulated by the level of force which was not previously found using linear models.Significance.Our results can be applied to avoid hand-cross talk during hand force decoding to improve the robustness of BMI robotic devices. In particular, we improve the fusion of EEG and fNIRS signals and offer hand-specific interpretability of the encoded forces which are valuable during motor rehabilitation assessment.

Interbrain Synchrony of Team Collaborative Decision-Making: An fNIRS Hyperscanning Study.

Zhang M, Jia H, Wang G.

Front Hum Neurosci. 2021 Jul 15;15:702959.
doi: 10.3389/fnhum.2021.702959. eCollection 2021.

In many situations, decision-making behaviors are mostly composed of team patterns (i.e., more than two persons). However, brain-based models that inform how team interactions contribute and impact team collaborative decision-making (TCDM) behavior, is lacking. To examine the neural substrates activated during TCDM in realistic, interpersonal interaction contexts, dyads were asked to model TCDM toward their opponent, in a multi-person prisoner's dilemma game, while neural activity was measured using functional near infrared spectroscopy. These experiments resulted in two main findings. First, there are different neural substrates between TCDM and ISDM, which were modulated by social environmental cues. i.e., the low incentive reward yielded higher activation within the left inferior frontal gyrus (IFG), in individual separately decision-making (ISDM) stage while the dorsolateral prefrontal cortex (DLPFC) and the middle frontopolar area was activated in TCDM stage. The high incentive reward evoked a higher interbrain synchrony (IBS) value in the right IFG in TCDM stage. Second, males showed higher activation in the DLPFC and the middle frontopolar area during ISDM, while females evoked higher IBS in the right IFG during TCDM. These sex effects suggest that in individual social dilemma situations, males and females may separately depend on non-social and social cognitive ability to make decisions, while in the social interaction situations of TCDM, females may depend on both social and non-social cognitive abilities. This study provide a compelling basis and interesting perspective for future neuroscience work of TCDM behaviors.

Crossing time windows optimization based on mutual information for hybrid BCI.

Meng M, Dai L, She Q, Ma Y, Kong W.

Math Biosci Eng. 2021 Sep 10;18(6):7919-7935.
doi: 10.3934/mbe.2021392.

Hybrid EEG-fNIRS brain-computer interface (HBCI) is widely employed to enhance BCI performance. EEG and fNIRS signals are combined to increase the dimensionality of the information. Time windows are used to select EEG and fNIRS singles synchronously. However, it ignores that specific modal signals have their own characteristics, when the task is stimulated, the information between the modalities will mismatch at the moment, which has a significant impact on the classification performance. Here we propose a novel crossing time windows optimization for mental arithmetic (MA) based BCI. The EEG and fNIRS signals were segmented separately by sliding time windows. Then crossing time windows (CTW) were combined with each one segment from EEG and fNIRS selected independently. Furthermore, EEG and fNIRS features were extracted using Filter Bank Common Spatial Pattern (FBCSP) and statistical methods from each sample. Mutual information was calculated for FBCSP and statistical features to characterize the discrimination of crossing time windows, and the optimal window would be selected based on the largest mutual information. Finally, a sparse structured framework of Fisher Lasso feature selection (FLFS) was designed to select the joint features, and conventional Linear Discriminant Analysis (LDA) was employed to perform classification. We used proposed method for a MA dataset. The classification

accuracy of the proposed method is 92.52 5.38% and higher than other methods, which shows the rationality and superiority of the proposed method.

Monitoring Processes and Their Neuronal Correlates as the Basis of Auditory Verbal Hallucinations in a Non-clinical Sample.

Storchak H, Hudak J, Dresler T, Haeussinger FB, Fallgatter AJ, Ehlis AC.

Front Psychiatry. 2021 Oct 11;12:644052.
doi: 10.3389/fpsyt.2021.644052. eCollection 2021.

Auditory verbal hallucinations (AVH) are a characteristic symptom of psychosis. An influential cognitive model accounting for the mechanisms in the generation of AVHs describes a defective monitoring of inner speech, leading to the misidentification of internally generated thoughts as externally generated events. In this study, we utilized an inner speech paradigm during a simultaneous measurement with functional near-infrared spectroscopy (fNIRS) and functional magnetic resonance imaging (fMRI), in order to replicate the findings of neural correlates of inner speech and auditory verbal imagery (AVI) in healthy subjects, reported in earlier studies, and to provide the first validation of the paradigm for fNIRS measurements. To this end, 20 healthy subjects were required to generate and silently recite first and second person sentences in their own voice (inner speech) and imagine the same sentences in a different, alien voice (AVI). Furthermore, questionnaires were deployed to assess the predisposition to acoustic hallucinations and schizotypal traits to investigate their connection to activation patterns associated with inner speech and monitoring processes. The results showed that both methods, fNIRS and fMRI, exhibited congruent activations in key brain areas, claimed to be associated with monitoring processes, indicating that the paradigm seems to be applicable using fNIRS alone. Furthermore, the results showed similar brain areas activated during inner speech and monitoring processes to those from earlier studies. However, our results indicate that the activations were dependent more on the sentence form and less on the imaging condition, showing more active brain areas associated with second person sentences. Integration of the sentence construction into the model of inner speech and deficient monitoring processes as the basis for the formation of AVHs should be considered in further studies. Furthermore, negative correlations between questionnaires' scores and activations in precentral gyrus and premotor cortex indicate a relationship of schizotypal characteristics and a deficient activation pattern.

Effects of Workstation Type on Mental Stress: FNIRS Study.

Alyan E, Saad NM, Kamel N.

Hum Factors. 2021 Nov;63(7):1230-1255.
doi: 10.1177/0018720820913173. Epub 2020 Apr 14.

OBJECTIVE: The purpose of this study is to examine the effect of the workstation type on the severity of mental stress by means of measuring prefrontal cortex (PFC) activation using functional near-infrared spectroscopy. BACKGROUND: Workstation type is known to influence worker's health and performance. Despite the practical implications of ergonomic workstations, limited information is available regarding their impact on brain activity and executive functions. METHOD: Ten healthy participants performed a Montreal imaging stress task (MIST) in ergonomic and nonergonomic workstations to investigate their effects on the severity of the induced mental stress. RESULTS: Cortical hemodynamic changes in the PFC were observed during the MIST in both the ergonomic and nonergonomic workstations. However, the ergonomic workstation exhibited improved MIST performance, which was positively correlated with the cortical activation on the right ventrolateral and the left dorsolateral PFC, as well as a marked decrease in salivary alpha-amylase activity compared with that of the nonergonomic workstation. Further analysis using the NASA Task Load Index revealed a higher weighted workload score in the nonergonomic workstation than that in the ergonomic workstation. CONCLUSION: The findings suggest that ergonomic

workstations could significantly improve cognitive functioning and human capabilities at work compared to a nonergonomic workstation. APPLICATION: Such a study could provide critical information on workstation design and development of mental stress that can be overlooked during traditional workstation design and mental stress assessments.

How to Calculate and Validate Inter-brain Synchronization in a fNIRS Hyperscanning Study.

Hu Y, Wang Z, Song B, Pan Y, Cheng X, Zhu Y, Hu Y.
J Vis Exp. 2021 Sep 8;(175).
doi: 10.3791/62801.

The dynamics between coupled brains of individuals have been increasingly represented by inter-brain synchronization (IBS) when they coordinate with each other, mostly using simultaneous-recording signals of brains (namely hyperscanning) with fNIRS. In fNIRS hyperscanning studies, IBS has been commonly assessed through the wavelet transform coherence (WTC) method because of its advantage on expanding time series into time-frequency space where oscillations can be seen in a highly intuitive way. The observed IBS can be further validated via the permutation-based random pairing of the trial, partner, and condition. Here, a protocol is presented to describe how to obtain brain signals via fNIRS technology, calculate IBS through the WTC method, and validate IBS by permutation in a hyperscanning study. Further, we discuss the critical issues when using the above methods, including the choice of fNIRS signals, methods of data preprocessing, and optional parameters of computations.In summary, using the WTC method and permutation is a potentially standard pipeline for analyzing IBS in fNIRS hyperscanning studies, contributing to both the reproducibility and reliability of IBS.

Altered complexity in resting-state fNIRS signal in autism: a multiscale entropy approach.

Zhang T, Huang W, Wu X, Sun W, Lin F, Sun H, Li J.
Physiol Meas. 2021 Aug 27;42(8).
doi: 10.1088/1361-6579/ac184d.

Objective.Feature extraction and recognition in brain signal processing is of great significance for understanding the neurological mechanism of autism spectrum disorder (ASD). Resting-state (RS) functional near-infrared spectroscopy measurement provides a way to investigate the possible alteration in ASD-related complexity of resting-state (RS) functional near-infrared spectroscopy (fNIRS) signals and to explore the relationship between brain functional connectivity and complexity.Approach.Using the multiscale entropy (MSE) of fNIRS signals recorded from the bilateral temporal lobes (TLs) on 25 children with ASD and 22 typical development (TD) children, the pattern of brain complexity was assessed for both the ASD and TD groups.Main results.The quantitative analysis of MSE revealed the increased complexity in RS-fNIRS in children with ASD, particularly in the left temporal lobe. The complexity in the RS signal and resting state functional connectivity (RSFC) were also observed to exhibit negative correlation in the medium magnitude.Significance.These results indicated that the MSE might serve as a novel measure for RS-fNIRS signals in characterizing and understanding ASD.

The Relationship between Motor Coordination and Imitation: An fNIRS Study.

Zhao W, Hui M, Zhang X, Li L.
Brain Sci. 2021 Aug 9;11(8):1052.
doi: 10.3390/brainsci11081052.

Although motor coordination and imitation are important factors affecting motor skill learning, few studies have examined the relationship between them in healthy adults. In order to address this in the present study, we used fNIRS to analyze the relationship between motor coordination and imitation in college students. Our results showed that: (1) motor coordination in female students was positively correlated with the average time taken to perform an imitation; (2) the mean imitation time was negatively correlated with the activation level of the supplementary motor cortex, primary somatosensory cortex, and angular gyrus of the mirror neuron system; (3) motor coordination in female students moderated mirror neuron system (MNS) activation and imitation. For women with low rather than high motor coordination, higher MNS activation was associated with a stronger imitation ability. These results demonstrate that motor coordination in female students is closely related to action imitation, and that it moderates the activation of the MNS, as measured via fNIRS.

Functional Brain Imaging Reliably Predicts Bimanual Motor Skill Performance in a Standardized Surgical Task.

Gao Y, Yan P, Kruger U, Cavuoto L, Schwaitzberg S, De S, Intes X.

IEEE Trans Biomed Eng. 2021 Jul;68(7):2058-2066.

doi: 10.1109/TBME.2020.3014299. Epub 2021 Jun 18.

Currently, there is a dearth of objective metrics for assessing bi-manual motor skills, which are critical for high-stakes professions such as surgery. Recently, functional near-infrared spectroscopy (fNIRS) has been shown to be effective at classifying motor task types, which can be potentially used for assessing motor performance level. In this work, we use fNIRS data for predicting the performance scores in a standardized bi-manual motor task used in surgical certification and propose a deep-learning framework 'Brain-NET' to extract features from the fNIRS data. Our results demonstrate that the Brain-NET is able to predict bi-manual surgical motor skills based on neuroimaging data accurately (R2=0.73). Furthermore, the classification ability of the Brain-NET model is demonstrated based on receiver operating characteristic (ROC) curves and area under the curve (AUC) values of 0.91. Hence, these results establish that fNIRS associated with deep learning analysis is a promising method for a bedside, quick and cost-effective assessment of bi-manual skill levels.

Multimodal Autoencoder Predicts fNIRS Resting State From EEG Signals.

Sirpal P, Damseh R, Peng K, Nguyen DK, Lesage F.

Neuroinformatics. 2021 Aug 10.

doi: 10.1007/s12021-021-09538-3. Online ahead of print.

In this work, we introduce a deep learning architecture for evaluation on multimodal electroencephalographic (EEG) and functional near-infrared spectroscopy (fNIRS) recordings from 40 epileptic patients. Long short-term memory units and convolutional neural networks are integrated within a multimodal sequence-to-sequence autoencoder. The trained neural network predicts fNIRS signals from EEG, sans a priori, by hierarchically extracting deep features from EEG full spectra and specific EEG frequency bands. Results show that higher frequency EEG ranges are predictive of fNIRS signals with the gamma band inputs dominating fNIRS prediction as compared to other frequency envelopes. Seed based functional connectivity validates similar patterns between experimental fNIRS and our model's fNIRS reconstructions. This is the first study that shows it is possible to predict brain hemodynamics (fNIRS) from encoded neural data (EEG) in the resting human epileptic brain based on power spectrum amplitude modulation of frequency oscillations in the context of specific hypotheses about how EEG frequency bands decode fNIRS signals.

Transcranial brain atlas for school-aged children and adolescents.

Zhang Z, Li Z, Xiao X, Zhao Y, Zuo XN, Zhu C.

Brain Stimul. 2021 Jul-Aug;14(4):895-905.
doi: 10.1016/j.brs.2021.05.004. Epub 2021 May 23.

BACKGROUND: Both fNIRS optodes and TMS coils are placed on the scalp, while the targeted brain activities are inside the brain. An accurate cranio-cortical correspondence is crucial to the precise localization of the cortical area under imaging or stimulation (i.e. transcranial locating), as well as guiding the placement of optodes/coils (i.e. transcranial targeting). However, the existing normative cranio-cortical correspondence data used as transcranial references are predominantly derived from the adult population, and whether and how correspondence changes during childhood and adolescence is currently unclear. OBJECTIVE: This study aimed to build the age-specific cranio-cortical correspondences for school-aged children and adolescents and investigate its differences to adults. METHODS: Age-specific transcranial brain atlases (TBAs) were built with age groups: 6-8, 8-10, 10-12, 12-14, 14-16, and 16-18 years. We compared the performance in both transcranial locating and targeting when using the age-appropriate TBA versus the adult TBA (derived from adult population) for children. RESULTS: These atlases provide age-specific probabilistic cranio-cortical correspondence at a high resolution (average scalp spacing of 2.8mm). Significant differences in cranio-cortical correspondence between children/adolescents and adults were found: the younger the child, the greater the differences. For children (aged 6-12 years), locating and targeting errors when using the adult TBA reached 10mm or more in the bilateral temporal lobe and frontal lobe. In contrast, the age-matched TBA reduced these errors to 4-5mm, an approximately 50% reduction in error. CONCLUSION: Our work provides an accurate and effective anatomical reference for studies in children and adolescents.

Task and Non-task Brain Activation Differences for Assessment of Depression and Anxiety by fNIRS.

Wen D, Lang X, Zhang H, Li Q, Yin Q, Chen Y, Xu Y.

Front Psychiatry. 2021 Nov 5;12:758092.
doi: 10.3389/fpsyt.2021.758092. eCollection 2021.

Diagnosis and treatment of the patients with major depression (MD) or the combined anxiety and depression (A&D) depend on the questionnaire, sometimes accompanied by tasks such as verbal fluency task (VFT). Functional near infrared spectroscopy (fNIRS) is emerging as an auxiliary diagnostic tool to evaluate brain function, providing an objective criterion to judge psychoses. At present, the conclusions derived from VFT or rest (non-task) studies are controversial. The purpose of this study is to evaluate if task performs better than non-task in separating healthy people from psychiatric patients. In this study, healthy controls (HCs) as well as the patients with MD or A&D were recruited (n = 10 for each group) to participate in the non-task and VFT tasks, respectively, and the brain oxygenation was longitudinally evaluated by using fNIRS. An approach of spectral analysis is used to analyze cerebral hemoglobin parameters (i.e., Oxy and Deoxy), characterizing the physiological fluctuations in the non-task and task states with magnitude spectrum and average power. Moreover, the standard deviation of oxygenation responses during the non-task was compared with the peak amplitude during the task, with the aim to explore the sensitivity of the VFT task to brain activation. The results show that there is no significant difference ($p > 0.05$) among the three groups in average power during non-task. The VFT task greatly enhanced the magnitude spectrum, leading to significant difference ($p < 0.05$) in average power between any of two groups (HC, MD, and A&D). Moreover, 40% patients with A&D have an intermediate peak (around 0.05 Hz) in the magnitude spectrum when performing the VFT task, indicating its advantage in characterizing A&D. We defined a rate of the non-task standard variation to the task peak amplitude (namely, SD-to-peak rate) and found that this rate is larger than 20% in 90% of the MD subjects. By contrast, only 40% HC subjects have an SD-to-peak rate larger than 20%. These results indicate that the non-task may not be sufficient to separate MD or A&D from HC. The VFT task could enhance the characteristics of the

magnitude spectrum, but its intensity needs to be elevated so as to properly explore brain functions related to psychoses.

Monitoring and Evaluation of Emotion Regulation by Aerobic Exercise and Motor Imagery Based on Functional Near-Infrared Spectroscopy.

Ding P, Wang F, Li S, Zhang W, Li H, Chen Z, Zhao L, Gong A, Fu Y.

Front Comput Neurosci. 2021 Oct 27;15:759360.
doi: 10.3389/fncom.2021.759360. eCollection 2021.

Objective: We sought to effectively alleviate the emotion of individuals with anxiety and depression, and explore the effects of aerobic exercise on their emotion regulation. Functional near-infrared spectroscopy (fNIRS) brain imaging technology is used to monitor and evaluate the process of aerobic exercise and imagination that regulates emotion. Approach:Thirty participants were scored by the state-trait anxiety inventory (STAI) and profile of mood states (POMS), and fNIRS images were collected before, after, and during aerobic exercise and motor imagery. Then, the oxygenated hemoglobin (HbO), deoxygenated hemoglobin (HbR), and total hemoglobin (HbT) concentrations and their average value were calculated, and the ratio of HbO concentration in the left and right frontal lobes was determined. Spearman's correlation coefficient was used to calculate the correlation between variations in the average scores of the two scales and in blood oxygen concentrations. Results: In comparison with motor imagery, STAI, and POMS scores decreased after 20 min of aerobic exercise. The prefrontal cortex had asymmetry and laterality (with the left side being dominant in emotion regulation). The increase in hemoglobin concentration recorded by fNIRS was negatively correlated with STAI and POMS scores. Aerobic exercise has a good effect on emotion regulation. Significance:The study showed that portable fNIRS could be effectively used for monitoring and evaluating emotion regulation by aerobic exercise. This study is expected to provide ideas for constructing fNIRS-based online real-time monitoring and evaluation of emotion regulation by aerobic exercise.

Interpersonal brain synchronization with instructor compensates for learner's sleep deprivation in interactive learning.

Pan Y, Guyon C, Borragn G, Hu Y, Peigneux P.

Biochem Pharmacol. 2021 Sep;191:114111.
doi: 10.1016/j.bcp.2020.114111. Epub 2020 Jun 20.

Recent advances shifted the focus on single-brain functioning toward two-brain communication during learning interactions, following the demonstration that interpersonal brain synchronization (IBS) can track instructor-learner information exchange. Here, we investigated (i) whether sleep deprivation (SD) that potentially impacts both social interactions and learning abilities modulates IBS, and (ii) conversely whether and to what extent IBS might compensate for SD-related learning deficits. Instructors (always with regular sleep, RS) were asked to teach numerical reasoning strategies to learners (either SD or RS), during which the activity of both brains was simultaneously recorded using functional near-infrared spectroscopy (fNIRS). SD learners initially performed below their baseline level, worse than RS learners, but learning improvement was comparable between RS and SD conditions after learning with the instructor. IBS within the instructor-learner dyads was higher in the SD (vs. RS) condition in the left inferior frontal cortex. In addition, clustered IBS (estimated by nonnegative matrix factorization) was correlated with performance improvement. Finally, Granger Causality analyses revealed biased causality with higher instructor-to-learner than learner-to-instructor directionality in brain signal processing. Together, these results indicate that SD-related learning deficits can to some extent be compensated via interactions with an instructor, as reflected by increased IBS and preserved learning ability. It suggests an essential role of the instructor in driving synchrony between teaching and SD learning brains during interactions.

Evaluation of fNIRS signal components elicited by cognitive and hypercapnic stimuli.

Reddy P, Izzetoglu M(#), Shewokis PA(#), Sangobowale M, Diaz-Arrastia R, Izzetoglu K(#).

Sci Rep. 2021 Dec 6;11(1):23457.
doi: 10.1038/s41598-021-02076-7.

Functional near infrared spectroscopy (fNIRS) measurements are confounded by signal components originating from multiple physiological causes, whose activities may vary temporally and spatially (across tissue layers, and regions of the cortex). Furthermore, the stimuli can induce evoked effects, which may lead to over or underestimation of the actual effect of interest. Here, we conducted a temporal, spectral, and spatial analysis of fNIRS signals collected during cognitive and hypercapnic stimuli to characterize effects of functional versus systemic responses. We utilized wavelet analysis to discriminate physiological causes and employed long and short source-detector separation (SDS) channels to differentiate tissue layers. Multi-channel measures were analyzed further to distinguish hemispheric differences. The results highlight cardiac, respiratory, myogenic, and very low frequency (VLF) activities within fNIRS signals. Regardless of stimuli, activity within the VLF band had the largest contribution to the overall signal. The systemic activities dominated the measurements from the short SDS channels during cognitive stimulus, but not hypercapnic stimulus. Importantly, results indicate that characteristics of fNIRS signals vary with type of the stimuli administered as cognitive stimulus elicited variable responses between hemispheres in VLF band and task-evoked temporal effect in VLF, myogenic and respiratory bands, while hypercapnic stimulus induced a global response across both hemispheres.

Neural correlates of distraction and reappraisal in the family context: Associations with symptoms of anxiety and depression in youth.

Bettis AH, Siciliano RE, Rogers BP, Ichinose M, Compas BE.

Child Neuropsychol. 2021 Jul;27(5):573-586.
doi: 10.1080/09297049.2020.1870675. Epub 2021 Jan 18.

Objective: Youth coping is consistently associated with risk and resilience for youth internalizing psychopathology. Integrating questionnaire and experimental methods is an important next step in understanding how youth develop, learn, and implement these skills and to identify possible neurobiological mechanisms that underlie these processes. The current study aims to explore associations among youth self-reported and laboratory-based measures of two methods of coping (distraction and reappraisal). Further, the current study aims to examine associations among neural correlates of distraction and reappraisal with symptoms of anxiety and depression in youth.Methods: Youth (N =69; M =12.24, SD=1.83; 52.9% female) completed self-report measures of secondary control coping (RSQ) and symptoms of anxiety (SCARED) and depression (CES-D) and a laboratory coping task. While completing the task, prefrontal hemodynamic changes were measured using functional near-infrared spectroscopy (fNIRS).Results: Neural activation during reappraisal was significantly negatively correlated with youth anxiety symptoms, and both neural activation and self-reported coping were significant independent predictors of anxiety. Youth self-reported coping was not associated with neural activation during reappraisal or distraction.Conclusions: The measurement of possible neural markers of risk and resilience in youth is an important area of continued research. Identification of possible mechanisms of change related to anxiety and depression in youth may inform targets of intervention.

Cortical activation during gait adaptability in people with Parkinson's disease.

Pelicioni PHS, Lord SR, Okubo Y, Menant JC.

Gait Posture. 2022 Jan;91:247-253.
doi: 10.1016/j.gaitpost.2021.10.038. Epub 2021 Oct 30.

BACKGROUND: People with Parkinson's disease (PD) have difficulties adapting their gait. While underlying neural mechanisms involving the prefrontal cortex (PFC) have been studied across various complex walking tasks, less is known about the premotor cortex (PMC) and supplementary motor area (SMA), key cortical regions for motor planning. This study compared frontal cortical regions activation patterns using functional near-infrared spectroscopy (fNIRS), between people with PD and healthy controls (HC) during gait adaptability tasks. METHODS: Forty-nine people with PD (mean (SD) age: 69.5 (7.9) years) and 21 HC (69.0 (5.9) years) completed a simple walk and three randomly presented gait adaptability tasks: (i) stepping on targets, (ii) avoiding obstacles and (iii) negotiating both targets and obstacles. Cortical activity in the dorsolateral PFC (DLPFC), SMA and PMC were recorded using fNIRS. Step length, velocity and accuracy and cortical activity were contrasted between the groups and walking conditions. RESULTS: Compared with the HC, the PD group exhibited greater PMC activation and walked significantly slower and took shorter steps in all conditions. A statistically significant group by condition interaction indicated an increase in DLPFC cortical activation in the HC participants when undertaking the obstacle avoidance task compared with the simple walk but no increase in cortical activation in the PD group when undergoing this more challenging gait task. CONCLUSIONS: Our findings suggest people with PD have little or no DLPFC, SMA and PMC capacity beyond what they need for simple walking and in consequence need to slow their gait velocity to meet the demands of target stepping and obstacle avoidance tasks. Such behavioral and neural patterns appear consistent with concepts of compensatory over-activation and capacity limitation.

Characterization of a Raspberry Pi as the Core for a Low-cost Multimodal EEG-fNIRS Platform.

Del Angel Arrieta F, Rojas Cisneros M, Rivas JJ, Castrejon LR, Sucar LE, Andreu-Perez J, Orihuela-Espina F.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:1288-1291.
doi: 10.1109/EMBC46164.2021.9629672.

Poor understanding of brain recovery after injury, sparsity of evaluations and limited availability of healthcare services hinders the success of neurorehabilitation programs in rural communities. The availability of neuroimaging ca-pacities in remote communities can alleviate this scenario supporting neurorehabilitation programs in remote settings. This research aims at building a multimodal EEG-fNIRS neuroimaging platform deployable to rural communities to support neurorehabilitation efforts. A Raspberry Pi 4 is chosen as the CPU for the platform responsible for presenting the neurorehabilitation stimuli, acquiring, processing and storing concurrent neuroimaging records as well as the proper synchronization between the neuroimaging streams. We present here two experiments to assess the feasibility and characterization of the Raspberry Pi as the core for a multimodal EEG-fNIRS neuroimaging platform; one over controlled conditions using a combination of synthetic and real data, and another from a full test during resting state. CPU usage, RAM usage and operation temperature were measured during the tests with mean operational records below 40% for CPU cores, 13.6% for memory and 58.85 C for temperatures. Package loss was inexistent on synthetic data and negligible on experimental data. Current consumption can be satisfied with a 1000 mAh 5V battery. The Raspberry Pi 4 was able to cope with the required workload in conditions of operation similar to those needed to support a neurorehabilitation evaluation.

A randomized-controlled neurofeedback trial in adult attention-deficit/hyperactivity disorder.

Barth B, Mayer-Carius K, Strehl U, Wyckoff SN, Haeussinger FB, Fallgatter AJ, Ehlis AC.

Sci Rep. 2021 Aug 19;11(1):16873.
doi: 10.1038/s41598-021-95928-1.

Attention-deficit/hyperactivity disorder (ADHD) is a childhood onset disorder persisting into adulthood for a large proportion of cases. Neurofeedback (NF) has shown promising results in children with ADHD, but randomized controlled trials in adults with ADHD are scarce. We aimed to compare slow cortical potential (SCP)- and functional near-infrared spectroscopy (fNIRS) NF to a semi-active electromyography biofeedback (EMG-BF)controlcondition regarding changes in symptoms and the impact of learning success, as well as changes in neurophysiological parameters in an adult ADHD population. Patients were randomly assigned to SCP-NF (n = 26), fNIRS-NF (n = 21) or EMG-BF (n = 20). Outcome parameters were assessed over 30 training sessions(pre, intermediate, post) and at 6-months follow-up (FU) including 3 booster sessions. EEG was recorded during two auditory Go/NoGo paradigms assessing the P300 and contingent negative variation (CNV). fNIRS measurements were conducted during an n-back- as well as a Go/NoGo task. All three groups showed equally significant symptom improvements suggesting placebo- or non-specific effects on the primary outcome measure. Only when differentiating between learners and non-learners, fNIRS learners displayed stronger reduction of ADHD global scores compared to SCP non-learners at FU, and fNIRS learners showed specifically low impulsivity ratings. 30.8% in the SCP-NF and 61.9% of participants in the fNIRS-NF learned to regulate the respective NF target parameter. We conclude thatsome adults with ADHD learn to regulate SCP amplitudes and especially prefrontal hemodynamic activity during NF. We did not find any significant differences in outcome between groups when looking at the whole sample. When evaluating learners only, they demonstrate superior effects as compared to non-learners, which suggests specific effects in addition to non-specific effects of NF when learning occurs.

Movement kinematics and cortical activation in children with and without autism spectrum disorder during sway synchrony tasks: an fNIRS study.

Su WC, Culotta M, Tsuzuki D, Bhat A.

Sci Rep. 2021 Jul 22;11(1):15035.
doi: 10.1038/s41598-021-94519-4.

Children with Autism Spectrum Disorder (ASD) have difficulties with socially embedded movements such as imitation and interpersonal synchrony (IPS); however, related movement characteristics and underlying neural mechanisms are not well understood. This study compared the movement characteristics and cortical activation patterns of children with and without ASD during a whole-body, sway synchrony task when different levels of social information were provided. Thirty children with and without ASD (mean age: 12.6years, SE: 0.6years) participated. Movement kinematics and fNIRS-based cortical activation were recorded when the child observed an adult tester sway side to side, when they swayed solo, or when they swayed face to face with the tester with or without fingertips touching (i.e., IPS). Children with ASD showed reduced synchrony and smaller sway amplitude compared to typically developing children without ASD. They showed reduced cortical activation over the inferior frontal gyrus and superior temporal sulcus during IPS and did not show significant increase in cortical activation when more social information was provided. The cortical activation findings were significantly associated with IPS behaviors and social communication performance. The ASD-related neurobiomarkers identified in our study could be used as objective measures to evaluate intervention effects in children with ASD.

Correcting physiological noise in whole-head functional near-infrared spectroscopy.

Zhang F, Cheong D, Khan AF, Chen Y, Ding L, Yuan H.

J Neurosci Methods. 2021 Aug 1;360:109262.
doi: 10.1016/j.jneumeth.2021.109262. Epub 2021 Jun 17.

BACKGROUND: Functional near-infrared spectroscopy (fNIRS) has been increasingly employed to monitor cerebral hemodynamics in normal and diseased conditions. However, fNIRS suffers from its susceptibility to superficial activity and systemic physiological noise. The objective of the study was to

establish a noise reduction method for fNIRS in a whole-head montage. NEW METHOD: We have developed an automated denoising method for whole-head fNIRS. A high-density montage consisting of 109 long-separation channels and 8 short-separation channels was used for recording. Auxiliary sensors were also used to measure motion, respiration and pulse simultaneously. The method incorporates principal component analysis and general linear model to identify and remove a globally uniform superficial component. Our denoising method was evaluated in experimental data acquired from a group of healthy human subjects during a visually cued motor task and further compared with a minimal preprocessing method and three established denoising methods in the literature. Quantitative metrics including contrast-to-noise ratio, within-subject standard deviation and adjusted coefficient of determination were evaluated. RESULTS: After denoising, whole-head topography of fNIRS revealed focal activations concurrently in the primary motor and visual areas. COMPARISON WITH EXISTING METHODS: Analysis showed that our method improves upon the four established preprocessing methods in the literature. CONCLUSIONS: An automatic, effective and robust preprocessing pipeline was established for removing physiological noise in whole-head fNIRS recordings. Our method can enable fNIRS as a reliable tool in monitoring large-scale, network-level brain activities for clinical uses.

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. 2021 Nov;24(11):873-884.
doi: 10.1080/1028415X.2019.1690288. Epub 2019 Nov 18.

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.

An fNIRS Investigation of Discrete and Continuous Cognitive Demands During Dual-Task Walking in Young Adults.

Rahman TT, Polskaia N, St-Amant G, Salzman T, Vallejo DT, Lajoie Y, Fraser SA.

Front Hum Neurosci. 2021 Nov 16;15:711054.
doi: 10.3389/fnhum.2021.711054. eCollection 2021.

Introduction: Dual-task studies have demonstrated that walking is attention-demanding for younger adults. However, numerous studies have attributed this to task type rather than the amount of required to

accomplish the task. This study examined four tasks: two discrete (i.e., short intervals of attention) and two continuous (i.e., sustained attention) to determine whether greater attentional demands result in greater dual-task costs due to an overloaded processing capacity. Methods: Nineteen young adults (21.5 3.6 years, 13 females) completed simple reaction time (SRT) and go/no-go (GNG) discrete cognitive tasks and n-back (NBK) and double number sequence (DNS) continuous cognitive tasks with or without self-paced walking. Prefrontal cerebral hemodynamics were measured using functional near-infrared spectroscopy (fNIRS) and performance was measured using response time, accuracy, and gait speed. Results: Repeated measures ANOVAs revealed decreased accuracy with increasing cognitive demands ($p = 0.001$) and increased dual-task accuracy costs ($p < 0.001$). Response times were faster during the single compared to dual-tasks during the SRT ($p = 0.005$) and NBK ($p = 0.004$). DNS gait speed was also slower in the dual compared to single task ($p < 0.001$). Neural findings revealed marginally significant interactions between dual-task walking and walking alone in the DNS ($p = 0.06$) and dual -task walking compared to the NBK cognitive task alone ($p = 0.05$). Conclusion: Neural findings suggest a trend towards increased PFC activation during continuous tasks. Cognitive and motor measures revealed worse performance during the discrete compared to continuous tasks. Future studies should consider examining different attentional demands of motor tasks.

Improving Diagnosis and Prognosis in Acute Severe Brain Injury: A Multimodal Imaging Protocol.

Kazazian K, Norton L, Laforge G, Abdalmalak A, Gofton TE, Debicki D, Slessarev M, Hollywood S, Lawrence KS, Owen AM.

Front Neurol. 2021 Dec 6;12:757219.
doi: 10.3389/fneur.2021.757219. eCollection 2021.

Multi-modal neuroimaging techniques have the potential to dramatically improve the diagnosis of the level consciousness and prognostication of neurological outcome for patients with severe brain injury in the intensive care unit (ICU). This protocol describes a study that will utilize functional Magnetic Resonance Imaging (fMRI), electroencephalography (EEG), and functional Near Infrared Spectroscopy (fNIRS) to measure and map the brain activity of acute critically ill patients. Our goal is to investigate whether these modalities can provide objective and quantifiable indicators of good neurological outcome and reliably detect conscious awareness. To this end, we will conduct a prospective longitudinal cohort study to validate the prognostic and diagnostic utility of neuroimaging techniques in the ICU. We will recruit 350 individuals from two ICUs over the course of 7 years. Participants will undergo fMRI, EEG, and fNIRS testing several times over the first 10 days of care to assess for residual cognitive function and evidence of covert awareness. Patients who regain behavioral awareness will be asked to complete web-based neurocognitive tests for 1 year, as well as return for follow up neuroimaging to determine which acute imaging features are most predictive of cognitive and functional recovery. Ultimately, multi-modal neuroimaging techniques may improve the clinical assessments of patients' level of consciousness, aid in the prediction of outcome, and facilitate efforts to find interventional methods that improve recovery and quality of life.

Maternal perinatal anxiety and neural responding to infant affective signals: Insights, challenges, and a road map for neuroimaging research.

Yatziv T, Vancor EA, Bunderson M, Rutherford HJV.

Neurosci Biobehav Rev. 2021 Dec;131:387-399.
doi: 10.1016/j.neubiorev.2021.09.043. Epub 2021 Sep 24.

Anxiety symptoms are common among women during pregnancy and the postpartum period, potentially having detrimental effects on both mother and child's well-being. Perinatal maternal anxiety interferes with a core facet of adaptive caregiving: mothers' sensitive responsiveness to infant affective

communicative 'cues.' This review summarizes the current research on the neural correlates of maternal processing of infant cues in the presence of perinatal anxiety, outlines its limitations, and offers next steps to advance future research. Functional neuroimaging studies examining the neural circuitry involved in, and electrophysiological studies examining the temporal dynamics of, processing infant cues during pregnancy and postpartum are reviewed. Studies have generally indicated mixed findings, although emerging themes suggest that anxiety may be implicated in several stages of processing infant cues- detection, interpretation, and reaction- contingent upon cue valence. Limitations include inconsistent designs, lack of differentiation between anxiety and depression symptoms, and limited consideration of parenting-specific (versus domain-general) anxiety. Future studies should incorporate longitudinal investigation of multiple levels of analysis spanning neural, cognitive, and observed aspects of sensitive caregiving.

Tracking Brain Development From Neonates to the Elderly by Hemoglobin Phase Measurement Using Functional Near-Infrared Spectroscopy.

Liang Z, Tian H, Yang HC, Arimitsu T, Takahashi T, Sassaroli A, Fantini S, Niu H, Minagawa Y, Tong Y.

IEEE J Biomed Health Inform. 2021 Jul;25(7):2497-2509.
doi: 10.1109/JBHI.2021.3053900. Epub 2021 Jul 28.

The biological and neurological processes during the lifespan are dynamic with significant alterations associated with different stages of life. The phase and coupling of oxy-hemoglobin (?[HbO]) and deoxy-hemoglobin concentration changes (?[Hb]) measured by functional near-infrared spectroscopy (fNIRS) are shown to characterize the neurovascular and metabolic development of infants. However, the changes in phase and coupling across the human lifespan remain mostly unknown. Here, fNIRS measurements of ?[HbO] and ?[Hb] conducted at two sites on different age populations (from newborns to elderly) were combined. Firstly, we assessed the influence of random noise on the calculation of the phase difference and phase-locking index (PLI) in fNIRS measurement. The results showed that the phase difference is close to p as the noise intensity approaches -8 dB, and the coupling strength (i.e., PLI) presents a u-shape curve as the noise increase. Secondly, phase difference and PLI in the frequency range 0.01-0.10 Hz were calculated after denoising. It showed that the phase difference increases from newborns to 3-4-month-olds babies. This phase difference persists throughout adulthood until finally being disrupted in the old age. The children's PLI is the highest, followed by that of adults. These two groups' PLI are significantly higher than those of infants and the elderly ($p < 0.001$). Lastly, a hemodynamic model was used to explain the observations and found close associations with cerebral autoregulation and speed of blood flow. These results demonstrate that the phase-related parameters measured by fNIRS can be used to study the brain and assess brain health throughout the lifespan.

An Examination of the Relationship Between Perfectionism and Neurological Functioning.

Petersen J, Ong CW, Hancock AS, Gillam RB, Levin ME, Twohig MP.

J Cogn Psychother. 2021 Aug 1;35(3):195-211.
doi: 10.1891/JCPSY-D-20-00037.

Clinical perfectionism is the rigid pursuit of high standards, interfering with functioning. Little research has explored neural patterns in clinical perfectionism. The present study explores neural correlates of clinical perfectionism, before and after receiving ten 50-minute, weekly sessions of acceptance and commitment therapy (ACT), as compared to low-perfectionist controls, in specific cortical structures: the dorsolateral prefrontal cortex (DLPFC), medial prefrontal cortex (MPFC), right inferior parietal lobule (IPL). Participants in the perfectionist condition ($n = 43$) were from a randomized controlled trial evaluating ACT for clinical perfectionism and low-perfectionist controls were undergraduate students ($n = 12$). Participants

completed three tasks (editing a passage, mirror image tracing, circle tracing) using functional near-infrared spectroscopy (fNIRS) to measure neural activation. Results indicate that ?in the DLPFC and MPFC of the perfectionists whereas activation in the other tasks were relatively similar. There were no differences were observed in the right DLPFC, MPFC, and right IPL between the posttreatment perfectionist and nonperfectionist control groups. Our findings suggest an unclear relationship between neural activation and perfectionism.

Reduced functional connectivity in the prefrontal cortex of elderly catatonia patients: A longitudinal study using functional near-infrared spectroscopy.

Nakamura T, Sasayama D, Hagiwara T, Kito H, Washizuka S.

Neurosci Res. 2021 Sep;170:322-329.
doi: 10.1016/j.neures.2020.10.004. Epub 2020 Dec 11.

Catatonia is a syndrome that manifests in patients with mental disorders and general medical conditions. However, functional changes to the brain that cause catatonia remain unknown. In the present study, we used functional near-infrared spectroscopy (fNIRS) to assess spontaneous hemodynamic activities in the brain at the times of onset and resolution of catatonic symptoms in patients with catatonia. We used 22-channel and 49-channel fNIRS to examine hemodynamic activities in the prefrontal cortex (PFC), and both frontal and parietal cortices, respectively. A total of ten patients who were diagnosed with catatonia were included in the study. Resting state measurements were taken for five minutes at the time of the onset and resolution of catatonic symptoms. Analyses were performed for the prefrontal region and the motor cortex within the parietal-frontal region of the brain. Functional connectivity between the cerebral hemispheres was evaluated systematically based on spontaneous oscillation of ?[HbO2]. In the PFC, the resting state functional connectivity (RSFC) was significantly lower in the catatonic state than in the eyes-closed non-catatonic state ($p = 0.047$). The study demonstrated that the RSFC in the PFC, measured using fNIRS, may be an objective indicator of the change in catatonic symptoms.

Investigating developmental changes in scalp-to-cortex correspondence using diffuse optical tomography sensitivity in infancy.

Fu X, Richards JE.

Neurophotonics. 2021 Jul;8(3):035003.
doi: 10.1117/1.NPh.8.3.035003. Epub 2021 Jul 24.

Significance: Diffuse optical tomography (DOT) uses near-infrared light spectroscopy (NIRS) to measure changes in cerebral hemoglobin concentration. Anatomical interpretations of NIRS data require accurate descriptions of the cranio-cerebral relations and DOT sensitivity to the underlying cortical structures. Such information is limited for pediatric populations because they undergo rapid head and brain development. Aim: We aim to investigate age-related differences in scalp-to-cortex distance and mapping between scalp locations and cortical regions of interest (ROIs) among infants (2 weeks to 24 months with narrow age bins), children (4 and 12 years), and adults (20 to 24 years). Approach: We used spatial scalp projection and photon propagation simulation methods with age-matched realistic head models based on MRIs. Results: There were age-group differences in the scalp-to-cortex distances in infancy. The developmental increase was magnified in children and adults. There were systematic age-related differences in the probabilistic mappings between scalp locations and cortical ROIs. Conclusions: Our findings have important implications in the design of sensor placement and making anatomical interpretations in NIRS and fNIRS research. Age-appropriate, realistic head models should be used to provide anatomical guidance for standalone DOT data in infants.

Effects of high-intensity interval exercise and moderate-intensity continuous exercise on executive function of healthy young males.

Zhu Y, Sun F, Chiu MM, Siu AY.

Physiol Behav. 2021 Oct 1;239:113505.
doi: 10.1016/j.physbeh.2021.113505. Epub 2021 Jun 19.

PURPOSE: This study compared the executive function (EF) performance induced by moderate-intensity continuous exercise (MICE) versus high-intensity interval exercise (HIIE), under two exercise modalities (i.e., running vs. cycling), and explored whether the changes in EF performance were related to the hemodynamics response of the cerebral prefrontal area of the brain. METHODS: In a randomized cross-over design, 16 male participants completed 4 main trials, i.e., 40min of moderate-intensity continuous running (MICR) or cycling (MICC) with 60% maximal oxygen consumption (VO2max), 33min of high-intensity interval running (HIIR) or cycling (HIIC). For HIIR or HIIC trials, the exercise intensity was 60% VO2max for the first 5min, followed by four 4-minute bouts of exercise at 90% VO2max, separated by 3-minute active recovery at 60% VO2max. EF was assessed via the Eriksen Flanker task (EFT) before (Pre), immediately after (Post 0), and 10min after exercise (Post 10). Functional near-infrared spectroscopy (fNIRS) measured oxygenated hemoglobin (O2Hb) and deoxygenated hemoglobin (HHb) concentrations in the prefrontal area. Each main trial measured the concentrations of blood glucose and lactate, heart rate, and rate of perceived exertion. RESULTS: (1) Compared to the reaction time in EFT during the pretest, the corresponding reaction time was shorter at Post 10 ($P < 0.01$) but not at Post 0 ($P=0.06$). Specifically, reaction time was shorter at Post 10 than in the pretest in HIIC ($P=0.04$), MICC ($P=0.01$), and HIIR ($P < 0.01$) but not MICR. (2) The fNIRS results revealed that O2Hb concentrations in the left dorsolateral prefrontal cortex area were much lower during Post 10 than during the pretest. (3) The blood lactate concentrations were not associated with EF performance regarding both accuracy and reaction time. CONCLUSION: Compared to the pretest, EF was greater after the 10-minute rest during recovery but not immediately after exercise. The different HIIE or MICE protocols adopted in the present study may elicit minor differences regarding their effects on EF.

Clinical Applications of Functional Near-Infrared Spectroscopy in Children and Adolescents with Psychiatric Disorders.

Lee YJ, Kim M, Kim JS, Lee YS, Shin JE.

Soa Chongsonyon Chongsin Uihak. 2021 Jul 1;32(3):99-103.
doi: 10.5765/jkacap.210011.

The purpose of this review is to examine the clinical use of functional near-infrared spectroscopy (fNIRS) in children and adolescents with psychiatric disorders. Many studies have been conducted using objective evaluation tools for psychiatric evaluation, such as predicting psychiatric symptoms and treatment responses. Compared to other tools, fNIRS has the advantage of being a noninvasive, inexpensive, and portable method and can be used with patients in the awake state. This study mainly focused on its use in patients with attention-deficit/hyperactivity disorder and autism spectrum disorder. We hope that research involving fNIRS will be actively conducted in various diseases in the future.

Prefrontal fNIRS-based clinical data analysis of brain functions in individuals abusing different types of drugs.

Gu X, Yang B, Gao S, Yan LF, Xu D, Wang W.

J Biomed Semantics. 2021 Nov 25;12(1):21.
doi: 10.1186/s13326-021-00256-y.

BACKGROUND: The activation degree of the orbitofrontal cortex (OFC) functional area in drug abusers is directly related to the craving for drugs and the tolerance to punishment. Currently, among the

clinical research on drug rehabilitation, there has been little analysis of the OFC activation in individuals abusing different types of drugs, including heroin, methamphetamine, and mixed drugs. Therefore, it becomes urgently necessary to clinically investigate the abuse of different drugs, so as to explore the effects of different types of drugs on the human brain. METHODS: Based on prefrontal high-density functional near-infrared spectroscopy (fNIRS), this research designs an experiment that includes resting and drug addiction induction. Hemoglobin concentrations of 30 drug users (10 on methamphetamine, 10 on heroin, and 10 on mixed drugs) were collected using fNIRS and analyzed by combining algorithm and statistics. RESULTS: Linear discriminant analysis (LDA), Support vector machine (SVM) and Machine-learning algorithm was implemented to classify different drug abusers. Oxygenated hemoglobin (HbO2) activations in the OFC of different drug abusers were statistically analyzed, and the differences were confirmed. Innovative findings: in both the Right-OFC and Left-OFC areas, methamphetamine abusers had the highest degree of OFC activation, followed by those abusing mixed drugs, and heroin abusers had the lowest. The same result was obtained when OFC activation was investigated without distinguishing the left and right hemispheres. CONCLUSIONS: The findings confirmed the significant differences among different drug abusers and the patterns of OFC activations, providing a theoretical basis for personalized clinical treatment of drug rehabilitation in the future.

Different types of physical exercise in brain activity of older adults: A systematic review.

Ferreira SA, Stein AM, Stavinski NGL, Teixeira DC, Queiroga MR, Bonini JS.

Exp Gerontol. 2021 Dec 24;159:111672.
doi: 10.1016/j.exger.2021.111672. Online ahead of print.

BACKGROUND: To verify the effects of different modalities of physical exercise on brain activity of older adults. METHODS: Systematic searches were conducted according to the PICOS strategy and the following databases were searched: PubMed, Web of Science, PsycInfo and Scielo. Two independent evaluators performed the initial selection from reading the title and abstract based on the stipulated eligibility criteria. RESULTS: The searches resulted in 1935 titles, of which 97 were duplicated and 1793 were excluded based on reading the titles and abstracts. This phase resulted in 45 articles for detailed analysis. At this stage, 35 articles were excluded because they did not meet the eligibility criteria. The information for qualitative analysis was extracted from 10 articles that met the criteria. CONCLUSION: There was improvement in the brain activity of older adults regardless of the type of physical exercise performed (aerobic, neuromuscular, flexibility or neuromotor), but with a discrete advantage for balance and coordination exercises (neuromotor).

Team-work, Team-brain: Exploring synchrony and team interdependence in a nine-person drumming task via multiparticipant hyperscanning and inter-brain network topology with fNIRS.

Liu T, Duan L, Dai R, Pelowski M, Zhu C.

Neuroimage. 2021 Aug 15;237:118147.
doi: 10.1016/j.neuroimage.2021.118147. Epub 2021 May 10.

Teamwork is indispensable in human societies. However, due to the complexity of studying ecologically valid synchronous team actions, requiring multiple members and a range of subjective and objective measures, the mechanism underlying the impact of synchrony on team performance is still unclear. In this paper, we simultaneously measured groups of nine-participants' (total N=180) fronto-temporal activations during a drum beating task using functional near infrared spectroscopy (fNIRS)-based hyperscanning and multi-brain network modeling, which can assess patterns of shared neural synchrony and attention/information sharing across entire teams. Participants (1) beat randomly without considering

others' drumming (random condition), (2) actively coordinated their beats with the entire group without other external cue (team-focus condition), and (3) beat together based on a metronome (shared-focus condition). Behavioral data revealed higher subjective and objective measures of drum-beat synchronization in the team-focus condition, as well as higher felt interdependence. The fNIRS data revealed that participants in the team-focus condition also showed higher interpersonal neural synchronization (INS) and higher Global Network Efficiency in their left TPJ and mPFC. Higher left TPJ Global Network Efficiency also predicted higher actual synchrony in the team-focus condition, with an effect size roughly 1.5 times that of subjective measures, but not in the metronome-enabled shared-focus condition. This result suggests that shared mental representations with high efficiency of information exchange across the entire team may be a key component of synchrony, adding to the understanding of the actual relation to team work.

Neuroscience and Consumer Behavior: Where to Now?

Balconi M, Sansone M.

Front Psychol. 2021 Jul 5;12:705850.
doi: 10.3389/fpsyg.2021.705850. eCollection 2021.
DOI: 10.3389/fpsyg.2021.705850 PMCID: PMC8287207 PMID: 34290656

The cortical organization of listening effort: New insight from functional near-infrared spectroscopy.

White BE, Langdon C.

Neuroimage. 2021 Oct 15;240:118324.
doi: 10.1016/j.neuroimage.2021.118324. Epub 2021 Jul 2.

Everyday challenges impact our ability to hear and comprehend spoken language with ease, such as accented speech (source factors), spectral degradation (transmission factors), complex or unfamiliar language use (message factors), and predictability (context factors). Auditory degradation and linguistic complexity in the brain and behavior have been well investigated, and several computational models have emerged. The work here provides a novel test of the hypotheses that listening effort is partially reliant on higher cognitive auditory attention and working memory mechanisms in the frontal lobe, and partially reliant on hierarchical linguistic computation in the brain's left hemisphere. We specifically hypothesize that these models are robust and can be applied in ecologically relevant and coarse-grain contexts that rigorously control for acoustic and linguistic listening challenges. Using functional near-infrared spectroscopy during an auditory plausibility judgment task, we show the hierarchical cortical organization for listening effort in the frontal and left temporal-parietal brain regions. In response to increasing levels of cognitive demand, we found (i) poorer comprehension, (ii) slower reaction times, (iii) increasing levels of perceived mental effort, (iv) increasing levels of brain activity in the prefrontal cortex, (v) hierarchical modulation of core language processing regions that reflect increasingly higher-order auditory-linguistic processing, and (vi) a correlation between participants' mental effort ratings and their performance on the task. Our results demonstrate that listening effort is partly reliant on higher cognitive auditory attention and working memory mechanisms in the frontal lobe and partly reliant on hierarchical linguistic computation in the brain's left hemisphere. Further, listening effort is driven by a voluntary, motivation-based attention system for which our results validate the use of a single-item post-task questionnaire for measuring perceived levels of mental effort and predicting listening performance. We anticipate our study to be a starting point for more sophisticated models of listening effort and even cognitive neuroplasticity in hearing aid and cochlear implant users.

Cortical hemodynamic mechanisms of reversal learning using high-resolution functional near-infrared spectroscopy: A pilot study.

Piau C, Mahmoudzadeh M, Kibleur A, Polosan M, David O, Wallois F.
Neurophysiol Clin. 2021 Oct;51(5):409-424.
doi: 10.1016/j.neucli.2021.08.001. Epub 2021 Sep 1.

OBJECTIVES: Reversal learning is widely used to analyze cognitive flexibility and characterize behavioral abnormalities associated with impulsivity and disinhibition. Recent studies using fMRI have focused on regions involved in reversal learning with negative and positive reinforcers. Although the frontal cortex has been consistently implicated in reversal learning, few studies have focused on whether reward and punishment may have different effects on lateral frontal structures in these tasks. METHODS: During this pilot study on eight healthy subjects, we used functional near infra-red spectroscopy (fNIRS) to characterize brain activity dynamics and differentiate the involvement of frontal structures in learning driven by reward and punishment. RESULTS: We observed functional hemispheric asymmetries between punishment and reward processing by fNIRS following reversal of a learned rule. Moreover, the left dorsolateral prefrontal cortex (l-DLPFC) and inferior frontal gyrus (IFG) were activated under the reward condition only, whereas the orbito-frontal cortex (OFC) was significantly activated under the punishment condition, with a tendency towards activation for the right cortical hemisphere (r-DLPFC and r-IFG). Our results are compatible with the suggestion that the DLPFC is involved in the detection of contingency change. We propose a new representation for reward and punishment, with left lateralization for the reward process. CONCLUSIONS: The results of this pilot study provide insights into the indirect neural mechanisms of reversal learning and behavioral flexibility and confirm the use of fNIRS imaging in reversal-learning tasks as a translational strategy, particularly in subjects who cannot undergo fMRI recordings.

Functional near-infrared spectroscopy brain imaging predicts symptom severity in youth exposed to traumatic stress.

Balters S, Li R, Espil FM, Piccirilli A, Liu N, Gundran A, Carrion VG, Weems CF, Cohen JA, Reiss AL.
J Psychiatr Res. 2021 Dec;144:494-502.
doi: 10.1016/j.jpsychires.2021.10.020. Epub 2021 Nov 2.

Functional near-infrared spectroscopy (fNIRS) is a non-invasive neuroimaging technique with the potential to enable the assessment of posttraumatic stress disorder (PTSD) brain biomarkers in an affordable and portable manner. Consistent with biological models of PTSD, functional magnetic resonance imaging (fMRI) and fNIRS studies of adults with trauma exposure and PTSD symptoms suggest increased activation in the dorsolateral prefrontal cortex (dlPFC) and ventrolateral PFC (vlPFC) in response to negative emotion stimuli. We tested this theory with fNIRS assessment among youth exposed to traumatic stress and experiencing PTSD symptoms (PTSS). A portable fNIRS system collected hemodynamic responses from (N=57) youth with PTSS when engaging in a classic emotion expression task that included fearful and neutral faces stimuli. The General Linear Model was applied to identify cortical activations associated with the facial stimuli. Subsequently, a prediction model was established via a Support Vector Regression to determine whether PTSS severity could be predicted based on fNIRS-derived cortical response measures and individual demographic information. Results were consistent with findings from adult fMRI and fNIRS studies of PTSS showing increased activation in the dlPFC and vlPFC in response to negative emotion stimuli. Subsequent prediction analysis revealed ten features (i.e., cortical responses from eight frontocortical fNIRS channels, age and sex) strongly correlated with PTSS severity ($r=0.65$, $p<.001$). Our findings suggest the potential utility of fNIRS as a portable tool for the detection of putative PTSS brain biomarkers.

Episodic Memory Encoding and Retrieval in Face-Name Paired Paradigm: An fNIRS

Study.

Yu Q, Cheval B, Becker B, Herold F, Chan CCH, Delevoye-Turrell YN, Gurin SMR, Loprinzi P, Mueller N, Zou L.

Brain Sci. 2021 Jul 19;11(7):951.
doi: 10.3390/brainsci11070951.

BACKGROUND: Episodic memory (EM) is particularly sensitive to pathological conditions and aging. In a neurocognitive context, the paired-associate learning (PAL) paradigm, which requires participants to learn and recall associations between stimuli, has been used to measure EM. The present study aimed to explore whether functional near-infrared spectroscopy (fNIRS) can be employed to determine cortical activity underlying encoding and retrieval. Moreover, we examined whether and how different aspects of task (i.e., novelty, difficulty) affects those cortical activities. METHODS: Twenty-two male college students (age: M = 20.55, SD = 1.62) underwent a face-name PAL paradigm under 40-channel fNIRS covering fronto-parietal and middle occipital regions. RESULTS: A decreased activity during encoding in a broad network encompassing the bilateral frontal cortex (Brodmann areas 9, 11, 45, and 46) was observed during the encoding, while an increased activity in the left orbitofrontal cortex (Brodmann area 11) was observed during the retrieval. Increased HbO concentration in the superior parietal cortices and decreased HbO concentration in the inferior parietal cortices were observed during encoding while dominant activation of left PFC was found during retrieval only. Higher task difficulty was associated with greater neural activity in the bilateral prefrontal cortex and higher task novelty was associated with greater activation in occipital regions. CONCLUSION: Combining the PAL paradigm with fNIRS provided the means to differentiate neural activity characterising encoding and retrieval. Therefore, the fNIRS may have the potential to complete EM assessments in clinical settings.

Artefact subspace reconstruction for both EEG and fNIRS co-registred signals.

Aloui N, Planat-Chretien A, Bonnet S.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:208-211.
doi: 10.1109/EMBC46164.2021.9629641.

Combining electroencephalography (EEG) to functional near-infrared spectroscopy (fNIRS) is a promising technique that has gained momentum thanks to their complementarity. While EEG measures the electrical activity of the brain, fNIRS records the variations in cerebral blood flow and related hemoglobin concentrations. However, both modalities are typically contaminated with artefacts. Muscle and eye artefacts, affect the EEG signals, while hemodynamic and oxygenation changes in the extracerebral compartment due to systemic changes (superficial layer) corrupt the fNIRS signals. Moreover, both signals are sensitive to sensor motion artefacts characterized by large amplitude. There are several well-established methods for removing artefacts for both modalities. The objective of this paper is to apply a common approach to denoise both EEG and fNIRS signals. Indeed Artifact Subspace Reconstruction (ASR) method, which is an automatic, online-capable and efficient method for deleting transient or large-amplitude EEG artefacts, can be a good alternative to also denoise fNIRS signals. In this paper, we first propose, a new more comprehensive formulation of ASR. Then, we study the effectiveness of the method in denoising both the EEG and fNIRS signals.

Clinical Utility of Functional Near-Infrared Spectroscopy for Assessment and Prediction of Suicidality: A Systematic Review.

Lee YQ, Tay GWN, Ho CSH.

Front Psychiatry. 2021 Oct 1;12:716276.
doi: 10.3389/fpsyt.2021.716276. eCollection 2021.

Introduction: Suicide is a pressing psychiatric concern worldwide with no established biomarker. While

there is some evidence of the clinical utility of functional near-infrared spectroscopy (fNIRS) in assessing and predicting suicidality, no systematic review of such evidence has been conducted to date. Therefore, this review aimed to systematically review and gather evidence from existing studies that used fNIRS signals to assess suicidality and its associated changes in the brain, and those that examined how such signals correlated with suicide symptomatology. Methods: PubMed, EMBASE, and Cochrane Library databases were used in a systematic literature search for English-language articles published between 2000 and December 19, 2020 that focused on the utility of fNIRS for (i) assessing suicidality and its associated changes in the brain, and (ii) correlating with suicide symptomatology. Studies were included if they utilised fNIRS to evaluate variations in fNIRS-measured cerebral hemodynamic responses in patients with different mental disorders (e.g., major depressive disorder, schizophrenia), as well as in healthy controls, of any age group. Quality of evidence was assessed using the Newcastle-Ottawa quality assessment scale. Results: A total of 7 cross-sectional studies were included in this review, all of which had acceptable quality. Across all studies, fNIRS demonstrated reduced cerebral hemodynamic changes in suicidal individuals when compared to non-suicidal individuals. One study also demonstrated the potential of fNIRS signals in correlating with the severity of suicidality. Conclusions: This review provides a comprehensive, updated review of evidence supporting the clinical utility of fNIRS in the assessment and prediction of suicidality. Further studies involving larger sample sizes, standardised methodology, and longitudinal follow-ups are needed.

Effect of muscle fatigue on brain activity in healthy individuals.

Takahashi R, Fujita K, Kobayashi Y, Ogawa T, Teranishi M, Kawamura M.

Brain Res. 2021 Aug 1;1764:147469.
doi: 10.1016/j.brainres.2021.147469. Epub 2021 Apr 8.

Fatigue is affected by both peripheral and central factors. However, the interrelationship between muscle fatigue and brain activity has not yet been clarified. This study aimed to clarify the effect of muscle fatigue due to sustained pinch movement on brain activity in healthy individuals using functional near-infrared spectroscopy (fNIRS). Ten healthy adults participated in the study. Pinch movement of isometric contraction was the task to be performed, and electromyogram of the first dorsal interosseous muscle and brain activity by fNIRS were measured in this period. The median power frequency (MdPF) was calculated as an index of muscle fatigue and the oxygen-Hb value in the bilateral premotor and motor areas was calculated as an index of brain activity. As a result, MdPF showed a significant decrease in the middle and later phases compared with that in the early phase ($p<0.05$, $p<0.001$, respectively) and a significant decrease in the later phase compared with that in the middle phase ($p<0.05$). The oxygen-Hb values in the motor cortex were not significantly different between the analysis sections. The oxygen-Hb values in the premotor cortex was significantly increased in the later phase ($p<0.05$) compared with that in the early phase. The premotor cortex was found to be specifically activated during muscle fatigue.

Task Complexity and Image Clarity Facilitate Motor and Visuo-Motor Activities in Mirror Therapy in Post-stroke Patients.

Bello UM, Chan CCH, Winser SJ.

Front Neurol. 2021 Sep 22;12:722846.
doi: 10.3389/fneur.2021.722846. eCollection 2021.

Introduction: Mirror therapy is effective in the recovery of upper-limb function among post-stroke patients. An important component of mirror therapy is imagining finger movements. This study aimed to determine the influence of finger movement complexity and mirror image clarity on facilitating motor and visuo-motor activities in post-stroke patients. Methods: Fifteen post-stroke patients and 18 right-handed healthy participants performed simple or complex finger tapping while viewing mirror images of these movements at varying levels of clarity. The physical setup was identical to typical mirror therapy.

Functional near infrared spectroscopy (fNIRS) was used to capture the brain activities elicited in the bilateral primary motor cortices (M1) and the precuneus using a block experimental design. Results: In both study groups, the "complex finger-tapping task with blurred mirror image" condition resulted in lower intensity ($p < 0.01$) and authenticity ($p < 0.01$) of the kinesthetic mirror illusion, and higher levels of perceived effort in generating the illusion ($p < 0.01$), relative to the "simple finger-tapping with clear mirror image" condition. Greater changes in the oxygenated hemoglobin (HbO) concentration were recorded at the ipsilesional and ipsilateral M1 in the "complex finger-tapping task with blurred mirror image" condition relative to that recorded in the "simple finger-tapping task with clear mirror image" condition ($p = 0.03$). These HbO concentration changes were not significant in the precuneus. Post-stroke patients showed greater changes than their healthy counterparts at the ipsilesional M1 ($F = 5.08$; $p = 0.03$; partial eta squared $= 0.14$) and the precuneus ($F = 7.71$; $p < 0.01$; partial eta squared $= 0.20$). Conclusion: The complexity and image clarity of the finger movements increased the neural activities in the ipsilesional motor cortex in the post-stroke patients. These findings suggest plausible roles for top-down attention and working memory in the treatment effects of mirror therapy. Future research can aim to corroborate these findings by using a longitudinal design to examine the use of mirror therapy to promote upper limb motor recovery in post-stroke patients.

Inter-group conflict affects inter-brain synchrony during synchronized movements.

Gamliel HN, Nevat M, Probolovski HZG, Karklinsky M, Han S, Shamay-Tsoory SG.

Neuroimage. 2021 Dec 15;245:118661.
doi: 10.1016/j.neuroimage.2021.118661. Epub 2021 Nov 17.

Interpersonal synchrony refers to alignment in time of interacting individuals. Recent neuroimaging findings indicate that the inferior frontal gyrus (IFG) - a core region of the observation-execution system - is not only activated during tasks that involve synchrony, but also coupled between interaction partners, suggesting a key role for the IFG in mediating interpersonal synchrony. In this study we investigated whether inter-brain synchrony (IBS) is modulated by inter-group relationships. We examined this question in the context of the Israeli-Palestinian conflict - one of the world's most prolonged and intractable conflicts. Using functional Near Infra-Red Spectroscopy (fNIRS) hyperscanning, we measured IBS among ingroup vs. inter-group dyads (same-nationality dyads and Jewish-Palestinian dyads, respectively) while they performed a task entailing 2D movement synchrony. The results point to an increase in behavioral synchrony and greater enjoyment in the ingroup dyads, compared to the inter-group dyads. Critically, IBS in the left IFG significantly increased throughout task and it was higher among ingroup compared to inter-group dyads. Our findings highlight the effect of group membership on IBS plasticity.

Modeling Brain Dynamics During Virtual Reality-Based Emergency Response Learning Under Stress.

Tyagi O, Hopko S, Kang J, Shi Y, Du J, Mehta RK.

Hum Factors. 2021 Dec 5:187208211054894.
doi: 10.1177/00187208211054894. Online ahead of print.

BACKGROUND: Stress affects learning during training, and virtual reality (VR) based training systems that manipulate stress can improve retention and retrieval performance for firefighters. Brain imaging using functional Near Infrared Spectroscopy (fNIRS) can facilitate development of VR-based adaptive training systems that can continuously assess the trainee's states of learning and cognition. OBJECTIVE: The aim of this study was to model the neural dynamics associated with learning and retrieval under stress in a VR-based emergency response training exercise. METHODS: Forty firefighters underwent an emergency shutdown training in VR and were randomly assigned to either a control or a stress group. The stress group experienced stressors including smoke, fire, and explosions during the familiarization and training phase.

Both groups underwent a stress memory retrieval and no-stress memory retrieval condition. Participant's performance scores, fNIRS-based neural activity, and functional connectivity between the prefrontal cortex (PFC) and motor regions were obtained for the training and retrieval phases. RESULTS: The performance scores indicate that the rate of learning was slower in the stress group compared to the control group, but both groups performed similarly during each retrieval condition. Compared to the control group, the stress group exhibited suppressed PFC activation. However, they showed stronger connectivity within the PFC regions during the training and between PFC and motor regions during the retrieval phases. DISCUSSION: While stress impaired performance during training, adoption of stress-adaptive neural strategies (i.e., stronger brain connectivity) were associated with comparable performance between the stress and the control groups during the retrieval phase.

Shedding light on pain for the clinic: a comprehensive review of using functional near-infrared spectroscopy to monitor its process in the brain.

Hu XS, Nascimento TD, DaSilva AF.

Pain. 2021 Dec 1;162(12):2805-2820.
doi: 10.1097/j.pain.0000000000002293.

Pain is a complex experience that involves sensation, emotion, and cognition. The subjectivity of the traditional pain measurement tools has expedited the interest in developing neuroimaging techniques to monitor pain objectively. Among noninvasive neuroimaging techniques, functional near-infrared spectroscopy (fNIRS) has balanced spatial and temporal resolution; yet, it is portable, quiet, and cost-effective. These features enable fNIRS to image the cortical mechanisms of pain in a clinical environment. In this article, we evaluated pain neuroimaging studies that used the fNIRS technique in the past decade. Starting from the experimental design, we reviewed the regions of interest, probe localization, data processing, and primary findings of these existing fNIRS studies. We also discussed the fNIRS imaging's potential as a brain surveillance technique for pain, in combination with artificial intelligence and extended reality techniques. We concluded that fNIRS is a brain imaging technique with great potential for objective pain assessment in the clinical environment.

Shining new light on sensory brain activation and physiological measurement in seals using wearable optical technology.

McKnight JC, Ruesch A, Bennett K, Bronkhorst M, Balfour S, Moss SEW, Milne R, Tyack PL, Kainerstorfer JM, Hastie GD.

Philos Trans R Soc Lond B Biol Sci. 2021 Aug 2;376(1830):20200224.
doi: 10.1098/rstb.2020.0224. Epub 2021 Jun 14.

Sensory ecology and physiology of free-ranging animals is challenging to study but underpins our understanding of decision-making in the wild. Existing non-invasive human biomedical technology offers tools that could be harnessed to address these challenges. Functional near-infrared spectroscopy (fNIRS), a wearable, non-invasive biomedical imaging technique measures oxy- and deoxyhaemoglobin concentration changes that can be used to detect localized neural activation in the brain. We tested the efficacy of fNIRS to detect cortical activation in grey seals (Halichoerus grypus) and identify regions of the cortex associated with different senses (vision, hearing and touch). The activation of specific cerebral areas in seals was detected by fNIRS in responses to light (vision), sound (hearing) and whisker stimulation (touch). Physiological parameters, including heart and breathing rate, were also extracted from the fNIRS signal, which allowed neural and physiological responses to be monitored simultaneously. This is, to our knowledge, the first time fNIRS has been used to detect cortical activation in a non-domesticated or laboratory animal. Because fNIRS is non-invasive and wearable, this study demonstrates its potential as a tool to quantitatively investigate sensory perception and brain function while simultaneously recording

heart rate, tissue and arterial oxygen saturation of haemoglobin, perfusion changes and breathing rate in free-ranging animals. This article is part of the theme issue 'Measuring physiology in free-living animals (Part I)'.

See, Hear, or Feel - to Speak: A Versatile Multiple-Choice Functional Near-Infrared Spectroscopy-Brain-Computer Interface Feasible With Visual, Auditory, or Tactile Instructions.

Nagels-Coune L, Riecke L, Benitez-Andonegui A, Klinkhammer S, Goebel R, De Weerd P, Lhrs M, Sorger B.

Front Hum Neurosci. 2021 Nov 25;15:784522.
doi: 10.3389/fnhum.2021.784522. eCollection 2021.

Severely motor-disabled patients, such as those suffering from the so-called "locked-in" syndrome, cannot communicate naturally. They may benefit from brain-computer interfaces (BCIs) exploiting brain signals for communication and therewith circumventing the muscular system. One BCI technique that has gained attention recently is functional near-infrared spectroscopy (fNIRS). Typically, fNIRS-based BCIs allow for brain-based communication via voluntarily modulation of brain activity through mental task performance guided by visual or auditory instructions. While the development of fNIRS-BCIs has made great progress, the reliability of fNIRS-BCIs across time and environments has rarely been assessed. In the present fNIRS-BCI study, we tested six healthy participants across three consecutive days using a straightforward four-choice fNIRS-BCI communication paradigm that allows answer encoding based on instructions using various sensory modalities. To encode an answer, participants performed a motor imagery task (mental drawing) in one out of four time periods. Answer encoding was guided by either the visual, auditory, or tactile sensory modality. Two participants were tested outside the laboratory in a cafeteria. Answers were decoded from the time course of the most-informative fNIRS channel-by-chromophore combination. Across the three testing days, we obtained mean single- and multi-trial (joint analysis of four consecutive trials) accuracies of 62.5 and 85.19%, respectively. Obtained multi-trial accuracies were 86.11% for visual, 80.56% for auditory, and 88.89% for tactile sensory encoding. The two participants that used the fNIRS-BCI in a cafeteria obtained the best single- (72.22 and 77.78%) and multi-trial accuracies (100 and 94.44%). Communication was reliable over the three recording sessions with multi-trial accuracies of 86.11% on day 1, 86.11% on day 2, and 83.33% on day 3. To gauge the trade-off between number of optodes and decoding accuracy, averaging across two and three promising fNIRS channels was compared to the one-channel approach. Multi-trial accuracy increased from 85.19% (one-channel approach) to 91.67% (two-/three-channel approach). In sum, the presented fNIRS-BCI yielded robust decoding results using three alternative sensory encoding modalities. Further, fNIRS-BCI communication was stable over the course of three consecutive days, even in a natural (social) environment. Therewith, the developed fNIRS-BCI demonstrated high flexibility, reliability and robustness, crucial requirements for future clinical applicability.

Depression Analysis and Recognition Based on Functional Near-Infrared Spectroscopy.

Wang R, Hao Y, Yu Q, Chen M, Humar I, Fortino G.

IEEE J Biomed Health Inform. 2021 Dec;25(12):4289-4299.
doi: 10.1109/JBHI.2021.3076762. Epub 2021 Dec 6.

Depression is the result of a complex interaction of social, psychological and physiological elements. Research into the brain disorders of patients suffering from depression can help doctors to understand the pathogenesis of depression and facilitate its diagnosis and treatment. Functional near-infrared spectroscopy (fNIRS) is a non-invasive approach to the detection of brain functions and activities. In this paper, a comprehensive fNIRS-based depression-processing architecture, including the layers of source, feature and

model, is first established to guide the deep modeling for fNIRS. In view of the complexity of depression, we propose a methodology in the time and frequency domains for feature extraction and deep neural networks for depression recognition combined with current research. It is found that compared to non-depression people, patients with depression have a weaker encephalic area connectivity and lower level of activation in the prefrontal lobe during brain activity. Finally, based on raw data, manual features and channel correlations, the AlexNet model shows the best performance, especially in terms of the correlation features and presents an accuracy rate of 0.90 and a precision rate of 0.91, which is higher than ResNet18 and machine-learning algorithms on other data. Therefore, the correlation of brain regions can effectively recognize depression (from cases of non-depression), making it significant for the recognition of brain functions in the clinical diagnosis and treatment of depression.

Photoneuromodulation makes a difficult cognitive task less arduous.

Chan AS, Lee TL, Hamblin MR, Cheung MC.

Sci Rep. 2021 Jul 1;11(1):13688.
doi: 10.1038/s41598-021-93228-2.

A positive effect of photoneuromodulation (PNM) has been found on cognitive and emotional functions in healthy populations. However, the hemodynamic changes associated with improved cognitive functions (i.e., memory and executive functions) are unexplored. Therefore, the present study investigated the hemodynamic changes associated with PNM using functional near-infrared spectroscopy (fNIRS). In this experiment, 33 young healthy adults were recruited and randomly assigned to control and experimental groups. A single PNM stimulation was applied to the forehead in the experimental group, while a sham stimulation (same procedure without machine activation) was performed for the control group. Before and after the stimulation, all participants performed an n-back task with 0-and 3-back conditions to assess their working memory function, and their hemodynamic responses during the tasks were measured by fNIRS. A significant group (experimental vs. control) time (before vs. after PNM) interaction in memory-related frontal activation was found. Specifically, only the experimental group had a significant reduction in frontal hemodynamic levels during the difficult task. Additionally, the memory-related frontal activation was significantly correlated with the immediate and delayed recall of the Rey-Osterrieth Complex Figure Test assessed at baseline. Therefore, PNM may reduce the cognitive efforts needed to complete tasks with high memory loads.

A low-cost, wearable, do-it-yourself functional near-infrared spectroscopy (DIY-fNIRS) headband.

Tsow F(#), Kumar A(#), Hosseini SH, Bowden A.

HardwareX. 2021 Oct;10:e00204.
doi: 10.1016/j.ohx.2021.e00204. Epub 2021 May 20.

Neuromonitoring in naturalistic environments is of increasing interest for a variety of research fields including psychology, economics, and productivity. Among functional neuromonitoring modalities, functional near-infrared spectroscopy (fNIRS) is well regarded for its potential for miniaturization, good spatial and temporal resolutions, and resilience to motion artifacts. Historically, the large size and high cost of fNIRS systems have precluded widespread adoption of the technology. In this article, we describe the first open source, fully integrated wireless fNIRS headband system with a single LED-pair source and four detectors. With ease of operation and comfort in mind, the system is encased in a soft, lightweight cloth and silicone enclosure. Accompanying computer and smartphone data collection software have also been provided, and the hardware has been validated using classic fNIRS tasks. This wear-and-go design can easily be scaled to accommodate a larger number of fNIRS channels and opens the door to easily collecting fNIRS data during routine activities in naturalistic conditions.

Development of an Integrated EEG/fNIRS Brain Function Monitoring System.

Mohamed M, Jo E, Mohamed N, Kim M, Yun JD, Kim JG.

Sensors (Basel). 2021 Nov 19;21(22):7703.
doi: 10.3390/s21227703.

In this study, a fully integrated electroencephalogram/functional near-infrared spectroscopy (EEG/fNIRS) brain monitoring system was designed to fulfill the demand for a miniaturized, light-weight, low-power-consumption, and low-cost brain monitoring system as a potential tool with which to screen for brain diseases. The system is based on the ADS1298IPAG Analog Front-End (AFE) and can simultaneously acquire two-channel EEG signals with a sampling rate of 250 SPS and six-channel fNIRS signals with a sampling rate of 8 SPS. AFE is controlled by Teensy 3.2 and powered by a lithium polymer battery connected to two protection circuits and regulators. The acquired EEG and fNIRS signals are monitored and stored using a Graphical User Interface (GUI). The system was evaluated by implementing several tests to verify its ability to simultaneously acquire EEG and fNIRS signals. The implemented system can acquire EEG and fNIRS signals with a CMRR of -115 dB, power consumption of 0.75 mW/ch, system weight of 70.5 g, probe weight of 3.1 g, and a total cost of USD 130. The results proved that this system can be qualified as a low-cost, light-weight, low-power-consumption, and fully integrated EEG/fNIRS brain monitoring system.

A bimodal deep learning architecture for EEG-fNIRS decoding of overt and imagined speech.

Cooney C, Folli R, Coyle DH.

IEEE Trans Biomed Eng. 2021 Dec 7;PP.
doi: 10.1109/TBME.2021.3132861. Online ahead of print.

OBJECTIVE: Brain-computer interfaces (BCI) studies are increasingly leveraging different attributes of multiple signal modalities simultaneously. Bimodal data acquisition protocols combining the temporal resolution of electroencephalography (EEG) with the spatial resolution of functional near-infrared spectroscopy (fNIRS) require novel approaches to decoding. METHODS: We present an EEG-fNIRS Hybrid BCI that employs a new bimodal deep neural network architecture consisting of two convolutional subnetworks (subnets) to decode overt and imagined speech. Features from each subnet are fused before further feature extraction and classification. Nineteen participants performed overt and imagined speech in a novel cue-based paradigm enabling investigation of stimulus and linguistic effects on decoding. RESULTS: Using the hybrid approach, classification accuracies (46.31% and 34.29% for overt and imagined speech, respectively (chance: 25%)) indicated a significant improvement on EEG used independently for imagined speech ($p=0.020$) while tending towards significance for overt speech ($p=0.098$). In comparison with fNIRS, significant improvements for both speech-types were achieved with bimodal decoding ($p<0.001$). There was a mean difference of 12.02% between overt and imagined speech with accuracies as high as 87.18% and 53%. Deeper subnets enhanced performance while stimulus effected overt and imagined speech in significantly different ways. CONCLUSION: The bimodal approach was a significant improvement on unimodal results for several tasks. Results indicate the potential of multi-modal deep learning for enhancing neural signal decoding. SIGNIFICANCE: This novel architecture can be used to enhance speech decoding from bimodal neural signals.

Cortical processing during table tennis - an fNIRS study in experts and novices.

Carius D, Kenville R, Maudrich D, Riechel J, Lenz H, Ragert P.

Eur J Sport Sci. 2021 Aug 17:1-11.
doi: 10.1080/17461391.2021.1953155. Online ahead of print.

Among the many factors that determine top athletic performance, little is known about the contribution of the brain. With the present study, we aimed to uncover aspects of this role by examining modulatory differences in brain processing as a function of expertise and task complexity in table tennis. For this purpose, 28 right-handed volunteers (14 experts and 14 novices) performed two table tennis strokes in a standardized manner. Hemodynamic response alterations reflecting neuronal activation were recorded during task execution using functional near-infrared spectroscopy (fNIRS) and analyzed within and between groups. Our results showed localized activation patterns in motor areas (primary motor cortex (M1), premotor cortex (PMC), and inferior parietal cortex (IPC)) for experts and novices. Compared to novices, experts completed more table tennis strokes and showed a significant increase in hemodynamic response alterations in channels corresponding to motor areas. Furthermore, we found significant correlations between the number of strokes and hemodynamic response magnitudes in individual channels of M1, PMC, and IPC. Taken together, our findings show that table tennis performance is accompanied by extensive activation of M1, PMC, and IPC. Furthermore, the observed difference in behavioral performance between experts and novices was associated with increased activation in M1, PMC, and IPC. We postulate that these differences in brain processing between experts and novices potentially imply modulatory distinctions related to increased movement speed or frequency but may also reflect an increased task familiarity of the experts.

Prefrontal Cortical Activity During Preferred and Fast Walking in Young and Older Adults: An fNIRS Study.

Belli V, Orcioli-Silva D, Beretta VS, Vitrio R, Zampier VC, Nbrega-Sousa P, Conceio NRD, Gobbi LTB.
Neuroscience. 2021 Oct 1;473:81-89.
doi: 10.1016/j.neuroscience.2021.08.019. Epub 2021 Aug 26.

Age-related changes may affect the performance during fast walking speed. Although, several studies have been focused on the contribution of the prefrontal cortex (PFC) during challenging walking tasks, the neural mechanism underling fast walking speed in older people remain poorly understood. Therefore, the aim of this study was to investigate the influence of aging on PFC activity during overground walking at preferred and fast speeds. Twenty-five older adults (67.375.31years) and 24 young adults (22.701.30years) walked overground in two conditions: preferred speed and fast walking speed. Five trials were performed for each condition. A wireless functional near-infrared spectroscopy (fNIRS) system measured PFC activity. Gait parameters were evaluated using the GAITRite system. Overall, older adults presented higher PFC activity than young adults in both conditions. Speed-related change in PFC activity was observed for older adults, but not for young adults. Older adults significantly increased activity in the left PFC from the preferred to fast walking condition whereas young adults had similar levels of PFC activity across conditions. Our findings suggest that older adults need to recruit additional prefrontal cognitive resources to control walking, indicating a compensatory mechanism. In addition, left PFC seems to be involved in the modulation of gait speed in older adults.

The use of broad vs restricted regions of interest in functional near-infrared spectroscopy for measuring cortical activation to auditory-only and visual-only speech.

Shader MJ, Luke R, Gouailhardou N, McKay CM.
Hear Res. 2021 Jul;406:108256.
doi: 10.1016/j.heares.2021.108256. Epub 2021 Apr 28.

As an alternative to fMRI, functional near-infrared spectroscopy (fNIRS) is a relatively new tool for observing cortical activation. However, spatial resolution is reduced compared to fMRI and often the exact locations of fNIRS optodes and specific anatomical information is not known. The aim of this study was to explore the location and range of specific regions of interest that are sensitive to detecting cortical

activation using fNIRS in response to auditory- and visual-only connected speech. Two approaches to a priori region-of-interest selection were explored. First, broad regions corresponding to the auditory cortex and occipital lobe were analysed. Next, the fNIRS Optode Location Decider (fOLD) tool was used to divide the auditory and visual regions into two subregions corresponding to distinct anatomical structures. The Auditory-A and -B regions corresponded to Heschl's gyrus and planum temporale, respectively. The Visual-A region corresponded to the superior occipital gyrus and the cuneus, and the Visual-B region corresponded to the middle occipital gyrus. The experimental stimulus consisted of a connected speech signal segmented into 12.5-sec blocks and was presented in either an auditory-only or visual-only condition. Group-level results for eight normal-hearing adult participants averaged over the broad regions of interest revealed significant auditory-evoked activation for both the left and right broad auditory regions of interest. No significant activity was observed for any other broad region of interest in response to any stimulus condition. When divided into subregions, there was a significant positive auditory-evoked response in the left and right Auditory-A regions, suggesting activation near the primary auditory cortex in response to auditory-only speech. There was a significant positive visual-evoked response in the Visual-B region, suggesting middle occipital gyrus activation in response to visual-only speech. In the Visual-A region, however, there was a significant negative visual-evoked response. This result suggests a significant decrease in oxygenated hemoglobin in the superior occipital gyrus as well as the cuneus in response to visual-only speech. Distinct response characteristics, either positive or negative, in adjacent subregions within the temporal and occipital lobes were fairly consistent on the individual level. Results suggest that temporal regions near Heschl's gyrus may be the most advantageous location in adults for identifying hemodynamic responses to complex auditory speech signals using fNIRS. In the occipital lobe, regions corresponding to the facial processing pathway may prove advantageous for measuring positive responses to visual speech using fNIRS.

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fNIRS-derived neurocognitive ratio as a biomarker for neuropsychiatric diseases.

Akin A.

Neurophotonics. 2021 Jul;8(3):035008.
doi: 10.1117/1.NPh.8.3.035008. Epub 2021 Sep 30.

Significance: Clinical use of fNIRS-derived features has always suffered low sensitivity and specificity due to signal contamination from background systemic physiological fluctuations. We provide an algorithm to extract cognition-related features by eliminating the effect of background signal contamination, hence improving the classification accuracy. Aim: The aim in this study is to investigate the classification accuracy of an fNIRS-derived biomarker based on global efficiency (GE). To this end, fNIRS data were collected during a computerized Stroop task from healthy controls and patients with migraine, obsessive compulsive disorder, and schizophrenia. Approach: Functional connectivity (FC) maps were computed from [HbO] time series data for neutral (N), congruent (C), and incongruent (I) stimuli using the partial correlation approach. Reconstruction of FC matrices with optimal choice of principal components yielded two independent networks: cognitive mode network (CM) and default mode network (DM). Results: GE values computed for each FC matrix after applying principal component analysis (PCA) yielded strong statistical significance leading to a higher specificity and accuracy. A new index, neurocognitive ratio (NCR), was computed by multiplying the cognitive quotients (CQ) and ratio of GE of CM to GE of DM. When mean values of NCR (NCR) over all stimuli were computed, they showed high sensitivity (100%), specificity (95.5%), and accuracy (96.3%) for all subjects groups. Conclusions: NCR can reliable be used as a biomarker to improve the classification of healthy to neuropsychiatric patients.

Comparison of Whole-Head Functional Near-Infrared Spectroscopy With Functional Magnetic Resonance Imaging and Potential Application in Pediatric Neurology.

Wagner JC, Zinos A, Chen WL, Conant L, Malloy M, Heffernan J, Quirk B, Sugar J, Prost R, Whelan JB, Beardsley SA, Whelan HT.
Pediatr Neurol. 2021 Sep;122:68-75.
doi: 10.1016/j.pediatrneurol.2021.06.003. Epub 2021 Jun 17.

BACKGROUND: Changes in cerebral blood flow in response to neuronal activation can be measured by time-dependent fluctuations in hemoglobin species within the brain; this is the basis of functional magnetic resonance imaging (fMRI) and functional near-infrared spectroscopy (fNIRS). There is a clinical need for portable neural imaging systems, such as fNIRS, to accommodate patients who are unable to tolerate an MR environment. OBJECTIVE: Our objective was to compare task-related full-head fNIRS and fMRI signals across cortical regions. METHODS: Eighteen healthy adults completed a same-day fNIRS-fMRI study, in which they performed right- and left-hand finger tapping tasks and a semantic-decision tones-decision task. First- and second-level general linear models were applied to both datasets. RESULTS: The finger tapping task showed that significant fNIRS channel activity over the contralateral primary motor cortex corresponded to surface fMRI activity. Similarly, significant fNIRS channel activity over the bilateral temporal lobe corresponded to the same primary auditory regions as surface fMRI during the semantic-decision tones-decision task. Additional channels were significant for this task that did not correspond to surface fMRI activity. CONCLUSION: Although both imaging modalities showed left-lateralized activation for language processing, the current fNIRS analysis did not show concordant or expected localization at the level necessary for clinical use in individual pediatric epileptic patients. Future work is needed to show whether fNIRS and fMRI are comparable at the source level so that fNIRS can be used in a clinical setting on individual patients. If comparable, such an imaging approach could be applied to children with neurological disorders.

Longitudinal infant fNIRS channel-space analyses are robust to variability parameters at the group-level: An image reconstruction investigation.

Collins-Jones LH, Cooper RJ, Bulgarelli C, Blasi A, Katus L, McCann S, Mason L, Mbye E, Touray E, Ceesay M, Moore SE, Lloyd-Fox S, Elwell CE; BRIGHT Study Team.
Neuroimage. 2021 Aug 15;237:118068.
doi: 10.1016/j.neuroimage.2021.118068. Epub 2021 Apr 26.

The first 1000days from conception to two-years of age are a critical period in brain development, and there is an increasing drive for developing technologies to help advance our understanding of neurodevelopmental processes during this time. Functional near-infrared spectroscopy (fNIRS) has enabled longitudinal infant brain function to be studied in a multitude of settings. Conventional fNIRS analyses tend to occur in the channel-space, where data from equivalent channels across individuals are combined, which implicitly assumes that head size and source-detector positions (i.e. array position) on the scalp are constant across individuals. The validity of such assumptions in longitudinal infant fNIRS analyses, where head growth is most rapid, has not previously been investigated. We employed an image reconstruction approach to analyse fNIRS data collected from a longitudinal cohort of infants in The Gambia aged 5- to 12-months. This enabled us to investigate the effect of variability in both head size and array position on the anatomical and statistical inferences drawn from the data at both the group- and the individual-level. We also sought to investigate the impact of group size on inferences drawn from the data. We found that variability in array position was the driving factor between differing inferences drawn from the data at both the individual- and group-level, but its effect was weakened as group size increased towards the full cohort size (N=53 at 5-months, N=40 at 8-months and N=45 at 12-months). We conclude that, at the group sizes in our dataset, group-level channel-space analysis of longitudinal infant fNIRS data is robust to assumptions about head size and array position given the variability in these parameters in our dataset. These findings support a more widespread use of image reconstruction techniques in longitudinal infant fNIRS studies.

Insights from a laboratory and naturalistic investigation on stress, rumination and frontal brain functioning in MDD: An fNIRS study.

Rosenbaum D, Int-Veen I, Laicher H, Torka F, Kroczek A, Rubel J, Lawyer G, Brger Z, Bihlmaier I, Storchak H, Velten-Schurian K, Dresler T, Tglich R, Schopp B, Nrk HC, Derntl B, Nieratschker V, Fallgatter AJ, Ehlis AC.

Neurobiol Stress. 2021 May 24;15:100344.
doi: 10.1016/j.ynstr.2021.100344. eCollection 2021 Nov.

Recent research has emphasized rumination as an important maintaining factor in various mental disorders. However, operationalization and therefore induction of rumination in experimental settings poses a major challenge in terms of ecological validity. As stress seems to play a key role in everyday situations eliciting rumination, we conducted two stress paradigms while assessing behavioral and neurophysiological measures. Aiming to replicate previous findings on induced rumination by means of the Trier Social Stress Test (TSST) and comparing them to physiological (pain) stress, a clinical sample of patients with Major Depressive Disorder (MDD; n=22) and healthy controls (HC; n=23) was recruited. Cortical blood oxygenation was assessed during the stress paradigms using functional near-infrared spectroscopy (fNIRS). Further, we used ecological momentary assessment (EMA) of stress, rumination and mood to be able to correlate ruminative responses during induced stress and everyday rumination. Our results showed that social stress but not physiological stress induced depressive rumination in MDD but not in HC. Further, rumination reactivity in response to social stress but not to physiological stress was significantly associated with rumination reactivity in everyday life as assessed with EMA. With respect to cortical oxygenation, MDD subjects showed hypoactivity in the Cognitive Control Network during the TSST, which mediated the differences between MDD and HC in post-stress rumination. Our findings emphasize the role of negative social triggers in depressive rumination and validate the TSST as an induction method for depressive rumination. The results inform future developments in psychotherapeutic treatment for depressive rumination.

Identification of impulsive adolescents with a functional near infrared spectroscopy (fNIRS) based decision support system.

Erdogan SB, Ykselen G, Yegl MM, Usanmaz R, Kiran E, Derman O, Akin A.

J Neural Eng. 2021 Oct 4;18(5).
doi: 10.1088/1741-2552/ac23bb.

Background.The gold standard for diagnosing impulsivity relies on clinical interviews, behavioral questionnaires and rating scales which are highly subjective.Objective.The aim of this study was to develop a functional near infrared spectroscopy (fNIRS) based classification approach for correct identification of impulsive adolescents. Taking into account the multifaceted nature of impulsivity, we propose that combining informative features from clinical, behavioral and neurophysiological domains might better elucidate the neurobiological distinction underlying symptoms of impulsivity.Approach. Hemodynamic and behavioral information was collected from 38 impulsive adolescents and from 33 non-impulsive adolescents during a Stroop task with concurrent fNIRS recordings. Connectivity-based features were computed from the hemodynamic signals and a neural efficiency metric was computed by fusing the behavioral and connectivity-based features. We tested the efficacy of two commonly used supervised machine-learning methods, namely the support vector machines (SVM) and artificial neural networks (ANN) in discriminating impulsive adolescents from their non-impulsive peers when trained with multi-domain features. Wrapper method was adapted to identify the informative biomarkers in each domain. Classification accuracies of each algorithm were computed after 10 runs of a 10-fold cross-validation procedure, conducted for 7 different combinations of the 3-domain feature set.Main results.Both SVM and ANN achieved diagnostic accuracies above 90% when trained with Wrapper-selected clinical, behavioral and fNIRS derived

features. SVM performed significantly higher than ANN in terms of the accuracy metric (92.2% and 90.16%, respectively,p= 0.005).Significance.Preliminary findings show the feasibility and applicability of both machine-learning based methods for correct identification of impulsive adolescents when trained with multi-domain data involving clinical interviews, fNIRS based biomarkers and neuropsychiatric test measures. The proposed automated classification approach holds promise for assisting the clinical practice of diagnosing impulsivity and other psychiatric disorders. Our results also pave the path for a computer-aided diagnosis perspective for rating the severity of impulsivity.

Cerebral Representation of Sound Localization Using Functional Near-Infrared Spectroscopy.

Tian X, Liu Y, Guo Z, Cai J, Tang J, Chen F, Zhang H.

Front Neurosci. 2021 Dec 14;15:739706.
doi: 10.3389/fnins.2021.739706. eCollection 2021.

Sound localization is an essential part of auditory processing. However, the cortical representation of identifying the direction of sound sources presented in the sound field using functional near-infrared spectroscopy (fNIRS) is currently unknown. Therefore, in this study, we used fNIRS to investigate the cerebral representation of different sound sources. Twenty-five normal-hearing subjects (aged 26 2.7, male 11, female 14) were included and actively took part in a block design task. The test setup for sound localization was composed of a seven-speaker array spanning a horizontal arc of 180 in front of the participants. Pink noise bursts with two intensity levels (48 dB/58 dB) were randomly applied via five loudspeakers (-90/-30/-0/+30/+90). Sound localization task performances were collected, and simultaneous signals from auditory processing cortical fields were recorded for analysis by using a support vector machine (SVM). The results showed a classification accuracy of 73.60, 75.60, and 77.40% on average at -90/0, 0/+90, and -90/+90 with high intensity, and 70.60, 73.6, and 78.6% with low intensity. The increase of oxyhemoglobin was observed in the bilateral non-primary auditory cortex (AC) and dorsolateral prefrontal cortex (dlPFC). In conclusion, the oxyhemoglobin (oxy-Hb) response showed different neural activity patterns between the lateral and front sources in the AC and dlPFC. Our results may serve as a basic contribution for further research on the use of fNIRS in spatial auditory studies.

The neurobehavioral relationship between executive function and creativity during early childhood.

Wang J, Sakata C, Moriguchi Y.

Dev Psychobiol. 2021 Nov;63(7):e22191.
doi: 10.1002/dev.22191.

Increasing evidence from behavior and neuroimaging research indicates that executive function (EF) is related to creativity. However, most of these studies focused on adult and adolescent populations. The relationship between EF and creativity is unknown when EF undergoes rapid development during early childhood, due to the preschoolers' marginal skills of expressing their ideas, orally or in writing. Using a nonverbal, open-ended test, the present study examined whether creative thinking was related to cognitive flexibility in young children. Preschool children (N=26) performed the Dimensional Change Card Sort (DCCS) and the Unusual Box Test (UBT), while their brain activation was recorded using functional near-infrared spectroscopy (fNIRS). We did not find any significant correlation between children's cognitive flexibility and creative thinking. However, fNIRS analyses showed that children's brain activation in the lateral prefrontal regions was significantly greater during the test phases of the UBT. Additionally, children who strongly recruited their ventrolateral prefrontal regions during the post-switch phases of the DCCS recruited the same regions while performing the UBT. Taken together, these findings suggest that children recruit their lateral prefrontal regions when expressing creative thinking, and that such creative thinking

could be partially supported by cognitive flexibility in early childhood.

Imagined speech increases the hemodynamic response and functional connectivity of the dorsal motor cortex.

Si X, Li S, Xiang S, Yu J, Ming D.
J Neural Eng. 2021 Oct 7;18(5).
doi: 10.1088/1741-2552/ac25d9.

Objective. Decoding imagined speech from brain signals could provide a more natural, user-friendly way for developing the next generation of the brain-computer interface (BCI). With the advantages of non-invasive, portable, relatively high spatial resolution and insensitivity to motion artifacts, the functional near-infrared spectroscopy (fNIRS) shows great potential for developing the non-invasive speech BCI. However, there is a lack of fNIRS evidence in uncovering the neural mechanism of imagined speech. Our goal is to investigate the specific brain regions and the corresponding cortico-cortical functional connectivity features during imagined speech with fNIRS.Approach. fNIRS signals were recorded from 13 subjects' bilateral motor and prefrontal cortex during overtly and covertly repeating words. Cortical activation was determined through the mean oxygen-hemoglobin concentration changes, and functional connectivity was calculated by Pearson's correlation coefficient.Main results. (a) The bilateral dorsal motor cortex was significantly activated during the covert speech, whereas the bilateral ventral motor cortex was significantly activated during the overt speech. (b) As a subregion of the motor cortex, sensorimotor cortex (SMC) showed a dominant dorsal response to covert speech condition, whereas a dominant ventral response to overt speech condition. (c) Broca's area was deactivated during the covert speech but activated during the overt speech. (d) Compared to overt speech, dorsal SMC(dSMC)-related functional connections were enhanced during the covert speech.Significance. We provide fNIRS evidence for the involvement of dSMC in speech imagery. dSMC is the speech imagery network's key hub and is probably involved in the sensorimotor information processing during the covert speech. This study could inspire the BCI community to focus on the potential contribution of dSMC during speech imagery.

The neurocognitive basis of morphological processing in typical and impaired readers.

Marks RA, Eggleston RL, Sun X, Yu CL, Zhang K, Nickerson N, Hu XS, Kovelman I.
Ann Dyslexia. 2021 Jul 13.
doi: 10.1007/s11881-021-00239-9. Online ahead of print.

Morphological awareness, or sensitivity to units of meaning, is an essential component of reading comprehension development. Current neurobiological models of reading and dyslexia have largely been built upon phonological processing models, yet reading for meaning is as essential as reading for sound. To fill this gap, the present study explores the relation between children's neural organization for morphological awareness and successful reading comprehension in typically developing and impaired readers. English-speaking children ages 6-11 (N = 97; mean age = 8.6years, 25% reading impaired) completed standard literacy assessments as well as an auditory morphological awareness task during functional near-infrared spectroscopy (fNIRS) neuroimaging, which included root (e.g., PERSON + al) and derivational (e.g., quick + LY) morphology. Regression analyses revealed that children's morphological awareness predicted unique variance in reading comprehension above and beyond demographic factors, vocabulary knowledge, and decoding ability. Neuroimaging analyses further revealed that children with stronger reading comprehension showed greater engagement of brain regions associated with integrating sound and meaning, including left inferior frontal, middle temporal, and inferior parietal regions. This effect was especially notable for the derivational morphology condition that involved manipulating more analytically demanding and semantically abstract units (e.g., un-, -ly, -ion). Together, these findings suggest that successful reading comprehension, and its deficit in dyslexia, may be related to the ability to manipulate morpho-

phonological units of word meaning and structure. These results inform theoretical perspectives on literacy and children's neural architecture for learning to read.

Classification of Individual Finger Movements from Right Hand Using fNIRS Signals.

Khan H, Noori FM, Yazidi A, Uddin MZ, Khan MNA, Mirtaheri P.

Sensors (Basel). 2021 Nov 28;21(23):7943.
doi: 10.3390/s21237943.

Functional near-infrared spectroscopy (fNIRS) is a comparatively new noninvasive, portable, and easy-to-use brain imaging modality. However, complicated dexterous tasks such as individual finger-tapping, particularly using one hand, have been not investigated using fNIRS technology. Twenty-four healthy volunteers participated in the individual finger-tapping experiment. Data were acquired from the motor cortex using sixteen sources and sixteen detectors. In this preliminary study, we applied standard fNIRS data processing pipeline, i.e., optical densities conversation, signal processing, feature extraction, and classification algorithm implementation. Physiological and non-physiological noise is removed using 4th order band-pass Butter-worth and 3rd order Savitzky-Golay filters. Eight spatial statistical features were selected: signal-mean, peak, minimum, Skewness, Kurtosis, variance, median, and peak-to-peak form data of oxygenated haemoglobin changes. Sophisticated machine learning algorithms were applied, such as support vector machine (SVM), random forests (RF), decision trees (DT), AdaBoost, quadratic discriminant analysis (QDA), Artificial neural networks (ANN), k-nearest neighbors (kNN), and extreme gradient boosting (XGBoost). The average classification accuracies achieved were 0.750.04, 0.750.05, and 0.770.06 using k-nearest neighbors (kNN), Random forest (RF) and XGBoost, respectively. KNN, RF and XGBoost classifiers performed exceptionally well on such a high-class problem. The results need to be further investigated. In the future, a more in-depth analysis of the signal in both temporal and spatial domains will be conducted to investigate the underlying facts. The accuracies achieved are promising results and could open up a new research direction leading to enrichment of control commands generation for fNIRS-based brain-computer interface applications.

A guide for the use of fNIRS in microcephaly associated to congenital Zika virus infection.

Sato JR, Junior CEB, de Arajo ELM, de Souza Rodrigues J, Andrade SM.

Sci Rep. 2021 Sep 29;11(1):19270.
doi: 10.1038/s41598-021-97450-w.

Congenital Zika Syndrome (CZS) is characterized by changes in cranial morphology associated with heterogeneous neurological manifestations and cognitive and behavioral impairments. In this syndrome, longitudinal neuroimaging could help clinicians to predict developmental trajectories of children and tailor treatment plans accordingly. However, regularly acquiring magnetic resonance imaging (MRI) has several shortcomings besides cost, particularly those associated with childrens' clinical presentation as sensitivity to environmental stimuli. The indirect monitoring of local neural activity by non-invasive functional near-infrared spectroscopy (fNIRS) technique can be a useful alternative for longitudinally accessing the brain function in children with CZS. In order to provide a common framework for advancing longitudinal neuroimaging assessment, we propose a principled guideline for fNIRS acquisition and analyses in children with neurodevelopmental disorders. Based on our experience on collecting fNIRS data in children with CZS we emphasize the methodological challenges, such as clinical characteristics of the sample, desensitization, movement artifacts and environment control, as well as suggestions for tackling such challenges. Finally, metrics based on fNIRS can be associated with established clinical metrics, thereby opening possibilities for exploring this tool as a long-term predictor when assessing the effectiveness of treatments aimed at children with severe neurodevelopmental disorders.

Interpersonal neural synchronization could predict the outcome of mate choice.

Yuan D, Zhang R, Liu J, Feng D, Hu Y, Li X, Wang Y, Zhou X.

Neuropsychologia. 2021 Dec 7;165:108112.
doi: 10.1016/j.neuropsychologia.2021.108112. Online ahead of print.

Although mate choice is crucial for adults, its neural basis remains elusive. In the current study, we combined the functional near-infrared spectroscopy (fNIRS)-based hyperscanning and speed-dating to investigate the inter-brain mechanism of mate choice. Each participant was paired with two opposite-sex partners (participants) in separate speed-dating sessions and was asked to decide whether to engage in a further relationship with the paired partner after each session. The physical attraction of the daters was rated by their partners at the beginning of the dating whereas the social attraction was rated after the dating. Interpersonal neural synchronization (INS) at the dorsolateral prefrontal cortex during speed-dating rather than reading task predicts the outcome of mate choice. Moreover, social attraction rather than physical attraction affects INS during speed-dating. These findings demonstrate for the first time that INS predicts the outcome of mate choice of interacting daters in ecologically valid settings during their initial romantic encounter.

Preferential responses to faces in superior temporal and medial prefrontal cortex in three-year-old children.

Richardson H, Taylor J, Kane-Grade F, Powell L, Bosquet Enlow M, Nelson CA.

Dev Cogn Neurosci. 2021 Aug;50:100984.
doi: 10.1016/j.dcn.2021.100984. Epub 2021 Jul 3.

Perceiving faces and understanding emotions are key components of human social cognition. Prior research with adults and infants suggests that these social cognitive functions are supported by superior temporal cortex (STC) and medial prefrontal cortex (MPFC). We used functional near-infrared spectroscopy (fNIRS) to characterize functional responses in these cortical regions to faces in early childhood. Three-year-old children (n = 88, M(SD) = 3.15(.16) years) passively viewed faces that varied in emotional content and valence (happy, angry, fearful, neutral) and, for fearful and angry faces, intensity (100%, 40%), while undergoing fNIRS. Bilateral STC and MPFC showed greater oxygenated hemoglobin concentration values to all faces relative to objects. MPFC additionally responded preferentially to happy faces relative to neutral faces. We did not detect preferential responses to angry or fearful faces, or overall differences in response magnitude by emotional valence (100% happy vs. fearful and angry) or intensity (100% vs. 40% fearful and angry). In exploratory analyses, preferential responses to faces in MPFC were not robustly correlated with performance on tasks of early social cognition. These results link and extend adult and infant research on functional responses to faces in STC and MPFC and contribute to the characterization of the neural correlates of early social cognition.

Stroke-induced alteration in multi-layer information transmission of cortico-motor system during elbow isometric contraction modulated by myoelectric-controlled interfaces.

Jian C, Liu H, Deng L, Wang X, Yan T, Song R.

J Neural Eng. 2021 Aug 25;18(4).
doi: 10.1088/1741-2552/ac18ae.

Objective. Human movement is a complex process requiring information transmission in inter-cortical, cortico-muscular and inter-muscular networks. Though motor deficits after stroke are associated with impaired networks in the cortico-motor system, the mechanisms underlying these networks are to date not fully understood. The purpose of this study is to investigate the changes in information transmission of

the inter-cortical, cortico-muscular and inter-muscular networks after stroke and the effect of myoelectric-controlled interface (MCI) dimensionality on such information transmission in each network.Approach. Fifteen healthy control subjects and 11 post-stroke patients were recruited to perform elbow tracking tasks within different dimensional MCIs in this study. Their electromyography (EMG) and functional near-infrared spectroscopy (fNIRS) signals were recorded simultaneously. Transfer entropy was used to analyse the functional connection that represented the information transmission in each network based on the fNIRS and EMG signals.Main results.The results found that post-stroke patients showed the increased inter-cortical connection versus healthy control subjects, which might be attributed to cortical reorganisation to compensate for motor deficits. Compared to healthy control subjects, a lower strength cortico-muscular connection was found in post-stroke patients due to the reduction of information transmission following a stroke. Moreover, the increased MCI dimensionality strengthened inter-cortical, cortico-muscular and inter-muscular connections because of higher visual information processing demands.Significance. These findings not only provide a comprehensive overview to evaluate changes in the cortico-motor system due to stroke, but also suggest that increased MCI dimensionality may serve as a useful rehabilitation tool for boosting information transmission in the cortico-motor system of post-stroke patients.

Relationship between cool and hot executive function in young children: A near-infrared spectroscopy study.

Moriguchi Y.

Dev Sci. 2021 Jul 30:e13165.
doi: 10.1111/desc.13165. Online ahead of print.

A theoretical distinction exists between the cool and hot aspects of executive function (EF). At the neural level, cool EF may be associated with activation in the lateral prefrontal cortex and the anterior cingulate cortex, whereas the orbitofrontal cortex may play a key role in hot EF. However, some recent studies have shown that young children show activity in the lateral prefrontal regions during hot EF tasks, suggesting that the distinction between hot and cool EF may not be as marked. Nevertheless, few neuroimaging studies have directly examined the relationship between cool and hot EF. In this study, preschool children (N=46, mean age=66.1 months) were given both cool (Dimensional Change Card Sort (DCCS) and Stroop-like tasks) and hot (delay of gratification) EF tasks, and neural activation during these tasks was measured using functional near-infrared spectroscopy (fNIRS). Correlational analyses and analysis of variance (ANOVA) were conducted to assess the relationship between cool and hot EF. At the behavioral level, a moderate correlation was found between DCCS and Stroop-like tasks, but no correlation emerged between cool and hot EF tasks. At the neural level, prefrontal activations during the cool EF tasks did not correlate with those during the hot EF task. Further, children showed stronger prefrontal activations during the DCCS tasks compared to the delay of gratification tasks. The results suggest that the neural basis of hot and cool EF may differ during early childhood.

Neuromodulatory effects of HD-tACS/tDCS on the prefrontal cortex: A resting-state fNIRS-EEG study.

Ghafoor U, Yang D, Hong KS.

IEEE J Biomed Health Inform. 2021 Nov 10;PP.
doi: 10.1109/JBHI.2021.3127080. Online ahead of print.

Transcranial direct and alternating current stimulation (tDCS and tACS, respectively) can modulate human brain dynamics and cognition. However, these modalities have not been compared using multiple imaging techniques concurrently. In this study, 15 participants participated in an experiment involving two sessions with a gap of 10 d. In the first and second sessions, tACS and tDCS were administered to the participants. The anode for tDCS was positioned at point FpZ, and four cathodes were positioned

over the left and right prefrontal cortices (PFCs) to target the frontal regions simultaneously. tDCS was administered with 1 mA current. tACS was supplied with a current of 1 mA (zero-to-peak value) at 10 Hz frequency. Stimulation was applied concomitantly with functional near-infrared spectroscopy and electroencephalography acquisitions in the resting-state. The statistical test showed significant alteration ($p < 0.001$) in the mean hemodynamic responses during and after tDCS and tACS periods. Between-group comparison revealed a significantly less ($p < 0.001$) change in the mean hemodynamic response caused by tACS compared with tDCS. As hypothesized, we successfully increased the hemodynamics in both left and right PFCs using tDCS and tACS. Moreover, a significant increase in alpha-band power ($p < 0.01$) and low beta band power ($p < 0.05$) due to tACS was observed after the stimulation period. Although tDCS is not frequency-specific, it increased but not significantly ($p > 0.05$) the powers of most bands including delta, theta, alpha, low beta, high beta, and gamma. These findings suggest that both hemispheres can be targeted and that both tACS and tDCS are equally effective in high-definition configurations, which may be of clinical relevance.

Functional near-infrared spectroscopy during the verbal fluency task of English-Speaking adults with mood disorders: A preliminary study.

Husain SF, McIntyre RS, Tang TB, Abd Latif MH, Tran BX, Linh VG, Thao TPN, Ho CS, Ho RC.
J Clin Neurosci. 2021 Dec;94:94-101.
doi: 10.1016/j.jocn.2021.10.009. Epub 2021 Oct 16.

Functional near-infrared spectroscopy (fNIRS) provides a direct and objective assessment of cerebral cortex function. It may be used to determine neurophysiological differences between psychiatric disorders with overlapping symptoms, such as major depressive disorder (MDD) and bipolar disorder (BD). Therefore, this preliminary study aimed to compare fNIRS signals during the verbal fluency task (VFT) of English-speaking healthy controls (HC), patients with MDD and patients with BD. Fifteen HCs, 15 patients with MDD and 15 patients with BD were recruited. Groups were matched for age, gender, ethnicity and education. Relative oxy-haemoglobin and deoxy-haemoglobin changes in the frontotemporal cortex was monitored with a 52-channel fNIRS system. Integral values of the frontal and temporal regions were derived as a measure cortical haemodynamic response magnitude. Both patient groups had lower frontal and temporal region integral values than HCs, and patients with MDD had lower frontal region integral value than patients with BD. Moreover, patients could be differentiated from HCs using the frontal and temporal integral values, and patient groups could be differentiated using the frontal region integral values. VFT performance, clinical history and symptom severity were not associated with integral values. These results suggest that prefrontal cortex haemodynamic dysfunction occurs in mood disorders, and it is more extensive in MDD than BD. The fNIRS-VFT paradigm may be a potential tool for differentiating MDD from BD in clinical settings, and these findings need to be verified in a larger sample of English-speaking patients with mood disorders.

Educational diversity and group creativity: Evidence from fNIRS hyperscanning.

Lu K, Qiao X, Yun Q, Hao N.
Neuroimage. 2021 Nov;243:118564.
doi: 10.1016/j.neuroimage.2021.118564. Epub 2021 Sep 7.

Educational diversity is defined as the diversity of educational backgrounds measured by multiple subjects. This study aimed to unveil the interpersonal neural correlates that underlie the effect of group educational diversity on group creativity. One hundred and sixteen college students were assigned to high educational diversity (HD; the members respectively majored in science or social science) or low educational diversity (LD; the members both majored in either science or social science) groups based on their academic majors. They were required to solve two problems that either demanded creativity (alternative uses task,

AUT) or not (object characteristics task). We used functional near-infrared spectroscopy (fNIRS)-based hyperscanning to simultaneously record the neural responses of pairs of interacting participants in each group. The LD group showed more AUT fluency and perspective-taking behaviours than the HD group, whereas no group difference was observed for AUT uniqueness. Additionally, collective flexibility was higher in the HD group than in the LD group. The fNIRS results showed that the interpersonal brain synchronisation (IBS) increments at the right angular gyrus and right primary somatosensory cortex were greater in the LD group than in the HD group. These findings indicate that although high educational diversity benefits cognitive flexibility, it does not necessarily lead to a better idea quality or greater idea quantity. The greater IBS increments and perspective-taking behaviours that we observed in the LD group may account for this.

A Motion Artifact Correction Procedure for fNIRS Signals Based on Wavelet Transform and Infrared Thermography Video Tracking.

Perpetuini D, Cardone D, Filippini C, Chiarelli AM, Merla A.
Sensors (Basel). 2021 Jul 28;21(15):5117.
doi: 10.3390/s21155117.

Functional near infrared spectroscopy (fNIRS) is a neuroimaging technique that allows to monitor the functional hemoglobin oscillations related to cortical activity. One of the main issues related to fNIRS applications is the motion artefact removal, since a corrupted physiological signal is not correctly indicative of the underlying biological process. A novel procedure for motion artifact correction for fNIRS signals based on wavelet transform and video tracking developed for infrared thermography (IRT) is presented. In detail, fNIRS and IRT were concurrently recorded and the optodes' movement was estimated employing a video tracking procedure developed for IRT recordings. The wavelet transform of the fNIRS signal and of the optodes' movement, together with their wavelet coherence, were computed. Then, the inverse wavelet transform was evaluated for the fNIRS signal excluding the frequency content corresponding to the optdes' movement and to the coherence in the epochs where they were higher with respect to an established threshold. The method was tested using simulated functional hemodynamic responses added to real resting-state fNIRS recordings corrupted by movement artifacts. The results demonstrated the effectiveness of the procedure in eliminating noise, producing results with higher signal to noise ratio with respect to another validated method.

Cardiorespiratory fitness and prefrontal cortex oxygenation during Stroop task in older males.

Goenarjo R, Dupuy O, Fraser S, Berryman N, Perrochon A, Bosquet L.
Physiol Behav. 2021 Dec 1;242:113621.
doi: 10.1016/j.physbeh.2021.113621. Epub 2021 Oct 12.

AIM: The aim of the current study was to assess whether executive function and prefrontal oxygenation are dependent on fitness level and age in older adults. METHODS: Twenty-four healthy males aged between 55 and 69 years old were recruited for this study. They were stratified by age, leading to the creation of two groups: 55-60 years old and 61-69 years old. A median split based on CRF created higher- and lower-fit categories of participants. Cerebral oxygenation was assessed using functional near-infrared spectroscopy (fNIRS) during a computerized Stroop task. Accuracy (% of correct responses) and reaction times (ms) were used as behavioural indicators of cognitive performances. Changes in oxygenated (?[HbO2]) and deoxygenated (?[HHb]) hemoglobin were measured to capture neural changes. Repeated measures ANOVAs (CRFAgeStroop conditions) were performed to test the null hypothesis of an absence of interaction between CRF, Age and executive performance. RESULTS: We also found an interaction between CRF and age on reaction times (p=.001), in which higher fitness levels were related to faster reaction times in the 61-69

year olds but not in the 55-60 year olds. Regarding ?HHb, the ANOVA revealed a main effect of CRF in the right PFC (p=.04), in which higher-fit participants had a greater ?[HHb] than the lower-fit (d=1.5). We also found fitness by age interaction for ?[HHb] in the right PFC (p=.04). CONCLUSION: Our results support the positive association of CRF on cerebral oxygenation and Stroop performance in healthy older males. They indicated that high-fit individuals performed better in the 61-69 year olds group, but not in the 55-60 years old group. We also observed a greater PFC oxygenation change (as measured by ?[HHb]) in the high-fit individuals.

Speech planning and execution in children who stutter: Preliminary findings from a fNIRS investigation.

Jackson ES, Wijeakumar S, Beal DS, Brown B, Zebrowski PM, Spencer JP.

J Clin Neurosci. 2021 Sep;91:32-42.
doi: 10.1016/j.jocn.2021.06.018. Epub 2021 Jun 28.

Few studies have investigated the neural mechanisms underlying speech production in children who stutter (CWS), despite the critical importance of understanding these mechanisms closer to the time of stuttering onset. The relative contributions of speech planning and execution in CWS therefore are also unknown. Using functional near-infrared spectroscopy, the current study investigated neural mechanisms of planning and execution in a small sample of 9-12year-old CWS and controls (N=12) by implementing two tasks that manipulated speech planning and execution loads. Planning was associated with atypical activation in bilateral inferior frontal gyrus and right supramarginal gyrus. Execution was associated with atypical activation in bilateral precentral gyrus and inferior frontal gyrus, as well as right supramarginal gyrus and superior temporal gyrus. The CWS exhibited some activation patterns that were similar to the adults who stutter (AWS) as reported in our previous study: atypical planning in frontal areas including left inferior frontal gyrus and atypical execution in fronto-temporo-parietal regions including left precentral gyrus, and right inferior frontal, superior temporal, and supramarginal gyri. However, differences also emerged. Whereas CWS and AWS both appear to exhibit atypical activation in right inferior and supramarginal gyri during execution, only CWS appear to exhibit this same pattern during planning. In addition, the CWS appear to exhibit atypical activation in left inferior frontal and right precentral gyri related to execution, whereas AWS do not. These preliminary results are discussed in the context of possible impairments in sensorimotor integration and inhibitory control for CWS.

Decoding a Music-Modulated Cognitive Arousal State using Electrodermal Activity and Functional Near-infrared Spectroscopy Measurements.

Yaghmour A, Rafiul Amin M, Faghih RT.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:1055-1060.
doi: 10.1109/EMBC46164.2021.9630879.

Biofeedback systems sense different physiological activities and help with gaining self-awareness. Understanding music's impact on the arousal state is of great importance for biofeedback stress management systems. In this study, we investigate a cognitive-stress-related arousal state modulated by different types of music. During our experiments, each subject was presented with neurological stimuli that elicit a cognitive-stress-related arousal response in a working memory experiment. Moreover, this cognitive-stress-related arousal was modulated by calming and vexing music played in the background. Electrodermal activity and functional near-infrared spectroscopy (fNIRS) measurements both contain information related to cognitive arousal and were collected in our study. By considering various fNIRS features, we selected three features based on variance, root mean square, and local fNIRS peaks as the most informative fNIRS observations in terms of cognitive arousal. The rate of neural impulse occurrence underlying EDA was taken as a binary observation. To retain a low computational complexity for our decoder and select the best fNIRS-based

observations, two features were chosen as fNIRS-based observations at a time. A decoder based on one binary and two continuous observations was utilized to estimate the hidden cognitive-stress-related arousal state. This was done by using a Bayesian filtering approach within an expectation-maximization framework. Our results indicate that the decoded cognitive arousal modulated by vexing music was higher than calming music. Among the three fNIRS observations selected, a combination of observations based on root mean square and local fNIRS peaks resulted in the best decoded states for our experimental settings. This study serves as a proof of concept for utilizing fNIRS and EDA measurements to develop a low-dimensional decoder for tracking cognitive-stress-related arousal levels.

Neural synchrony predicts children's learning of novel words.

Piazza EA, Cohen A, Trach J, Lew-Williams C.

Cognition. 2021 Sep;214:104752.
doi: 10.1016/j.cognition.2021.104752. Epub 2021 May 6.

Social interactions, such as joint book reading, have a well-studied influence on early development and language learning. Recent work has begun to investigate the neural mechanisms that underlie shared representations of input, documenting neural synchrony (measured using intersubject temporal correlations of neural activity) between individuals exposed to the same stimulus. Neural synchrony has been found to predict the quality of engagement with a stimulus and with communicative cues, but studies have yet to address how neural synchrony among children may relate to real-time learning. Using functional near-infrared spectroscopy (fNIRS), we recorded the neural activity of 45 children (3.5-4.5years) during joint book reading with an adult experimenter. The custom children's book contained four novel words and objects embedded in an unfolding story, as well as a range of narrative details about object functions and character roles. We observed synchronized neural activity between child participants during book reading and found a positive correlation between learning and intersubject neural synchronization in parietal cortex, an area implicated in narrative-level processing in adult research. Our findings suggest that signature patterns of neural engagement with the dynamics of stories facilitate children's learning.

Effect of exergaming versus combined exercise on cognitive function and brain activation in frail older adults: A randomised controlled trial.

Liao YY, Chen IH, Hsu WC, Tseng HY, Wang RY.

Ann Phys Rehabil Med. 2021 Sep;64(5):101492.
doi: 10.1016/j.rehab.2021.101492. Epub 2021 Jul 15.

BACKGROUND: Cognitive impairment is prevalent among frail older adults. Traditional exercise and exergaming positively affect cognition in healthy older people. However, few studies have investigated the effects of exergaming on cognition and brain activation in frail older adults. OBJECTIVE: This study compared the effect of Kinect based exergaming (EXER) and combined physical exercise (CPE) training on cognitive function and brain activation in frail older adults in Taiwan. We hypothesised that EXER would be superior to CPE in this population. METHODS: We randomised 46 community-dwelling frail older adults to the EXER or CPE group for 36 sessions (three 60-min training sessions per week) over 12 weeks. Outcome measures for cognitive function included global cognition measured by the Montreal Cognitive Assessment, executive function measured by the Executive Interview 25, verbal memory measured by the Chinese version of the California Verbal Learning Test, attention measured by the Stroop Colour and Word Test and Trail Making Test (part B), and working memory measured by spatial n-back tests. Prefrontal cortex activation during the global cognition test was documented with functional near-infrared spectroscopy (fNIRS). RESULTS: Both groups improved significantly in global cognition ($P<0.05$), executive function ($P<0.05$), and attention ($P<0.05$) after the 12-week intervention. The grouptime interaction indicated that EXER training significantly enhanced global cognition more than

CPE training (F(1,44)=5.277, P=0.026). Moreover, only the EXER group showed significant improvements in verbal (P<0.05) and working (P<0.05) memory after the intervention. The fNIRS hemodynamics data revealed decreased activation in prefrontal cortices of both groups (P<0.05) during the post-training cognitive assessment, thereby suggesting greater neural efficiency; however, we found no significant group difference. CONCLUSION: In frail older adults, exergaming and CPE could improve cognitive function, most likely by increasing neural efficiency. Moreover, exergaming may be superior to CPE, particularly in improving global cognition.

Cognitive and Motor Cortical Activity During Cognitively Demanding Stepping Tasks in Older People at Low and High Risk of Falling.

Pelicioni PHS, Lord SR, Sturnieks DL, Halmy B, Menant JC.

Front Med (Lausanne). 2021 Jul 12;8:554231.
doi: 10.3389/fmed.2021.554231. eCollection 2021.

Background: Choice stepping reaction time tasks are underpinned by neuropsychological, sensorimotor, and balance systems and therefore offer good indices of fall risk and physical and cognitive frailty. However, little is known of the neural mechanisms for impaired stepping and associated fall risk in older people. We investigated cognitive and motor cortical activity during cognitively demanding stepping reaction time tasks using functional near-infrared spectroscopy (fNIRS) in older people at low and high fall risk. Methods: Ninety-five older adults [mean (SD) 71.4 (4.9) years, 23 men] were categorized as low or high fall risk [based on 12-month fall history (=2 falls) and/or Physiological Profile Assessment fall risk score =1]. Participants performed a choice stepping reaction time test and a more cognitively demanding Stroop stepping task on a computerized step mat. Cortical activity in cognitive [dorsolateral prefrontal cortex (DLPFC)] and motor (supplementary motor area and premotor cortex) regions was recorded using fNIRS. Stepping performance and cortical activity were contrasted between the groups and between the choice and Stroop stepping conditions. Results: Compared with the low fall risk group (n = 71), the high fall risk group (n = 24) exhibited significantly greater DLPFC activity and increased intra-individual variability in stepping response time during the Stroop stepping task. The high fall risk group DLPFC activity was greater during the performance of Stroop stepping task in comparison with choice stepping reaction time. Regardless of group, the Stroop stepping task elicited increased cortical activity in the supplementary motor area and premotor cortex together with increased mean and intra-individual variability of stepping response times. Conclusions: Older people at high fall risk exhibited increased DLPFC activity and stepping response time variability when completing a cognitively demanding stepping test compared with those at low fall risk and to a simpler choice-stepping reaction time test. This increased hemodynamic response might comprise a compensatory process for postural control deficits and/or reflect a degree of DLPFC neural inefficiency in people with increased fall risk.

Bidirectional Connectivity Between Broca's Area and Wernicke's Area During Interactive Verbal Communication.

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

Brain Connect. 2021 Jul 26.
doi: 10.1089/brain.2020.0790. Online ahead of print.

Aim: This investigation aims to advance the understanding of neural dynamics that underlies live and natural interactions during spoken dialogue between two individuals. Introduction: The underlying hypothesis is that functional connectivity between canonical speech areas in the human brain will be modulated by social interaction. Methods: Granger causality was applied to compare directional connectivity across Broca's and Wernicke's areas during verbal conditions consisting of interactive and noninteractive communication. Thirty-three pairs of healthy adult participants alternately talked and listened to each other

while performing an object naming and description task that was either interactive or not during hyperscanning with functional near-infrared spectroscopy (fNIRS). In the noninteractive condition, the speaker named and described a picture-object without reference to the partner's description. In the interactive condition, the speaker performed the same task but included an interactive response about the preceding comments of the partner. Causality measures of hemodynamic responses from Broca's and Wernicke's areas were compared between real, surrogate, and shuffled trials within dyads. Results: The interactive communication was characterized by bidirectional connectivity between Wernicke's and Broca's areas of the listener's brain. Whereas this connectivity was unidirectional in the speaker's brain. In the case of the noninteractive condition, both speaker's and listener's brains showed unidirectional top-down (Broca's area to Wernicke's area) connectivity. Conclusion: Together, directional connectivity as determined by Granger analysis reveals bidirectional flow of neuronal information during dynamic two-person verbal interaction for processes that are active during listening (reception) and not during talking (production). Findings are consistent with prior contrast findings (general linear model) showing neural modulation of the receptive language system associated with Wernicke's area during a two-person live interaction. Impact statement The neural dynamics that underlies real-life social interactions is an emergent topic of interest. Dynamically coupled cross-brain neural mechanisms between interacting partners during verbal dialogue have been shown within Wernicke's area. However, it is not known how within-brain long-range neural mechanisms operate during these live social functions. Using Granger causality analysis, we show bidirectional neural activity between Broca's and Wernicke's areas during interactive dialogue compared with a noninteractive control task showing only unidirectional activity. Findings are consistent with an Interactive Brain Model where long-range neural mechanisms process interactive processes associated with rapid and spontaneous spoken social cues.

Looking Back at the Next 40 Years of ASD Neuroscience Research.

McPartland JC, Lerner MD, Bhat A, Clarkson T, Jack A, Koohsari S, Matuskey D, McQuaid GA, Su WC, Trevisan DA.

J Autism Dev Disord. 2021 Dec;51(12):4333-4353.
doi: 10.1007/s10803-021-05095-5. Epub 2021 May 27.

During the last 40years, neuroscience has become one of the most central and most productive approaches to investigating autism. In this commentary, we assemble a group of established investigators and trainees to review key advances and anticipated developments in neuroscience research across five modalities most commonly employed in autism research: magnetic resonance imaging, functional near infrared spectroscopy, positron emission tomography, electroencephalography, and transcranial magnetic stimulation. Broadly, neuroscience research has provided important insights into brain systems involved in autism but not yet mechanistic understanding. Methodological advancements are expected to proffer deeper understanding of neural circuitry associated with function and dysfunction during the next 40years.

Hemodynamic changes in athletes' brains: is there any adaptation?

Manci E, Deniz OC, Guducu C, Gunay E, Bediz CS.

Gen Physiol Biophys. 2021 Sep;40(5):387-396.
doi: 10.4149/gpb_2021027.

This study compared the hemodynamic changes in the prefrontal cortex during sprint interval training (SIT) and recovery periods in sedentary and athletes. SIT was performed on a cycling ergometer on 12 male athletes and 9 sedentary participants. A functional near-infrared spectroscopy (fNIRS) device was used to record the hemodynamic changes of the prefrontal cortex throughout the protocol. The oxyhemoglobin (Oxy-Hb) levels in the prefrontal cortex were increased significantly, and the power outputs were decreased in repetitive Wingate anaerobic tests (WAnTs) in Sedentary and Athletes group ($p < 0.001$). In addition,

the Sedentary group had higher Oxy-Hb values ($p < 0.001$). However, the recovery times decreased significantly after all WAnTs ($p < 0.05$). Despite the increased fatigue, athletes performed better with less Oxy-Hb than the sedentary participants. Also, the recovery of the Oxy-Hb values in the prefrontal region was faster in athletes. These results may highlight a possible brain adaptation in athletes.

The neurodevelopmental basis of humor appreciation: A fNIRS study of young children.

Mayseless N, Reiss AL.

PLoS One. 2021 Dec 8;16(12):e0259422.
doi: 10.1371/journal.pone.0259422. eCollection 2021.

Humor is crucial for social development. Despite this, very few studies have examined the neurodevelopment of humor in very young children, and none to date have used functional near-infrared spectroscopy (fNIRS) to study this important cognitive construct. The main aim of the current study was to characterize the neural basis of humor processing in young children between the ages of 6-8 years. Thirty-five healthy children (6-8 years old) watched funny and neutral video clips while undergoing fNIRS imaging. We observed activation increases in left temporo-occipito-parietal junction (TOPJ), inferior-parietal lobe (IPL), dorsolateral-prefrontal cortex (DLPFC) and right inferior frontal gyrus (IFG) and superior parietal lobe (SPL) regions. Activation in left TOPJ was positively correlated with age. In addition, we found that coherence increased in humor viewing compared to neutral content, mainly between remote regions. This effect was different for boys and girls, as boys showed a more pronounced increase in coherence for funny compared to neutral videos, more so in frontoparietal networks. These results expand our understanding of the neurodevelopment of humor by highlighting the effect of age on the neural basis of humor appreciation as well as emphasizing different developmental trajectories of boys and girls.

Ventrolateral prefrontal hemodynamic responses in autism spectrum disorder with and without depression.

Ohtani T, Wakabayashi A, Sutoh C, Oshima F, Hirano Y, Shimizu E.

PLoS One. 2021 Aug 27;16(8):e0256780.
doi: 10.1371/journal.pone.0256780. eCollection 2021.

In clinical settings, autism spectrum disorder (ASD) with comorbid depression is often difficult to diagnose, and should be considered in treatment. However, to our knowledge, no functional imaging study has examined the difference between ASD adolescents with and without comorbid depression. We aimed to compare the characteristics and prefrontal brain function of ASD with and without depression in order to identify a biological marker that can be used to detect the difference. Twenty-eight drug-nave adolescents with ASD (14 ASD with and 14 ASD without depression) and 14 age- and gender-matched adolescents with typical development were evaluated using several variables. These included intelligence quotient, autism quotient, depression severity using the Beck Depression Inventory 2nd edition (BDI-II), and level of social functioning using the Social Adaptation Self-evaluation Scale (SASS). In addition, frontotemporal hemodynamic responses during a verbal fluency task (VFT) were measured using functional near-infrared spectroscopy (fNIRS). The ASD group, including both of the ASD with and ASD without depression groups, showed smaller hemodynamic responses than the typical development group in portions of the left dorsolateral prefrontal cortex (DLPFC), bilateral ventrolateral prefrontal cortex (VLPFC) and anterior part of the temporal cortex (aTC) during the VFT. Moreover, the smaller hemodynamic responses in the right VLPFC during the VFT in the ASD group were associated with the worse BDI-II and SASS scores. Furthermore, the ASD with depression group showed smaller hemodynamic responses in the right VLPFC during the VFT than the ASD without depression group in a direct comparison. Adolescents with ASD showed reduced activation in broad frontotemporal regions during a cognitive task compared with those

with typical development. More specifically, the right VLPFC activation reflected the level of self-estimated depression and social functioning in the ASD subjects, and could be used to discriminate between ASD adolescents with and without depression.

Examining the relationships among adolescent health behaviours, prefrontal function, and academic achievement using fNIRS.

Papasideris M, Ayaz H, Safati AB, Morita PP, Hall PA.

Dev Cogn Neurosci. 2021 Aug;50:100983.
doi: 10.1016/j.dcn.2021.100983. Epub 2021 Jul 1.

Several adolescent health behaviours have been hypothesized to improve academic performance via their beneficial impact on cognitive control and functional aspects of the prefrontal cortex (PFC). The primary objective of this study is to examine the association between lifestyle behaviours and academic performance in a sample of adolescents, and to examine the extent to which activity within the PFC and behavioural indices of inhibition may mediate this relationship. Sixty-seven adolescents underwent two study sessions five days apart. Sleep and physical activity were measured using wrist-mounted accelerometry; eating habits, substance use and academic achievement were measured by self-report. Prefrontal function was quantified by Multi-Source Interference Task (MSIT) performance, and task-related activity via functional near-infrared spectroscopy (fNIRS). Higher levels of physical activity predicted higher MSIT accuracy scores (= .321, ? = 0.019) as well as greater activation within the right dlPFC (b = .008, SE = .004, ? = .0322). Frequency of fast-food consumption and substance use were negatively associated with MSIT accuracy scores (= -0.307, ? = .023) and Math grades (b = -3.702, SE = 1.563, ? = .022), respectively. Overall, the results of this study highlight the importance of lifestyle behaviours as predictors of prefrontal function and academic achievement in youth.

Intraoperative Resting-State Functional Connectivity Based on RGB Imaging.

Caredda C, Mahieu-Williame L, Sablong R, Sdika M, Schneider FC, Guyotat J, Montcel B.

Diagnostics (Basel). 2021 Nov 9;11(11):2067.
doi: 10.3390/diagnostics11112067.

RGB optical imaging is a marker-free, contactless, and non-invasive technique that is able to monitor hemodynamic brain response following neuronal activation using task-based and resting-state procedures. Magnetic resonance imaging (fMRI) and functional near infra-red spectroscopy (fNIRS) resting-state procedures cannot be used intraoperatively but RGB imaging provides an ideal solution to identify resting-state networks during a neurosurgical operation. We applied resting-state methodologies to intraoperative RGB imaging and evaluated their ability to identify resting-state networks. We adapted two resting-state methodologies from fMRI for the identification of resting-state networks using intraoperative RGB imaging. Measurements were performed in 3 patients who underwent resection of lesions adjacent to motor sites. The resting-state networks were compared to the identifications provided by RGB task-based imaging and electrical brain stimulation. Intraoperative RGB resting-state networks corresponded to RGB task-based imaging (DICE:0.550.29). Resting state procedures showed a strong correspondence between them (DICE:0.660.11) and with electrical brain stimulation. RGB imaging is a relevant technique for intraoperative resting-state networks identification. Intraoperative resting-state imaging has several advantages compared to functional task-based analyses: data acquisition is shorter, less complex, and less demanding for the patients, especially for those unable to perform the tasks.

The Neural Processing of Vocal Emotion After Hearing Reconstruction in Prelingual

Deaf Children: A Functional Near-Infrared Spectroscopy Brain Imaging Study.

Wang Y, Liu L, Zhang Y, Wei C, Xin T, He Q, Hou X, Liu Y.

Front Neurosci. 2021 Jul 28;15:705741.
doi: 10.3389/fnins.2021.705741. eCollection 2021.

As elucidated by prior research, children with hearing loss have impaired vocal emotion recognition compared with their normal-hearing peers. Cochlear implants (CIs) have achieved significant success in facilitating hearing and speech abilities for people with severe-to-profound sensorineural hearing loss. However, due to the current limitations in neuroimaging tools, existing research has been unable to detail the neural processing for perception and the recognition of vocal emotions during early stage CI use in infant and toddler CI users (ITCI). In the present study, functional near-infrared spectroscopy (fNIRS) imaging was employed during preoperative and postoperative tests to describe the early neural processing of perception in prelingual deaf ITCIs and their recognition of four vocal emotions (fear, anger, happiness, and neutral). The results revealed that the cortical response elicited by vocal emotional stimulation on the left pre-motor and supplementary motor area (pre-SMA), right middle temporal gyrus (MTG), and right superior temporal gyrus (STG) were significantly different between preoperative and postoperative tests. These findings indicate differences between the preoperative and postoperative neural processing associated with vocal emotional stimulation. Further results revealed that the recognition of vocal emotional stimuli appeared in the right supramarginal gyrus (SMG) after CI implantation, and the response elicited by fear was significantly greater than the response elicited by anger, indicating a negative bias. These findings indicate that the development of emotional bias and the development of emotional perception and recognition capabilities in ITCIs occur on a different timeline and involve different neural processing from those in normal-hearing peers. To assess the speech perception and production abilities, the Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS) and Speech Intelligibility Rating (SIR) were used. The results revealed no significant differences between preoperative and postoperative tests. Finally, the correlates of the neurobehavioral results were investigated, and the results demonstrated that the preoperative response of the right SMG to anger stimuli was significantly and positively correlated with the evaluation of postoperative behavioral outcomes. And the postoperative response of the right SMG to anger stimuli was significantly and negatively correlated with the evaluation of postoperative behavioral outcomes.

Modifications in Prefrontal Cortex Oxygenation in Linear and Curvilinear Dual Task Walking: A Combined fNIRS and IMUs Study.

Belluscio V, Casti G, Ferrari M, Quaresima V, Sappia MS, Horschig JM, Vannozzi G.

Sensors (Basel). 2021 Sep 14;21(18):6159.
doi: 10.3390/s21186159.

Increased oxygenated hemoglobin concentration of the prefrontal cortex (PFC) has been observed during linear walking, particularly when there is a high attention demand on the task, like in dual-task (DT) paradigms. Despite the knowledge that cognitive and motor demands depend on the complexity of the motor task, most studies have only focused on usual walking, while little is known for more challenging tasks, such as curved paths. To explore the relationship between cortical activation and gait biomechanics, 20 healthy young adults were asked to perform linear and curvilinear walking trajectories in single-task and DT conditions. PFC activation was assessed using functional near-infrared spectroscopy, while gait quality with four inertial measurement units. The Figure-of-8-Walk-Test was adopted as the curvilinear trajectory, with the "Serial 7s" test as concurrent cognitive task. Results show that walking along curvilinear trajectories in DT led to increased PFC activation and decreased motor performance. Under DT walking, the neural correlates of executive function and gait control tend to be modified in response to the cognitive resources imposed by the motor task. Being more representative of real-life situations, this approach to curved walking has the potential to reveal crucial information and to improve people' s balance, safety, and life's quality.

Functional Brain Network Analysis of Knowledge Transfer While Engineering Problem-Solving.

Wang F, Jiang Z, Li X, Bu L, Ji Y.

Front Hum Neurosci. 2021 Oct 25;15:713692.
doi: 10.3389/fnhum.2021.713692. eCollection 2021.

As a complex cognitive activity, knowledge transfer is mostly correlated to cognitive processes such as working memory, behavior control, and decision-making in the human brain while engineering problem-solving. It is crucial to explain how the alteration of the functional brain network occurs and how to express it, which causes the alteration of the cognitive structure of knowledge transfer. However, the neurophysiological mechanisms of knowledge transfer are rarely considered in existing studies. Thus, this study proposed functional connectivity (FC) to describe and evaluate the dynamic brain network of knowledge transfer while engineering problem-solving. In this study, we adopted the modified Wisconsin Card-Sorting Test (M-WCST) reported in the literature. The neural activation of the prefrontal cortex was continuously recorded for 31 participants using functional near-infrared spectroscopy (fNIRS). Concretely, we discussed the prior cognitive level, knowledge transfer distance, and transfer performance impacting the wavelet amplitude and wavelet phase coherence. The paired t-test results showed that the prior cognitive level and transfer distance significantly impact FC. The Pearson correlation coefficient showed that both wavelet amplitude and phase coherence are significantly correlated to the cognitive function of the prefrontal cortex. Therefore, brain FC is an available method to evaluate cognitive structure alteration in knowledge transfer. We also discussed why the dorsolateral prefrontal cortex (DLPFC) and occipital face area (OFA) distinguish themselves from the other brain areas in the M-WCST experiment. As an exploratory study in NeuroManagement, these findings may provide neurophysiological evidence about the functional brain network of knowledge transfer while engineering problem-solving.

Measurement of the Directional Information Flow in fNIRS-Hyperscanning Data using the Partial Wavelet Transform Coherence Method.

Zhou S(#), Long Y(#), Lu C.

J Vis Exp. 2021 Sep 3;(175).
doi: 10.3791/62927.

Social interaction is of vital importance for human beings. While the hyperscanning approach has been extensively used to study interpersonal neural synchronization (INS) during social interactions, functional near-infrared spectroscopy (fNIRS) is one of the most popular techniques for hyperscanning naturalistic social interactions because of its relatively high spatial resolution, sound anatomical localization, and exceptionally high tolerance of motion artifacts. Previous fNIRS-based hyperscanning studies usually calculate a time-lagged INS using wavelet transform coherence (WTC) to describe the direction and temporal pattern of information flow between individuals. However, the results of this method might be confounded by the autocorrelation effect of the fNIRS signal of each individual. For addressing this issue, a method termed partial wavelet transform coherence (pWTC) was introduced, which aimed to remove the autocorrelation effect and maintain the high temporal-spectrum resolution of the fNIRS signal. In this study, a simulation experiment was performed first to show the effectiveness of the pWTC in removing the impact of autocorrelation on INS. Then, step-by-step guidance was offered on the operation of the pWTC based on the fNIRS dataset from a social interaction experiment. Additionally, a comparison between the pWTC method and the traditional WTC method and that between the pWTC method and the Granger causality (GC) method was drawn. The results showed that pWTC could be used to determine the INS difference between different experimental conditions and INS's directional and temporal pattern between individuals during naturalistic social interactions. Moreover, it provides better temporal and frequency resolution than the traditional WTC and better flexibility than the GC method. Thus, pWTC is a strong candidate for

inferring the direction and temporal pattern of information flow between individuals during naturalistic social interactions.

Interpersonal Neural Synchrony During Father-Child Problem Solving: An fNIRS Hyperscanning Study.

Nguyen T, Schleihauf H, Kungl M, Kayhan E, Hoehl S, Vrticka P.
Child Dev. 2021 Jul;92(4):e565-e580.
doi: 10.1111/cdev.13510. Epub 2021 Jan 10.

Interpersonal neural synchrony (INS) has been previously evidenced in mother-child interactions, yet findings concerning father-child interaction are wanting. The current experiment examined whether fathers and their 5- to 6-year-old children (N=66) synchronize their brain activity during a naturalistic interaction, and addressed paternal and child factors related to INS. Compared to individual problem solving and rest, father-child dyads showed increased INS in bilateral dorsolateral prefrontal cortex and left temporo-parietal junction during cooperative problem solving. Furthermore, the father's attitude toward his role as a parent was positively related to INS during the cooperation condition. These results highlight the implication of the father's attitude to parenting in INS processes for the first time.

Evaluation of a personalized functional near infra-red optical tomography workflow using maximum entropy on the mean.

Cai Z, Uji M, Aydin , Pellegrino G, Spilkin A, Delaire , Abdallah C, Lina JM, Grova C.
Hum Brain Mapp. 2021 Oct 15;42(15):4823-4843.
doi: 10.1002/hbm.25566. Epub 2021 Aug 3.

In the present study, we proposed and evaluated a workflow of personalized near infra-red optical tomography (NIROT) using functional near-infrared spectroscopy (fNIRS) for spatiotemporal imaging of cortical hemodynamic fluctuations. The proposed workflow from fNIRS data acquisition to local 3D reconstruction consists of: (a) the personalized optimal montage maximizing fNIRS channel sensitivity to a predefined targeted brain region; (b) the optimized fNIRS data acquisition involving installation of optodes and digitalization of their positions using a neuronavigation system; and (c) the 3D local reconstruction using maximum entropy on the mean (MEM) to accurately estimate the location and spatial extent of fNIRS hemodynamic fluctuations along the cortical surface. The workflow was evaluated on finger-tapping fNIRS data acquired from 10 healthy subjects for whom we estimated the reconstructed NIROT spatiotemporal images and compared with functional magnetic resonance imaging (fMRI) results from the same individuals. Using the fMRI activation maps as our reference, we quantitatively compared the performance of two NIROT approaches, the MEM framework and the conventional minimum norm estimation (MNE) method. Quantitative comparisons were performed at both single subject and group-level. Overall, our results suggested that MEM provided better spatial accuracy than MNE, while both methods offered similar temporal accuracy when reconstructing oxygenated (HbO) and deoxygenated hemoglobin (HbR) concentration changes evoked by finger-tapping. Our proposed complete workflow was made available in the brainstorm fNIRS processing plugin-NIRSTORM, thus providing the opportunity for other researchers to further apply it to other tasks and on larger populations.

EEG Electrode Selection for a Two-Class Motor Imagery Task in a BCI Using fNIRS Prior Data.

Moslehi AH, Davies TC.
Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:6627-6630.

doi: 10.1109/EMBC46164.2021.9630786.

This study investigated the possibility of using functional near infrared spectroscopy (fNIRS) during right- and left-hand motor imagery tasks to select an optimum set of electroencephalography (EEG) electrodes for a brain computer interface. fNIRS has better spatial resolution allowing areas of brain activity to more readily be identified. The ReliefF algorithm was used to identify the most reliable fNIRS channels. Then, EEG electrodes adjacent to those channels were selected for classification. This study used three different classifiers of linear and quadratic discriminant analyses, and support vector machine to examine the proposed method.Clinical Relevance- Reducing the number of sensors in a BCI makes the system more usable for patients with severe disabilities.

A Chiral fNIRS Spotlight on Cerebellar Activation in a Finger Tapping Task.

Rocco G, Lebrun J, Meste O, Magnie-Mauro MN.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:1018-1021.
doi: 10.1109/EMBC46164.2021.9629565.

Functional Magnetic Resonance Imaging (fMRI) has been so far the golden standard to study the functional aspects of the cerebellum. In this paper, a low-cost alternative imaging, i.e. functional Near-Infrared Spectroscopy (fNIRS) is demonstrated to achieve successful measurements of the cerebellar hemodynamics towards the challenging observation of motor and cognitive processes at the cerebellar level. The excitation and reception optodes need to be properly placed to circumvent a major hindering from the shielding by the neck muscles. A simple experimental protocol, i.e. finger tapping task, was implemented to observe the subject's engagement and the presence of functional asymmetries. Marked differences among subjects with different levels of lateralization were clearly noticed in terms of activation and latencies, together with peaks in the hemodynamic response following neural activation. These preliminary results suggest also differences in the hemodynamic behavior between the brain and the cerebellum and encourage future and extended analysis in this direction.Clinical Relevance-This establishes the possibility to use a novel technique (fNIRS) to study cerebellar hemodynamics instead of fMRI.

Cerebral hemodynamic response during a live action-observation and action-execution task: A fNIRS study.

Miguel HO, Condy EE, Nguyen T, Zeytinoglu S, Blick E, Bress K, Khaksari K, Dashtestani H, Millerhagen J, Shahmohammadi S, Fox NA, Gandjbakhche A.

PLoS One. 2021 Aug 13;16(8):e0253788.
doi: 10.1371/journal.pone.0253788. eCollection 2021.

Although many studies have examined the location of the action observation network (AON) in human adults, the shared neural correlates of action-observation and action-execution are still unclear partially due to lack of ecologically valid neuroimaging measures. In this study, we aim to demonstrate the feasibility of using functional near infrared spectroscopy (fNIRS) to measure the neural correlates of action-observation and action execution regions during a live task. Thirty adults reached for objects or observed an experimenter reaching for objects while their cerebral hemodynamic responses including oxy-hemoglobin (HbO) and deoxy-hemoglobin (HbR) were recorded in the sensorimotor and parietal regions. Our results indicated that the parietal regions, including bilateral superior parietal lobule (SPL), bilateral inferior parietal lobule (IPL), right supra-marginal region (SMG) and right angular gyrus (AG) share neural activity during action-observation and action-execution. Our findings confirm the applicability of fNIRS for the study of the AON and lay the foundation for future work with developmental and clinical populations.

An Overview on Cognitive Function Enhancement through Physical Exercises.

Srinivas NS, Vimalan V, Padmanabhan P, Gulys B.

Brain Sci. 2021 Sep 29;11(10):1289.
doi: 10.3390/brainsci11101289.

This review is extensively focused on the enhancement of cognitive functions while performing physical exercises categorized into cardiovascular exercises, resistance training, martial arts, racquet sports, dancing and mind-body exercises. Imaging modalities, viz. functional magnetic resonance imaging (fMRI), functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG), have been included in this review. This review indicates that differences are present in cognitive functioning while changing the type of physical activity performed. This study concludes that employing fNIRS helps overcome certain limitations of fMRI. Further, the effects of physical activity on a diverse variety of the population, from active children to the old people, are discussed.

Brief Report: Classification of Autistic Traits According to Brain Activity Recoded by fNIRS Using e-Complexity Coefficients.

Dahan A, Dubnov YA, Popkov AY, Gutman I, Probolovski HG.

J Autism Dev Disord. 2021 Sep;51(9):3380-3390.
doi: 10.1007/s10803-020-04793-w. Epub 2020 Nov 18.

Individuals with ASD have been shown to have different pattern of functional connectivity. In this study, brain activity of participants with many and few autistic traits, was recorded using an fNIRS device, as participants preformed an interpersonal synchronization task. This type of task involves synchronization and functional connectivity of different brain regions. A novel method for assessing signal complexity, using e-complexity coefficients, applied for the first i.e. on fNIRS recording, was used to classify brain recording of participants with many/few autistic traits. Successful classification was achieved implying that this method may be useful for classification of fNIRS recordings and that there is a difference in brain activity between participants with low and high autistic traits as they perform an interpersonal synchronization task.

Genetic variation in the oxytocin system and its link to social motivation in human infants.

Krol KM, Namaky N, Monakhov MV, Lai PS, Ebstein R, Grossmann T.

Psychoneuroendocrinology. 2021 Sep;131:105290.
doi: 10.1016/j.psyneuen.2021.105290. Epub 2021 May 29.

Frontal brain asymmetry has been linked to motivational processes in infants and adults, with left lateralization reflecting motivation to approach and right lateralization reflecting motivation to withdraw. We examined the hypothesis that variability in infants' social motivation may be linked to genetic variation in the oxytocin system. Eleven-month-old infants' brain responses and looking preferences to smiling and frowning individuals were assessed in conjunction with a polymorphism in CD38 (rs3796863) linked to autism spectrum disorder (ASD) and reduced oxytocin. Frontal brain asymmetry and looking preferences differed as a function of CD38 genotype. While non-risk A-allele carriers displayed left lateralization to smiling faces (approach) and a heightened looking preference for the individual who smiled, infants with the CC (ASD risk) genotype displayed withdrawal from smiling faces and a preference for the individual who frowned. Findings demonstrate that the oxytocin system is linked to brain and behavioral markers of social motivation in infancy.

Speech token detection and discrimination in individual infants using functional near-infrared spectroscopy.

Mao D, Wunderlich J, Savkovic B, Jeffreys E, Nicholls N, Lee OW, Eager M, McKay CM.
Sci Rep. 2021 Dec 14;11(1):24006.
doi: 10.1038/s41598-021-03595-z.

Speech detection and discrimination ability are important measures of hearing ability that may inform crucial audiological intervention decisions for individuals with a hearing impairment. However, behavioral assessment of speech discrimination can be difficult and inaccurate in infants, prompting the need for an objective measure of speech detection and discrimination ability. In this study, the authors used functional near-infrared spectroscopy (fNIRS) as the objective measure. Twenty-three infants, 2 to 10months of age participated, all of whom had passed newborn hearing screening or diagnostic audiology testing. They were presented with speech tokens at a comfortable listening level in a natural sleep state using a habituation/dishabituation paradigm. The authors hypothesized that fNIRS responses to speech token detection as well as speech token contrast discrimination could be measured in individual infants. The authors found significant fNIRS responses to speech detection in 87% of tested infants (false positive rate 0%), as well as to speech discrimination in 35% of tested infants (false positive rate 9%). The results show initial promise for the use of fNIRS as an objective clinical tool for measuring infant speech detection and discrimination ability; the authors highlight the further optimizations of test procedures and analysis techniques that would be required to improve accuracy and reliability to levels needed for clinical decision-making.

Disentangling age and schooling effects on inhibitory control development: An fNIRS investigation.

McKay C, Wijeakumar S, Rafetseder E, Shing YL.
Dev Sci. 2021 Dec 5:e13205.
doi: 10.1111/desc.13205. Online ahead of print.

Children show marked improvements in executive functioning (EF) between 4 and 7years of age. In many societies, this time period coincides with the start of formal school education, in which children are required to follow rules in a structured environment, drawing heavily on EF processes such as inhibitory control. This study aimed to investigate the longitudinal development of two aspects of inhibitory control, namely response inhibition and response monitoring and their neural correlates. Specifically, we examined how their longitudinal development may differ by schooling experience, and their potential significance in predicting academic outcomes. Longitudinal data were collected in two groups of children at their homes. At T1, all children were roughly 4.5 years of age and neither group had attended formal schooling. One year later at T2, one group (P1, n=40) had completed one full year of schooling while the other group (KG, n=40) had stayed in kindergarten. Behavioural and brain activation data (measured with functional near-infrared spectroscopy, fNIRS) in response to a Go/No-Go task and measures of academic achievement were collected. We found that P1 children, compared to KG children, showed a greater change over time in activation related to response monitoring in the bilateral frontal cortex. The change in left frontal activation difference showed a small positive association with math performance. Overall, the school environment is important in shaping the development of the brain functions underlying the monitoring of one own's performance.

Motor Cortex Activation During Writing in Focal Upper-Limb Dystonia: An fNIRS Study.

Pra R, Balardin J, de Faria DD, Paulo AM, Sato JR, Baltazar CA, Borges V, Azevedo Silva SMC, Ferraz HB, de Carvalho Aguiar P.
Neurorehabil Neural Repair. 2021 Aug;35(8):729-737.

doi: 10.1177/15459683211019341. Epub 2021 May 28.

BACKGROUND: Functional imaging studies have associated dystonia with abnormal activation in motor and sensory brain regions. Commonly used techniques such as functional magnetic resonance imaging impose physical constraints, limiting the experimental paradigms. Functional near-infrared spectroscopy (fNIRS) offers a new noninvasive possibility for investigating cortical areas and the neural correlates of complex motor behaviors in unconstrained settings. METHODS: We compared the cortical brain activation of patients with focal upper-limb dystonia and controls during the writing task under naturalistic conditions using fNIRS. The primary motor cortex (M1), the primary somatosensory cortex (S1), and the supplementary motor area were chosen as regions of interest (ROIs) to assess differences in changes in both oxyhemoglobin (oxy-Hb) and deoxyhemoglobin (deoxy-Hb) between groups. RESULTS: Group average activation maps revealed an expected pattern of contralateral recruitment of motor and somatosensory cortices in the control group and a more bilateral pattern of activation in the dystonia group. Between-group comparisons focused on specific ROIs revealed an increased activation of the contralateral M1 and S1 cortices and also of the ipsilateral M1 cortex in patients. CONCLUSIONS: Overactivity of contralateral M1 and S1 in dystonia suggest a reduced specificity of the task-related cortical areas, whereas ipsilateral activation possibly indicates a primary disorder of the motor cortex or an endophenotypic pattern. To our knowledge, this is the first study using fNIRS to assess cortical activity in dystonia during the writing task under natural settings, outlining the potential of this technique for monitoring sensory and motor retraining in dystonia rehabilitation.

Feasibility of combining functional near-infrared spectroscopy with electroencephalography to identify chronic stroke responders to cerebellar transcranial direct current stimulation-a computational modeling and portable neuroimaging methodological study.

Rezaee Z, Ranjan S, Solanki D, Bhattacharya M, Srivastava MVP, Lahiri U, Dutta A.

Cerebellum. 2021 Dec;20(6):853-871.
doi: 10.1007/s12311-021-01249-4. Epub 2021 Mar 6.

Feasibility of portable neuroimaging of cerebellar transcranial direct current stimulation (ctDCS) effects on the cerebral cortex has not been investigated vis–vis cerebellar lobular electric field strength. We studied functional near-infrared spectroscopy (fNIRS) in conjunction with electroencephalography (EEG) to measure changes in the brain activation at the prefrontal cortex (PFC) and the sensorimotor cortex (SMC) following ctDCS as well as virtual reality-based balance training (VBaT) before and after ctDCS treatment in 12 hemiparetic chronic stroke survivors. We performed general linear modeling (GLM) that putatively associated the lobular electric field strength with the changes in the fNIRS-EEG measures at the ipsilesional and contra-lesional PFC and SMC. Here, fNIRS-EEG measures were found in the latent space from canonical correlation analysis (CCA) between the changes in total hemoglobin (tHb) concentrations (0.01-0.07Hz and 0.07-0.13Hz bands) and log10-transformed EEG bandpower within 1-45 Hz where significant (Wilks' lambda>0.95) canonical correlations were found only for the 0.07-0.13-Hz band. Also, the first principal component (97.5% variance accounted for) of the mean lobular electric field strength was a good predictor of the latent variables of oxy-hemoglobin (O2Hb) concentrations and log10-transformed EEG bandpower. GLM also provided insights into non-responders to ctDCS who also performed poorly in the VBaT due to ideomotor apraxia. Future studies should investigate fNIRS-EEG joint-imaging in a larger cohort to identify non-responders based on GLM fitting to the fNIRS-EEG data.

Combining Frontal Transcranial Direct Current Stimulation With Walking Rehabilitation to Enhance Mobility and Executive Function: A Pilot Clinical Trial.

Clark DJ, Chatterjee SA, Skinner JW, Lysne PE, Sumonthee C, Wu SS, Cohen RA, Rose DK, Woods AJ.

Neuromodulation. 2021 Jul;24(5):950-959.

doi: 10.1111/ner.13250. Epub 2020 Aug 18.

OBJECTIVES: This pilot study assessed whether frontal lobe transcranial direct current stimulation (tDCS) combined with complex walking rehabilitation is feasible, safe, and shows preliminary efficacy for improving walking and executive function. MATERIALS AND METHODS: Participants were randomized to one of the following 18-session interventions: active tDCS and rehabilitation with complex walking tasks (Active/Complex); sham tDCS and rehabilitation with complex walking tasks (Sham/Complex); or sham tDCS and rehabilitation with typical walking (Sham/Typical). Active tDCS was delivered over F3 (cathode) and F4 (anode) scalp locations for 20 min at 2mA intensity. Outcome measures included tests of walking function, executive function, and prefrontal activity measured by functional near infrared spectroscopy. RESULTS: Ninety percent of participants completed the intervention protocol successfully. tDCS side effects of tingling or burning sensations were low (average rating less than two out of 10). All groups demonstrated gains in walking performance based on within-group effect sizes (d = 0.50) for one or more assessments. The Sham/Typical group showed the greatest gains for walking based on between-group effect sizes. For executive function, the Active/Complex group showed the greatest gains based on moderate to large between-group effect sizes (d=0.52-1.11). Functional near-infrared spectroscopy (fNIRS) findings suggest improved prefrontal cortical activity during walking. CONCLUSIONS: Eighteen sessions of walking rehabilitation combined with tDCS is a feasible and safe intervention for older adults. Preliminary effects size data indicate a potential improvement in executive function by adding frontal tDCS to walking rehabilitation. This study justifies future larger clinical trials to better understand the benefits of combining tDCS with walking rehabilitation.

Changes in visual cortical function in moderately myopic patients: a functional near-infrared spectroscopy study.

Zhang Y, Lin X, Bi A, Cao N, Zhang T, Wang S, Wen Y, Bi H.

Ophthalmic Physiol Opt. 2022 Jan;42(1):36-47.
doi: 10.1111/opo.12921. Epub 2021 Nov 19.

PURPOSE: To investigate haemoglobin oxygenation in the visual cortexof myopic patients using functional near-infrared spectroscopy (fNIRS). METHODS: The experiment consisted of two parts. Part 1 examined functional changes in the visual cortex before and after refractive correction in myopic patients. Subjects were divided into normal controls, uncorrected and corrected myopes. Part 2 examined functional changes in the visual cortex caused by lens-induced myopia in normal subjects, and whether this activity recovered after a period of rest. Here, subjects were divided into three groups: emmetropes, lens-induced myopia and a rest group.The rest group completed a test with the uncorrected eye following lens removal and 5min of rest. The visual stimulus was a black and white checkerboard. fNIRS was used to detect changes in oxyhaemoglobin content within the visual cortex. The original fNIRS data were analysed using MATLAB to obtain the values (the visual cortical activity response caused by the task); these were used to calculate ?, which represents the degree of change in oxygenated haemoglobin caused by visual stimulation. RESULTS: The ? value measured in each single channel or only in the region of interest (ROI) was significantly higher in the emmetropic control group than the uncorrected myopic group. After optical correction, the responses of myopic subjects approached those of the emmetropes and were not significantly different. If myopia was induced in emmetropic subjects by imposing defocus with positive lenses, a decline in functional activity was observed similar that observed in uncorrected myopes. Activity recovered after the lenses were removed. CONCLUSIONS: Myopic defocus reduced the level of haemoglobin oxygenation in the visual cortex, but activity could be restored by optical correction.

A Graph-Based Feature Extraction Algorithm Towards a Robust Data Fusion Framework for Brain-Computer Interfaces.

Zhu S, Hosni SI, Huang X, Borgheai SB, McLinden J, Shahriari Y, Ostadabbas S.
Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:878-881.
doi: 10.1109/EMBC46164.2021.9630804.

OBJECTIVE: The topological information hidden in the EEG spectral dynamics is often ignored in the majority of the existing brain-computer interface (BCI) systems. Moreover, a systematic multimodal fusion of EEG with other informative brain signals such as functional near-infrared spectroscopy (fNIRS) towards enhancing the performance of the BCI systems is not fully investigated. In this study, we present a robust EEG-fNIRS data fusion framework utilizing a series of graph-based EEG features to investigate their performance on a motor imaginary (MI) classification task. METHOD: We first extract the amplitude and phase sequences of users' multi-channel EEG signals based on the complex Morlet wavelet time-frequency maps, and then convert them into an undirected graph to extract EEG topological features. The graph-based features from EEG are then selected by a thresholding method and fused with the temporal features from fNIRS signals after each being selected by the least absolute shrinkage and selection operator (LASSO) algorithm. The fused features were then classified as MI task vs. baseline by a linear support vector machine (SVM) classifier. RESULTS: The time-frequency graphs of EEG signals improved the MI classification accuracy by 5% compared to the graphs built on the band-pass filtered temporal EEG signals. Our proposed graph-based method also showed comparable performance to the classical EEG features based on power spectral density (PSD), however with a much smaller standard deviation, showing its robustness for potential use in a practical BCI system. Our fusion analysis revealed a considerable improvement of 17% as opposed to the highest average accuracy of EEG only and 3% compared with the highest fNIRS only accuracy demonstrating an enhanced performance when modality fusion is used relative to single modal outcomes. SIGNIFICANCE: Our findings indicate the potential use of the proposed data fusion framework utilizing the graph-based features in the hybrid BCI systems by making the motor imaginary inference more accurate and more robust.

Integration of social status and trust through interpersonal brain synchronization.

Cheng X, Zhu Y, Hu Y, Zhou X, Pan Y, Hu Y.
Neuroimage. 2021 Dec 3;246:118777.
doi: 10.1016/j.neuroimage.2021.118777. Online ahead of print.

Trust can be a dynamic social process, during which the social identity of the interacting agents (e.g., an investor and a trustee) can bias trust outcomes. Here, we investigated how social status modulates trust and the neural mechanisms underlying this process. An investor and a trustee performed a 10-round repeated trust game while their brain activity was being simultaneously recorded using functional near-infrared spectroscopy. The social status (either high or low) of both investors and trustees was manipulated via a math competition task. The behavioral results showed that in the initial round, individuals invested more in low-status partners. However, the investment ratio increased faster as the number of rounds increased during trust interaction when individuals were paired with a high-status partner. This increasing trend was particularly prominent in the low (investor)-high (trustee) status group. Moreover, the low-high group showed increased investor-trustee brain synchronization in the right temporoparietal junction as the number of rounds increased, while brain activation in the right dorsolateral prefrontal cortex of the investor decreased as the number of rounds increased. Both interpersonal brain synchronization and brain activation predicted investment performance at the early stage; furthermore, two-brain data provided earlier predictions than did single-brain data. These effects were detectable in the investment phase in the low-high group only; no comparable effects were observed in the repayment phase or other groups. Overall, this study demonstrated a multi-brain mechanism for the integration of social status and trust.

Brain-Wide Diffuse Optical Tomography Based on Cap-Based, Whole-Head fNIRS

Recording.

Khan AF, Zhang F, Yuan H, Ding L.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:3609-3612.
doi: 10.1109/EMBC46164.2021.9630249.

Diffuse optical tomography (DOT), based on functional near-infrared spectroscopy, is a portable, low-cost, noninvasive functional neuroimaging technology for studying the human brain in normal and diseased conditions. The goal of the present study was to evaluate the performance of a cap-based brain-wide DOT (BW-DOT) framework in mapping brain-wide networked activities. We first analyzed point-spread-function (PSF)-based metrics on a realistic head geometry. Our simulation results indicated that these metrics of the optode cap varied across the brain and were of lower quality in brain areas deep or away from the optodes. We further reconstructed brain-wide resting-state networks using experimental data from healthy participants, which resembled the template networks established in the fMRI literature. The preliminary results of the present study highlight the importance of evaluating PSF-based metrics on realistic head geometries for DOT and suggest that BW-DOT technology is a promising functional neuroimaging tool for studying brain-wide neural activities and large-scale neural networks, which was not available by patch-based DOT. A full-scope evaluation and validation in more realistic head models and more participants are needed in the future to establish the findings of the present study further.Clinical relevance- Via simulations and experimental evaluation, this work establishes a novel framework to image large-scale brain networks, which benefits the patient population, such as bedridden patients, infants, etc., who otherwise cannot undergo conventional brain monitoring modalities like fMRI and PET.

Positive emotion of self-referential contexts could facilitate adult's novel word learning: An fNIRS study.

Li E, Xiao F, Zou T, Guo J.

Brain Lang. 2021 Oct;221:104994.
doi: 10.1016/j.bandl.2021.104994. Epub 2021 Jul 22.

Learning words through contextual inference is a key way to enlarge one's vocabulary especially for adults. However, few studies focused on the effects of different information contained in contexts on novel word learning. The present study used behavioral and fNIRS techniques to investigate the influences of positive, neutral and negative emotions inherent in self-related or other-related referential contexts. Participants were asked to perform a semantic consistency and a source judgment task after learning the relations between novel words and concepts in different contexts. The results showed that self-reference during lexical encoding could promote word learning generally. More importantly, there existed a self-positivity bias which is manifested in the significant interactions between contextual emotions and referential value. These interactions are related to the neural activities of the DLPFC and IFG. These results revealed the contextual information's integrative contributions to semantic meaning acquisition and episodic source memory related with novel word learning.

NIRS-ICA: A MATLAB Toolbox for Independent Component Analysis Applied in fNIRS Studies.

Zhao Y, Sun PP, Tan FL, Hou X, Zhu CZ.

Front Neuroinform. 2021 Jul 14;15:683735.
doi: 10.3389/fninf.2021.683735. eCollection 2021.

Independent component analysis (ICA) is a multivariate approach that has been widely used in analyzing brain imaging data. In the field of functional near-infrared spectroscopy (fNIRS), its promising effectiveness has been shown in both removing noise and extracting neuronal activity-related sources. The application of ICA remains challenging due to its complexity in usage, and an easy-to-use toolbox ded-

icated to ICA processing is still lacking in the fNIRS community. In this study, we propose NIRS-ICA, an open-source MATLAB toolbox to ease the difficulty of ICA application for fNIRS studies. NIRS-ICA incorporates commonly used ICA algorithms for source separation, user-friendly GUI, and quantitative evaluation metrics assisting source selection, which facilitate both removing noise and extracting neuronal activity-related sources. The options used in the processing can also be reported easily, which promotes using ICA in a more reproducible way. The proposed toolbox is validated and demonstrated based on both simulative and real fNIRS datasets. We expect the release of the toolbox will extent the application for ICA in the fNIRS community.

The Potential Role of fNIRS in Evaluating Levels of Consciousness.

Abdalmalak A, Milej D, Norton L, Debicki DB, Owen AM, Lawrence KS.

Front Hum Neurosci. 2021 Jul 8;15:703405.

doi: 10.3389/fnhum.2021.703405. eCollection 2021.

Over the last few decades, neuroimaging techniques have transformed our understanding of the brain and the effect of neurological conditions on brain function. More recently, light-based modalities such as functional near-infrared spectroscopy have gained popularity as tools to study brain function at the bedside. A recent application is to assess residual awareness in patients with disorders of consciousness, as some patients retain awareness albeit lacking all behavioural response to commands. Functional near-infrared spectroscopy can play a vital role in identifying these patients by assessing command-driven brain activity. The goal of this review is to summarise the studies reported on this topic, to discuss the technical and ethical challenges of working with patients with disorders of consciousness, and to outline promising future directions in this field.

Changes in prefrontal cortex activation with exercise in knee osteoarthritis patients with chronic pain: An fNIRS study.

ztrk , Algun ZC, Bombaci H, Erdogan SB.

J Clin Neurosci. 2021 Aug;90:144-151.

doi: 10.1016/j.jocn.2021.05.055. Epub 2021 Jun 7.

The role of exercise on pain modulatory mechanism of the prefrontal areas is not clear. We aimed to determine the effects of exercise on functional activity of the prefrontal cortex in patients with knee osteoarthritis (OA) with chronic pain and to assess the relationships between changes in clinical variables and cortical hemodynamics with exercise via functional near-infrared spectroscopy (fNIRS). Fifteen patients with knee OA with chronic pain were included. All participants attended an exercise program 3 times a week for 6weeks. Pain during activity was assessed by visual analogue scale (VAS). Pain catastrophization, kinesiophobia and functionality were also measured. Brain hemodynamic activity was assessed with a 47-channel fNIRS system before and after the exercise. Pain, pain catastrophization, kinesiophobia and functionality scores significantly improved ($p<0.05$) while functional activity of the dorsolateral prefrontal cortex (DLPFC) during painful stimuli was significantly reduced after exercise program ($p<0.05$). Change in cortical hemodynamic activity within the DLPFC was significantly correlated with change in pain perception ($R=0.54$, $p<0.05$) and pain catastrophization scores ($R=0.44$, $p<0.05$). Exercise resulted in improvements in clinical assessments of pain severity and pain catastrophization which was accompanied by alterations in prefrontal cortex activation. We provided evidence about the pain modulatory effects of exercise at cortical level which is correlated with clinical improvements in patients with chronic pain. We demonstrate the feasibility and potential of fNIRS methodology for i) elucidating the neural mechanisms underlying chronic and stimulus evoked pain, and ii) exploring the effect of treatment methods on brain functionality.

Reduced Brain Activation in Response to Social Cognition Tasks in Autism Spectrum Disorder with and without Depression.

Ohtani T, Matsuo K, Sutoh C, Oshima F, Hirano Y, Wakabayashi A, Shimizu E.

Neuropsychiatr Dis Treat. 2021 Sep 28;17:3015-3024.
doi: 10.2147/NDT.S327608. eCollection 2021.

PURPOSE: In clinical settings, diagnosing comorbid depression in individuals with autism spectrum disorder (ASD) is often difficult. Neuroimaging studies have reported reduced activation of frontal and temporal regions during emotional face recognition task (EFRT) in ASD and depression. However, to the best of our knowledge, no study has examined differences in frontotemporal activation during EFRT between ASD with and without comorbid depression. We aimed to compare the frontotemporal hemodynamic responses to the EFRT in ASD with and without depression and to find clues to help in discriminating the characteristics between them. PATIENTS AND METHODS: In 24 drug-nave young adults with ASD (12 with depression [ASD-Dep(+)] and 12 without depression [ASD-Dep(-)]) and 12 with typical development (TD), frontotemporal hemodynamic responses during an EFRT were measured using functional near-infrared spectroscopy (fNIRS). RESULTS: The ASD groups showed reduced activation during EFRT than the TD group in the right ventrolateral prefrontal cortex (VLPFC). Moreover, the ASD-Dep(+) group showed reduced activation during EFRT than the ASD-Dep(-) group in the right anterior temporal cortex (aTC), and reduced activation than the TD group in the left VLPFC. CONCLUSION: The observed results might reflect reduced regional activation in ASD and ASD with comorbid depression.

Abnormal functional connectivity within the prefrontal cortex in interstitial cystitis/bladder pain syndrome (IC/BPS): A pilot study using resting state functional near-infrared spectroscopy (rs-fNIRS).

Pang D, Liao L.

Neurourol Urodyn. 2021 Aug;40(6):1634-1642.
doi: 10.1002/nau.24729. Epub 2021 Jun 15.

PURPOSE: To investigate the abnormalities of functional connectivity (FC) within the prefrontal cortex (PFC) of patients with interstitial cystitis/bladder pain syndrome (IC/BPS) based on resting state functional near-infrared spectroscopy (rs-fNIRS) data using FC matrix analysis. MATERIALS AND METHODS: Ten patients with IC/BPS (females, 9; mean age, 56.9 12.432 years) and 15 age- and gender-matched healthy controls (HC) (females, 12; mean age, 55.067 7.46 years) participated in this rs-fNIRS study. Two rs-fNIRS scans were performed (when the bladder was empty and when the desire to void was strong). The Pearson's correlation coefficient between the time series of the 22 channels was calculated to obtain a 22 22 FC matrix for each subject. A two-sample t-test ($p < .05$) was performed to compare group differences in the FC matrix between patients with IC/BPS and HC. RESULTS: FC was significantly decreased within the PFC in the IC/BPS group based on a two-sample t-test ($p < .05$) compared with HC. FC decreased in a wider range of brain regions during the strong desire to void state (4 brain regions and 28 edges) when compared with the empty bladder state (3 brain regions and 18 edges). CONCLUSION: FC abnormalities in IC/BPS patients may lead to frontal lobe disorders involved in processing sensory integration, motivation drive, emotional control, and decision-making whether to urinate, leading to urinary control dysfunction manifested as typical clinical IC/BPS symptoms. Our results may provide new insight into the pathogenesis of IC/BPS and new brain biomarkers for diagnosis.

Brain Cortical Activation during Imagining of the Wrist Movement Using Functional Near-Infrared Spectroscopy (fNIRS).

Jalalvandi M, Riyahi Alam N, Sharini H, Hashemi H, Nadimi M.

J Biomed Phys Eng. 2021 Oct 1;11(5):583-594.
doi: 10.31661/jbpe.v0i0.1051. eCollection 2021 Oct.

BACKGROUND: fNIRS is a useful tool designed to record the changes in the density of blood's oxygenated hemoglobin (oxyHb) and deoxygenated hemoglobin (deoxyHb) molecules during brain activity. This method has made it possible to evaluate the hemodynamic changes of the brain during neuronal activity in a completely non-aggressive manner. OBJECTIVE: The present study has been designed to investigate and evaluate the brain cortex activities during imagining of the execution of wrist motor tasks by comparing fMRI and fNIRS imaging methods. MATERIAL AND METHODS: This novel observational Optical Imaging study aims to investigate the brain motor cortex activity during imagining of the right wrist motor tasks in vertical and horizontal directions. To perform the study, ten healthy young right-handed volunteers were asked to think about right-hand movements in different directions according to the designed movement patterns. The required data were collected in two wavelengths, including 845 and 763 nanometers using a 48 channeled fNIRS machine. RESULTS: Analysis of the obtained data showed the brain activity patterns during imagining of the execution of a movement are formed in various points of the motor cortex in terms of location. Moreover, depending on the direction of the movement, activity plans have distinguishable patterns. The results showed contralateral M1 was mainly activated during imagining of the motor cortex ($p<0.05$). CONCLUSION: The results of our study showed that in brain imaging, it is possible to distinguish between patterns of activities during wrist motion in different directions using the recorded signals obtained through near-infrared Spectroscopy. The findings of this study can be useful in further studies related to movement control and BCI.

Comparison of Functional Connectivity during Visual-Motor Illusion, Observation, and Motor Execution.

Sakai K, Tanabe J, Goto K, Kumai K, Ikeda Y.

J Mot Behav. 2021 Sep 13:1-9.
doi: 10.1080/00222895.2021.1976717. Online ahead of print.

This study investigated the functional connectivity during visual-motor illusion and compared it with observation and motor execution using functional near-infrared spectroscopy (fNIRS). Thirty subjects were randomly assigned to: illusion, observation, and motor execution group. Illusion group watched own finger joint movement video image and induced kinesthetic illusion, while the other group only performed observation or motor execution. Continuous brain activity was measured using fNIRS and functional connectivity was analyzed. The illusion group perceived (using 7-point Likert scale) a higher degree of kinesthetic illusion and sense of body ownership than the observation group. Visual-motor illusion was associated with stronger functional connectivity between the left premotor cortex and the left parietal area compared with observation and motor execution only, suggesting that these areas respond to visual-motor illusion.

Learning to diagnose X-rays: a neuroscientific study of practice-related activation changes in the prefrontal cortex.

Rotgans JI.

Diagnosis (Berl). 2021 Dec 6.
doi: 10.1515/dx-2021-0104. Online ahead of print.

OBJECTIVES: Medical expertise manifests itself by the ability of a physician to rapidly diagnose patients. How this expertise develops from a neural-activation perspective is not well understood. The objective of the present study was to investigate practice-related activation changes in the prefrontal cortex (PFC) as medical students learn to diagnose chest X-rays. METHODS: The experimental paradigm consisted of a learning and a test phase. During the learning phase, 26 medical students were trained

to diagnose four out of eight chest X-rays. These four cases were presented repeatedly and corrective feedback was provided. During the test phase, all eight cases were presented together with near- and far-transfer cases to examine whether participants' diagnostic learning went beyond simple rote recognition of the trained X-rays. During both phases, participants' PFC was scanned using functional near-infrared spectroscopy. Response time and diagnostic accuracy were recorded as behavioural indicators. One-way repeated measures ANOVA were conducted to analyse the data. RESULTS: Results revealed that participants' diagnostic accuracy significantly increased during the learning phase ($F=6.72$, $p<0.01$), whereas their response time significantly decreased ($F=16.69$, $p<0.001$). Learning to diagnose chest X-rays was associated with a significant decrease in PFC activity ($F=33.21$, $p<0.001$) in the left dorsolateral prefrontal cortex, the orbitofrontal area, the frontopolar area and the frontal eye field. Further, the results of the test phase indicated that participants' diagnostic accuracy was significantly higher for the four trained cases, second highest for the near-transfer, third highest for the far-transfer cases and lowest for the untrained cases ($F=167.20$, $p<0.001$) and response time was lowest for the trained cases, second lowest for the near-transfer, third lowest for the far-transfer cases and highest for the untrained cases ($F=9.72$, $p<0.001$). In addition, PFC activity was lowest for the trained and near-transfer cases, followed by the far-transfer cases and highest for the untrained cases ($F=282.38$, $p<0.001$). CONCLUSIONS: The results suggest that learning to diagnose X-rays is associated with a significant decrease in PFC activity. In terms of dual-process theory, these findings support the notion that students initially rely more on slow analytical system-2 reasoning. As expertise develops, system-2 reasoning transitions into faster and automatic system-1 reasoning.

Relationship Between Acute Physical Fatigue and Cognitive Function During Orthostatic Challenge in Men and Women: A Neuroergonomics Investigation.

Mehta RK, Nuamah J.

Hum Factors. 2021 Dec;63(8):1437-1448.
doi: 10.1177/0018720820936794. Epub 2020 Jul 17.

BACKGROUND: Postflight orthostatic challenge (OC), resulting from blood pooling in lower extremities, is a major health concern among astronauts that fly long-duration missions. Additionally, astronauts undergo physical demanding tasks resulting in acute fatigue, which can affect performance. However, the effects of concurrent OC and acute physical fatigue on performance have not been adequately investigated. OBJECTIVE: The purpose of this study was to determine the relationship between acute physical fatigue and cognitive function during OC. METHODS: Sixteen healthy participants performed the mental arithmetic task and psychomotor tracking tasks in the absence and presence of a prior 1-hour physically fatiguing exercise, on separate days under OC (induced via lower body negative pressure). We recorded task performances on the cognitive tests and prefrontal cortex oxygenation using functional near-infrared spectroscopy, along with physiological and subjective responses. RESULTS: The introduction of the cognitive tasks during OC increased cerebral oxygenation; however, oxygenation decreased significantly with the cognitive tasks under the acute fatigue conditions, particularly during the tracking task and in males. These differences were accompanied by comparable task performances. DISCUSSION: The findings suggest that mental arithmetic is a more effective countermeasure than psychomotor tracking under acute physical fatigue during OC. Whereas females did not show a significant difference in cerebral oxygenation due to task, males did, suggesting that it may be important to consider gender differences when developing countermeasures against OC.

Most favorable stimulation duration in the sensorimotor cortex for fNIRS-based BCI.

Afzal Khan MN, Hong KS.

Biomed Opt Express. 2021 Sep 2;12(10):5939-5954.

doi: 10.1364/BOE.434936. eCollection 2021 Oct 1.

One of the primary objectives of the brain-computer interface (BCI) is to obtain a command with higher classification accuracy within the shortest possible time duration. Therefore, this study evaluates several stimulation durations to propose a duration that can yield the highest classification accuracy. Furthermore, this study aims to address the inherent delay in the hemodynamic responses (HRs) for the command generation time. To this end, HRs in the sensorimotor cortex were evaluated for the functional near-infrared spectroscopy (fNIRS)-based BCI. To evoke brain activity, right-hand-index finger poking and tapping tasks were used. In this study, six different stimulation durations (i.e., 1, 3, 5, 7, 10, and 15 s) were tested on 10 healthy male subjects. Upon stimulation, different temporal features and multiple time windows were utilized to extract temporal features. The extracted features were then classified using linear discriminant analysis. The classification results using the main HR showed that a 5 s stimulation duration could yield the highest classification accuracy, i.e., 74%, with a combination of the mean and maximum value features. However, the results were not significantly different from the classification accuracy obtained using the 15 s stimulation. To further validate the results, a classification using the initial dip was performed. The results obtained endorsed the finding with an average classification accuracy of 73.5% using the features of minimum peak and skewness in the 5 s window. The results based on classification using the initial dip for 5 s were significantly different from all other tested stimulation durations ($p < 0.05$) for all feature combinations. Moreover, from the visual inspection of the HRs, it is observed that the initial dip occurred as soon as the task started, but the main HR had a delay of more than 2 s. Another interesting finding is that impulsive stimulation in the sensorimotor cortex can result in the generation of a clearer initial dip phenomenon. The results reveal that the command for the fNIRS-based BCI can be generated using the 5 s stimulation duration. In conclusion, the use of the initial dip can reduce the time taken for the generation of commands and can be used to achieve a higher classification accuracy for the fNIRS-BCI within a 5 s task duration rather than relying on longer durations.

Cognitive Reserve Moderates the Efficiency of Prefrontal Cortex Activation Patterns of Gait in Older Adults.

Holtzer R, Ross D, O'Brien C, Izzetoglu M, Wagshul ME.

J Gerontol A Biol Sci Med Sci. 2021 Oct 4:glab288.
doi: 10.1093/gerona/glab288. Online ahead of print.

BACKGROUND: Cognitive Reserve (CR) protects against cognitive decline, but whether CR influences the efficiency of cortical control of gait has not been reported. The current study addressed this important gap in the literature. Specifically, we determined the role of CR in moderating the efficiency of functional Near-Infrared-Spectroscopy (fNIRS)-derived HbO2 in the prefrontal cortex (PFC) assessed during active walking. We hypothesized that higher CR would be associated with more efficient brain activation patterns. METHODS: Participants were 55 (mean age=74.84; %female=49.1) older adults who underwent the combined walking/fNIRS protocol and had MRI data. We used an established dual-task walking paradigm that consisted of three task conditions: Single-Task-Walk (STW), Single-Task-Alpha (STA, cognitive task) and Dual-Task-Walk (DTW). Using the residuals approach, CR was derived from a word-reading test score by removing variance accounted for by socio-demographic variables, tests of current cognitive functions and a measure of structural brain integrity. RESULTS: CR moderated the change in fNIRS-derived HbO2 in the PFC across tasks. Higher CR was associated with smaller increases in fNIRS-derived HbO2 from the single tasks to dual task walking (CR x DTW compared to STW: estimate = .183; $p < .001$; CR x DTW compared to STA: estimate =.257; $p < .001$). The moderation effect of CR remained significant when adjusting for multiple covariates and concurrent moderation effects of measures of gait performance, current cognitive functions and structural integrity of the brain. CONCLUSION: The current study provided first evidence that higher CR was associated with better neural efficiency of walking in older adults.

Shining a light on cultural neuroscience: Recommendations on the use of fNIRS to study how sociocultural contexts shape the brain.

Arredondo MM.

Cultur Divers Ethnic Minor Psychol. 2021 Jul 22.
doi: 10.1037/cdp0000469. Online ahead of print.

Functional near-infrared spectroscopy (fNIRS) is a portable neuroimaging technique that may serve as a methodological tool for studying how sociocultural contexts can shape the human brain and impact cognition and behavior. The use of fNIRS in community-based research may (a) advance theoretical knowledge in psychology and neuroscience, particularly regarding underrepresented ethnic-racial communities; (b) increase diversity in samples; and (c) provide neurobiological evidence of sociocultural factors supporting human development. The review aims to introduce the use of fNIRS, including its practicalities and limitations, to new adopters inquiring how sociocultural inputs affect the brain. The review begins with an introduction to cultural neuroscience, and a review on the use of fNIRS follows. Next, benefits and guidelines to the design of fNIRS research in naturalistic environments (in the community or in the field) using a cultural lens are discussed. Strengths-based and community-based approaches in cultural neuroscience are recommended throughout. (PsycInfo Database Record (c) 2021 APA, all rights reserved).

Editorial: Inter- and Intra-subject Variability in Brain Imaging and Decoding.

Wei CS, Keller CJ, Li J, Lin YP, Nakanishi M, Wagner J, Wu W, Zhang Y, Jung TP.

Front Comput Neurosci. 2021 Nov 29;15:791129.
doi: 10.3389/fncom.2021.791129. eCollection 2021.

Comment on Editorial on the Research Topic Inter- and Intra-subject Variability in Brain Imaging and Decoding.

Father-child dyads exhibit unique inter-subject synchronization during co-viewing of animation video stimuli.

Azhari A, Bizzego A, Esposito G.

Soc Neurosci. 2021 Oct;16(5):522-533.
doi: 10.1080/17470919.2021.1970016. Epub 2021 Aug 27.

Inter-subjectsynchronization reflects the entrainment of two individuals to each other's brain signals. In parent-childdyads, synchronization indicates an attunement to each other's emotional states. Despite the ubiquity with which parents and their children watch screen media together, no study has investigated synchronization in father-childdyads during co-viewing. The present study examined whether father-child dyads would exhibit inter-subjectsynchronization that is unique to the dyad and hence would not be observed in control dyads (i.e., randomly paired signals). Hyperscanning fNIRS was used to record the prefrontal cortex (PFC) signals of 29 fathers and their preschool-agedchildren as they co-viewed children's shows. Three 1-minvideos from "Brave", "Peppa Pig" and "The Incredibles" were presented to each dyad and children's ratings of video positivity and familiarity were obtained. Four PFC clusters were analyzed: medial left, medial right, frontal left and frontal right clusters. Results demonstrated that true father-childdyads showed significantly greater synchronization than control dyads in the medial left cluster during the emotionally arousing conflict scene. Dyads with older fathers displayed less synchrony and older fathers, compared to younger ones, exhibited greater activity. These findings suggest unique inter-subjectsynchronization in father-childdyads during co-viewing which is potentially modulated by parental age.

The Effects of Virtual Reality Treatment on Prefrontal Cortex Activity in Patients With Social Anxiety Disorder: Participatory and Interactive Virtual Reality Treatment Study.

Lee H, Choi J, Jung D, Hur JW, Cho CH.

J Med Internet Res. 2021 Dec 17;23(12):e31844.
doi: 10.2196/31844.

BACKGROUND: Attempts to use virtual reality (VR) as a treatment for various psychiatric disorders have been made recently, and many researchers have identified the effects of VR in psychiatric disorders. Studies have reported that VR therapy is effective in social anxiety disorder (SAD). However, there is no prior study on the neural correlates of VR therapy in patients with SAD. OBJECTIVE: The aim of this study is to find the neural correlates of VR therapy by evaluating the treatment effectiveness of VR in patients with SAD using portable functional near-infrared spectroscopy (fNIRS). METHODS: Patients with SAD (n=28) were provided with 6 sessions of VR treatment that was developed for exposure to social situations with a recording system of each participant's self-introduction in VR. After each VR treatment session, the first-person view (video 1) and third-person view (video 2) clips of the participant's self-introduction were automatically generated. The functional activities of prefrontal regions were measured by fNIRS while watching videos 1 and 2 with a cognitive task, before and after whole VR treatment sessions, and after the first session of VR treatment. We compared the data of fNIRS between patients with SAD and healthy controls (HCs; n=27). RESULTS: We found that reduction in activities of the right frontopolar prefrontal cortex (FPPFC) in HCs was greater than in the SAD group at baseline (t=-2.01, P=.049). Comparing the frontal cortex activation before and after VR treatment sessions in the SAD group showed significant differences in activities of the FPPFC (right: t=-2.93, P<.001; left: t=-2.25, P=.03) and the orbitofrontal cortex (OFC) (right: t=-2.10, P=.045; left: t=-2.21, P=.04) while watching video 2. CONCLUSIONS: Activities of the FPPFC and OFC were associated with symptom reduction after VR treatment for SAD. Our study findings might provide a clue to understanding the mechanisms underlying VR treatment for SAD. TRIAL REGISTRATION: Clinical Research Information Service (CRIS) KCT0003854; https://tinyurl.com/559jp2kp.

How Mother-Child Interactions are Associated with a Child's Compliance.

Zhao H, Cheng T, Zhai Y, Long Y, Wang Z, Lu C.

Cereb Cortex. 2021 Jul 29;31(9):4398-4410.
doi: 10.1093/cercor/bhab094.

While social interaction between a mother and her child has been found to play an important role in the child's committed compliance, the underlying neurocognitive process remains unclear. To investigate this process, we simultaneously recorded and assessed brain activity in 7-year-old children and in children's mothers or strangers during a free-play task using functional near-infrared spectroscopy-based hyperscanning. The results showed that a child's committed compliance was positively associated with the child's responsiveness but was negatively associated with mutual responsiveness and was not associated with the mother's responsiveness during mother-child interactions. Moreover, interpersonal neural synchronization (INS) at the temporoparietal junction mediated the relationship between the child's responsiveness and the child's committed compliance during mother-child interactions when the child's brain activity lagged behind that of the mother. However, these effects were not found during stranger-child interactions, nor were there significant effects in the mother-child pair when no real interactions occurred. Finally, we found a transfer effect of a child's committed compliance from mother-child interactions to stranger-child interactions via the mediation of mother-child INS, but the opposite did not occur. Together, these findings suggest that a child's responsiveness during mother-child interactions can significantly facilitate her or his committed compliance by increasing mother-child INS.

Developmental fronto-parietal shift of brain activation during mental arithmetic across the lifespan: A registered report protocol.

Artemenko C.

PLoS One. 2021 Aug 25;16(8):e0256232.
doi: 10.1371/journal.pone.0256232. eCollection 2021.

Arithmetic processing is represented in a fronto-parietal network of the brain. However, activation within this network undergoes a shift from domain-general cognitive processing in the frontal cortex towards domain-specific magnitude processing in the parietal cortex. This is at least what is known about development from findings in children and young adults. In this registered report, we set out to replicate the fronto-parietal activation shift for arithmetic processing and explore for the first time how neural development of arithmetic continues during aging. This study focuses on the behavioral and neural correlates of arithmetic and arithmetic complexity across the lifespan, i.e., childhood, where arithmetic is first learned, young adulthood, when arithmetic skills are already established, and old age, when there is lifelong arithmetic experience. Therefore, brain activation during mental arithmetic will be measured in children, young adults, and the elderly using functional near-infrared spectroscopy (fNIRS). Arithmetic complexity will be manipulated by the carry and borrow operations in two-digit addition and subtraction. The findings of this study will inform educational practice, since the carry and borrow operations are considered as obstacles in math achievement, and serve as a basis for developing interventions in the elderly, since arithmetic skills are important for an independent daily life.

Neural Variability in the Prefrontal Cortex as a Reflection of Neural Flexibility and Stability in Patients With Parkinson Disease.

Maidan I, Hacham R, Galperin I, Giladi N, Holtzer R, Hausdorff JM, Mirelman A.

Neurology. 2021 Dec 14:10.1212/WNL.0000000000013217.
doi: 10.1212/WNL.0000000000013217. Online ahead of print.

BACKGROUND AND OBJECTIVES: Functional Near-Infrared Spectroscopy (fNIRS) studies provide direct evidence to the important role of the prefrontal cortex (PFC) during walking in aging and Parkinson's disease (PD). Most studies mainly explored mean HbO2 levels, while moment-to-moment variability measures have been rarely investigated. Variability measures can inform on flexibility that is imperative for adaptive function. We hypothesized that patients with PD will show less variability in HbO2 signals during walking compared to healthy controls. METHODS: 206 participants, 57 healthy controls (age: 68.91.0 years; 27 women) and 149 idiopathic PD patients (age: 69.80.6 years, 50 women, disease duration: 8.275.51 years) performed usual walking and dual-task walking (serial 3 subtractions) with an fNIRS system placed on the forehead. HbO2 variability was calculated using the standard deviation (SD), range, and mean detrended time series of fNIRS-derived HbO2 signal evaluated during each walking task. HbO2 variability was compared between groups and between walking tasks using mixed model analyses. RESULTS: Higher variability (SD, range, mean detrended time series) was observed during dual-task walking, compared to usual walking ($p<0.025$), but this was derived from the differences within the healthy control group (group X task interaction: $p<0.007$). On the other hand, task repetition demonstrated reduced variability in healthy controls but increased variability in patients with PD (interaction group*walk-repetition: $p<0.048$). The MDS-UPDRS motor score correlated with HbO2 range ($r=0.142$, $p=0.050$) and HbO2 SD ($r=0.173$, $p=0.018$) during usual walking in all participants. DISCUSSION: In this study, we suggest a new way to interpret changes in HbO2 variability. We relate increased HbO2 variability to flexible adaptation to environmental challenges and decreased HbO2 variability to the stability of performance. Our results show that both are limited in PD however, further investigation of these concepts is required. Moreover, HbO2 variability measures are an important aspect of brain function that adds new insights into the role of PFC during walking with aging and PD. CLASSIFICATION OF EVIDENCE: This study provides

Class III evidence that patients with PD have more variability within Hb02 signals during usual-walking, compared to healthy controls, but not during dual-task walking.

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fNIRS & e-drum: An ecological approach to monitor hemodynamic and behavioural effects of rhythmic auditory cueing training.

Curzel F, Brigadoi S, Cutini S.

Brain Cogn. 2021 Jul;151:105753.

doi: 10.1016/j.bandc.2021.105753. Epub 2021 May 18.

Converging evidence suggests a beneficial effect of rhythmic music-therapy in easing motor dysfunctions. Nevertheless, the neural systems underpinning both the direct effect and the influence of rhythm on movement control and execution during training in ecological settings are still largely unknown. In this study, we propose an ecological approach to monitor brain activity and behavioural performance during rhythmic auditory cueing short-term training. Our approach envisages the combination of functional near-infrared spectroscopy (fNIRS), which is a non-invasive neuroimaging technique that allows unconstrained movements of participants, with electronic drum (e-drum), which is an instrument able to collect behavioural tapping data in real time. The behavioural and brain effects of this short-term training were investigated on a group of healthy participants, who well tolerated the experimental settings, since none of them withdrew from the study. The rhythmic auditory cueing short-term training improved beat regularity and decreased group variability. At the group level, the training resulted in a reduction of brain activity primarily in premotor areas. Furthermore, participants with the highest behavioural improvement during training showed the smallest reduction in brain activity. Overall, we conclude that our study could pave the way towards translating the proposed approach to clinical settings.

A field study of mental workload: conventional bus drivers versus bus rapid transit drivers.

Piranveyseh P, Kazemi R, Soltanzadeh A, Smith A.

Ergonomics. 2021 Oct 21:1-11.

doi: 10.1080/00140139.2021.1992021. Online ahead of print.

Road traffic accidents are increasing worldwide and cause a high number of fatalities and injuries. Mental Work Load (MWL) is a contributing factor in road safety. The primary aim of this work was to study important MWL factors and then compare conventional and BRT (Bus Rapid Transit) drivers' MWL. This study evaluated bus drivers' MWL using the Driving Activity Load Index (DALI) questionnaire conducted with 123 bus drivers in Tehran. The results revealed significant differences between conventional and BRT drivers' mental workload. Moreover, data modelling showed that some organisational and environmental factors such as bus type, working hours per day, road maze, and route traffic volume contribute to drivers' mental workload. These findings suggest some essential customised factors that may help measure and offer practical solutions for decreasing the level of bus drivers' MWL in real-world road driving. Practitioner summaryMental workload is affected by several contributing factors. Depending on the working context, some of these contributing factors have a more significant influence on the level of the experienced MWL. Therefore, the main factors influencing the MWL of BRT and conventional bus drivers were assessed in their real-life environment.Abbreviations: MWL: mental work load; BRT: bus rapid transit; CB: conventional bus; DALI: driving activity load index; NASA-TLX: NASA task load index; SWAT: subjective workload assessment technique; EEG: electroencephalography electrocardiogram; fNIRS: functional magnetic resonance imaging; ITS: intelligent transportation systems; AVL: automated vehicle location.

Functional Near-Infrared Spectroscopy as a Target Navigator for rTMS Modulation in Patients with Hemiplegia: A Randomized Control Study.

Chang PW, Lu CF, Chang ST, Tsai PY.

Neurol Ther. 2021 Nov 13.
doi: 10.1007/s40120-021-00300-0. Online ahead of print.

INTRODUCTION: Although repetitive transcranial magnetic stimulation (rTMS) is efficacious for motor neuromodulation in stroke survivors, high interindividual variability for responsiveness remains a concern. Target probing on the skull using a proper brain-mapping technique may help overcome this challenge. This study assessed the feasibility of functional near-infrared spectroscopy (fNIRS) as a target navigator in rTMS treatment for motor facilitation in patients with stroke. METHODS: Fifty-one patients with stroke were enrolled in this randomized controlled study. The patients were assigned to three groups: fNIRS-guided rTMS treatment (fNIRS group, n = 20), motor evoked potential (MEP)-guided rTMS treatment (MEP group, n = 16), and sham (n = 15) group. Motor assessments, including Fugl-Meyer Assessment (FMA), Wolf Motor Function Test (WMFT), and muscle strength, were conducted at baseline and after the 10-session rTMS treatment. RESULTS: The fNIRS-guided hotspot (fNIRS-HS) was obtained for each patient, even those for whom the MEP-guided hotspot was undetectable. Both intervention groups exhibited significant improvements in muscle strength, FMA, and WMFT scores ($P < 0.001$) compared with the sham group. The fNIRS group achieved significantly greater improvement in elbow function ($P = 0.001$) than the MEP group. CONCLUSION: fNIRS can be a reliable tool for hotspot navigation for motor neuromodulation in patients with stroke. With high sensitivity to cortical oxygenation changes, this navigation system achieved a superior outcome to the traditional MEP-based method in patients with stroke. fNIRS-based systems may also facilitate the integration of machine learning, thus enabling precision medicine for neuromodulation. TRIAL REGISTRATION: https://clinicaltrials.gov ; Unique identifier: NCT02006615.

Quantified assessment of deep brain stimulation on Parkinson's patients with task fNIRS measurements and functional connectivity analysis: a pilot study.

Yu N(#), Liang S, Lu J, Shu Z, Li H, Yu Y, Wu J, Han J.

Chin Neurosurg J. 2021 Jul 5;7(1):34.
doi: 10.1186/s41016-021-00251-3.

BACKGROUND: Deep brain stimulation (DBS) has proved effective for Parkinson's disease (PD), but the identification of stimulation parameters relies on doctors' subjective judgment on patient behavior. METHODS: Five PD patients performed 10-meter walking tasks under different brain stimulation frequencies. During walking tests, a wearable functional near-infrared spectroscopy (fNIRS) system was used to measure the concentration change of oxygenated hemoglobin (?HbO2) in prefrontal cortex, parietal lobe and occipital lobe. Brain functional connectivity and global efficiency were calculated to quantify the brain activities. RESULTS: We discovered that both the global and regional brain efficiency of all patients varied with stimulation parameters, and the DBS pattern enabling the highest brain efficiency was optimal for each patient, in accordance with the clinical assessments and DBS treatment decision made by the doctors. CONCLUSIONS: Task fNIRS assessments and brain functional connectivity analysis promise a quantified and objective solution for patient-specific optimization of DBS treatment. TRIAL REGISTRATION: Name: Accurate treatment under the multidisciplinary cooperative diagnosis and treatment model of Parkinson's disease. Registration number is ChiCTR1900022715. Date of registration is April 23, 2019.

Frequent, Short Physical Activity Breaks Reduce Prefrontal Cortex Activation but Preserve Working Memory in Middle-Aged Adults: ABBaH Study.

Heiland EG, Tarassova O, Fernstrm M, English C, Ekblom , Ekblom MM.

Front Hum Neurosci. 2021 Sep 16;15:719509.
doi: 10.3389/fnhum.2021.719509. eCollection 2021.

Prolonged sitting is increasingly common and may possibly be unfavorable for cognitive function and mood. In this randomized crossover study, the effects of frequent, short physical activity breaks during prolonged sitting on cognitive task-related activation of the prefrontal cortex were investigated. The effects on working memory, psychological factors, and blood glucose were also examined, and whether arterial stiffness moderated prefrontal cortex activation. Thirteen subjects (mean age 50.5 years; eight men) underwent three 3-h sitting conditions, interrupted every 30-min by a different 3-min break on separate, randomized-ordered days: seated social interactions (SOCIAL), walking (WALK), or simple resistance activities (SRA). Arterial stiffness was assessed at baseline. Before and after each 3-h condition, psychological factors (stress, mood, sleepiness, and alertness) were assessed through questionnaires and functional near-infrared spectroscopy (fNIRS) was used to measure changes in prefrontal oxygenated hemoglobin (Oxy-Hb), indicative of cortical activation, while performing working memory tasks [1- (baseline), 2-, and 3-back]. Blood glucose levels were continuously measured throughout the conditions. Results revealed no significant changes in Oxy-Hb during the 2-back compared with the 1-back test in any condition, and no time-by-condition interactions. During the 3-back test, there was a significant decrease in Oxy-Hb compared with the 1-back after the WALK condition in the right prefrontal cortex, but there were no time-by-condition interactions, although 3-back reaction time improved only in the WALK condition. Mood and alertness improved after the WALK condition, which was significantly different from the SOCIAL condition. Arterial stiffness moderated the effects, such that changes in Oxy-Hb were significantly different between WALK and SOCIAL conditions only among those with low arterial stiffness. Blood glucose during the interventions did not differ between conditions. Thus, breaking up prolonged sitting with frequent, short physical activity breaks may reduce right prefrontal cortex activation, with improvements in some aspects of working memory, mood, and alertness. Clinical Trial Registration:www.ClinicalTrials.gov, identifier NCT04137211.

Depressive and anxiety symptoms are related to decreased lateral prefrontal cortex functioning during cognitive control in older people.

Yeung MK, Lee TL, Chan AS.

Biol Psychol. 2021 Nov;166:108224.
doi: 10.1016/j.biopsycho.2021.108224. Epub 2021 Nov 14.

Some studies have found a relationship between negative emotional symptoms and decreased lateral PFC functioning during a cognitive control task in healthy younger adults. Here, we asked whether this relationship is also present in the general older population and across different functional domains of the lateral PFC. Thirty-six older people (13 males) self-reported their recent depressive and anxiety symptoms. They also took two cognitive control tasks known to differentially engage the lateral frontoparietal network (digit n-back task) and the lateral frontotemporal network (Category Fluency Test) while hemodynamic changes in the PFC were monitored by functional near-infrared spectroscopy (fNIRS). Both depressive and anxiety symptoms were associated with decreased activation in the bilateral lateral PFC during cognitive control performance. Interestingly, these relationships were driven by the n-back task. Our findings suggest that depressive and anxiety symptoms are related to decreased lateral PFC functioning in particular domains of cognitive control among older people.

Effects of acute psychosocial stress on interpersonal cooperation and competition in young women.

Zhang R, Zhou X, Feng D, Yuan D, Li S, Lu C, Li X.

Brain Cogn. 2021 Jul;151:105738.
doi: 10.1016/j.bandc.2021.105738. Epub 2021 Apr 27.

Although tend-and-befriend is believed to be the dominant stress response in women, little is known regarding the effects of acute psychosocial stress on different dynamic social interactions. To measure these effects, 80 female participants were recruited, paired into the dyads, and instructed to complete cooperative and competitive key-pressing tasks after experiencing acute stress or a control condition. Each dyad of participants should press the key synchronously when the signal was presented in the cooperative task and as fast as possible in the competitive task. During the tasks, brain activities of prefrontal and right temporo-parietal areas were recorded from each dyad using functional near-infrared spectroscopy (fNIRS). The results showed that acute psychosocial stress evidently promoted competitive behavior, accompanied by increased interpersonal neural synchronization (INS) in the right dorsolateral prefrontal cortex. Despite the lack of a significant difference in the overall cooperation rate, the response time difference between two stressed participants markedly declined over time with more widespread INS in the prefrontal cortex, suggesting that there ensued cooperative improvement among stressed women. These findings behaviorally and neurologically revealed context-dependent response patterns to psychosocial stress in women during dynamic social interactions.

Dual-task walking and automaticity after Stroke: Insights from a secondary analysis and imaging sub-study of a randomised controlled trial.

Collett J, Fleming MK, Meester D, Al-Yahya E, Wade DT, Dennis A, Salvan P, Meaney A, Cockburn J, Dawes J, Johansen-Berg H, Dawes H.

Clin Rehabil. 2021 Nov;35(11):1599-1610.
doi: 10.1177/02692155211017360. Epub 2021 May 30.

OBJECTIVE: To test the extent to which initial walking speed influences dual-task performance after walking intervention, hypothesising that slow walking speed affects automatic gait control, limiting executive resource availability. DESIGN: A secondary analysis of a trial of dual-task (DT) and single-task (ST) walking interventions comparing those with good (walking speed ?0.8 m s-1, n = 21) and limited (walking speed <0.79 m s-1, n = 24) capacity at baseline. SETTING: Community. SUBJECTS: Adults six-months post stroke with walking impairment. INTERVENTIONS: Twenty sessions of 30 minutes treadmill walking over 10 weeks with (DT) or without (ST) cognitive distraction. Good and limited groups were formed regardless of intervention received. MAIN MEASURES: A two-minute walk with (DT) and without (ST) a cognitive distraction assessed walking. fNIRS measured prefrontal cortex activation during treadmill walking with (DT) and without (ST) Stroop and planning tasks and an fMRI sub-study used ankle-dorsiflexion to simulate walking. RESULTS: ST walking improved in both groups (?baseline: Good = 8.9 13.4 m, limited = 5.38.9 m, Group time = P < 0.151) but only the good walkers improved DT walking (?baseline: Good = 10.4 13.9 m, limited = 1.3 7.7 m, Group time = P < 0.025). fNIRS indicated increased ispilesional prefrontal cortex activation during DT walking following intervention (P = 0.021). fMRI revealed greater DT cost activation for limited walkers, and increased resting state connectivity of contralesional M1 with cortical areas associated with conscious gait control at baseline. After the intervention, resting state connectivity between ipsilesional M1 and bilateral superior parietal lobe, involved in integrating sensory and motor signals, increased in the good walkers compared with limited walkers. CONCLUSION: In individual who walk slowly it may be difficult to improve dual-task walking ability.Registration: ISRCTN50586966.

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devfOLD: a toolbox for designing age-specific fNIRS channel placement.

Fu X, Richards JE.

Neurophotonics. 2021 Oct;8(4):045003.
doi: 10.1117/1.NPh.8.4.045003. Epub 2021 Dec 6.

Significance: Near-infrared spectroscopy (NIRS) is a noninvasive technique that uses scalp-placed sensors to measure cerebral hemoglobin concentration. Commercial NIRS instruments do not allow for whole-

head coverage and do not intrinsically indicate which brain areas generate the NIRS signal. Hence, the challenge is to design source-detector channel arrangement that maximizes sensitivity to a given brain region of interest (ROI). Existing methods for optimizing channel placement design have been developed using adult head models. Thus, they have limited utility for developmental research. Aim: We aim to build an application from an existing toolbox (fOLD) that guides NIRS channel configuration based on age group, stereotaxic atlas, and ROI (devfOLD). Approach: The devfOLD provides NIRS channel-to-ROI specificity computed using photon propagation simulation with realistic head models from infant, child, and adult age groups. Results: Cortical locations and user-specified specificity cut-off values influence the between-age consistency and differences in the ROI-to-channel correspondence among the example infant and adult age groups. Conclusions: The study highlights the importance of incorporating age-specific head models for optimizing NIRS channel configurations. The devfOLD toolbox is publicly shared and compatible with multiple operating systems.

Characterization of Mayer-wave oscillations in functional near-infrared spectroscopy using a physiologically informed model of the neural power spectra.

Luke R, Shader MJ, McAlpine D.

Neurophotonics. 2021 Oct;8(4):041001.
doi: 10.1117/1.NPh.8.4.041001. Epub 2021 Dec 8.

Significance: Mayer waves are spontaneous oscillations in arterial blood pressure that can mask cortical hemodynamic responses associated with neural activity of interest. Aim: We aim to characterize the properties of oscillations in the functional near-infrared spectroscopy (fNIRS) signal generated by Mayer waves in a large sample of fNIRS recordings. Further, we aim to determine the impact of short-channel correction for the attenuation of these unwanted signal components. Approach: Mayer-wave oscillation parameters were extracted from 310 fNIRS measurements using the fitting oscillations and one-over-f method to compute normative values. The effect of short-channel correction on Mayer-wave oscillation power was quantified on 222 measurements. The practical benefit of the short-channel correction approach for reducing Mayer waves and improving response detection was also evaluated on a subgroup of 17 fNIRS measurements collected during a passive auditory speech detection experiment. Results: Mayer-wave oscillations had a mean frequency of 0.108Hz, bandwidth of 0.04Hz, and power of 3.5 M2/Hz . The distribution of oscillation signal power was positively skewed, with some measurements containing large Mayer waves. Short-channel correction significantly reduced the amplitude of these undesired signals; greater attenuation was observed for measurements containing larger Mayer-wave oscillations. Conclusions: A robust method for quantifying Mayer-wave oscillations in the fNIRS signal spectrum was presented and used to provide normative parameterization. Short-channel correction is recommended as an approach for attenuating Mayer waves, particularly in participants with large oscillations.

Workplace design-related stress effects on prefrontal cortex connectivity and neurovascular coupling.

Alyan E, Saad NM, Kamel N, Rahman MA.

Appl Ergon. 2021 Oct;96:103497.
doi: 10.1016/j.apergo.2021.103497. Epub 2021 Jun 15.

This study aims to evaluate the effect of workstation type on the neural and vascular networks of the prefrontal cortex (PFC) underlying the cognitive activity involved during mental stress. Workstation design has been reported to affect the physical and mental health of employees. However, while the functional effects of ergonomic workstations have been documented, there is little research on the influence of workstation design on the executive function of the brain. In this study, 23 healthy volunteers in ergonomic and non-ergonomic workstations completed the Montreal imaging stress task, while their brain activity

was recorded using the synchronized measurement of electroencephalography and functional near-infrared spectroscopy. The results revealed desynchronization in alpha rhythms and oxygenated hemoglobin, as well as decreased functional connectivity in the PFC networks at the non-ergonomic workstations. Additionally, a significant increase in salivary alpha-amylase activity was observed in all participants at the non-ergonomic workstations, confirming the presence of induced stress. These findings suggest that workstation design can significantly impact cognitive functioning and human capabilities at work. Therefore, the use of functional neuroimaging in workplace design can provide critical information on the causes of workplace-related stress.

Response of the Cerebral Cortex to Resistance and Non-resistance Exercise Under Different Trajectories: A Functional Near-Infrared Spectroscopy Study.

Shi P, Li A, Yu H.

Front Neurosci. 2021 Oct 13;15:685920.
doi: 10.3389/fnins.2021.685920. eCollection 2021.

Background: At present, the effects of upper limb movement are generally evaluated from the level of motor performance. The purpose of this study is to evaluate the response of the cerebral cortex to different upper limb movement patterns from the perspective of neurophysiology. Method: Thirty healthy adults (12 females, 18 males, mean age 23.9 0.9 years) took resistance and non-resistance exercises under four trajectories (T1: left and right straight-line movement; T2: front and back straight-line movement; T3: clockwise and anticlockwise drawing circle movement; and T4: clockwise and anticlockwise character ? movement). Each movement included a set of periodic motions composed of a 30-s task and a 30-s rest. Functional near-infrared spectroscopy (fNIRS) was used to measure cerebral blood flow dynamics. Primary somatosensory cortex (S1), supplementary motor area (SMA), pre-motor area (PMA), primary motor cortex (M1), and dorsolateral prefrontal cortex (DLPFC) were chosen as regions of interests (ROIs). Activation maps and symmetric heat maps were applied to assess the response of the cerebral cortex to different motion patterns. Result: The activation of the brain cortex was significantly increased during resistance movement for each participant. Specifically, S1, SMA, PMA, and M1 had higher participation during both non-resistance movement and resistance movement. Compared to non-resistance movement, the resistance movement caused an obvious response in the cerebral cortex. The task state and the resting state were distinguished more obviously in the resistance movement. Four trajectories can be distinguished under non-resistance movement. Conclusion: This study confirmed that the response of the cerebral motor cortex to different motion patterns was different from that of the neurophysiological level. It may provide a reference for the evaluation of resistance training effects in the future.

Prefrontal Cortex Activation During Verbal Fluency Task and Tower of London Task in Schizophrenia and Major Depressive Disorder.

Xiang Y, Li Y, Shu C, Liu Z, Wang H, Wang G.

Front Psychiatry. 2021 Oct 8;12:709875.
doi: 10.3389/fpsyt.2021.709875. eCollection 2021.

Background: Cognitive dysfunction is a common clinical feature of mental disorders. A number of functional near-infrared spectroscopy (fNIRS) studies have shown reduced prefrontal activation during the verbal fluency task (VFT) in schizophrenia (SZ) and major depressive disorder (MDD). However, no studies have examined and compared the brain activation patterns during the Tower of London (TOL), which is another classic, high-sensitivity executive function testing tool, in these two serious mental disorders. This study aimed to assess the characteristics of brain activation during the two different cognitive tasks in SZ and MDD patients. Methods: This study recruited 30 patients with SZ, 30 patients with MDD, and 30 demographically matched healthy controls (HCs). The hemodynamic changes of the prefrontal

cortex (PFC) were measured using 32-channel fNIRS during performance of the TOL task and VFT task. Results: SZ patients showed poorer VFT performance than MDD patients and HCs, and the two patient groups showed poorer TOL performance than HCs. Compared to HCs, both of the patient groups exhibited a significant decreased activation in the extensive PFC. Particularly in certain channels in the dorsolateral PFC (DLPFC), SZ patients exhibited significantly decreased hemodynamic changes than the MDD patients. Conclusions: Patients with SZ and MDD have different levels of impairment in different cognitive domains and different patterns of brain activation during the two cognitive tasks. Further research is needed to determine the use of fNIRS for clinical evaluation and diagnosis.

Neural and biomechanical tradeoffs associated with human-exoskeleton interactions.

Zhu Y, Weston EB, Mehta RK, Marras WS.

Appl Ergon. 2021 Oct;96:103494.
doi: 10.1016/j.apergo.2021.103494. Epub 2021 Jun 11.

Industrial passive low-back exoskeletons have gained recent attention as ergonomic interventions to manual handling tasks. This research utilized a two-armed experimental approach (single vs dual-task paradigms) to quantify neural and biomechanical tradeoffs associated with short-term human-exoskeleton interaction (HEI) during asymmetrical lifting in twelve healthy adults balanced by gender. A dynamic, electromyography-assisted spine model was employed that indicated statistical, but marginal, biomechanical benefits of the tested exoskeleton, which diminished with the introduction of the cognitive dual-task. Using Near Infrared Spectroscopy (fNIRS)-based brain connectivity analyses, we found that the tested exoskeleton imposed greater neurocognitive and motor adaptation efforts by engaging action monitoring and error processing brain networks. Collectively, these findings indicate that a wearer's biomechanical response to increased cognitive demands in the workplace may offset the mechanical advantages of exoskeletons. We also demonstrate the utility of ambulatory fNIRS to capture the neural cost of HEI without the need for elaborate dual-task manipulations.

Evaluation of the Short-Term Music Therapy on Brain Functions of Preterm Infants Using Functional Near-Infrared Spectroscopy.

Ren H, Zou L, Wang L, Lu C, Yuan Y, Dai C, Chen W.

Front Neurol. 2021 Sep 28;12:649340.
doi: 10.3389/fneur.2021.649340. eCollection 2021.

Music contains substantial contents that humans can perceive and thus has the capability to evoke positive emotions. Even though neonatal intensive care units (NICUs) can provide preterm infants a developmental environment, they still cannot fully simulate the environment in the womb. The reduced maternal care would increase stress levels in premature infants. Fortunately, music intervention has been proved that it can improve the NICU environment, such as stabilize the heart rate and the respiratory rate, reduce the incidence of apnea, and improve feeding. However, the effects of music therapy on the brain development of preterm infants need to be further investigated. In this paper, we evaluated the influence of short-term music therapy on the brain functions of preterm infants measured by functional near-infrared spectroscopy (fNIRS). We began by investigating how premature babies perceive structural information of music by calculating the correlations between music features and fNIRS signals. Then, the influences of short-term music therapy on brain functions were evaluated by comparing the resting-state functional connectivity before and after the short-term music therapy. The results show that distinct brain regions are responsible for processing corresponding musical features, indicating that preterm infants have the capability to process the complex musical content. However, the results of network analysis show that short-term music intervention is insufficient to cause the changes in cerebral functional connectivity. Therefore, long-term music therapy may be required to achieve the deserved effects on brain functional

connectivity.

LSTM based GAN Networks for Enhancing Ternary Task Classification Using fNIRS Data.

Wickramaratne SD, Mahmud MS.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:1043-1046.
doi: 10.1109/EMBC46164.2021.9630000.

Brain activation patterns vary according to the tasks performed by the subject. Neuroimaging techniques can be used to map the functioning of the cortex to capture brain activation patterns. Functional near-infrared spectroscopy (fNIRS) is a neuroimaging technique increasingly used for task classification based on brain activation patterns. fNIRS can be widely used in population studies due to the technology's economic,non-invasive, and portable nature. The multidimensional and complex nature of fNIRS data makes it ideal for deep learning algorithms for classification. Most deep learning algorithms need a large amount of data to be appropriately trained. Generative networks can be used in such cases where a substantial amount of data is required. Still, the collection is complex due to various constraints. Conditional Generative Adversarial Networks (CGAN) can generate artificial samples of a specific category to improve the deep learning classifier's accuracy when the sample size is insufficient. The proposed system uses an LSTM based CGAN with an LSTM classifier to enhance the accuracy through data augmentation. The system can determine whether the subject's task is a Left Finger Tap, Right Finger Tap, or Foot Tap based on the fNIRS data patterns. The authors obtained a task classification accuracy of 90.2% for the LSTM based GAN combination.Clinical relevance- Acquiring medical data present practical difficulties due to time, money, labor, and economic cost. The deep learning-based model can better perform medical image classification than hand-crafted features when dealing with many data. GAN-based networks can be valuable in the medical field where collecting extensive data is not feasible. GAN-generated synthetic data can be used to improve the classification accuracy of classification systems.

Medial prefrontal brain activity correlates with emerging symptoms of anxiety and depression in late adolescence: A fNIRS study.

Papasideris M, Ayaz H, Hall PA.

Dev Psychobiol. 2021 Nov;63(7):e22199.
doi: 10.1002/dev.22199.

The brain undergoes dramatic changes over the course of the adolescent years, and these developmental changes are implicated in the emergence of disorders that involve negative emotionality. Late adolescence might be the window within which brain networks manifest vulnerabilities to depressive and anxiety symptomology; particularly within the prefrontal cortex (PFC), which houses emotional control (dorsolateral) and emotional processing (medial) nodes. Given the comorbidity of depressive and anxious symptomology, it may be that the neural signature is similar for both within the developing PFC. In a sample of 67 adolescents (M=15.97 years, SD=1.36), we used functional near-infrared spectroscopy (fNIRS) to examine the neural signature of emergent anxiety and depressive symptoms among younger and older adolescents. We further examined the extent to which neural signatures of anxiety and depressive symptoms within the PFC were similar or different. Findings revealed that self-reported anxiety and depressive symptoms were highly correlated, and that the neural signatures of both within the PFC were similar, corresponding with the medial subregions of the PFC (i.e., those involved in evaluative processing). These findings were evident only in later adolescence, suggesting the possibility of a common vulnerability for anxiety and depressive disorders emerging around this developmental window.

Doll play prompts social thinking and social talking: Representations of internal state language in the brain.

Hashmi S, Vanderwert RE, Paine AL, Gerson SA.

Dev Sci. 2021 Jul 21:e13163.
doi: 10.1111/desc.13163. Online ahead of print.

Doll play provides opportunities for children to practice social skills by creating imaginary worlds, taking others' perspectives, and talking about others' internal states. Previous research using functional near-infrared spectroscopy (fNIRS) found a region over the posterior superior temporal sulcus (pSTS) was more active during solo doll play than solo tablet play, implying that doll play might present opportunities for rehearsing theory of mind and empathy skills, even when playing alone. In this research, we addressed this more directly by investigating 4-8-year-old children's (N=33) use of internal state language (ISL; i.e., references to emotions, desires, and cognitions) when playing with dolls and on tablets, both by themselves and with a social partner, and their associated brain activity in the pSTS using fNIRS. We found that children used more ISL about others when playing with dolls than when playing on tablets, particularly when they were playing alone. This mirrored the patterns seen in pSTS activity in previous research. When individual variability in ISL about others was considered, more ISL about others was linked to stronger pSTS activation. Thus, variability in pSTS activity during play is not about the perceptual or physical differences between toys (e.g., dolls are more human-like) but about what children think about when they engage in different kinds of play. This is the first research to investigate brain activity during spontaneously occurring ISL and indicates that children have a tendency to take and discuss others' perspectives during doll play, with implications for social processing in the brain. A video abstract of this article can be viewed at https://youtu.be/58HgxbuhBzU.

Changes in cortical hemodynamics with the emergence of skilled motor ability in infants: An fNIRS study.

Nishiyori R, Harris MK, Baur K, Meehan SK.

Brain Res. 2021 Dec 1;1772:147666.
doi: 10.1016/j.brainres.2021.147666. Epub 2021 Sep 24.

The brain activity changes during infancy that underpin the emergence of functional motor skills, such as reaching and stepping, are not well understood. The current study used functional near-infrared spectroscopy (fNIRS) to examine the hemodynamic response across the frontal, mid-coronal plane (sensorimotor cortex) and external occipital protuberance (cerebellar cortex) regions of typically developing infants (5 to 13months) during reach-to-grasp or supported treadmill stepping behaviour. Motor ability was assessed using the third edition of the Motor Subscale of the Bayley Scales of Infant Development (BSID-III). Infants with enhanced motor ability demonstrated greater oxy-hemoglobin (HbO) concentration in the contralateral anterior mid-coronal and frontal-dorsal areas during right-handed reach-to-grasp. During bilateral reaching behavior, infants with enhanced motor ability showed greater HbO increases in right frontal-dorsal regions and lower HbO increases in left anterior mid-coronal areas. In contrast, infants' motor ability was associated with changes in de-oxyhemoglobin (HbR) concentration in the ipsilateral anterior mid-coronal, contralateral frontal and left external occipital protuberance regions during left-handed reaching behavior. These relationships between upper limb hemodynamics and infant motor ability are consistent with increased lateralization and cognitive-motor coupling as motor skills emerge. During stepping behavior, infants with enhanced motor ability demonstrated smaller increases in HbR concentration in the bilateral external occipital protuberance region consistent with an emerging efficiency as cruising and independent stepping behavior is still nascent. Together, the current results identify several distinct neural markers of functional motor ability during infancy that may be relevant to diagnostic testing and rehabilitation of developmental movement disorders.

Abnormal Cortical Activation Patterns Among Chinese-Speaking Schizophrenia Patients During Category and Letter Verbal Fluency Tasks Revealed by Multi-Channel Functional Near-Infrared Spectroscopy.

Li J, Mu J, Shen C, Yao G, Feng K, Zhang X, Liu P.

Front Psychiatry. 2021 Nov 25;12:790732.
doi: 10.3389/fpsyt.2021.790732. eCollection 2021.

Background: Functional near-infrared spectroscopy (fNIRS) has many advantages over other neuroimaging modalities for routine measurement of task-dependent cortical activation, but most fNIRS studies of schizophrenia have used letter fluency tasks (LFTs). Further, performances on category fluency tasks (CFTs) and LFTs may be distinct in Chinese patients due to the unique semantic features of Chinese written characters. To identify unique disease biomarkers measurable by fNIRS in Chinese schizophrenia patients, this study compared cortical oxygenated hemoglobin changes ([oxy-Hb]) during a Chinese LFT and CFT between patients and healthy controls. Methods: Inpatients of the Second Affiliated Hospital of Xinxiang Medical University were recruited from Match 2020 to July 2021. The Positive and Negative Symptom Scale (PANSS) was used to evaluate psychiatric symptoms. Dynamic changes in [oxy-Hb], an indicator of neural activity, were measured during CFT and LFT performance by 52-channel fNIRS. Results: Forty-seven schizophrenia inpatients and 29 healthy controls completed all tests. Schizophrenia patients showed significant cortical activation at 15 channels covering the left hemisphere and 17 channels over the right hemisphere during the CFT. During the LFT, activity was significantly increased at only six channels, all over the left hemisphere (FDR $P < 0.05$). In healthy controls, significant [oxy-Hb] increases were found at 24 channels over the left hemisphere and 19 channels over the right hemisphere during CFT. While during the LFT, the significant increases were found at 7 channels all over the left hemisphere (FDR $P < 0.05$). When years of education was included as a covariate, the schizophrenia group demonstrated no significant hypoactivation relative to healthy controls at any channel after FDR correction (FDR $P < 0.05$) during CFT while demonstrated significant hypoactivation at channel 11 during LFT (FDR $P < 0.05$). There were no significant associations between PANSS scores and [oxy-Hb] changes after FDR correction (FDR $P < 0.05$). Conclusions: Left lateralization during CFT was reduced among schizophrenia patients and may be related to the semantic deficit. The Chinese-CFT could be a more sensitive indicator of frontal-temporal dysfunction in schizophrenia.

Changes in Sensorimotor Cortical Activation in Children Using Prostheses and Prosthetic Simulators.

Copeland C, Mukherjee M, Wang Y, Fraser K, Zuniga JM.

Brain Sci. 2021 Jul 27;11(8):991.
doi: 10.3390/brainsci11080991.

This study aimed to examine the neural responses of children using prostheses and prosthetic simulators to better elucidate the emulation abilities of the simulators. We utilized functional near-infrared spectroscopy (fNIRS) to evaluate the neural response in five children with a congenital upper limb reduction (ULR) using a body-powered prosthesis to complete a 60 s gross motor dexterity task. The ULR group was matched with five typically developing children (TD) using their non-preferred hand and a prosthetic simulator on the same hand. The ULR group had lower activation within the primary motor cortex (M1) and supplementary motor area (SMA) compared to the TD group, but nonsignificant differences in the primary somatosensory area (S1). Compared to using their non-preferred hand, the TD group exhibited significantly higher action in S1 when using the simulator, but nonsignificant differences in M1 and SMA. The non-significant differences in S1 activation between groups and the increased activation evoked by the simulator's use may suggest rapid changes in feedback prioritization during tool use. We suggest that prosthetic simulators may elicit increased reliance on proprioceptive and tactile feedback during motor tasks. This knowledge may help to develop future prosthesis rehabilitative training or the improvement of tool-based skills.

The Effect of Socioeconomic Disparities on Prefrontal Activation in Initiating Joint Attention: A Functional Near-Infrared Spectroscopy Evidence From Two Socioeconomic Status Groups.

Ding K, Li C, Li Y, Wang H, Yu D.

Front Hum Neurosci. 2021 Dec 10;15:741872.
doi: 10.3389/fnhum.2021.741872. eCollection 2021.

Low socioeconomic status (SES) may generally have a long-lasting negative effect on cognitive development, and show deficits in the development of executive functions. However, it is unclear whether there is an SES-dependent disparity in the functional brain development of the prefrontal cortex. By collecting task-related functional near-infrared spectroscopy (fNIRS) data and behavioral data (e.g., intelligence, language, home reading environment (HRE), family income, and parental education level), the current study aimed to detect whether the SES of preschool children (N = 86) is associated with prefrontal activation during the joint attention task. Results verified that low-SES children show lower right prefrontal activation during joint attention than Relatively High-SES children. In addition, our findings confirmed the mediating effect of HRE on the association between SES and brain activation during joint attention, as well as that between SES and language ability. These results suggest that SES contributes to functional development of the prefrontal regions, and the improvement of HRE could be a potential strategy to intervene SES-related disparities on child development.

Phonetic versus spatial processes during motor-oriented imitations of visuo-labial and visuo-lingual speech: A functional near-infrared spectroscopy study.

Zhao T, Hu A, Su R, Lyu C, Wang L, Yan N.

Eur J Neurosci. 2021 Dec 1.
doi: 10.1111/ejn.15550. Online ahead of print.

While a large amount of research has studied the facilitation of visual speech on auditory speech recognition, few have investigated the processing of visual speech gestures in motor-oriented tasks that focus on the spatial and motor features of the articulator actions instead of the phonetic features of auditory and visual speech. The current study examined the engagement of spatial and phonetic processing of visual speech in a motor-oriented speech imitation task. Functional near-infrared spectroscopy (fNIRS) was used to measure the haemodynamic activities related to spatial processing and audiovisual integration in the superior parietal lobe (SPL) and the posterior superior/middle temporal gyrus (pSTG/pMTG) respectively. In addition, visuo-labial and visuo-lingual speech were compared with examine the influence of visual familiarity and audiovisual association on the processes in question. fNIRS revealed significant activations in the SPL but found no supra-additive audiovisual activations in the pSTG/pMTG, suggesting that the processing of audiovisual speech stimuli was primarily focused on spatial processes related to action comprehension and preparation, whereas phonetic processes related to audiovisual integration was minimal. Comparisons between visuo-labial and visuo-lingual speech imitations revealed no significant difference in the activation of the SPL or the pSTG/pMTG, suggesting that a higher degree of visual familiarity and audiovisual association did not significantly influence how visuo-labial speech was processed compared with visuo-lingual speech. The current study offered insights on the pattern of visual-speech processing under a motor-oriented task objective and provided further evidence for the modulation of multimodal speech integration by voluntary selective attention and task objective.

Integration of the Cortical Haemodynamic Response Measured by Functional Near-Infrared Spectroscopy and Amino Acid Analysis to Aid in the Diagnosis of Major Depressive Disorder.

Ong SK, Husain SF, Wee HN, Ching J, Kovalik JP, Cheng MS, Schwarz H, Tang TB, Ho CS.
Diagnostics (Basel). 2021 Oct 25;11(11):1978.
doi: 10.3390/diagnostics11111978.

BACKGROUND: Major depressive disorder (MDD) is a debilitating condition with a high disease burden and medical comorbidities. There are currently few to no validated biomarkers to guide the diagnosis and treatment of MDD. In the present study, we evaluated the differences between MDD patients and healthy controls (HCs) in terms of cortical haemodynamic responses during a verbal fluency test (VFT) using functional near-infrared spectroscopy (fNIRS) and serum amino acid profiles, and ascertained if these parameters were correlated with clinical characteristics. METHODS: Twenty-five (25) patients with MDD and 25 age-, gender-, and ethnicity-matched HCs were recruited for the study. Real-time monitoring of the haemodynamic response during completion of a VFT was quantified using a 52-channel NIRS system. Serum samples were analysed and quantified by liquid chromatography-mass spectrometry for amino acid profiling. Receiver-operating characteristic (ROC) curves were used to classify potential candidate biomarkers. RESULTS: The MDD patients had lower prefrontal and temporal activation during completion of the VFT than HCs. The MDD patients had lower mean concentrations of oxy-Hb in the left orbitofrontal cortex (OFC), and lower serum histidine levels. When the oxy-haemoglobin response was combined with the histidine concentration, the sensitivity and specificity of results improved significantly from 66.7% to 73.3% and from 65.0% to 90.0% respectively, as compared to results based only on the NIRS response. CONCLUSIONS: These findings demonstrate the use of combination biomarkers to aid in the diagnosis of MDD. This technique could be a useful approach to detect MDD with greater precision, but additional studies are required to validate the methodology.

Secondary rewards acquire enhanced incentive motivation via increasing anticipatory activity of the lateral orbitofrontal cortex.

Yang X, Liu X, Zeng Y, Wu R, Zhao W, Xin F, Yao S, Kendrick KM, Ebstein RP, Becker B.
Brain Struct Funct. 2021 Sep;226(7):2339-2355.
doi: 10.1007/s00429-021-02333-5. Epub 2021 Jul 12.

The motivation to strive for and consume primary rewards such as palatable food is bound by devaluation mechanisms, yet secondary rewards such as money may not be bound by these regulatory mechanisms. The present study therefore aimed at determining diverging devaluation trajectories for primary (chocolate milk) and secondary (money) reinforcers on the behavioral and neural level. Devaluation procedures withrepeated exposure to reward combined with a choice (Experiment 1) and an incentive delay (Experiment 2) paradigm consistently revealed decreasing hedonic value for the primary reward as reflected by decreasing hedonic evaluation and choice preferencewith repeated receipt, while hedonic value and preferences for the secondary reward increased. Concomitantly acquired functional near-infrared spectroscopy (fNIRS) data during the incentive delay paradigm revealed that increasing value of the secondary reward was accompanied by increasing anticipatory activation in the lateral orbitofrontal cortex, while during the consummatory phase the secondary reinforcer associated with higher medial orbitofrontal activity irrespective of devaluation stage. Overall, the findings suggest that-in contrast to primary reinforcers-secondary reinforcers, i.e. money, can acquire progressively enhanced incentive motivation with repeated receipt, suggesting a mechanism which could promote escalating striving to obtain secondary rewards.

Acupuncture With deqi Modulates the Hemodynamic Response and Functional Connectivity of the Prefrontal-Motor Cortical Network.

Si X, Xiang S, Zhang L, Li S, Zhang K, Ming D.
Front Neurosci. 2021 Aug 16;15:693623.
doi: 10.3389/fnins.2021.693623. eCollection 2021.

Erratum in Front Neurosci. 2021 Nov 10;15:773069.

Accent discrimination abilities during the first days of life: An fNIRS study.

Giordano V, Alexopoulos J, Spagna A, Benavides-Varela S, Peganc K, Kothgassner OD, Klebermass-Schrehof K, Olischar M, Berger A, Bartha-Doering L.

Brain Lang. 2021 Dec;223:105039.
doi: 10.1016/j.bandl.2021.105039. Epub 2021 Oct 19.

Humans are biologically endowed with the faculty of language. However, the way neonates can crack this complex communicative code is yet not totally understood. While phonetic discrimination has been widely investigated in neonates, less is known about the role of supra-segments patterns in the recognition of native language. Therefore, the aim of this study was to evaluate accent discrimination abilities in newborns in a sentential prosody paradigm. We used near-infared spectroscopy to investigate accent discrimination in 21 full-term born infants within the first days of life. Sentential prosody was used to investigate: (a) native accent, (b) foreign accent, and (c) flattened accent. Neonates revealed a significantly smaller hemodynamic response to native accent compared to flattened accent and foreign accent, respectively. Cluster-based permutation analysis revealed two clusters with a significant difference between the two conditions native accent and foreign accent. The first cluster covered the middle and superior frontal, middle and superior temporal, central, and parietal areas within the left hemisphere. The second cluster, located in the right hemisphere, covered inferior, middle, and superior frontal, central, middle and superior temporal areas. We therefore conclude that neonates can differentiate prosodic features like accents within the same language a few days after birth.

Bi-Anodal Transcranial Direct Current Stimulation Combined With Treadmill Walking Decreases Motor Cortical Activity in Young and Older Adults.

Orcioli-Silva D, Islam A, Baker MR, Gobbi LTB, Rochester L, Pantall A.

Front Aging Neurosci. 2021 Dec 3;13:739998.
doi: 10.3389/fnagi.2021.739998. eCollection 2021.

Background: Walking in the "real world" involves motor and cognitive processes. In relation to this, declines in both motor function and cognition contribute to age-related gait dysfunction. Transcranial direct current stimulation (tDCS) and treadmill walking (STW) have potential to improve gait, particularly during dual-task walking (DTW); walking whilst performing a cognitive task. Our aims were to analyze effects of combined anodal tDCS + STW intervention on cortical activity and gait during DTW. Methods: Twenty-three young adults (YA) and 21 older adults (OA) were randomly allocated to active or sham tDCS stimulation groups. Participants performed 5-min of mixed treadmill walking (alternating 30 s bouts of STW and DTW) before and after a 20-min intervention of active or sham tDCS + STW. Anodal electrodes were placed over the left prefrontal cortex (PFC) and the vertex (Cz) using 9 cm2 electrodes at 0.6 mA. Cortical activity of the PFC, primary motor cortex (M1), premotor cortex (PMC), and supplementary motor area (SMA) bilaterally were recorded using a functional near-infrared spectroscopy (fNIRS) system. Oxygenated hemoglobin (HbO2) levels were analyzed as indicators of cortical activity. An accelerometer measured gait parameters. We calculated the difference between DTW and STW for HbO2 and gait parameters. We applied linear mixed effects models which included age group (YA vs. OA), stimulation condition (sham vs. active), and time (pre- vs. post-intervention) as fixed effects. Treadmill belt speed was a covariate. Partial correlation tests were also performed. Results: A main effect of age group was observed. OA displayed higher activity bilaterally in the PFC and M1, unilaterally in the right PMC and higher gait variability than YA. M1 activity decreased in both YA and OA following active tDCS + STW. There was no overall effect of tDCS + STW on PFC activity or gait parameters. However, negative correlations were observed between changes in left PFC and stride length variability following active tDCS

+ STW intervention. Conclusion: Increased activity in multiple cortical areas during DTW in OA may act as a compensatory mechanism. Reduction in M1 activity following active tDCS + STW with no observed gait changes suggests improved neural efficiency.

Is left-behind a real reason for children's social cognition deficit? An fNIRS study on the effect of social interaction on left-behind preschooler's prefrontal activation.

Ding K, Li C, Jia H, Zhang M, Yu D.

PLoS One. 2021 Sep 17;16(9):e0254010.
doi: 10.1371/journal.pone.0254010. eCollection 2021.

The left-behind phenomenon, caused by parent out-migration, has become a common social issue and might lead to long-term and potential risks for children in rural areas of China. It is important to investigate the effect of social interaction on prefrontal activation of left-behind children in China because of possible effects of parent out-migration on children's social cognition. We recruited 81 rural Chinese preschoolers aged 52-76 months (mean = 64.98 6.321 months) preschoolers with three different statuses of parental out-migration (including non-, partially, and completely left-behind children). Using functional Near-Infrared Spectroscopy (fNIRS), we compared behavior and brain activation and in three groups (non-, partially-, completely-left-behind children) under two different social interaction conditions (child-teacher and child-stranger situation). Results revealed that initiating joint attention (IJA) may evoke higher brain activation than responding to joint attention (RJA) in the prefrontal cortex (PFC), especially in the case of initiating joint attention with the stranger. In addition, the activation of joint attention was positively correlated with children's language score, cognitive flexibility, and facial expression recognition. More importantly, partially-left-behind children evoked higher brain activation in the IJA condition and presented a higher language level than completely/non-left-behind children. The current study provides insight into the neural basis of left-behind children's development and revealed for the first time that family economic level and left-behind status may contribute to the lower social cognition.

Sleep deprivation alters task-related changes in functional connectivity of the frontal cortex: A near-infrared spectroscopy study.

Mukli P, Csipo T, Lipecz A, Stylianou O, Racz FS, Owens CD, Perry JW, Tarantini S, Sorond FA, Kellawan JM, Purebl G, Yang Y, Sonntag WE, Csiszar A, Ungvari ZI, Yabluchanskiy A.

Brain Behav. 2021 Aug;11(8):e02135.
doi: 10.1002/brb3.2135. Epub 2021 Jun 22.

Sleep deprivation (SD) is known to be associated with decreased cognitive performance; however, the underlying mechanisms are poorly understood. As interactions between distinct brain regions depend on mental state, functional brain networks established by these connections typically show a reorganization during task. Hence, analysis of functional connectivity (FC) could reveal the task-related change in the examined frontal brain networks. Our objective was to assess the impact of SD on static FC in the prefrontal and motor cortices and find whether changes in FC correlate with changes in neuropsychological scores. Healthy young male individuals (n=10, 27.63.7years of age) participated in the study. A battery of tests from the Cambridge Neuropsychological Test Automated Battery (CANTAB) and 48 channel functional near-infrared spectroscopy (fNIRS) measurements were performed before and after 24hr of SD. Network metrics were obtained by graph theoretical analysis using the fNIRS records in resting state and during finger-tapping sessions. During task, SD resulted in a significantly smaller decrease in the number and strength of functional connections (characterizing FC) in the frontal cortex. Changes in the global connection strengths correlated with decreased performance in the paired association learning test. These results indicate a global impact of SD on functional brain networks in the frontal lobes.

Conditional-GAN Based Data Augmentation for Deep Learning Task Classifier Improvement Using fNIRS Data.

Wickramaratne SD, Mahmud MS.

Front Big Data. 2021 Jul 29;4:659146.
doi: 10.3389/fdata.2021.659146. eCollection 2021.

Functional near-infrared spectroscopy (fNIRS) is a neuroimaging technique used for mapping the functioning human cortex. fNIRS can be widely used in population studies due to the technology's economic, non-invasive, and portable nature. fNIRS can be used for task classification, a crucial part of functioning with Brain-Computer Interfaces (BCIs). fNIRS data are multidimensional and complex, making them ideal for deep learning algorithms for classification. Deep Learning classifiers typically need a large amount of data to be appropriately trained without over-fitting. Generative networks can be used in such cases where a substantial amount of data is required. Still, the collection is complex due to various constraints. Conditional Generative Adversarial Networks (CGAN) can generate artificial samples of a specific category to improve the accuracy of the deep learning classifier when the sample size is insufficient. The proposed system uses a CGAN with a CNN classifier to enhance the accuracy through data augmentation. The system can determine whether the subject's task is a Left Finger Tap, Right Finger Tap, or Foot Tap based on the fNIRS data patterns. The authors obtained a task classification accuracy of 96.67% for the CGAN-CNN combination.

Relationship between Short-Range and Homotopic Long-Range Resting State Functional Connectivity in Temporal Lobes in Autism Spectrum Disorder.

Wu X, Lin F, Sun W, Zhang T, Sun H, Li J.

Brain Sci. 2021 Nov 5;11(11):1467.
doi: 10.3390/brainsci11111467.

To investigate the relationship between short-range and homotopic long-range resting state functional connectivity (RSFC) in children with autism spectrum disorder (ASD) and typically developing (TD) children, we analyzed functional near-infrared spectroscopy (fNIRS) RSFC in 25 children with ASD and 22 age-matched TD children. The resting state fNIRS signals, including spontaneous fluctuations in the oxygenated hemoglobin (HbO2) and deoxygenated hemoglobin (Hb) concentrations, were recorded from the bilateral temporal lobes. We found that (1) there was no difference in the short-range RSFC between the left and right hemisphere in either ASD or TD group; (2) both the short-range and homotopic long-range RSFC were weaker in the ASD than TD group; and (3) the short-range RSFC was stronger than the homotopic long-range RSFC in the ASD group, whereas no such difference was observed in the TD group. These observations might be helpful for a better understanding of the underlying cortical mechanism in ASD.

Maternal sensitivity and infant neural response to touch: an fNIRS study.

Mateus V, Osrio A, Miguel HO, Cruz S, Sampaio A.

Soc Cogn Affect Neurosci. 2021 Dec 30;16(12):1256-1263.
doi: 10.1093/scan/nsab069.

The mother's attunement to her infant's emotional needs influences her use of touching behaviors during mother-infant interactions. Moreover, maternal touch appears to modulate infants' physiological responses to affective touch. However, little is known about the impact of maternal sensitivity on infants' touch processing at a brain level. This study explored the association between maternal sensitivity when infants (N = 24) were 7 months old and their patterns of cortical activation to touch at 12 months. Brain activation was measured using functional near-infrared spectroscopy. Changes in oxy-hemoglobin

(HbO2) and deoxy-hemoglobin (HHb) concentrations were measured in the left somatosensory cortex and right temporal cortex while infants received two types of tactile stimulation-affective and discriminative touch. Results showed that a lower maternal sensitivity was associated with a higher HbO2 response for discriminative touch over the temporal region. Additionally, infants of less sensitive mothers tended to present a higher response in HbO2 for affective touch over the somatosensory region. These findings suggest that less sensitive interactions might result in a lower exposure to maternal touch, which can be further related to infants' neural processing of touch.

Decreased Right Prefrontal Synchronization Strength and Asymmetry During Joint Attention in the Left-Behind Children: A Functional Near-Infrared Spectroscopy Study.

Ding K, Wang H, Li C, Liu F, Yu D.

Front Physiol. 2021 Nov 11;12:759788.
doi: 10.3389/fphys.2021.759788. eCollection 2021.

Although there are millions of left-behind children in China, the researches on brain structure and functions in left-behind children are not sufficient at the brain imaging level. This study aimed to explore whether there is decreased prefrontal synchronization during joint attention in left-behind children. Sixty children (65.12 6.54 months, 29 males) with 34 left-behind children were recruited. The functional near-infrared spectroscopy (fNIRS) imaging data from the prefrontal cortex during joint attention, as well as behavioral measures (associated with family income, intelligence, language, and social-emotional abilities), were collected. Results verified that brain imaging data and behavioral measures are correlative and support that left-behind children have deficits in social-emotional abilities. More importantly, left-behind children showed decreased synchronization strength and asymmetry in the right middle frontal gyrus during joint attention. The findings suggest that decreased right prefrontal synchronization strength and asymmetry during joint attention might be vulnerability factors in the development of left-behind children.

Frontotemporal activation differs between perception of simulated cochlear implant speech and speech in background noise: An image-based fNIRS study.

Defenderfer J, Forbes S, Wijeakumar S, Hedrick M, Plyler P, Buss AT.

Neuroimage. 2021 Oct 15;240:118385.
doi: 10.1016/j.neuroimage.2021.118385. Epub 2021 Jul 10.

In this study we used functional near-infrared spectroscopy (fNIRS) to investigate neural responses in normal-hearing adults as a function of speech recognition accuracy, intelligibility of the speech stimulus, and the manner in which speech is distorted. Participants listened to sentences and reported aloud what they heard. Speech quality was distorted artificially by vocoding (simulated cochlear implant speech) or naturally by adding background noise. Each type of distortion included high and low-intelligibility conditions. Sentences in quiet were used as baseline comparison. fNIRS data were analyzed using a newly developed image reconstruction approach. First, elevated cortical responses in the middle temporal gyrus (MTG) and middle frontal gyrus (MFG) were associated with speech recognition during the low-intelligibility conditions. Second, activation in the MTG was associated with recognition of vocoded speech with low intelligibility, whereas MFG activity was largely driven by recognition of speech in background noise, suggesting that the cortical response varies as a function of distortion type. Lastly, an accuracy effect in the MFG demonstrated significantly higher activation during correct perception relative to incorrect perception of speech. These results suggest that normal-hearing adults (i.e., untrained listeners of vocoded stimuli) do not exploit the same attentional mechanisms of the frontal cortex used to resolve naturally degraded speech and may instead rely on segmental and phonetic analyses in the temporal lobe to discriminate vocoded speech.

fNIRS Monitoring of Infant Prefrontal Cortex During Crawling and an Executive Functioning Task.

Weibley H, Di Filippo M, Liu X, Lazenby L, Goscha J, Ferreira A, Muscalu L, Rader N.

Front Behav Neurosci. 2021 Aug 13;15:675366.
doi: 10.3389/fnbeh.2021.675366. eCollection 2021.

Functional near-infrared spectroscopy (fNIRS)is a brain-imaging technology used to reveal brain activity by measuring blood oxygenation. Using fNIRS we measured activity in the left prefrontal lobe of 8-14 month-old infants as they crawled or were pushed in a stroller and as they were given a passive attention task or an active executive function (EF) task. For each task, we measured peak total hemoglobin concentration and peak Oxy relative to baseline. Results revealed differences in peak Oxy levels for crawling vs. strolling and between the EF and passive cognitive tasks, with total hemoglobin greater for the EF task than the passive attention task. These results support the theoretical view that both active locomotion and EF engage the prefrontal cortex (PFC) during early development.

Prefrontal cortex alterations in major depressive disorder, generalized anxiety disorder and their comorbidity during a verbal fluency task assessed by multi-channel near-infrared spectroscopy.

Hu S, Li XJ, Law S, Shen CY, Yao GQ, Zhang XQ, Li J, Chen GF, Xu B, Liu XM, Ma XY, Feng K, Liu PZ.

Psychiatry Res. 2021 Dec;306:114229.
doi: 10.1016/j.psychres.2021.114229. Epub 2021 Sep 28.

Major depressive disorder (MDD) and generalized anxiety disorder (GAD) are frequently comorbid with each other, and both associated with substantial cognitive impairments; however, it is still unclear whether their impairments are neurobiologically similar or distinct. This study aims to investigate the cognitive functions of the prefrontal cortex (PFC) in patients with MDD and GAD during the verbal fluency task (VFT) using functional near-infrared spectroscopy (fNIRS). Fifty-two patients with MDD, fifty-one patients with GAD, fifty-two patients with the comorbidity of MDD and GAD (CMG), and forty-seven healthy controls (HC) participated in the study. Significant hypoactivation in the left ventrolateral and the left dorsolateral PFC was common in all patient groups when compared to HCs, suggesting a shared etiology. Furthermore, MDD patients showed significant hypoactivation at the right frontal pole cortex (FPoC) when compared to HCs and significant hypoactivation at the middle FPoC when compared to the CMG patients. Our work is the first fNIRS study to reveal the shared and unique neurobiological profiles of MDD, GAD and their comorbidity under the same standard experimentation condition, suggesting fNIRS holds promise as an adjutant to assist clinical diagnosis.

Optical Mapping of Brain Activity Underlying Directionality and Its Modulation by Expertise in Mandarin/English Interpreting.

He Y, Hu Y, Yang Y, Li D, Hu Y.

Front Hum Neurosci. 2021 Aug 6;15:649578.
doi: 10.3389/fnhum.2021.649578. eCollection 2021.

Recent neuroimaging research has suggested that unequal cognitive efforts exist between interpreting from language 1 (L1) to language 2 (L2) compared with interpreting from L2 to L1. However, the neural substrates that underlie this directionality effect are not yet well understood. Whether directionality is modulated by interpreting expertise also remains unknown. In this study, we recruited two groups of Mandarin (L1)/English (L2) bilingual speakers with varying levels of interpreting expertise and asked them to perform interpreting and reading tasks. Functional near-infrared spectroscopy (fNIRS) was used to collect

cortical brain data for participants during each task, using 68 channels that covered the prefrontal cortex and the bilateral perisylvian regions. The interpreting-related neuroimaging data was normalized by using both L1 and L2 reading tasks, to control the function of reading and vocalization respectively. Our findings revealed the directionality effect in both groups, with forward interpreting (from L1 to L2) produced more pronounced brain activity, when normalized for reading. We also found that directionality was modulated by interpreting expertise in both normalizations. For the group with relatively high expertise, the activated brain regions included the right Broca's area and the left premotor and supplementary motor cortex; whereas for the group with relatively low expertise, the activated brain areas covered the superior temporal gyrus, the dorsolateral prefrontal cortex (DLPFC), the Broca's area, and visual area 3 in the right hemisphere. These findings indicated that interpreting expertise modulated brain activation, possibly because of more developed cognitive skills associated with executive functions in experienced interpreters.

Scarcity Mindset Neuro Network Decoding With Reward: A Tree-Based Model and Functional Near-Infrared Spectroscopy Study.

Jiang X, Zhou C, Ao N, Gu W, Li J, Chen Y.

Front Hum Neurosci. 2021 Nov 24;15:736415.
doi: 10.3389/fnhum.2021.736415. eCollection 2021.

Resource scarcity imposes challenging demands on the human cognitive system. Insufficient resources cause the scarcity mindset to affect cognitive performance, while reward enhances cognitive function. Here, we examined how reward and scarcity simultaneously contribute to cognitive performance. Experimental manipulation to induce a polar scarcity mindset and reward conditions within participants under functional near-infrared spectroscopy (fNIRS) recording was implemented to explore the mechanism underlying the scarcity mindset and reward in terms of behavior and neurocognition. Participants showed decreased functional connectivity from the dorsolateral prefrontal cortex (DLPFC) to the ventrolateral prefrontal cortex (VLPFC) with a scarcity mindset, a region often implicated in cognitive control. Moreover, under reward conditions, the brain activation of the maximum total Hb bold signal was mainly located in the left hemisphere [channels 1, 3, and 4, left ventrolateral prefrontal cortex (L-VLPFC) and channel 6, left dorsolateral prefrontal cortex (L-DLPFC)], and there was also significant brain activation of the right dorsolateral prefrontal cortex (R-DLPFC) in the right hemisphere (channel 17). Furthermore, these data indicate the underlying neural changes of the scarcity mentality and demonstrate that brain activities may underlie reward processing. Additionally, the base-tree machine learning model was trained to detect the mechanism of reward function in the prefrontal cortex (PFC). According to SHapley Additive exPlanations (SHAP), channel 8 contributed the most important effect, as well as demonstrating a high-level interrelationship with other channels.

Taking a Deeper Look at the Brain: Predicting Visual Perceptual and Working Memory Load from High-Density fNIRS Data.

Wang J, Grant T, Velipasalar Gursoy S, Geng B, Hirshfield L.

IEEE J Biomed Health Inform. 2021 Dec 9;PP.
doi: 10.1109/JBHI.2021.3133871. Online ahead of print.

Predicting workload using physiological sensors has taken on a diffuse set of methods in recent years. However, the majority of these methods train models on small datasets, with small numbers of channel locations on the brain, limiting a models ability to transfer across participants, tasks, or experimental sessions. In this paper, we introduce a new method of modeling a large, cross-participant and cross-session set of high density functional near infrared spectroscopy (fNIRS) data by using an approach grounded in cognitive load theory and employing a Bi-Directional Gated Recurrent Unit (BiGRU) incorporating attention mechanism and self-supervised label augmentation (SLA). We show that our proposed CNN-

BiGRU-SLA model can learn and classify different levels of working memory load (WML) and visual processing load (VPL) across participants. Importantly, we leverage a multi-label classification scheme, where our models are trained to predict simultaneously occurring levels of WML and VPL. We evaluate our model using leave-one-participant-out (LOOCV) as well as 10-fold cross validation. Using LOOCV, for binary classification (off/on), we reached an F1-score of 0.9179 for WML and 0.8907 for VPL across 22 participants (each participant did 2 sessions). For multi-level (off, low, high) classification, we reached an F1-score of 0.7972 for WML and 0.7968 for VPL. Using 10-fold cross validation, for multi-level classification, we reached an F1-score of 0.7742 for WML and 0.7741 for VPL.

Cortical processing of dynamic bodies in the superior occipito-temporal regions of the infants' brain: Difference from dynamic faces and inversion effect.

Kobayashi M, Kanazawa S, Yamaguchi MK, O'Toole AJ.

Neuroimage. 2021 Dec 1;244:118598.
doi: 10.1016/j.neuroimage.2021.118598. Epub 2021 Sep 27.

Previous functional neuroimaging studies imply a crucial role of the superior temporal regions (e.g., superior temporal sulcus: STS) for processing of dynamic faces and bodies. However, little is known about the cortical processing of moving faces and bodies in infancy. The current study used functional near-infrared spectroscopy (fNIRS) to directly compare cortical hemodynamic responses to dynamic faces (videos of approaching people with blurred bodies) and dynamic bodies (videos of approaching people with blurred faces) in infants' brain. We also examined the body-inversion effect in 5- to 8-month-old infants using hemodynamic responses as a measure. We found significant brain activity for the dynamic faces and bodies in the superior area of bilateral temporal cortices in both 5- to 6-month-old and 7- to 8-month-old infants. The hemodynamic responses to dynamic faces occurred across a broader area of cortex in 7- to 8-month-olds than in 5- to 6-month-olds, but we did not find a developmental change for dynamic bodies. There was no significant activation when the stimuli were presented upside down, indicating that these activation patterns did not result from the low-level visual properties of dynamic faces and bodies. Additionally, we found that the superior temporal regions showed a body inversion effect in infants aged over 5 months: the upright dynamic body stimuli induced stronger activation compared to the inverted stimuli. The most important contribution of the present study is that we identified cortical areas responsive to dynamic bodies and faces in two groups of infants (5-6-months and 7-8-months of age) and we found different developmental trends for the processing of bodies and faces.

Working Memory Performance under a Negative Affect Is More Susceptible to Higher Cognitive Workloads with Different Neural Haemodynamic Correlates.

Feng YX, Kiguchi M, Ung WC, Dass SC, Mohd Hani AF, Tang TB, Ho ETW.

Brain Sci. 2021 Jul 15;11(7):935.
doi: 10.3390/brainsci11070935.

The effect of stress on task performance is complex, too much or too little stress negatively affects performance and there exists an optimal level of stress to drive optimal performance. Task difficulty and external affective factors are distinct stressors that impact cognitive performance. Neuroimaging studies showed that mood affects working memory performance and the correlates are changes in haemodynamic activity in the prefrontal cortex (PFC). We investigate the interactive effects of affective states and working memory load (WML) on working memory task performance and haemodynamic activity using functional near-infrared spectroscopy (fNIRS) neuroimaging on the PFC of healthy participants. We seek to understand if haemodynamic responses could tell apart workload-related stress from situational stress arising from external affective distraction. We found that the haemodynamic changes towards affective stressor- and workload-related stress were more dominant in the medial and lateral PFC, respectively. Our study

reveals distinct affective state-dependent modulations of haemodynamic activity with increasing WML in n-back tasks, which correlate with decreasing performance. The influence of a negative effect on performance is greater at higher WML, and haemodynamic activity showed evident changes in temporal, and both spatial and strength of activation differently with WML.

Acute VR competitive cycling exercise enhanced cortical activations and brain functional network efficiency in MA-dependent individuals.

Qi L, Yin Y, Bu L, Tang Z, Tang L, Dong G.

Neurosci Lett. 2021 Jul 13;757:135969.
doi: 10.1016/j.neulet.2021.135969. Epub 2021 May 21.

BACKGROUND: Methamphetamine (MA) dependence is associated with elevated rates cognitive impairment in MA users. The objective of the present study was to investigate the effects of virtual reality (VR) competitive cycling excise on the neurocognitive functions and on negative affectivity of MA-dependent individuals. METHODS: Thirty MA-dependent individuals performed a colour-word Stroop task and underwent a profile of mood states (POMS) scale assessment both before and after a 10 min VR competitive cycling exercise. Functional near-infrared spectroscopy (fNIRS) were recorded during the pre-and post-exercise Stroop tasks and during rest. RESULTS: After acute exercise, neural activity, along with improved Stroop performance, was enhanced significantly in the dorsolateral prefrontal cortex. Also observed during post-exercise Stroop tasks was a more efficient network architecture in the topological organization of brain networks than during the pre-exercise Stroop tasks. As for resting states before versus after exercisethe, we detected an increased functional connectivity between the prefrontal cortex and the motor cortex after exercise. CONCLUSIONS: These results suggest that an acute bout of VR competitive cycling exercise facilitates executive information processing by enhancing task-related cortical activations and brain functional network efficiency in MA-dependent individuals.

Dynamic inter-brain synchrony in real-life inter-personal cooperation: A functional near-infrared spectroscopy hyperscanning study.

Li R, Mayseless N, Balters S, Reiss AL.

Neuroimage. 2021 Sep;238:118263.
doi: 10.1016/j.neuroimage.2021.118263. Epub 2021 Jun 11.

How two brains communicate with each other during social interaction is highly dynamic and complex. Multi-person (i.e., hyperscanning) studies to date have focused on analyzing the entire time series of brain signals to reveal an overall pattern of inter-brain synchrony (IBS). However, this approach does not account for the dynamic nature of social interaction. In the present study, we propose a data-driven approach based on sliding windows and k-mean clustering to capture the dynamic modulation of IBS patterns during interactive cooperation tasks. We used a portable functional near-infrared spectroscopy (fNIRS) system to measure brain hemodynamic response between interacting partners (20 dyads) engaged in a creative design task and a 3D model building task. Results indicated that inter-personal communication during naturalistic cooperation generally presented with a series of dynamic IBS states along the tasks. Compared to the model building task, the creative design task appeared to involve more complex and active IBS between multiple regions in specific dynamic IBS states. In summary, the proposed approach stands as a promising tool to distill complex inter-brain dynamics associated with social interaction into a set of representative brain states with more fine-grained temporal resolution. This approach holds promise for advancing our current understanding of the dynamic nature of neurocognitive processes underlying social interaction.

Coupling between prefrontal brain activity and respiratory sinus arrhythmia in infants and adults.

Nguyen T, Hoehl S, Bertenthal BI, Abney DH.

Dev Cogn Neurosci. 2021 Dec 13;53:101047.
doi: 10.1016/j.dcn.2021.101047. Online ahead of print.

Self-regulation is an essential aspect of healthy child development. Even though infants are dependent on their caregivers for co-regulation during the first years, they begin to gain early regulatory abilities through social interactions as well as their own cognitive development. These early regulatory abilities continue to increase with the maturation of both the prefrontal cortex and the vagal system. Importantly, theoretical accounts have suggested that the prefrontal cortex and the vagal system are linked through forward and backward feedback loops via the limbic system. Decreased coupling within this link is suggested to be associated with psychopathology. The primary goal of this study is to examine whether intrapersonal coupling of prefrontal brain activity and respiratory sinus arrythmia is evident in infancy. Using the simultaneous assessment of functional near-infrared spectroscopy and electrocardiography, we will use Cross-Recurrence Quantification Analysis to assess the coupling of prefrontal brain activity and respiratory sinus arrhythmia in 69 4-6-month-old infants and their mothers during rest. Understanding the developmental emergence of the neurobiological correlates of self- regulation will allow us to help identify neurodevelopmental risk factors.

Changes in prefrontal cerebral hemodynamics during intermittent pain stimulation to gingiva: Preliminary study using functional near infrared spectroscopy.

Sakuma S, Inamoto K, Yamaguchi Y, Takagi S, Higuchi N.

J Dent Sci. 2021 Jul;16(3):980-986.
doi: 10.1016/j.jds.2020.09.013. Epub 2020 Nov 2.

BACKGROUND/PURPOSE: Elucidating the transmission mechanism of pain signals from the orofacial area and the corresponding modification mechanism will not only aid in the understanding of pain mechanisms but also provide useful information regarding the development of pain mitigation methods. In this study, the involvement of the pain suppression system in the trigeminal area was investigated through an analysis of the activation status over time in the prefrontal cortex using functional near-infrared spectroscopy (fNIRS). MATERIALS AND METHODS: In 28 healthy, right-handed male volunteers (average age, 30.14.2 years) as subjects, a mild, intermittent, acute pain stimulus was administered through the implementation of pocket probing of the gingiva surrounding the right maxillary central incisor. In the prefrontal cortex, the levels of hemoglobin (Hb) were measured using the fNIRS measurement system. Average values of both oxy-Hb and deoxy-Hb were calculated at four stages: rest stage, 20s prior to the pain stimulus application, and three stages at 20-s intervals within 1min of stimulation. One-way analysis of variance and multiple comparisons were used to compare representative values to investigate the changes due to pain. RESULTS: Oxy-Hb levels decreased the most during the 20s stage directly after stimulus application. This change was seen mainly on the contralateral side, after which it returned to the resting baseline level before the stimulus application. CONCLUSION: Our data demonstrate that in healthy males, a mechanism exists to mitigate pain involving the pain suppression system in the 20s after feeling mild pain to the gingiva.

Grey-box modeling and hypothesis testing of functional near-infrared spectroscopy-based cerebrovascular reactivity to anodal high-definition tDCS in healthy humans.

Arora Y, Walia P, Hayashibe M, Muthalib M, Chowdhury SR, Perrey S, Dutta A.

PLoS Comput Biol. 2021 Oct 6;17(10):e1009386.
doi: 10.1371/journal.pcbi.1009386. eCollection 2021 Oct.

Transcranial direct current stimulation (tDCS) has been shown to evoke hemodynamics response; however, the mechanisms have not been investigated systematically using systems biology approaches. Our study presents a grey-box linear model that was developed from a physiologically detailed multi-compartmental neurovascular unit model consisting of the vascular smooth muscle, perivascular space, synaptic space, and astrocyte glial cell. Then, model linearization was performed on the physiologically detailed nonlinear model to find appropriate complexity (Akaike information criterion) to fit functional near-infrared spectroscopy (fNIRS) based measure of blood volume changes, called cerebrovascular reactivity (CVR), to high-definition (HD) tDCS. The grey-box linear model was applied on the fNIRS-based CVR during the first 150 seconds of anodal HD-tDCS in eleven healthy humans. The grey-box linear models for each of the four nested pathways starting from tDCS scalp current density that perturbed synaptic potassium released from active neurons for Pathway 1, astrocytic transmembrane current for Pathway 2, perivascular potassium concentration for Pathway 3, and voltage-gated ion channel current on the smooth muscle cell for Pathway 4 were fitted to the total hemoglobin concentration (tHb) changes from optodes in the vicinity of 4x1 HD-tDCS electrodes as well as on the contralateral sensorimotor cortex. We found that the tDCS perturbation Pathway 3 presented the least mean square error (MSE, median <2.5%) and the lowest Akaike information criterion (AIC, median -1.726) from the individual grey-box linear model fitting at the targeted-region. Then, minimal realization transfer function with reduced-order approximations of the grey-box model pathways was fitted to the ensemble average tHb time series. Again, Pathway 3 with nine poles and two zeros (all free parameters), provided the best Goodness of Fit of 0.0078 for Chi-Square difference test of nested pathways. Therefore, our study provided a systems biology approach to investigate the initial transient hemodynamic response to tDCS based on fNIRS tHb data. Future studies need to investigate the steady-state responses, including steady-state oscillations found to be driven by calcium dynamics, where transcranial alternating current stimulation may provide frequency-dependent physiological entrainment for system identification. We postulate that such a mechanistic understanding from system identification of the hemodynamics response to transcranial electrical stimulation can facilitate adequate delivery of the current density to the neurovascular tissue under simultaneous portable imaging in various cerebrovascular diseases.

Antidepressant Monotherapy and Combination Therapy with Acupuncture in Depressed Patients: A Resting-State Functional Near-Infrared Spectroscopy (fNIRS) Study.

Wong YK(#), Wu JM(#), Zhou G, Zhu F, Zhang Q, Yang XJ, Qin Z, Zhao N, Chen H, Zhang ZJ.
Neurotherapeutics. 2021 Aug 24.
doi: 10.1007/s13311-021-01098-3. Online ahead of print.

Depression is a common psychiatric illness affecting over 300 million people globally. Acupuncture has been reported to be a safe complementary treatment for depression. This study is aimed to investigate the efficacy and mechanism of combining acupuncture with antidepressants in treating depression compared to the sole use of antidepressants. Seventy depression patients were randomly assigned to the treatment group (n = 50) and control group (n = 20). The treatment group received acupuncture combined antidepressants treatment for 3weeks, while the control group took antidepressants monotherapy for 3weeks. Among the 70 patients, 40 participants (20 control; 20 treatment) were randomized for studying functional connectivity (FC) of the dorsolateral prefrontal cortex (DLPFC) measured by the functional near-infrared spectroscopy. The primary outcome was HAMD-17 and secondary outcomes were PHQ-9, and the relationships of resting-state FC (rsFC) with the depression severity. PHQ-9 and HAMD-17 scores in the treatment group were significantly lower than those in the control group at Week 3 (p = 0.01) with effect sizes of -0.4 and -0.61 respectively. The rsFC in F1, F3, AF3, AF7, FC3, FC5 (left DLPFC, 10-20 system), AF8, and F6 (right DLPFC) in the treatment group had significant temporal correlation ($p < 0.05$, FDR corrected) in DLPFC compared to the channels in the control group. No significant correlation was found between the changes of rsFC and depression severity. In conclusion, depressed patients receiving acupuncture combined with

antidepressants have improvement of depressive symptoms and the stronger rsFC in the DLPFC compared to those using antidepressants alone.

Pre-SMA activation and the perception of contagiousness and authenticity in laughter sounds.

Billing ADN, Cooper RJ, Scott SK.

Cortex. 2021 Oct;143:57-68.
doi: 10.1016/j.cortex.2021.06.010. Epub 2021 Jul 16.

Functional near-infrared spectroscopy and behavioural methods were used to examine the neural basis of the behavioural contagion and authenticity of laughter. We demonstrate that the processing of laughter sounds recruits networks previously shown to be related to empathy and auditory-motor mirror networks. Additionally, we found that the differences in the levels of activation in response to volitional and spontaneous laughter could predict an individual's perception of how contagious they found the laughter to be.

Getting in synch: Unpacking the role of parent-child synchrony in the development of internalizing and externalizing behaviors.

Quiones-Camacho LE, Hoyniak CP, Wakschlag LS, Perlman SB.

Dev Psychopathol. 2021 Sep 15:1-13.
doi: 10.1017/S0954579421000468. Online ahead of print.

While substantial research supports the role of parent-child interactions on the emergence of psychiatric symptoms, few studies have explored biological mechanisms for this association. The current study explored behavioral and neural parent-child synchronization during frustration and play as predictors of internalizing and externalizing behaviors across a span of 1.5 years. Parent-child dyads first came to the laboratory when the child was 4-5 years old and completed the Disruptive Behavior Diagnostic Observation Schedule: Biological Synchrony (DB-DOS: BioSync) task while functional near-infrared spectroscopy (fNIRS) data were recorded. Parents reported on their child's internalizing and externalizing behaviors using the Child Behavior Checklist (CBCL) four times over 1.5 years. Latent growth curve (LGC) modeling was conducted to assess neural and behavioral synchrony as predictors of internalizing and externalizing trajectories. Consistent with previous investigations in this age range, on average, internalizing and externalizing behaviors decreased over the four time points. Parent-child neural synchrony during a period of play predicted rate of change in internalizing but not externalizing behaviors such that higher parent-child neural synchrony was associated with a more rapid decrease in internalizing behaviors. Our results suggest that a parent-child dyad's ability to coordinate neural activation during positive interactions might serve as a protective mechanism in the context of internalizing behaviors.

Neural Activation via Acupuncture in Patients With Major Depressive Disorder: A Functional Near-Infrared Spectroscopy Study.

Zhang T, Zhang J, Huang J, Zheng Z, Wang P.

Front Psychiatry. 2021 Nov 12;12:669533.
doi: 10.3389/fpsyt.2021.669533. eCollection 2021.

Background and Objective: Acupuncture is used as an alternative treatment for patients with major depressive disorder (MDD). The associated therapeutic effect of acupuncture is often attributed to its modulatory effect on the activity of the pre-frontal cortex (PFC), although the mechanism is not well-studied. We employed a repeated measures design to investigate the brain modulatory effect of acupuncture

on the PFC in a group of patients with MDD and investigated whether the modulatory effect is influenced by the severity of the disease. Methods: A total of 47 patients diagnosed with MDD were enrolled in this functional near-infrared spectroscopy experiment. The severity of depressive symptoms was measured at baseline using the Hamilton Depression Rating Scale-24 (HAMD). The cortical activation in the bilateral PFC areas during a verbal fluency task (VFT) was measured before and after a single session of acupuncture in the Baihui acupoint. We further explored the potential correlation between the severity of MDD and task-related activation before and after acupuncture. Results: A single session of acupuncture significantly tended to enhance the activation level of the left frontopolar cortex in patients with severe depression during VFT, but a null effect was found in those with mild to moderate depression. Among patients with severe depression, a strong correlation was observed between HAMD scores and the change in VFT-related activation after acupuncture in the left dorsolateral PFC (DLPFC). Conclusion: A single session of acupuncture did not significantly modulate the activation of the left PFC in patients with mild to moderate depression; however, it demonstrated a tendency to enhance the activation of the frontopolar area in patients with severe depression. Among patients with severe depression, there is a correlation between the activation by acupuncture of left DLPFC during executive functioning and the severity of depressive symptoms, suggesting that the brain activity induced by acupuncture is likely to be influenced by the baseline disease severity in patients with MDD.

Syntactic and Semantic Processing in Japanese Sentence Reading: A Research Using Functional Near-Infrared Spectroscopy (fNIRS).

Zhao L, Kojima H, Yasunaga D, Irie K.

J Psycholinguist Res. 2021 Nov 13.
doi: 10.1007/s10936-021-09818-8. Online ahead of print.

In order to examine whether syntactic processing is a necessary prerequisite for semantic integration in Japanese, cortical activation was monitored while participants engaged in silent reading task. Congruous sentences (CON), semantic violation sentences (V-SEM), and syntactic violation sentences (V-SYN) were presented in the experiment. The participants' oxygenated hemoglobin concentration changes during the reading task were measured using functional near-infrared spectroscopy. The results suggest that the CON sentences did not require additional cognitive load on syntactic processing or semantic processing. The V-SEM sentences demanded great cognitive load on semantic processing. Besides, it also elicited great cognitive load on syntactic processing. The V-SYN sentences induced great cognitive load on syntactic processing, but it did not induce additional load on semantic processing. These evidence demonstrates that, in Japanese language processing, the difficultness of semantic processing could influence the difficultness of syntactic processing, while the difficultness of syntactic processing would not influence the difficultness of semantic processing. Our findings are suggestive of the possibility that in Japanese language reading, semantic processing precedes syntactic processing, or semantic processing and syntactic processing are in parallel.

A practical guide for synthetic fNIRS data generation.

Gemignani J, Gervain J.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:828-831.
doi: 10.1109/EMBC46164.2021.9631014.

The use of a large and diversified ground-truth synthetic fNIRS dataset enables researchers to objectively validate and compare data analysis procedures. In this work, we describe each step of the synthetic data generation workflow and we provide tools to generate the dataset.

Higher anxiety rating does not mean poor speech performance: dissociation of the neural mechanisms of anticipation and delivery of public speaking.

Kuai SG, Liang Q, He YY, Wu HN.

Brain Imaging Behav. 2021 Aug;15(4):1934-1943.
doi: 10.1007/s11682-020-00387-3. Epub 2020 Oct 9.

Public speaking anxiety refers to feelings of nervousness when anticipating or delivering a speech. However, the relationship between anxiety in the anticipation phase and speech delivery phase is unclear. In this study, we used functional near-infrared spectroscopy to record participants' brain activities when they were anticipating or performing public speaking tasks in an immersive virtual reality environment. Neuroimaging results showed that participants' subjective ratings of public anxiety in the anticipation phase but not the delivery phase were correlated with activities in the dorsolateral prefrontal cortex, the inferior frontal gyrus, and the precentral and postcentral gyrus. In contrast, their speaking performance could be predicted by activities in the temporal gyrus and the right postcentral gyrus in the delivery phase. This suggests a dissociation in the neural mechanisms between anxiety in preparation and execution of a speech. The conventional anxiety questionnaire is a good predictor of anticipatory anxiety, but cannot predict speaking performance. Using virtual reality to establish a situational test could be a better approach to assess in vivo public speaking performance.

Sleep deprivation impairs cognitive performance, alters task-associated cerebral blood flow and decreases cortical neurovascular coupling-related hemodynamic responses.

Csipo T(#), Lipecz A(#), Owens C, Mukli P, Perry JW, Tarantini S, Balasubramanian P, Nyl-Tth , Yabluchanska V, Sorond FA, Kellawan JM, Purebl G, Sonntag WE, Csiszar A, Ungvari Z, Yabluchanskiy A.

Sci Rep. 2021 Oct 25;11(1):20994.
doi: 10.1038/s41598-021-00188-8.

Sleep deprivation (SD) is a common condition and an important health concern. In addition to metabolic and cardiovascular risks, SD associates with decreases in cognitive performance. Neurovascular coupling (NVC, "functional hyperemia") is a critical homeostatic mechanism, which maintains adequate blood supply to the brain during periods of intensive neuronal activity. To determine whether SD alters NVC responses and cognitive performance, cognitive and hemodynamic NVC assessments were conducted prior to and 24h post-SD in healthy young male individuals (n = 10, 27 3years old). Cognition was evaluated with a battery of tests from the Cambridge Neuropsychological Test Automated Battery (CANTAB). Hemodynamic components of NVC were measured by transcranial Doppler sonography (TCD) during cognitive stimulation, dynamic retinal vessel analysis (DVA) during flicker light stimulation, and functional near infrared spectroscopy (fNIRS) during finger tapping motor task. Cognitive assessments revealed impairments in reaction time and sustained attention after 24h of SD. Functional NIRS analysis revealed that SD significantly altered hemodynamic responses in the prefrontal cortex and somatosensory cortex during a motor task. NVC-related vascular responses measured by DVA and TCD did not change significantly. Interestingly, TCD detected decreased task-associated cerebral blood flow (CBF) in the right middle cerebral artery in sleep deprived participants. Our results demonstrate that 24h of SD lead to impairments in cognitive performance together with altered CBF and hemodynamic components of cortical NVC responses.

Brain Activity in the Prefrontal Cortex during Cognitive Tasks and Dual Tasks in Community-Dwelling Elderly People with Pre-Frailty: A Pilot Study for Early Detection of Cognitive Decline.

Maruya K, Arai T, Fujita H.

Healthcare (Basel). 2021 Sep 23;9(10):1250.
doi: 10.3390/healthcare9101250.

We aimed to detect brain abnormalities during cognitive and motor tasks in older individuals with pre-frailty, as this could prevent dementia. Sixty elderly participants (mean age: 76.3 years; 27 healthy and 33 with pre-frailty) were included, and their motor function, cognitive function, and dual-task abilities (gait with calculation and while carrying a ball) were evaluated. Total hemoglobin (t-Hb) was measured using functional near-infrared spectroscopy (fNIRS) during tasks and resting periods. The pre-frailty group had a slightly lower gait speed than the healthy group, but there was no significant difference in cognitive function. In the pre-frailty group, the t-Hb values during the normal gait and cognitive tasks were higher than the resting value in the right prefrontal cortex, while in the healthy group, only the word frequency task (WFT) was higher. Furthermore, in the WFT, the t-Hb values were significantly lower in the pre-frailty group than in the healthy group. The results showed that pre-frail subjects had lower brain activation during the WFT in the right prefrontal cortex and excessive activity during walking, even without a noticeable cognitive decline. The differences in cerebral blood flow under the pre-frailty conditions may be a clue to detecting cognitive decline earlier.

Rehabilitation with accurate adaptability walking tasks or steady state walking: A randomized clinical trial in adults post-stroke.

Clark DJ, Rose DK, Butera KA, Hoisington B, DeMark L, Chatterjee SA, Hawkins KA, Otzel DM, Skinner JW, Christou EA, Wu SS, Fox EJ.

Clin Rehabil. 2021 Aug;35(8):1196-1206.
doi: 10.1177/02692155211001682. Epub 2021 Mar 16.

OBJECTIVE: To assess changes in walking function and walking-related prefrontal cortical activity following two post-stroke rehabilitation interventions: an accurate adaptability (ACC) walking intervention and a steady state (SS) walking intervention. DESIGN: Randomized, single blind, parallel group clinical trial. SETTING: Hospital research setting. SUBJECTS: Adults with chronic post-stroke hemiparesis and walking deficits. INTERVENTIONS: ACC emphasized stepping accuracy and walking adaptability, while SS emphasized steady state, symmetrical stepping. Both included 36 sessions led by a licensed physical therapist. ACC walking tasks recruit cortical regions that increase corticospinal tract activation, while SS walking activates the corticospinal tract less intensely. MAIN MEASURES: The primary functional outcome measure was preferred steady state walking speed. Prefrontal brain activity during walking was measured with functional near infrared spectroscopy to assess executive control demands. Assessments were conducted at baseline, post-intervention (three months), and follow-up (six months). RESULTS: Thirty-eight participants were randomized to the study interventions (mean age 59.6 9.1 years; mean months post-stroke 18.0 10.5). Preferred walking speed increased from baseline to post-intervention by 0.13 0.11 m/s in the ACC group and by 0.14 0.13 m/s in the SS group. The Time Group interaction was not statistically significant (P = 0.86). Prefrontal fNIRS during walking decreased from baseline to post-intervention, with a marginally larger effect in the ACC group (P = 0.05). CONCLUSIONS: The ACC and SS interventions produced similar changes in walking function. fNIRS suggested a potential benefit of ACC training for reducing demand on prefrontal (executive) resources during walking.

Functional Near-Infrared Spectroscopy Neurofeedback Enhances Human Spatial Memory.

Hou X, Xiao X, Gong Y, Li Z, Chen A, Zhu C.

Front Hum Neurosci. 2021 Sep 29;15:681193.
doi: 10.3389/fnhum.2021.681193. eCollection 2021.

Spatial memory is an important cognitive function for human daily life and may present dysfunction

or decline due to aging or clinical diseases. Functional near-infrared spectroscopy neurofeedback (fNIRS-NFB) is a promising neuromodulation technique with several special advantages that can be used to improve human cognitive functions by manipulating the neural activity of targeted brain regions or networks. In this pilot study, we intended to test the feasibility of fNIRS-NFB to enhance human spatial memory ability. The lateral parietal cortex, an accessible cortical region in the posterior medial hippocampal-cortical network that plays a crucial role in human spatial memory processing, was selected as the potential feedback target. A placebo-controlled fNIRS-NFB experiment was conducted to instruct individuals to regulate the neural activity in this region or an irrelevant control region. Experimental results showed that individuals learned to up-regulate the neural activity in the region of interest successfully. A significant increase in spatial memory performance was found after 8-session neurofeedback training in the experimental group but not in the control group. Furthermore, neurofeedback-induced neural activation increase correlated with spatial memory improvement. In summary, this study preliminarily demonstrated the feasibility of fNIRS-NFB to improve human spatial memory and has important implications for further applications.

Association of executive function capacity with gait motor imagery ability and PFC activity: An fNIRS study.

Kotegawa K, Teramoto W.

Neurosci Lett. 2022 Jan 1;766:136350.
doi: 10.1016/j.neulet.2021.136350. Epub 2021 Nov 13.

Individual differences exist in gait motor imagery ability. However, little is known about the underlying neural mechanisms. We previously conducted a study using functional near-infrared spectroscopy (fNIRS), which showed that participants who overestimated mental walking times to a greater degree exhibited greater activation in the right prefrontal cortex (PFC). The PFC is implicated in executive functions (EFs), including working memory (WM). Thus, this study investigated whether individual differences in EF capacity are associated with gait motor imagery ability and PFC activity. Thirty volunteers participated (mean age: 21.71.8years) in the study. Their EF capacity was assessed by the Trail Making Test - Part B (TMT-B). We measured the accuracy of gait motor imagery and PFC activity during mental walking using fNIRS, while changing task difficulty by varying the path width. The results showed that the overestimation of mental walking time over actual walking time and right PFC activity increased with an increase in the TMT-B times. These results suggest that the EF capacity, including WM, is strongly associated with gait motor imagery ability and right PFC activity. The brain network that includes the right PFC may play an important role in the maintenance and manipulation of gait motor imagery.

Classification of fNIRS data with LDA and SVM: a proof-of-concept for application in infant studies.

Gemignani J.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:824-827.
doi: 10.1109/EMBC46164.2021.9629951.

This study presents the implementation of a within-subject classification method, based on the use of Linear Discriminant Analysis (LDA) and Support Vector Machines (SVM), for the classification of hemodynamic responses. Using a synthetic dataset that closely resembles real experimental infant functional near-infrared spectroscopy (fNIRS) data, the impact of different levels of noise and different HRF amplitudes on the classification performances of the two classifiers are quantitively investigated.

Detecting Residual Awareness in Patients With Prolonged Disorders of Consciousness:

An fNIRS Study.

Li M, Yang Y, Zhang Y, Gao Y, Jing R, Dang Y, Chen X, He J, Si J.

Front Neurol. 2021 Jul 28;12:618055.
doi: 10.3389/fneur.2021.618055. eCollection 2021.

Recent advances in neuroimaging technologies have provided insights into detecting residual consciousness and assessing cognitive abilities in patients with disorders of consciousness (DOC). Functional near-infrared spectroscopy (fNIRS) is non-invasive and portable and can be used for longitudinal bedside monitoring, making it uniquely suited for evaluating brain function in patients with DOC at appropriate spatiotemporal resolutions. In this pilot study, an active command-driven motor imagery (MI) paradigm based on fNIRS was used to detect residual consciousness in patients with prolonged DOC. A support vector machine (SVM) classifier was used to classify yes-or-no responses. The results showed that relatively reliable responses were detected from three out of five patients in a minimally consciousness state (MCS). One of the patients answered all the questions accurately when assessed according to this method. This study confirmed the feasibility of using portable fNIRS technology to detect residual cognitive ability in patients with prolonged DOC by active command-driven motor imagery. We hope to detect the exact level of consciousness in DOC patients who may have a higher level of consciousness.

Links between socioeconomic disadvantage, neural function, and working memory in early childhood.

Li X, Lipschutz R, Hernandez SM, Biekman B, Shen S, Montgomery DA, Perlman SB, Pollonini L, Bick J.

Dev Psychobiol. 2021 Sep;63(6):e22181.
doi: 10.1002/dev.22181. Epub 2021 Aug 22.

Children reared in socioeconomically disadvantaged environments are at risk for academic, cognitive, and behavioral problems. Mounting evidence suggests that childhood adversities, encountered at disproportionate rates in contexts of socioeconomic risk, shape the developing brain in ways that explain disparities. Circuitries that subserve neurocognitive functions related to memory, attention, and cognitive control are especially affected. However, most work showing altered neural function has focused on middle childhood and adolescence. Understanding alterations in brain development during foundational points in early childhood is a key next step. To address this gap, we examined functional near-infrared-spectroscopy-based neural activation during a working memory (WM) task in young children aged 4-7 years (N=30) who varied in socioeconomic risk exposure. Children who experienced greater disadvantage (lower income to needs ratio and lower Hollingshead index) exhibited lower activation in the lateral prefrontal cortex than children who experienced less to no disadvantage. Variability in prefrontal cortex activation, but not behavioral performance on the WM task, was associated with worse executive functioning in children as reported by parents. These findings add to existing evidence that exposure to early adversity, such as socioeconomic risk, may lead to foundational changes in the developing brain, which increases risk for disparities in functioning across multiple cognitive and social domains.

Home assessment of visual working memory in pre-schoolers reveals associations between behaviour, brain activation and parent reports of life stress.

McKay CA, Shing YL, Rafetseder E, Wijeakumar S.

Dev Sci. 2021 Jul;24(4):e13094.
doi: 10.1111/desc.13094. Epub 2021 Mar 9.

Visual working memory (VWM) is reliably predictive of fluid intelligence and academic achievements. The objective of the current study was to investigate individual differences in pre-schoolers' VWM processing by examining the association between behaviour, brain function and parent-reported measures related

to the child's environment. We used a portable functional near-infrared spectroscopy system to record from the frontal and parietal cortices of 4.5-year-old children (N=74) as they completed a colour change-detection VWM task in their homes. Parents were asked to fill in questionnaires on temperament, academic aspirations, home environment and life stress. Children were median-split into a low-performing (LP) and a high-performing (HP) group based on the number of items they could successfully remember during the task. LPs increasingly activated channels in the left frontal and bilateral parietal cortices with increasing load, whereas HPs showed no difference in activation. Our findings suggest that LPs recruited more neural resources than HPs when their VWM capacity was challenged. We employed mediation analyses to examine the association between the difference in activation between the highest and lowest loads and variables from the questionnaires. The difference in activation between loads in the left parietal cortex partially mediated the association between parent-reported stressful life events and VWM performance. Critically, our findings show that the association between VWM capacity, left parietal activation and indicators of life stress is important to understand the nature of individual differences in VWM in pre-school children.

Dysfunction in interpersonal neural synchronization as a mechanism for social impairment in autism spectrum disorder.

Quiones-Camacho LE, Fishburn FA, Belardi K, Williams DL, Huppert TJ, Perlman SB.

Autism Res. 2021 Aug;14(8):1585-1596.
doi: 10.1002/aur.2513. Epub 2021 Apr 13.

Social deficits in autism spectrum disorder (ASD) have been linked to atypical activation of the mentalizing network. This work, however, has been limited by a focus on the brain activity of a single person during computerized social tasks rather than exploring brain activity during in vivo interactions. The current study assessed neural synchronization during a conversation as a mechanism for social impairment in adults with ASD (n=24) and matched controls (n=26). Functional near-infrared spectroscopy (fNIRS) data were collected from the prefrontal cortex (PFC) and tempoparietal junction (TPJ). Participants self-reported on their social communication and videos of the interaction were coded for utterances and conversational turns. As expected, controls showed more neural synchrony than participants with ASD in the TPJ. Also as expected, controls showed less social communication impairment than participants with ASD. However, participants with ASD did not have fewer utterances compared with control subjects. Overall, less neural synchrony in the TPJ was associated with higher social impairment and marginally fewer utterances. Our findings advance our understanding of social difficulties in ASD by linking them to decreased neural synchronization of the TPJ. LAY SUMMARY: The coordination of brain responses is important for efficient social interactions. The current study explored the coordination of brain responses in neurotypical adults and adults with ASD to investigate if difficulties in social interactions are related to difficulties coordinating brain responses in ASD. We found that participants with ASD had more difficulties coordinating brain responses during a conversation with an interacting partner. Additionally, we found that the level of coordination in brain responses was linked to problems with social communication.

Assessing Computational Methods to Quantify Mother-Child Brain Synchrony in Naturalistic Settings Based on fNIRS Signals.

Bizzego A, Azhari A, Esposito G.

Neuroinformatics. 2021 Nov 30.
doi: 10.1007/s12021-021-09558-z. Online ahead of print.

Mother-child brain-to-brain synchrony captures the temporal similarities in brain signals between dyadic partners, and has been shown to emerge during the display of joint behaviours. Despite the rise in the number of studies that investigate synchrony in naturalistic contexts, the use of varying methodological approaches to compute synchrony remains a central problem. When dyads engage in unstructured social

interactions, the wide range of behavioural cues they display contribute to the use of varying lengths of signals to compute synchrony. The present functional Near-infrared Spectroscopy (fNIRS) study investigates how different methods to quantify brain signals during joint and non-joint portions of dyadic play affect the outcome of brain-to-brain synchrony. Three strategies to cope with unstructured data are tested and different signal lengths of 15, 20, 25, 30, 35, 40, 45s were used to determine the optimal method to sensitively capture synchrony. Results showed that using all available portions of the signals generated a greater number of less conservative results compared to the other two strategies, which were to compute the average synchrony for the joint and non-joint signals portions and to compute the difference between the average synchrony of joint and non-joint portions. From the different signal durations, only length portions of 25s to 35s generated significant results. These findings demonstrate that differences in computational approaches and signal lengths affect synchrony measurements and should be considered in naturalistic synchrony studies.

Negative affective processing is associated with cognitive control in early childhood: An fNIRS study().

Ding K, Li C, Wang J, Yu D.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:3423-3426.

doi: 10.1109/EMBC46164.2021.9629783.

The association between emotion and cognition has recently gathered interest in the field of cognitive neuroscience. However, the neural mechanism of negative emotion processing and its association with cognitive control in early childhood remains unclear. In the present study, we compared the processing of three emotions (i.e., negative, neutral, and positive emotions) and investigated the association between negative emotion processing and cognitive control in children aged 4-6 years (N = 43). Results indicated that children revealed greater brain activation when processing negative emotions than processing neutral and positive emotions. We also found a significant negative association between brain activation during negative emotion processing and reaction times of cognitive control, which represented children with better cognitive control evoked higher brain activation when processing negative emotions. The current study proposes a neural mechanism underlying emotion processing and provides important insights into the risk and future behavioral outcomes of potential psychological disorders.

Distinct Contributions of Genes and Environment to Visual Size Illusion and the Underlying Neural Mechanism.

Chen L, Xu Q, Shen L, Yuan T, Wang Y, Zhou W, Jiang Y.

Cereb Cortex. 2021 Aug 11:bhab262.

doi: 10.1093/cercor/bhab262. Online ahead of print.

As exemplified by the Ebbinghaus illusion, the perceived size of an object can be significantly biased by its surrounding context. The phenomenon is experienced by humans as well as other species, hence likely evolutionarily adaptive. Here, we examined the heritability of the Ebbinghaus illusion using a combination of the classic twin method and multichannel functional near-infrared spectroscopy. Results show that genes account for over 50% of the variance in the strength of the experienced illusion. Interestingly, activations evoked by the Ebbinghaus stimuli in the early visual cortex are explained by genetic factors whereas those in the posterior temporal cortex are explained by environmental factors. In parallel, the feedforward functional connectivity between the occipital cortex and the temporal cortex is modulated by genetic effects whereas the feedback functional connectivity is entirely shaped by environment, despite both being significantly correlated with the strength of the experienced illusion. These findings demonstrate that genetic and environmental factors work in tandem to shape the context-dependent visual size illusion, and shed new light on the links among genes, environment, brain, and subjective experience.

Neuroimaging guided tES to facilitate complex laparoscopic surgical tasks - insights from functional near-infrared spectroscopy.

Walia P, Fu Y, Schwaitzberg SD, Intes X, De S, Cavuoto L, Dutta A.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:7437-7440.
doi: 10.1109/EMBC46164.2021.9631005.

Fundamentals of Laparoscopic Surgery (FLS) is a prerequisite for board certification in general surgery in the USA. In FLS, the suturing task with intracorporeal knot tying is considered the most complex task. Transcranial direct current stimulation (tDCS) of the dorsolateral prefrontal cortex (PFC) has been shown to facilitate FLS surgical skill acquisition where 2mA tDCS for 15min with the anode over F3 (10/10 EEG montage) and cathode over F4 has improved performance score in an open knot-tying task. Since PFC has a functional organization related to the hierarchy of cognitive control, we performed functional near-infrared spectroscopy (fNIRS) to investigate PFC sub-domain activation during a more complex FLS suturing task with intracorporeal knot tying. We performed fNIRS-based analysis using AtlasViewer software on two expert surgeons and four novice medical students. We found an average cortical activation mainly at the left frontopolar PFC across the experts, while the average cortical activation across the novices was primarily at the left pars opercularis of the inferior frontal gyrus and ventral premotor cortex, inferior parietal lobule, and supramarginal gyrus. Here, the average cortical activation across the novices included not only the cognitive control related brain regions but also motor control complexity related brain regions. Therefore, we present a computational pipeline to identify a 4x1 high-definition (HD) tDCS montage of motor complexity related PFC sub-regions using ROAST software.Clinical Relevance-A computational pipeline for fNIRS-guided tES to individualize electrode montage that may facilitate FLS surgical training in our future studies.

Chopstick operation training with the left non-dominant hand.

Sawamura D, Sakuraba S, Yoshida K, Hasegawa N, Suzuki Y, Yoshida S, Honke T, Sakai S.

Transl Neurosci. 2021 Oct 22;12(1):385-395.
doi: 10.1515/tnsci-2020-0189. eCollection 2021 Jan 1.

BACKGROUND: Training a non-dominant hand is important for rehabilitating people who are required to change handedness. However, improving the dexterity in using chopsticks with a non-dominant hand through training remains unclear. This study is aimed to measure whether chopstick training improves non-dominant hand chopstick operation skills and leads to acquisition of skill levels similar to those of the dominant hand. METHODS: This single-blinded randomized controlled trial enrolled 34 healthy young right-handed subjects who scored >70 points on the Edinburgh Handedness Questionnaire Inventory. They were randomly allocated to training or control groups. The training group participated in a 6-week chopstick training program with the non-dominant left hand, while the control group did not. Asymmetry of chopstick operation skill, perceived psychological stress, and oxygen-hemoglobin concentration as a brain activity measure in each hemisphere were measured before and after training. RESULTS: Participants in the training group had significantly lower asymmetry than those in the control group during the post-training assessment ($F[1,30] = 5.54$, $p = 0.03$, partial ? $2 = 0.156$). Only perceived psychological stress had a significantly higher asymmetry during the post-training assessment ($t[15] = 3.81$, $p < 0.01$). CONCLUSION: Six weeks of chopstick training improved non-dominant chopstick operation skills, and a performance level similar to that of the dominant hand was acquired.

Comparison of Functional Connectivity in the Prefrontal Cortex during a Simple and an Emotional Go/No-Go Task in Female versus Male Groups: An fNIRS Study.

Nguyen T, Condy EE, Park S, Friedman BH, Gandjbakhche A.

Brain Sci. 2021 Jul 9;11(7):909.
doi: 10.3390/brainsci11070909.

Inhibitory control is a cognitive process to suppress prepotent behavioral responses to stimuli. This study aimed to investigate prefrontal functional connectivity during a behavioral inhibition task and its correlation with the subject's performance. Additionally, we identified connections that are specific to the Go/No-Go task. The experiment was performed on 42 normal, healthy adults who underwent a vanilla baseline and a simple and emotional Go/No-Go task. Cerebral hemodynamic responses were measured in the prefrontal cortex using a 16-channel near infrared spectroscopy (NIRS) device. Functional connectivity was calculated from NIRS signals and correlated to the Go/No-Go performance. Strong connectivity was found in both the tasks in the right hemisphere, inter-hemispherically, and the left medial prefrontal cortex. Better performance (fewer errors, faster response) is associated with stronger prefrontal connectivity during the simple Go/No-Go in both sexes and the emotional Go/No-Go connectivity in males. However, females express a lower emotional Go/No-Go connectivity while performing better on the task. This study reports a complete prefrontal network during a simple and emotional Go/No-Go and its correlation with the subject's performance in females and males. The results can be applied to examine behavioral inhibitory control deficits in population with neurodevelopmental disorders.

Compromised Brain Activity With Age During a Game-Like Dynamic Balance Task: Single- vs. Dual-Task Performance.

de Rond V, Orcioli-Silva D, Dijkstra BW, Orban de Xivry JJ, Pantall A, Nieuwboer A.

Front Aging Neurosci. 2021 Jul 5;13:657308.
doi: 10.3389/fnagi.2021.657308. eCollection 2021.

Background: Postural control and cognition are affected by aging. We investigated whether cognitive distraction influenced neural activity differently in young and older adults during a game-like mediolateral weight-shifting task with a personalized task load. Methods: Seventeen healthy young and 17 older adults performed a balance game, involving hitting virtual wasps, serial subtractions and a combination of both (dual-task). A motion analysis system estimated each subject's center of mass position. Cortical activity in five regions was assessed by measuring oxygenated hemoglobin (HbO2) with a functional Near-Infrared Spectroscopy system. Results: When adding cognitive load to the game, weight-shifting speed decreased irrespective of age, but older adults reduced the wasp-hits more than young adults. Accompanying these changes, older adults decreased HbO2 in the left pre-frontal cortex (PFC) and frontal eye fields (FEF) compared to single-tasking, a finding not seen in young adults. Additionally, lower HbO2 levels were found during dual-tasking compared to the summed activation of the two single tasks in all regions except for the right PFC. These relative reductions were specific for the older age group in the left premotor cortex (PMC), the right supplementary motor area (SMA), and the left FEF. Conclusion: Older adults showed more compromised neural activity than young adults when adding a distraction to a challenging balance game. We interpret these changes as competitive downgrading of neural activity underpinning the age-related deterioration of game performance during dual-tasking. Future work needs to ascertain if older adults can train their neural flexibility to withstand balance challenges during daily life activities.

Studying Brain Activation during Skill Acquisition via Robot-Assisted Surgery Training.

Izzetoglu K, Aksoy ME, Agrali A, Kitapcioglu D, Gungor M, Simsek A.

Brain Sci. 2021 Jul 16;11(7):937.
doi: 10.3390/brainsci11070937.

Robot-assisted surgery systems are a recent breakthrough in minimally invasive surgeries, offering numerous benefits to both patients and surgeons including, but not limited to, greater visualization of the

operation site, greater precision during operation and shorter hospitalization times. Training on robot-assisted surgery (RAS) systems begins with the use of high-fidelity simulators. Hence, the increasing demand of employing RAS systems has led to a rise in using RAS simulators to train medical doctors. The aim of this study was to investigate the brain activity changes elicited during the skill acquisition of resident surgeons by measuring hemodynamic changes from the prefrontal cortex area via a neuroimaging sensor, namely, functional near-infrared spectroscopy (fNIRS). Twenty-four participants, who are resident medical doctors affiliated with different surgery departments, underwent an RAS simulator training during this study and completed the sponge suturing tasks at three different difficulty levels in two consecutive sessions/blocks. The results reveal that cortical oxygenation changes in the prefrontal cortex were significantly lower during the second training session (Block 2) compared to the initial training session (Block 1) ($p < 0.05$).

Inter-Brain Synchrony in Open-Ended Collaborative Learning: An fNIRS-Hyperscanning Study.

Zhao N, Zhu Y, Hu Y.
J Vis Exp. 2021 Jul 21;(173).
doi: 10.3791/62777.

fNIRS hyperscanning is widely used to detect the neurobiological underpinnings of social interaction. With this technique, researchers qualify the concurrent brain activity of two or more interactive individuals with a novel index called inter-brain synchrony (IBS) (i.e., phase and/or amplitude alignment of the neuronal or hemodynamic signals across time). A protocol for conducting fNIRS hyperscanning experiments on collaborative learning dyads in a naturalistic learning environment is presented here. Further, a pipeline of analyzing IBS of oxygenated hemoglobin (Oxy-Hb) signal is explained. Specifically, the experimental design, the process of NIRS data recording, data analysis methods, and future directions are all discussed. Overall, implementing a standardized fNIRS hyperscanning pipeline is a fundamental part of second-person neuroscience. Also, this is in line with the call for open-science to aid the reproducibility of research.

Refined prefrontal working memory network as a neuromarker for Alzheimer's disease.

Kim E, Yu JW, Kim B, Lim SH, Lee SH, Kim K, Son G, Jeon HA, Moon C, Sakong J, Choi JW.
Biomed Opt Express. 2021 Oct 29;12(11):7199-7222.
doi: 10.1364/BOE.438926. eCollection 2021 Nov 1.

Detecting Alzheimer's disease (AD) is an important step in preventing pathological brain damage. Working memory (WM)-related network modulation can be a pathological feature of AD, but is usually modulated by untargeted cognitive processes and individual variance, resulting in the concealment of this key information. Therefore, in this study, we comprehensively investigated a new neuromarker, named "refined network," in a prefrontal cortex (PFC) that revealed the pathological features of AD. A refined network was acquired by removing unnecessary variance from the WM-related network. By using a functional near-infrared spectroscopy (fNIRS) device, we evaluated the reliability of the refined network, which was identified from the three groups classified by AD progression: healthy people (N=31), mild cognitive impairment (N=11), and patients with AD (N=18). As a result, we identified edges with significant correlations between cognitive functions and groups in the dorsolateral PFC. Moreover, the refined network achieved a significantly correlating metric with neuropsychological test scores, and a remarkable three-class classification accuracy (95.0%). These results implicate the refined PFC WM-related network as a powerful neuromarker for AD screening.

To Regulate or Not to Regulate: Emotion Regulation in Participants With Low and High Impulsivity.

Maier MJ, Schiel JE, Rosenbaum D, Hautzinger M, Fallgatter AJ, Ehlis AC.

Front Behav Neurosci. 2021 Jul 30;15:645052.
doi: 10.3389/fnbeh.2021.645052. eCollection 2021.

Successful emotion regulation plays a key role in psychological health and well-being. This study examines (1) whether cognitive control and corresponding neural connectivity are associated with emotion regulation and (2) to what extent external instructions can improve emotion regulation in individuals with low vs. high cognitive control capacity. For this, emotion regulation capabilities and the impact of emotion regulation on a subsequent emotional Stroop task was tested in participants with low (N = 25) vs. high impulsivity (N = 32). The classification according to impulsivity is based upon the stable correlation between high impulsivity and reduced cognitive control capacity. A negative emotion inducing movie scene was presented with the instruction to either suppress or allow all emotions that arose. This was followed by an emotional Stroop task. Electromyography (EMG) over the corrugator supercilii was used to assess the effects of emotion regulation. Neurophysiological mechanisms were measured using functional near-infrared spectroscopy over frontal brain areas. While EMG activation was low in the low-impulsive group independent of instruction, high-impulsive participants showed increased EMG activity when they were not explicitly instructed to suppress arising emotions. Given the same extent of functional connectivity within frontal lobe networks, the low-impulsive participants controlled their emotions better (less EMG activation) than the high-impulsive participants. In the Stroop task, the low-impulsive subjects performed significantly better. The emotion regulation condition had no significant effect on the results. We conclude that the cognitive control network is closely associated with emotion regulation capabilities. Individuals with high cognitive control show implicit capabilities for emotion regulation. Individuals with low cognitive control require external instructions (= explicit emotion regulation) to achieve similarly low expressions of emotionality. Implications for clinical applications aiming to improve emotion regulation are discussed.

Low-Frequency Magnetic Stimulation of Shenmen Acupoint Reduces Blood Oxygen Levels in the Prefrontal Cortex of Healthy Subjects: A Near-Infrared Brain Functional Imaging Study.

Yuan J, Zheng Z, Cao Y, Chen J, Li YY, Lei YL.

Chin J Integr Med. 2021 Aug;27(8):585-588.
doi: 10.1007/s11655-021-3291-z. Epub 2021 Apr 21.

OBJECTIVE: To explore the effect of low-frequency magnetic stimulation at Shenmen (HT 7) acupoint on blood oxygen levels in the prefrontal cortex of healthy subjects. METHODS: Functional near-infrared spectroscopy (fNIRS) technology was used to collect real-time data of oxygenated hemoglobin (oxy-Hb) in the prefrontal cortex of 16 healthy subjects at resting state and low-frequency magnetic stimulation of Shenmen. The mean and integral values of blood oxygen concentration were analyzed. RESULTS: Compared with the resting state, the mean and integral values of blood oxygen concentration were decreased during the task period, recovery period, and the whole process in the magnetic stimulation of Shenmen acupoint ($P<0.05$). In particular, the difference was statistically significant in the recovery period ($P<0.01$). CONCLUSIONS: The prefrontal cortex was widely activated and produced an immediate effect by reducing the local blood oxygen concentration at low-frequency magnetic stimulation of Shenmen acupoint, which verifies the sedative effect of Shenmen acupoint.

Speaker-Listener Neural Coupling Reveals an Adaptive Mechanism for Speech Comprehension in a Noisy Environment.

Li Z, Li J, Hong B, Nolte G, Engel AK, Zhang D.

Cereb Cortex. 2021 Aug 26;31(10):4719-4729.
doi: 10.1093/cercor/bhab118.

Comprehending speech in noise is an essential cognitive skill for verbal communication. However, it remains unclear how our brain adapts to the noisy environment to achieve comprehension. The present study investigated the neural mechanisms of speech comprehension in noise using an functional near-infrared spectroscopy-based inter-brain approach. A group of speakers was invited to tell real-life stories. The recorded speech audios were added with meaningless white noise at four signal-to-noise levels and then played to listeners. Results showed that speaker-listener neural couplings of listener's left inferior frontal gyri (IFG), that is, sensorimotor system, and right middle temporal gyri (MTG), angular gyri (AG), that is, auditory system, were significantly higher in listening conditions than in the baseline. More importantly, the correlation between neural coupling of listener's left IFG and the comprehension performance gradually became more positive with increasing noise level, indicating an adaptive role of sensorimotor system in noisy speech comprehension; however, the top behavioral correlations for the coupling of listener's right MTG and AG were only obtained in mild noise conditions, indicating a different and less robust mechanism. To sum up, speaker-listener coupling analysis provides added value and new sight to understand the neural mechanism of speech-in-noise comprehension.

Control of Transcranial Direct Current Stimulation Duration by Assessing Functional Connectivity of Near-Infrared Spectroscopy Signals.

Yaqub MA, Hong KS, Zafar A, Kim CS.

Int J Neural Syst. 2022 Jan;32(1):2150050.
doi: 10.1142/S0129065721500507. Epub 2021 Oct 5.

Transcranial direct current stimulation (tDCS) has been shown to create neuroplasticity in healthy and diseased populations. The control of stimulation duration by providing real-time brain state feedback using neuroimaging is a topic of great interest. This study presents the feasibility of a closed-loop modulation for the targeted functional network in the prefrontal cortex. We hypothesize that we cannot improve the brain state further after reaching a specific state during a stimulation therapy session. A high-definition tDCS of 1[Formula: see text]mA arranged in a ring configuration was applied at the targeted right prefrontal cortex of 15 healthy male subjects for 10[Formula: see text]min. Functional near-infrared spectroscopy was used to monitor hemoglobin chromophores during the stimulation period continuously. The correlation matrices obtained from filtered oxyhemoglobin were binarized to form subnetworks of short- and long-range connections. The connectivity in all subnetworks was analyzed individually using a new quantification measure of connectivity percentage based on the correlation matrix. The short-range network in the stimulated hemisphere showed increased connectivity in the initial stimulation phase. However, the increase in connection density reduced significantly after 6[Formula: see text]min of stimulation. The short-range network of the left hemisphere and the long-range network gradually increased throughout the stimulation period. The connectivity percentage measure showed a similar response with network theory parameters. The connectivity percentage and network theory metrics represent the brain state during the stimulation therapy. The results from the network theory metrics, including degree centrality, efficiency, and connection density, support our hypothesis and provide a guideline for feedback on the brain state. The proposed neuro-feedback scheme is feasible to control the stimulation duration to avoid overdosage.

Cerebral Hemodynamic Responses to the Difficulty Level of Ambulatory Tasks in Patients With Parkinson's Disease: A Systematic Review and Meta-Analysis.

Lin JP, Feng HS, Zhai H, Shen X.

Neurorehabil Neural Repair. 2021 Sep;35(9):755-768.
doi: 10.1177/15459683211028548. Epub 2021 Jun 25.

Background. Ambulatory tasks are the important components of balance training which effectively improve postural stability and functional activities in persons with Parkinson's disease (PD). The difficulty level of an ambulatory task is usually set in the form of attention, direction, speed, or amplitude requirement. Objectives. This study aimed to explore the neural mechanisms of cerebral hemodynamic responses to the difficulty level of ambulatory tasks in persons with PD. Methods. We included ten studies that examined cerebral hemodynamic responses during ambulatory tasks at different difficulty levels in persons with PD. The change in hemodynamic responses was synthesized and meta-analyzed. Results. Patients during "ON" medication had higher relative change in oxygenated hemoglobin (?HBO2) in the prefrontal cortex in response to difficulty levels of ambulatory tasks, which is comparable to that in healthy elderly individuals. However, patients during "OFF" medication did not show cortical activation in response to difficulty levels. During the lower-difficulty tasks, patients during "ON" medication demonstrated higher ?HBO2 than healthy elderly participants and patients during "OFF" medication. Factors found to significantly contribute to the heterogeneity across studies included subjects' type and cognitive status, task duration, setting, and filter used for functional near-infrared spectroscopy (fNIRS) data pre-processing. Conclusions. The findings suggest that ambulatory task at a higher difficulty level could be necessary to train the cortical capacity of PD persons, which should be conducted during "ON" medication; meanwhile, the contributing factors to the heterogeneity of studies would be useful as a reference when designing comparable fNIRS studies.

Cooperation with partners of differing social experience: An fNIRS-based hyperscanning study.

Sun B, Xiao W, Lin S, Shao Y, Li W, Zhang W.

Brain Cogn. 2021 Nov;154:105803.
doi: 10.1016/j.bandc.2021.105803. Epub 2021 Oct 21.

Previous studies have shown the brain synchronization of all team members while completing a collaborative task. Moreover, this effect is influenced by a team's compositional elements, such as gender (opposite or same) or relationships (i.e., friends, lovers, or strangers) among team members. However, whether interpersonal brain synchronization (IBS) is affected by team members' experience, as well as the temporal dynamics of such brain synchronization, remains to be investigated. In the current study, we combined behavioral methods and functional near-infrared spectroscopy-based hyperscanning to examine the effect of member experience on team cooperation by an adopted continuous joint drawing task with 21 student-student dyads (S-S dyads) and 22 teacher-student dyads (T-S dyads). The results revealed that team members with differing experiences (T-S dyads) perform better than those with similar ones (S-S dyads). Moreover, we observed IBS in the left frontopolar region (channel 11). However, we did not observe significant changes of the task-related IBS across time. Besides, IBS was negatively correlated with the participants' behavioral performance. Our findings demonstrate the importance of social experience in teamwork in the real world and suggest a possible mechanism for cooperation from a temporal and spatial perspective.

Aerobic Exercise Combined With Transcranial Direct Current Stimulation Over the Prefrontal Cortex in Parkinson Disease: Effects on Cortical Activity, Gait, and Cognition.

Conceio NR, Gobbi LTB, Nbrega-Sousa P, Orcioli-Silva D, Beretta VS, Lirani-Silva E, Okano AH, Vitrio R.

Neurorehabil Neural Repair. 2021 Aug;35(8):717-728.
doi: 10.1177/15459683211019344. Epub 2021 May 28.

BACKGROUND: Since people with Parkinson disease (PD) rely on limited prefrontal executive re-

sources for the control of gait, interventions targeting the prefrontal cortex (PFC) may help in managing PD-related gait impairments. Transcranial direct current stimulation (tDCS) can be used to modulate PFC excitability and improve prefrontal cognitive functions and gait. OBJECTIVE: We investigated the effects of adding anodal tDCS applied over the PFC to a session of aerobic exercise on gait, cognition, and PFC activity while walking in people with PD. METHODS: A total of 20 people with PD participated in this randomized, double-blinded, sham-controlled crossover study. Participants attended two 30-minute sessions of aerobic exercise (cycling at moderate intensity) combined with different tDCS conditions (active- or sham-tDCS), 1 week apart. The order of sessions was counterbalanced across the sample. Anodal tDCS (2 mA for 20 minutes [active-tDCS] or 10 s [sham-tDCS]) targeted the PFC in the most affected hemisphere. Spatiotemporal gait parameters, cognitive functions, and PFC activity while walking were assessed before and immediately after each session. RESULTS: Compared with the pre-assessment, participants decreased step time variability (effect size: -0.4), shortened simple and choice reaction times (effect sizes: -0.73 and -0.57, respectively), and increased PFC activity in the stimulated hemisphere while walking (effect size: 0.54) only after aerobic exercise + active-tDCS. CONCLUSION: The addition of anodal tDCS over the PFC to a session of aerobic exercise led to immediate positive effects on gait variability, processing speed, and executive control of walking in people with PD.

Explainable artificial intelligence based analysis for interpreting infant fNIRS data in developmental cognitive neuroscience.

Andreu-Perez J, Emberson LL, Kiani M, Filippetti ML, Hagras H, Rigato S.

Commun Biol. 2021 Sep 15;4(1):1077.
doi: 10.1038/s42003-021-02534-y.

In the last decades, non-invasive and portable neuroimaging techniques, such as functional near infrared spectroscopy (fNIRS), have allowed researchers to study the mechanisms underlying the functional cognitive development of the human brain, thus furthering the potential of Developmental Cognitive Neuroscience (DCN). However, the traditional paradigms used for the analysis of infant fNIRS data are still quite limited. Here, we introduce a multivariate pattern analysis for fNIRS data, xMVPA, that is powered by eXplainable Artificial Intelligence (XAI). The proposed approach is exemplified in a study that investigates visual and auditory processing in six-month-old infants. xMVPA not only identified patterns of cortical interactions, which confirmed the existent literature; in the form of conceptual linguistic representations, it also provided evidence for brain networks engaged in the processing of visual and auditory stimuli that were previously overlooked by other methods, while demonstrating similar statistical performance.

The effects of target size and error rate on the cognitive demand and stress during augmented reality interactions.

Kia K, Hwang J, Kim IS, Ishak H, Kim JH.

Appl Ergon. 2021 Nov;97:103502.
doi: 10.1016/j.apergo.2021.103502. Epub 2021 Jun 22.

This study investigated the effects of target size and error rate on cognitive demand during augmented reality (AR) interactions. In a repeated-measures laboratory study, twenty participants performed two AR tasks (omni-directional pointing and cube placing) with different target sizes and error rates. During the AR tasks, we measured cerebral oxygenation using functional near-infrared spectroscopy (fNIRS), perceived workload using the NASA-TLX questionnaire, stress using the Short Stress State Questionnaire, and task performance (task completion time). The results showed that the AR tasks with more interaction errors increased cerebral oxygenation, perceived workload, and task completion time while the target size significantly affected physical demand and task completion time. These results suggest that appropriate target sizes and low system errors may reduce potential cognitive demand in AR interactions.

Bilingualism alters infants' cortical organization for attentional orienting mechanisms.

Arredondo MM, Aslin RN, Werker JF.

Dev Sci. 2021 Aug 21:e13172.
doi: 10.1111/desc.13172. Online ahead of print.

A bilingual environment is associated with changes in the brain's structure and function. Some suggest that bilingualism also improves higher-cognitive functions in infants as young as 6-months, yet whether this effect is associated with changes in the infant brain remains unknown. In the present study, we measured brain activity using functional near-infrared spectroscopy in monolingual- and bilingual-raised 6- and 10-month-old infants. Infants completed an orienting attention task, in which a cue was presented prior to an object appearing on the same (Valid) or opposite (Invalid) side of a display. Task performance did not differ between the groups but neural activity did. At 6-months, both groups showed greater activity for Valid (>Invalid) trials in frontal regions (left hemisphere for bilinguals, right hemisphere for monolinguals). At 10-months, bilinguals showed greater activity for Invalid (>Valid) trials in bilateral frontal regions, while monolinguals showed greater brain activity for Valid (>Invalid) trials in left frontal regions. Bilinguals' brain activity trended with their parents' reporting of dual-language mixing when speaking to their child. These findings are the first to indicate how early (dual) language experience can alter the cortical organization underlying broader, non-linguistic cognitive functions during the first year of life.

The Underlying neural mechanisms of interpersonal situations on collaborative ability: A hyperscanning study using functional near-infrared spectroscopy.

Yang Q, Song X, Dong M, Li J, Proctor RW.

Soc Neurosci. 2021 Oct;16(5):549-563.
doi: 10.1080/17470919.2021.1965017. Epub 2021 Aug 11.

The collaborative ability to coordinate an individual with others is critical to performance of joint actions. Prior studies found that different types of interpersonal situations have more or less impact on the collaborative ability of joint actions, but the results are controversial. To clarify the influence of interpersonal situations on collaborative ability, we adopted the joint Simon task, a choice-reaction task that two people perform together. Functional near-infrared spectroscopy (fNIRS) was used to study the neural mechanisms of interpersonal situations on collaborative ability and task performance under payoffs that fostered competition or cooperation. The fNIRS results showed that significant inter-brain neural synchronization (INS) occurred in the bilateral inferior parietal lobule (IPL) for both situations. Moreover, for the competition situation, the pairs also shown a significant INS in the right IPL. These results imply that the bilateral IPL is involved in cooperation and competition due to involvement of common concern and understanding of intention. The right IPL may be more crucial for competition because of the psychological resources involved in distinguishing self and others. Eventually, the INS in competition was better than in the other situations, correlating with higher performance of the joint task as well.

Quantification of perfusion and metabolism in an autism mouse model assessed by diffuse correlation spectroscopy and near-infrared spectroscopy.

Rinehart B, Poon CS, Sunar U.

J Biophotonics. 2021 Nov;14(11):e202000454.
doi: 10.1002/jbio.202000454. Epub 2021 Aug 9.

There is a need for quantitative biomarkers for early diagnosis of autism. Cerebral blood flow and oxidative metabolism parameters may show superior contrasts for improved characterization. Diffuse

correlation spectroscopy (DCS) has been shown to be reliable method to obtain cerebral blood flow contrast in animals and humans. Thus, in this study, we evaluated the combination of DCS and fNIRS in an established autism mouse model. Our results indicate that autistic group had significantly (P=.001) lower (40%) blood flow (1.16 0.26) 10-8 cm2 /s), and significantly (P=.015) lower (70%) oxidative metabolism (52.4 16.6 mol/100 g/min) compared to control group ([1.93 0.74] 10-8 cm2 /s, 177.2 45.8 mol/100 g/min, respectively). These results suggest that the combination of DCS and fNIRS can provide hemodynamic and metabolic contrasts for in vivo assessment of autism pathological conditions noninvasively.

Investigating Cortical Responses to Noise-Vocoded Speech in Children with Normal Hearing Using Functional Near-Infrared Spectroscopy (fNIRS).

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

J Assoc Res Otolaryngol. 2021 Dec;22(6):703-717.
doi: 10.1007/s10162-021-00817-z. Epub 2021 Sep 28.

Whilst functional neuroimaging has been used to investigate cortical processing of degraded speech in adults, much less is known about how these signals are processed in children. An enhanced understanding of cortical correlates of poor speech perception in children would be highly valuable to oral communication applications, including hearing devices. We utilised vocoded speech stimuli to investigate brain responses to degraded speech in 29 normally hearing children aged 6-12years. Intelligibility of the speech stimuli was altered in two ways by (i) reducing the number of spectral channels and (ii) reducing the amplitude modulation depth of the signal. A total of five different noise-vocoded conditions (with zero, partial or high intelligibility) were presented in an event-related format whilst participants underwent functional near-infrared spectroscopy (fNIRS) neuroimaging. Participants completed a word recognition task during imaging, as well as a separate behavioural speech perception assessment. fNIRS recordings revealed statistically significant sensitivity to stimulus intelligibility across several brain regions. More intelligible stimuli elicited stronger responses in temporal regions, predominantly within the left hemisphere, while right inferior parietal regions showed an opposite, negative relationship. Although there was some evidence that partially intelligible stimuli elicited the strongest responses in the left inferior frontal cortex, a region previous studies have suggested is associated with effortful listening in adults, this effect did not reach statistical significance. These results further our understanding of cortical mechanisms underlying successful speech perception in children. Furthermore, fNIRS holds promise as a clinical technique to help assess speech intelligibility in paediatric populations.

The duration of intrauterine development influences discrimination of speech prosody in infants.

Alexopoulos J, Giordano V, Janda C, Benavides-Varela S, Seidl R, Doering S, Berger A, Bartha-Doering L.

Dev Sci. 2021 Sep;24(5):e13110.
doi: 10.1111/desc.13110. Epub 2021 Apr 4.

Auditory speech discrimination is essential for normal language development. Children born preterm are at greater risk of language developmental delays. Using functional near-infrared spectroscopy at term-equivalent age, the present study investigated early discrimination of speech prosody in 62 neonates born between week 23 and 41 of gestational age (GA). We found a significant positive correlation between GA at birth and neural discrimination of forward versus backward speech at term-equivalent age. Cluster analysis identified a critical threshold at around week 32 of GA, pointing out the existence of subgroups. Infants born before week 32 of GA exhibited a significantly different pattern of hemodynamic response to speech stimuli compared to infants born at or after week 32 of GA. Thus, children born before the GA of 32weeks are especially vulnerable to early speech discrimination deficits. To support their early language

development, we therefore suggest a close follow-up and additional speech and language therapy especially in the group of children born before week 32 of GA.

Investigation of effect of modulation frequency on high-density diffuse optical tomography image quality.

Fan W, Dehghani H, Eggebrecht AT.

Neurophotonics. 2021 Oct;8(4):045002.
doi: 10.1117/1.NPh.8.4.045002. Epub 2021 Nov 24.

Significance: By incorporating multiple overlapping functional near-infrared spectroscopy (fNIRS) measurements, high-density diffuse optical tomography (HD-DOT) images human brain function with fidelity comparable to functional magnetic resonance imaging (fMRI). Previous work has shown that frequency domain high-density diffuse optical tomography (FD-HD-DOT) may further improve image quality over more traditional continuous wave (CW) HD-DOT. Aim: The effects of modulation frequency on image quality as obtainable with FD-HD-DOT is investigated through simulations with a realistic noise model of functional activations in human head models, arising from 11 source modulation frequencies between CW and 1000MHz. Approach: Simulations were performed using five representative head models with an HD regular grid of 158 light sources and 166 detectors and an empirically derived noise model. Functional reconstructions were quantitatively assessed with multiple image quality metrics including the localization error (LE), success rate, full width at half maximum, and full volume at half maximum (FVHM). All metrics were evaluated against CW-based models. Results: Compared to CW, localization accuracy is improved by >40% throughout brain depths of 13 to 25mm below the surface with 300 to 500MHz modulation frequencies. Additionally, the reliable field of view in brain tissue is enlarged by 35% to 48% within an optimal frequency of 300MHz after considering realistic noise, depending on the dynamic range of the system. Conclusions: These results point to the tremendous opportunities in further development of high bandwidth FD-HD-DOT system hardware for applications in human brain mapping.

Prefrontal cortex activation during dual-task walking in older adults is moderated by thickness of several cortical regions.

Ross D, Wagshul ME, Izzetoglu M, Holtzer R.

Geroscience. 2021 Aug;43(4):1959-1974.
doi: 10.1007/s11357-021-00379-1. Epub 2021 Jun 24.

Dual tasking, a defined facet of executive control processes, is subserved, in part, by the prefrontal cortex (PFC). Previous functional near-infrared spectroscopy (fNIRS) studies revealed elevated PFC oxygenated hemoglobin (HbO2) under Dual-Task-Walk (DTW) compared to Single-Task Walk (STW) conditions. Based on the concept of neural inefficiency (i.e., greater activation coupled with similar or worse performance), we hypothesized that decreased cortical thickness across multiple brain regions would be associated with greater HbO2 increases from STW to DTW. Participants were 55 healthy community-dwelling older adults, whose cortical thickness was measured via MRI. HbO2 levels in the PFC, measured via fNIRS, were assessed during active walking under STW and DTW conditions. Statistical analyses were adjusted for demographics and behavioral performance. Linear mixed-effects models revealed that the increase in HbO2 from STW to DTW was moderated by cortical thickness in several regions. Specifically, thinner cortex in specific regions of the frontal, parietal, temporal, and occipital lobes, cingulate cortex, and insula was associated with greater increases in HbO2 levels from single to dual-task walking. In conclusion, participants with thinner cortex in regions implicated in higher order control of walking employed greater neural resources, as measured by increased HbO2, in the PFC during DTW, without demonstrating benefits to behavioral performance. To our knowledge, this is the first study to examine cortical thickness as a marker of neural inefficiency during active walking.

Experiencing Happiness Together Facilitates Dyadic Coordination through the Enhanced Interpersonal Neural Synchronization.

Li Y, Chen M, Zhang R, Xianchun L.

Soc Cogn Affect Neurosci. 2021 Oct 20:nsab114.
doi: 10.1093/scan/nsab114. Online ahead of print.

Experiencing positive emotions together facilitates interpersonal understanding and promotes subsequent social interaction among individuals. However, the neural underpinnings of such emotional-social effect remain to be discovered. Current study employed the fNIRS-based hyperscanning to investigate the above mentioned relationship. After participants in dyad watching movie clips with happily or neutral emotion, they were asked to perform the interpersonal cooperative task, with their neural activation of prefrontal cortex (PFC) being recorded simultaneously via functional near infrared spectroscopy. Results suggested that compared with the neutral movie watching together, a higher interpersonal neural synchronization (INS) in left inferior frontal gyrus during participant dyads watching happiness movie together. Subsequently, dyads in happiness showed more effective coordination interaction during performed the interpersonal cooperation task compared to those in the neutral condition, and such facilitated effect was associated with increased cooperation-related INS at left middle frontal cortex. A mediation analysis showed that the coordination interaction fully mediated the relationship between the emotion-induced INS during the happiness movie-viewing and the cooperation-related INS in interpersonal cooperation. Taken together, our findings suggest that the faciliatory effect experiencing happiness together has on interpersonal cooperation can be reliably reflected by the INS magnitude at the brain level.

Application of Depth Selectivity Filter to Brain Function Measurement by fNIRS.

Fukuda K, Wakamatsu Y, Fujii M.

Annu Int Conf IEEE Eng Med Biol Soc. 2021 Nov;2021:3787-3790.
doi: 10.1109/EMBC46164.2021.9629723.

In brain function measurement by fNIRS, reducing the effect of the hemodynamic change on the signal is important. In this study, a depth-selective filter, which is one of the reduction methods, was applied to the brain function measurement and its reduction effect was verified. A Stroop GO/NO-GO task, which is expected to produce a response in the frontal region was used. The experiments showed the effectiveness of reducing the hemodynamic changes with the depth-selective filter. It can be used as a preprocessing tool for estimating the activated region.

The Effect of Yoga Meditation Practice on Young Adults' Inhibitory Control: An fNIRS Study.

Jiang D, Liu Z, Sun G.

Front Hum Neurosci. 2021 Sep 13;15:725233.
doi: 10.3389/fnhum.2021.725233. eCollection 2021.

Objectives: The present study aimed to test the effect of yoga meditation (YoMed) practice on inhibitory control of young adults. Methods: A total of 50 participants (23 male, 21-28 years old) from a university in Jinan, Shandong Province were enrolled in this study. Participants were randomly assigned to a YoMed group or a Control group. Participants' basic information, physical activity, and inhibitory control were measured. A multi-channel continuous-wave near-infrared spectrometer was used to monitor the brain's hemodynamic responses. Results: After the intervention, we found significant differences in Flanker tasks between the YoMed group and Control group. The accuracy in the YoMed group was higher than those in the Control group ($p < 0.05$). Analysis of fNIRS data showed that oxyhemoglobin (oxy-Hb) levels in the prefrontal cortex (PFC) increased in the YoMed group during the Flanker tasks after the

YoMed intervention. Conclusion: YoMed has a temporarily promoting effect on the brain activation of young adults. It is an effective and appropriate exercise to improve the inhibitory control of young adults.

Abnormally reduced frontal cortex activity during Trail-Making-Test in prodromal parkinson's disease-a fNIRS study.

Hofmann A, Rosenbaum D, Int-Veen I, Ehlis AC, Brockmann K, Dehnen K, von Thaler AK, Berg D, Fallgatter AJ, Metzger FG; TREND Study Consortium.

Neurobiol Aging. 2021 Sep;105:148-158.
doi: 10.1016/j.neurobiolaging.2021.04.014. Epub 2021 Apr 28.

Parkinson's Disease (PD) is a neurodegenerative disorder leading to typical motor as well as a range of non-motor symptoms, including cognitive decline mainly characterized by executive deficits. The latter are known to appear years before the typical motor signs, thus representing the prodromal phase of PD. However, appropriate methods for measuring executive dysfunction in this context are not well established yet. Traditionally, executive performance is associated with frontal structures. Here, we investigated prodromal, early PD patients and healthy controls regarding their executive functioning on the behavioral and neural level, measured by the Trail-Making-Test (TMT) combined with functional near-infrared spectroscopy. We observed significantly reduced neural activity in the right dorsolateral prefrontal cortex within PD patients compared to controls completing the TMT-A and -B in contrast to the TMT-C, but no differences on a behavioral level. These promising results need to be confirmed and checked for reliability in future studies to extend the spectrum of markers applied in prodromal PD.

The Immediate Effects of Intermittent Theta Burst Stimulation of the Cerebellar Vermis on Cerebral Cortical Excitability During a Balance Task in Healthy Individuals: A Pilot Study.

Tan HX, Wei QC, Chen Y, Xie YJ, Guo QF, He L, Gao Q.

Front Hum Neurosci. 2021 Nov 12;15:748241.
doi: 10.3389/fnhum.2021.748241. eCollection 2021.

Objective: This pilot study aimed to investigate the immediate effects of single-session intermittent theta-burst stimulation (iTBS) on the cerebellar vermis during a balance task, which could unveil the changes of cerebral cortical excitability in healthy individuals. Subjects: A total of seven right-handed healthy subjects (26.86 5.30 years) were included in this study. Interventions: Each subject received single-session iTBS on cerebellar vermis in a sitting position. Main Measures: Before and after the intervention, all subjects were asked to repeat the balance task of standing on the left leg three times. Each task consisted of 15 s of standing and 20 s of resting. Real-time changes in cerebral cortex oxygen concentrations were monitored with functional near-infrared spectroscopy (fNIRS). During the task, changes in blood oxygen concentration were recorded and converted into the mean HbO2 for statistical analysis. Results: After stimulation, the mean HbO2 in the left SMA ($P = 0.029$) and right SMA ($P = 0.043$) significantly increased compared with baseline. However, no significant changes of mean HbO2 were found in the bilateral dorsolateral prefrontal lobe ($P > 0.05$). Conclusion: Single-session iTBS on the cerebellar vermis in healthy adults can increase the excitability of the cerebral cortex in the bilateral supplementary motor areas during balance tasks. Clinical Trial Registration: [www.ClinicalTrials.gov], identifier [ChiCTR2100048915].

Erratum to: Effects of prefrontal theta burst stimulation on neuronal activity and subsequent eating behavior: an interleaved rTMS and fNIRS study.

Fatakdawala I, Ayaz H, Safati AB, Sakib MN, Hall PA.

Soc Cogn Affect Neurosci. 2021 Sep 7;16(9):1021.
doi: 10.1093/scan/nsab040.
Erratum for Soc Cogn Affect Neurosci. 2021 Feb 22;:

Comparison of Brain Activation Patterns during Olfactory Stimuli between Recovered COVID-19 Patients and Healthy Controls: A Functional Near-Infrared Spectroscopy (fNIRS) Study.

Ho RC, Sharma VK, Tan BYQ, Ng AYY, Lui YS, Husain SF, Ho CS, Tran BX, Pham QH, McIntyre RS, Chan ACY.

Brain Sci. 2021 Jul 23;11(8):968.
doi: 10.3390/brainsci11080968.

Impaired sense of smell occurs in a fraction of patients with COVID-19 infection, but its effect on cerebral activity is unknown. Thus, this case report investigated the effect of COVID-19 infection on frontotemporal cortex activity during olfactory stimuli. In this preliminary study, patients who recovered from COVID-19 infection (n = 6) and healthy controls who never contracted COVID-19 (n = 6) were recruited. Relative changes in frontotemporal cortex oxy-hemoglobin during olfactory stimuli was acquired using functional near-infrared spectroscopy (fNIRS). The area under curve (AUC) of oxy-hemoglobin for the time interval 5 s before and 15 s after olfactory stimuli was derived. In addition, olfactory function was assessed using the Sniffin' Sticks 12-identification test (SIT-12). Patients had lower SIT-12 scores than healthy controls ($p = 0.026$), but there were no differences in oxy-hemoglobin AUC between healthy controls and patients ($p > 0.05$). This suggests that past COVID-19 infection may not affect frontotemporal cortex function, and these preliminary results need to be verified in larger samples.

Neuroimaging Guided Transcranial Electrical Stimulation in Enhancing Surgical Skill Acquisition. Comment on Hung et al. The Efficacy of Transcranial Direct Current Stimulation in Enhancing Surgical Skill Acquisition: A Preliminary Meta-Analysis of Randomized Controlled Trials. Brain Sci. 2021, 11, 707.

Walia P, Kumar KN, Dutta A.

Brain Sci. 2021 Aug 18;11(8):1078.
doi: 10.3390/brainsci11081078.
Comment on Brain Sci. 11:707.

Simultaneous functional near-infrared spectroscopy (fNIRS) and electroencephalogram (EEG) to elucidate neurovascular modulation by transcranial electrical stimulation (tES).

Dutta A.

Brain Stimul. 2021 Sep-Oct;14(5):1093-1094.
doi: 10.1016/j.brs.2021.07.019. Epub 2021 Jul 29.
Comment on Brain Stimul. 2021 Jul-Aug;14(4):837-847.

Corrigendum: Performance Improvement for Detecting Brain Function Using fNIRS: A Multi-Distance Probe Configuration With PPL Method.

Chen X, Song X, Chen L, An X, Ming D.

Front Hum Neurosci. 2021 Nov 4;15:786352.

doi: 10.3389/fnhum.2021.786352. eCollection 2021.
Erratum for Front Hum Neurosci. 2020 Nov 06;14:569508.